Dielectric Property Measurements Set Up: Hioki 3532-50 Hitester

Electrical Characterization Lab

DEPARTMENT OF PURE AND APPLIED PHYSICS

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Contents

1. BASIC OPERATION MODULE
2. 3532-50 LCR HITESTER OVERVIEW
3. 3532-50 LCR HITESTER MANUAL
4. RS-232C INTERFACE MANUAL
5. KEITHLEY 6514 LECTROMETER MANUAL
6. PSM1735 NumetriQ MULTIMETER MANUAL

Basic Operational Manual

On

LCR-Meter Setup

(HIOKI 3532-50 HiTESTER), High Temperature Furnace

Department of Pure & Applied Physics

Guru Ghasidas Vishwavidyalaya (A Central University), Bilaspur,Chhattisgarh, India, 495009.

- **Note:-** Measurements such as AC or DC Resistance, inductance, impedance, conductance, conductivity, resistivity, permittivity, tangent loss, quality factor of materials and other dielectric parameter can be Measured through **Hioki 3532-50 LCR HITESTER** setup.

(a) Basic operation & Room Temperature Measurement:

- ✓ **Turn On the Hioki 3532-50 LCR HITESTER and PC.**
- ✓ **Wait at least 1 hour to stabilize the Hioki 3532-50 LCR HITESTER.**
- ✓ **Using four probe wires calibration is done through open and Short calibration.**
- ✓ **Sample over which measurement is performed, is between sample holder after calibration of BNC cable which are connected to the two high current and potential port and other two wires are connected to the low current and low potentials as well. (** ***silver conducting paste should be coated on upper and lower surface of sample.*** **)**
- ✓ **After stabilization, Hioki 3532-50 LCR HITESTER is connected to PC through USB cable.**
- ✓ **LCR Meter Software is opened, where** ***'LCR_Meters'*** **dialogue box is visible in interface of software in which** ***I/O COM3*** **option is first set with Hioki 3532-50 LCR HITESTER by clicking on it.**
- ✓ **Other details regarding sample and measurements can be filled in their respective place such Thickness(mm), Area (mm^2), frequency,**

temperature, and 17 different parameter of materials which is mentioned in this manual at the end.

- ✓ **By choosing mode of measurement from the interface of software One can start the measurement and can get the desired data.**

- ✓ **Measurement can be done with two different variables:**
  (1) Temperature Vs Parameter
  (2) Frequency Vs Parameter

- ✓ **By clicking start, measurement can be started.**
  (b) Temperature Dependent measurements:
  1. High Temperature measurement using high temperature furnace.

- ✓ **Turn on the furnace and leave it for 1 hour to get stabilized temperature. Before operating the high temp furnace, make sure that the temperature is stabilized.**

- ✓ **A cable is connected to Hioki IM3536 LCR METER from furnace to sense current temperature inside the furnace.**

- ✓ **Manually, desired temperature sweep is set at constant frequencies or vice versa and desired data is obtained.**

HIOKI

LCR HiTESTER 3532-50

Component measuring instruments

Shorten line tact time via high speed measuring power

Versatile LCR meters with 5 ms measurement capabilities

The LCR HiTESTER 3532-50 features variable measurement frequencies over broad ranges.
The 3532-50 can provide 42 Hz to 5 MHz, for measurements with precise ±0.08% basic accuracy. With this high performance, along with its ease of use, broad set of functions and low price, this LCR measurement instrument achieves outstanding cost performance.
The 3532-50 is especially suitable for laboratory applications such as for evaluating operating characteristics, and with its 5 ms fastest response, versatile interface options and comparator functions, this instrument is also ideal for a broad range of production line applications.

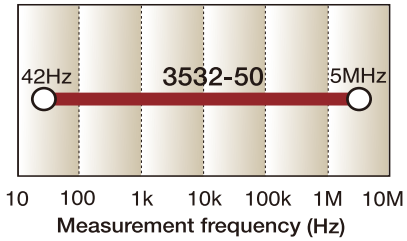
CE

Covering Wide Frequency Range : 42 Hz to 5 MHz

3532-50 Features

■ Higher frequency range

The measurement frequency can be freely set to any value in the 42 Hz to 5 MHz range. In particular this makes it easy to test sample characteristics in the high frequency range.



■ High resolution and high accuracy

The measurement resolution provides a full five digits, with a basic measurement accuracy is ± 0.08%.

■ Fastest measurement time 5 ms

Four sampling rates can be selected: FAST, NORMAL, SLOW, and SLOW2. The most rapid measurement time of 5 ms (displaying |Z|) gives rapid sampling for improved production line efficiency.
(The measurement frequency range varies from one parameter to another.)

■ Fourteen parameters measured

The following parameters can be measured, and selected parameters can be captured by a computer: |Z|, |Y|, θ, Rp (DCR*), Rs (ESR, DCR*), G, X, B, Lp, Ls, Cp, Cs, D (tan δ), and Q.

■ Interactive touch panel operation

Operation is extremely simple: touch the item on the screen to be changed, and the possible settings appear in sequence. The neat and simple front panel eliminates all key switches, for a clutter-free design.

■ Wide setting range for measurement voltage and current

In addition to normal open-loop signal generation, the **3532-50** provides for voltage/current dependent evaluation, in constant voltage and constant current modes. The signal levels can be set over wide ranges, from 10 mV to 5 Vrms, and from 10 μA to 100 mA (up to 1 MHz).

■ Simultaneous setting and measurement

Measurement frequency, measurement signal level, and other measurement conditions can be changed while monitoring the measurement results, enabling effective trial measurements and setting of evaluation conditions.

■ Memory for thirty sets of measurement conditions

Up to thirty sets of measurement conditions, including comparator values, provide rapid response to constantly changing components on flexible production lines. With multiple measurement conditions in memory, up to five different measurements can be made sequentially. The comparator function lets a single unit provide the logical AND result for this sequence of tests.

■ Four simultaneous measurement items

Any four of the fourteen parameters can be chosen for simultaneous measurement and display.

■ Enlarged display function

Up to four parameters can be displayed enlarged, for easy observation of the measurement values in production line and other situations where the unit is read at a distance.

■ Correlation correction function

The constants a and b can be set in the following correction function expression:

Corrected value = a × measurement value + b

■ Printer output

With the optional PRINTER 9442, measurement values, comparator results, and screen printouts can be obtained.

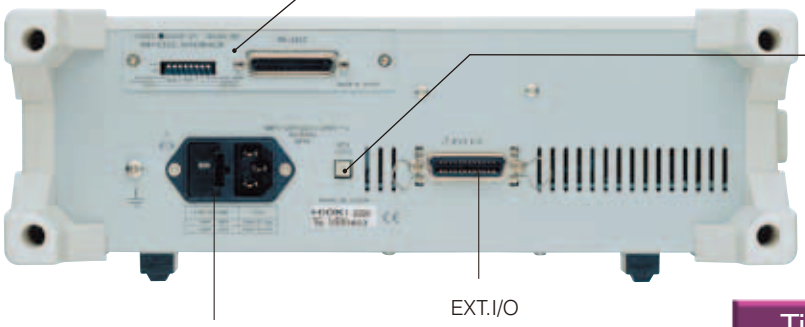
■ DC bias measurement

Using the optional DC BIAS UNIT 9268 (max. DC ±40V) or DC BIAS UNIT 9269 (max. DC ±2A) , voltage and current bias measurements are simple.

■ External I/O interface

The EXT. I/O connector can input trigger signals, and provides a key lock on/off function, and remote control of the measurement condition loading. Output signals include comparator results and measurement completed signals, for complete line automation.

Rear view of 3532-50



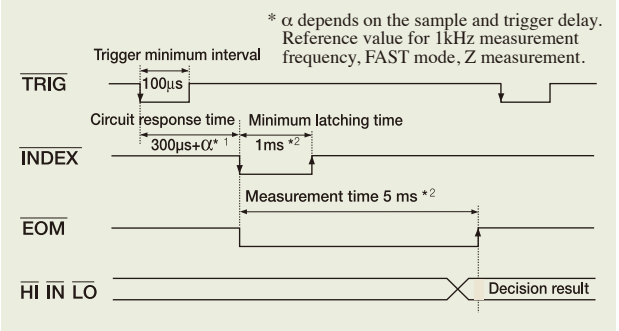
EXT. I/O signals

● Outputs
- Internal DC power (+5 V output)
- Comparator result
- Analog measurement in progress
- End-of-measurement

● Inputs
- External DC power supply (+5 V to +24 V can be supplied by external device)
- External trigger signal
- Key lock on/off function
- Memory setting selection

Timing chart for EXT. I/O sequencing

The following chart shows the timing sequence of the trigger (TRIG), analog measurement completion (INDEX), and end-of-measurement (EOM) signals from the EXT. I/O connector.



■ 3532-50 specifications

	3532-50
Measurement parameters	|Z|, |Y|, θ, Rp, Rs (ESR), G, X, B, Cp, Cs, Lp, Ls, D (tan δ), Q
Measurement ranges |Z|, R, X	10.00 mΩ to 200.00 MΩ (depending on measurement frequency and signal levels)
θ	-180.00° to +180.00°
C	0.3200 pF to 370.00 mF
L	16.000 nH to 750.00 kH
D	0.00001 to 9.99999
Q	0.01 to 999.99
|Y|, G, B	5.0000 nS to 99.999 S
Basic accuracy	Z : ± 0.08% rdg. θ : ± 0.05°
Measurement frequency	42 Hz to 5 MHz
Measurement signal levels	10 mV to 5 V rms / 10µA to 100 mA rms
Output impedance	50 Ω
Display screen	LCD with backlight / 99999 (full 5 digits)
Measurement time (typical values for displaying |Z|)	FAST : 5 ms, NORMAL : 21 ms, SLOW 1 / 2 : 72 ms / 140 ms
Settings in memory	Maximum 30 sets
Comparator functions	HI/IN/LO settings for two measurement parameters; percentage, Δ%, or absolute value settings
DC bias	External DC bias ± 40 V max.(option) (3522-50 used alone ± 10 V max./ using 9268 ± 40 V max.)
External printer	PRINTER 9442 (option)
External interfaces	GP-IB or RS-232C (selectable options), external I/O for sequencer use
Power source	100, 120, 220 or 240 V(±10%) AC (selectable), 50/60 Hz
Maximum rated power	50 VA approx.

Measurement ranges : All parameter ranges are determined by the |Z| range.
100 mΩ, 1 Ω, 10 Ω, 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, 1 MΩ, 10 MΩ, 100 MΩ

Measurement frequency : 42 Hz to 5 MHz (± 0.005%)
Up to 1 kHz (0.1 Hz steps); 1 kHz to 10 kHz (1 Hz); 10 kHz to 100 kHz (10 Hz); 100 kHz to 1 MHz (100 Hz); 1MHz to 5 MHz (1 kHz)

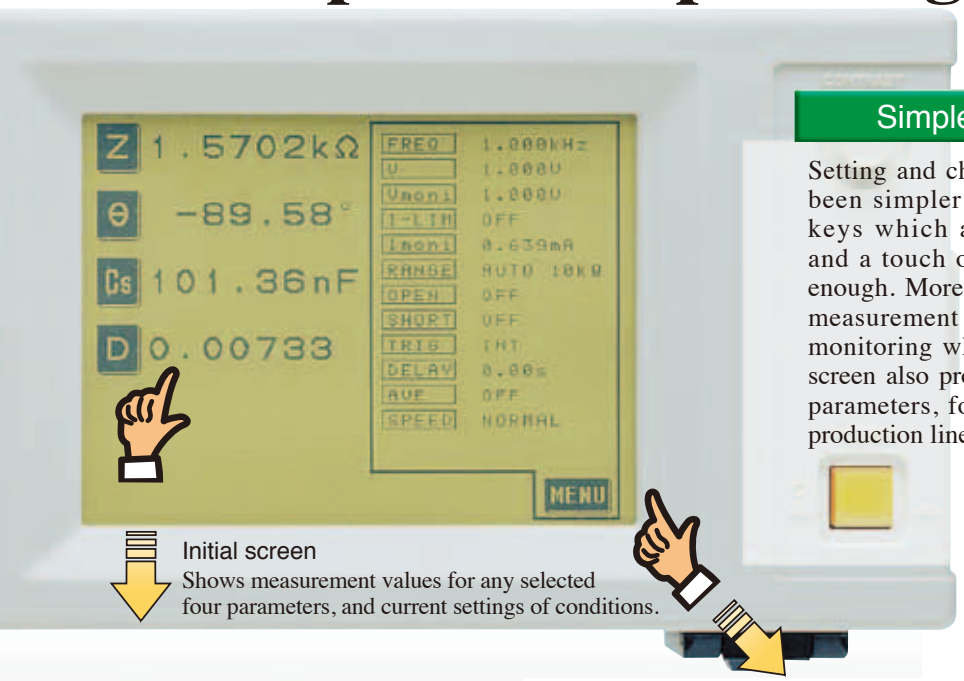
Measurement levels :
[Voltage and constant voltage]
10 mV to 5 V rms (DC to 1 MHz)
50 mV to 1 V rms (1 MHz to 5 MHz)
Maximum short-circuit current 100 mA rms
1 mV steps

[Constant current]
10 µA to 100 mA rms (DC to 1 MHz)
50 µA to 20 mA rms (1 MHz to 5 MHz)
Maximum voltage 5 V rms
10 µA rms steps

Dimensions and mass : 348W × 113H × 273D mm; 5.7 kg approx.
(13.86"W × 4.88"H × 12.72"D ; 229.68 oz. approx.)

Conforming standards :
EMC EN61326
EN61000-3-2
EN61000-3-3
Safety EN61010
Power supply; Pollution degree 2 Overvoltage Category Ⅱ
(anticipated transient overvoltage 2500 V)
Test terminals; Pollution degree 2 Overvoltage Category I
(anticipated transient overvoltage 330 V)

Changing Settings During Measurement
Test conditions can now come closer to a component's operating conditions

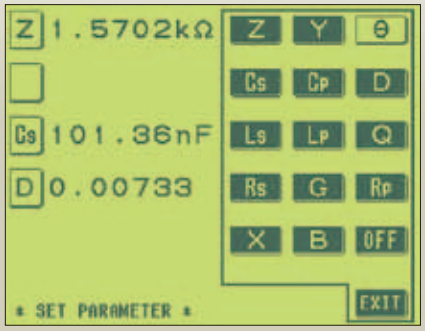


Initial screen
Shows measurement values for any selected four parameters, and current settings of conditions.

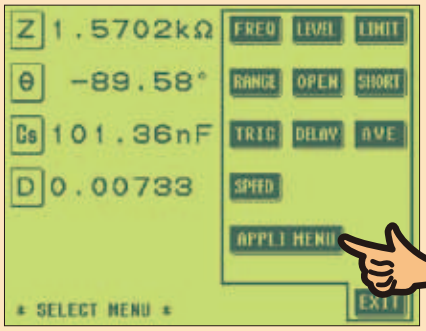
Simple touch panel operation

Setting and changing the test conditions have never been simpler with this intuitive touch panel. The keys which are active appear in reverse video, and a touch of the item or value to be changed is enough. Moreover, the setting screens also show the measurement values in real time, allowing flexible monitoring while changing test signal settings. The screen also provides an enlarged display for any four parameters, for increased visibility at a distance on production lines.

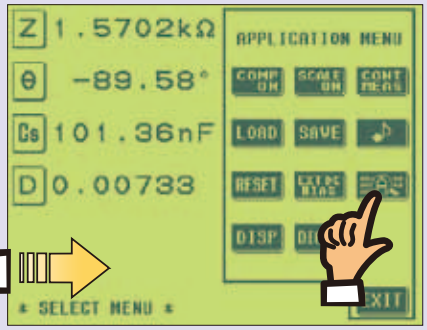
Parameter setting screen
Select any four of the parameters for display.



Menu screen
Select an item, and switch to the corresponding setting screen.



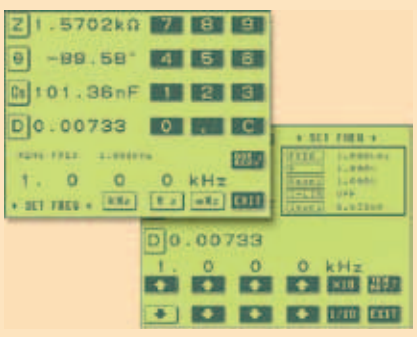
Application menu
Save and load measurement conditions, and set comparator execution, enlarged display, and so on.

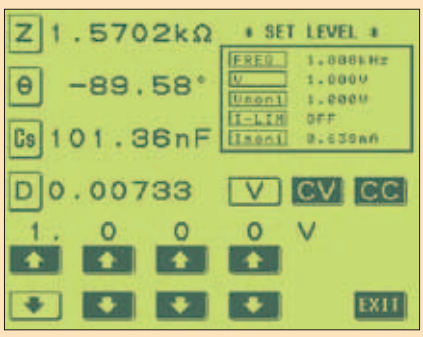


Measurement frequency

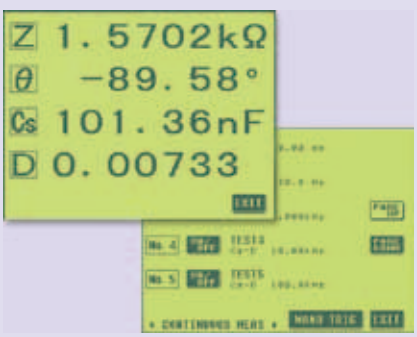
Level setting screens

Use the numeric keypad or digit keys to enter the setting values, changing the test frequency or level while monitoring the measurement. The level setting can be open-circuit voltage, constant voltage, or constant current.





Enlarged display and comparator setting screens
Set the enlarged display or select the settings saved in memory to execute continuous measurement.

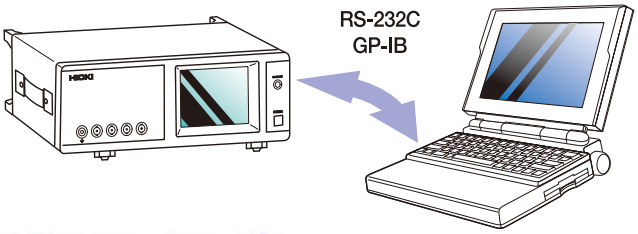


Personal computer link

Effective Analysis and Processing of Measurement Data

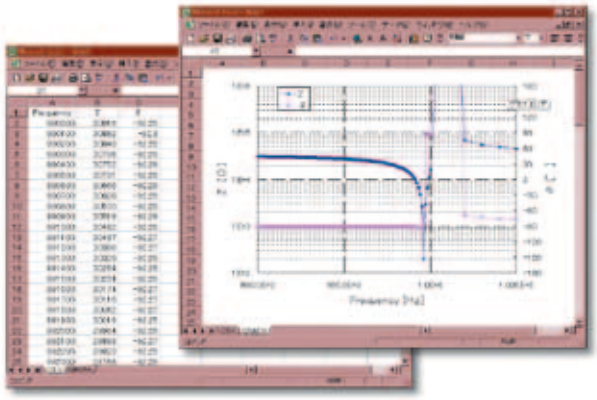
External control by computer

By installing the optional RS-232C INTERFACE 9593-01 or GP-IB INTERFACE 9518-01, all of the 3532-50 functions other than power on/off can be controlled from a computer.



Graphing with a spreadsheet program

Measurement data captured by a personal computer can be displayed graphically by using standard spreadsheet software. The example below uses the provision for continuously varying frequency to capture the frequency characteristics for a 1 MHz quartz oscillator measured with the 3532-50 into Excel, then presents the results graphically. The four-digit resolution for the frequency allows the characteristics of the steep resonance peak to be shown on the graph.



Similar to the main unit, you can also select up to 4 items to monitor.
Data for the selected items will be filed.

Items such as the sweep frequency and data output directory can be set.
In addition, the unit can also be set to output data whenever the return key is hit.

By utilizing the RS-232C interface, sample freeware that will enable measurement data to be output onto an Excel spreadsheet while the measured frequency is being swept is also available.
Please inquire with your local HIOKI distributor.

■ RS-232C INTERFACE 9593-01 specification

Transmission method	: Start-stop asynchronous
Transmission rates	: 2,400/4,800/9,600 and 19,200 baud
Data bits	: 7 or 8
Parity	: Odd, even or none
Stop bits	: 1 or 2
Delimiter	: CR+LF, CR
Flow control	: Hardware (According to DIP switch setting)
Connection	: D-sub 25-pin, male/male connector, reverse connection

■ PRINTER 9442

The optional PRINTER 9442 allows measurement results and screen copies to be printed. This is convenient for permanent records of inspections and so forth.

(Connection requires the optional RS-232C INTERFACE 9593-01, CONNECTION CABLE 9446, and AC ADAPTER.)

Resulting measurement data can be output not only to a printer, but also other media such as a PC or sequencer. Using the RS-232C interface makes transferring the inspection data simple and convenient.

Example Print-out

```
Cs 984.16n F      D  0.00017
Cs 984.14n F      D  0.00017
Cs 984.10n F      D  0.00017
Cs 984.20n F      D  0.00034


Cs 983.91n F   LO  D  0.00052   HI
Cs 983.89n F   LO  D  0.00034   IN
Cs 984.03n F   IN  D  0.00017   LO
Cs 983.89n F   LO  D  0.00052   HI
Cs 983.95n F   LO  D  0.00034   IN
Cs 983.95n F   LO  D  0.00052   HI
```

Flexible Measurement Signals Widen Scope for Application

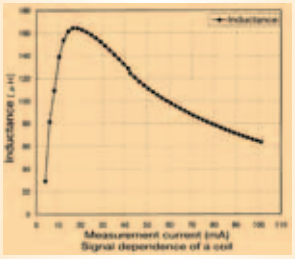
Applications

■ Evaluation of signal-dependent components

Since any test signal can be selected, it is possible to measure the inductance of winding, floating capacitance, characteristics at operating frequency, and low frequency resistance components.

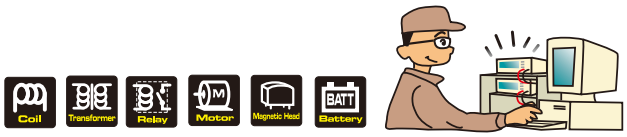
Example of measuring signal dependence of coils

For chokes, transformers, and other components with an inductive core, the values depend on the measurement signal. By varying the measurement current, measurements showing the signal dependence of the coil can be shown as a graph.

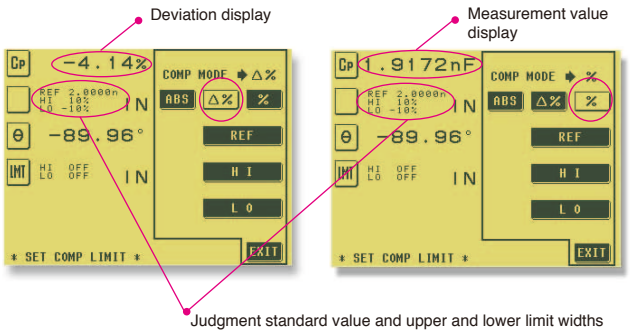


The 3532-50 provides three modes for selecting the measurement signal according to the component characteristics: open-circuit voltage (V), constant voltage (CV), or constant current (CC).

V mode : set V0
CV mode : set V0 so that the voltage across the component is the CV value (Vcv)
CC mode : set V0 so that the current through the component is the CC value (Icc)
Vm : voltage monitor value
Im : current monitor value
R0 : output impedance (50 Ω constant)

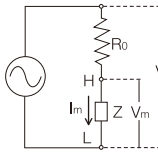


Comparator setting screen with additional Δ% display



The screen at left shows an example of the Δ% setting; The screen at right shows an example of the % setting from current models. In either, the judgement range is a percentage of the reference values.
The Δ% display is easy to interpret because the measurement value is displayed as a deviation.

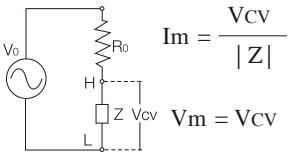
V mode



$$Im = \frac{V0}{|R0 + Z|}$$

$$Vm = \frac{|Z|}{|R0 + Z|} + V0$$

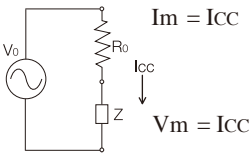
CV mode



$$Im = \frac{Vcv}{|Z|}$$

$$Vm = Vcv$$

CC mode

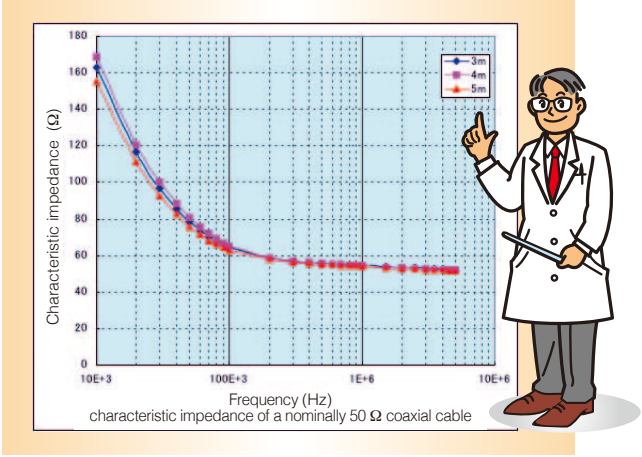


$$Im = Icc$$

$$Vm = Icc \times |Z|$$

Pass-fail judgment of cables by characteristic impedance

To ensure reliable connections and communications, characteristic impedance and inter-conductor capacitance are typically specified for interfaces and cable connectors used to interconnect high frequency instruments. The 3532-50 supports pass-fail judgment of such cables and connectors intended for communications and interfaces.
The graph at the right shows actual measurement results of the characteristic impedance of a nominally 50 Ω coaxial cable.



Measurement accuracy and ranges *

Conditions : temperature range 23 °C ±5 °C (73 °F ±9 °F), 80% rh or less (no condensation)
After a 60-minute warm-up period, and open-circuit and short-circuit corrections are made.
Using the TEST FIXTURE 9262, and measurement signal level: 0.501 V to 1.000 V; measurement speed SLOW2.
* Measurement ranges and accuracy depend on the test fixture used, the measurement signal levels, and the measurement speed.

3532-50 Accuracy

Range	Impedance	42 to 99.99 Hz	100.0 Hz to 1.000 kHz	1.001 to 10.00 kHz	10.01 to 100.0 kHz	100.1 k to 1.000 MHz	1.001 to 5 MHz
100 MΩ	200 MΩ	A=4 B=4	A=2	B=2			
	10 MΩ	A=2.5 B=2	A=1	B=1.5			
10 MΩ	10 MΩ	A=0.8 B=0.4	A=0.4	B=0.2	A=1 B=0.5		
	1 MΩ	A=1 B=0.2	A=0.25	B=0.1	A=1 B=0.5		
1 MΩ	1 MΩ	A=0.4 B=0.05	A=0.15	B=0.05	A=0.3 B=0.08	A=3 B=1	
	100 kΩ	A=0.3 B=0.1	A=0.15	B=0.02	A=0.3 B=0.08	A=3 B=0.5	
100 kΩ	100 kΩ	A=0.35 B=0.01	A=0.08 B=0.01	A=0.15 B=0.01	A=0.25 B=0.04	A=0.4 B=0.3	* A=2 B=0.5
	10 kΩ	A=0.25 B=0.01	A=0.05 B=0.01	A=0.08 B=0.01	A=0.15 B=0.02	A=0.3 B=0.3	A=2 B=0.3
10 kΩ	10 kΩ						
	1 kΩ	A=0.35 B=0.01	A=0.08	B=0.01	A=0.2 B=0.02	A=0.3 B=0.03	* A=1.5 B=0.2
1 kΩ	1 kΩ	A=0.25 B=0.005	A=0.05	B=0.005	A=0.08 B=0.02	A=0.15 B=0.02	A=1 B=0.2
	100 Ω						
100 Ω	100 Ω	A=0.35 B=0.02	A=0.08	B=0.02	A=0.2 B=0.02	A=0.3 B=0.03	* A=1.5 B=0.2
	10 Ω	A=0.25 B=0.01	A=0.05	B=0.01	A=0.08 B=0.02	A=0.15 B=0.02	A=1 B=0.2
10 Ω	10 Ω	A=0.4 B=0.04	A=0.2	B=0.03	A=0.2 B=0.03	A=0.4 B=0.1	* A=2 B=1
	1 Ω	A=0.3 B=0.1	A=0.1	B=0.02	A=0.15 B=0.02	A=0.3 B=0.05	A=2 B=0.5
1Ω	1 Ω	A=0.7 B=0.4		A=0.4 B=0.3		A=1 B=1	
	100 mΩ	A=1 B=0.2		A=0.25 B=0.2		A=0.7 B=0.5	*1.001 MHz and above accuracy × $\frac{(f\ [MHz]+3)}{4}$
100 mΩ	100 mΩ	A=4 B=4		A=3 B=2			
	10 mΩ	A=2.5 B=2		A=2 B=1			

The expression for calculating accuracy is different in the ranges above 1 kΩ and below 100 Ω.
For details refer to the following expressions.

Range 1 kΩ and above...

$$\text{Accuracy} = A + \frac{B \times |\,10 \times Zx - \text{range}\,|}{\text{Range}}$$

Range 100 Ω and below...

$$\text{Accuracy} = A + \frac{B \times |\,\text{range} - Zx\,| \times 10}{\text{Range}}$$

Zx is the measured impedance of the sample (|Z|).

Upper figure A .. basic accuracy for |Z| (± % rdg.)
B is coefficient for sample impedance

Lower figure A .. basic accuracy for θ (± deg.)
B is coefficient for sample impedance

■ Method of determining accuracy

- The measurement accuracy can be calculated from the impedance of the sample, the measurement range, the measurement frequency, and the basic accuracy A and coefficient B from the above tables.
- The expression for calculating accuracy is different in the ranges above 1 kΩ and below 100 Ω.
- For C and L, find the basic accuracy A and coefficient B either by direct measurement of the impedance or by approximate calculation as follows.

$$|Zx\ (\Omega)| \cong \omega L\ (H)\ (\theta \cong 90^\circ)$$

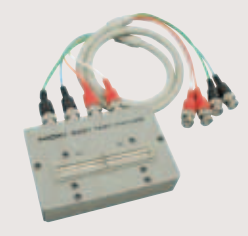
$$\cong \frac{1}{\omega C\ (F)}\quad (\theta \cong -90^\circ)$$

$$\cong R\ (\Omega)\ (\theta \cong 0^\circ)$$

Options for a wide range of applications

FOUR-TERMINAL PROBE 9140
DC to 100 kHz

PINCHER PROBE 9143
DC to 5 MHz



TEST FIXTURE 9261
DC to 5 MHz

TEST FIXTURE 9262
DC to 5 MHz

SMD TEST FIXTURE 9263
DC to 5 MHz
Measurable object size: 1.0 to 10 mm

* All cable lengths are 1 m (39.37").

DC BIAS VOLTAGE UNIT 9268
Maximum applied voltage: ± 40 V DC
42 Hz to 5 MHz

DC BIAS VOLTAGE UNIT 9268-01
for HDMI
Maximum applied voltage: ± 4 V DC
42 Hz to 5 MHz

DC BIAS CURRENT UNIT 9269
Maximum applied current: ± 2 A DC
42 Hz to 100 kHz

Bias unit attached

PRINTER 9442

●Printing method Recording width: Thermal serial dot printer/112 mm (4.41")
●Printing speed: 52.5 cps ●Power supply: AC ADAPTER 9443 or supplied nickel-hydrogen battery pack (prints 3000 lines on full charge from 9443) ●Dimensions and masst: 160W × 66.5H × 170D mm; 580 g apprpx. (6.30"W × 2.62"H × 6.70"D; 20.46 oz. apprpx.)

* Connecting the PRINTER 9442 requires the optional RS-232C INTERFACE 9593-01, CONNECTION CABLE 9446, and AC ADAPTER.

LCR HiTESTER 3532-50

(Standard accessories: power cord, spare power fuse (1 A for 100/120 V rating, 0.5 A for 220/240 V rating)

Test fixtures are not supplied with the unit.
Select an optional test fixture when ordering.

■ Optional accessories

FOUR-TERMINAL PROBE 9140
PINCHER PROBE 9143
TEST FIXTURE 9261
TEST FIXTURE 9262 (direct connection type)
SMD TEST FIXTURE 9263 (direct connection type)
DC BIAS VOLTAGE UNIT 9268
DC BIAS VOLTAGE UNIT 9268-01 (for HDMI)
DC BIAS CURRENT UNIT 9269
CONNECTION CORD 9165 (for 9268/9269; BNC to BNC; 1.5 m/59.06")
CONNECTION CORD 9166 (for 9268/9269; BNC to clips; 1.5 m/59.06")
RS-232C INTERFACE 9593-01 *Not CE marked
GP-IB INTERFACE 9518-01
GP-IB CONNECTION CABLE 9151-02 (2 m/78.74")
PRINTER 9442
CONNECTION CABLE 9446 (for 9442)
RECORDING PAPER 1196 (for 9442 / 25 m/984.25", 10 rolls)
AC ADAPTER 9443-01 (for 9442, Japan)
AC ADAPTER 9443-02 (for 9442, EU)

9443-02 (for EU)

9443-01 (for Japan)

Note: Company names and Product names appearing in this catalog are trademarks or registered trademarks of various companies.

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HIOKI

INSTRUCTION MANUAL

3532-50

LCR HiTESTER

HIOKI E. E. CORPORATION

Contents

Introduction i
Shipping Check ii
Safety iii
⚠ Points for Attention During Use v
Layout of This Manual vi

Chapter 1 Product Overview 1

1.1 Product Overview 1
1.2 Product Features 2
1.3 Names and Functions of Parts 3

Chapter 2 Before Starting Measurement 7

⚠ 2.1 Connecting the Power Cord 7
⚠ 2.2 Connecting the Test Leads 8
2.2.1 Establishing the Connections 8
2.3 Turning the Power On and Off 10

Chapter 3 Outline of Operation 11

3.1 About the Touch Panel 11
3.2 About the Screen 12
3.2.1 Control Screen Sequence 14
3.3 Basic Measurement 15
3.3.1 Basic Flow up to Testing of the Sample 15
3.3.2 Setting the Test Parameters to be Displayed (Cs, D) 16
3.3.3 Setting the Test Frequency 18
3.3.4 Setting the Constant Voltage Level 21
3.3.5 Setting Open Circuit Compensation 23
3.3.6 Setting Short Circuit Compensation 26
3.3.7 Starting Testing 28

Chapter 4 Detailed Description of Functions 29

4.1 Description of the Screens 29
4.1.1 The Initial Screen 30
4.1.2 The Menu Screen and Application Menu Screen 31
4.2 Setting the Parameters to be Displayed 32
4.2.1 Control Screen Sequence 32
4.2.2 Details of the Setting Process 32
4.2.3 Series Equivalent Circuit Mode and Parallel Equivalent Circuit Mode 34

4.3 Setting the Test Frequency 35
4.3.1 Control Screen Sequence 35
4.3.2 Selecting the Input Method 36
4.3.3 Input Using the Ten Key Screen 37
4.3.4 Input Using the Digit Screen 38
4.4 Setting the Test Signal Level 39
4.4.1 Control Screen Sequence 39
4.4.2 Selecting the Level Type 40
4.4.3 Setting the Open Circuit Voltage (V) Level 42
4.4.4 Setting the Constant Voltage (CV) Level 43
4.4.5 Setting the Constant Current (CC) Level 44
4.5 Setting the Voltage/Current Limit 45
4.5.1 Control Screen Sequence 45
4.5.2 Details of the Setting Process 46
4.6 Setting the Ranging 48
4.6.1 Control Screen Sequence 48
4.6.2 Setting the Ranging 49
4.6.3 Setting AUTO Ranging 49
4.6.4 Setting the Ranging to HOLD 50
4.7 Open Circuit Compensation 52
4.7.1 Control Screen Sequence 52
4.7.2 Setting the Compensation Method 53
4.7.3 ALL Compensation 54
4.7.4 Spot Compensation 56
4.7.5 When an Error Message Appears and Compensation Has Stopped 59
4.7.6 Clearing Compensation Data 59
4.8 Short Circuit Compensation 60
4.8.1 Control Screen Sequence 60
4.8.2 Setting the Compensation Method 61
4.8.3 ALL Compensation 63
4.8.4 Spot Compensation 65
4.8.5 When an Error Message Appears and Compensation Has Stopped 68
4.8.6 Clearing Compensation Data 68
4.9 Open Circuit Compensation and Short Circuit Compensation 69
4.10 Setting the Trigger 71
4.10.1 Control Screen Sequence 71
4.10.2 Details of the Setting Process 72

4.11 Setting the Trigger Delay 74
4.11.1 Control Screen Sequence 74
4.11.2 Details of the Setting Process 75
4.12 Setting Averaging 77
4.12.1 Control Screen Sequence 77
4.12.2 Details of the Setting Process 78
4.13 Setting the Testing Speed 80
4.13.1 Control Screen Sequence 80
4.13.2 Details of the Setting Process 81
4.14 Setting the Measurement Cable Length 82
4.14.1 Control Screen Sequence 82
4.14.2 Details of the Setting Process 83
4.15 Setting and Activating the Comparator 84
4.15.1 Control Screen Sequence 85
4.15.2 Setting the Comparator 85
4.15.3 Returning from Comparator Operation to Normal Testing 88
4.15.4 Choosing How to Set the Upper and Lower Limit Values 88
4.15.5 Setting the Upper or Lower Limit Value as an Absolute Value (ABS) 90
4.15.6 Setting the Upper or Lower Limit Value as a Percentage (%) Relative to a Standard Value 92
4.15.7 Displaying Measurement Values as Deviations from the Reference Value (Δ%) 95
4.16 Setting and Activating the Scaling 97
4.16.1 Control Screen Sequence 97
4.16.2 Setting Scaling 98
4.16.3 Canceling the Scaling Function 99
4.16.4 Setting the Compensation Coefficient (a, b) 100
4.17 Panel Save Function 102
4.17.1 Control Screen Sequence 102
4.17.2 Details of the Setting Process 103
4.18 Panel Load Function 106
4.18.1 Control Screen Sequence 106
4.18.2 Details of the Setting Process 107
4.19 Setting the Beep Sound 109
4.19.1 Control Screen Sequence 109
4.19.2 Details of the Setting Process 110
4.20 Enlarged Display of Measurement Values 111
4.20.1 Control Screen Sequence 111
4.20.2 Details of the Setting Process 112

4.21 System Reset 113
4.21.1 Control Screen Sequence 113
4.21.2 Details of the Setting Process 114
4.22 Continuous Test Function 116
4.22.1 Control Screen Sequence 116
4.22.2 Details of the Setting Process 117
4.23 Setting the Number of Displayed Digits 120
4.23.1 Control Screen Sequence 120
4.23.2 Details of the Setting Process 121
4.24 Setting for Display 122
4.24.1 Control Screen Sequence 122
4.24.2 Details of the Setting Process 123
4.25 Key Lock Function 124
4.25.1 Turning the Key Lock On and Off 124

Chapter 5 Applications 125

5.1 Example of Comparator Application 125
5.2 Testing High Impedance Elements 127
5.3 Testing an Element in a Circuit 128
5.4 External Interference 129
5.4.1 Countermeasures Against Interference from the Power Supply Line 129
5.4.2 Countermeasures Against Noise from the Test Cables 131
⚠ 5.5 The EXT I/O Connector 132
5.5.1 Pinouts for the EXT I/O Connector 132
5.5.2 Signal Lines for the EXT I/O Connector 133
5.5.3 Circuit Construction and Connections for the EXT I/O Connector 135
5.5.4 Electrical Characteristics of the Output Signals 136
5.6 Testing Using EXT I/O 137
5.6.1 Normal Testing 137
5.6.2 Test on the Continuous Test Screen 138
5.7 Supplying DC Bias 140
5.7.1 How to Supply a DC Bias Voltage 141
5.7.2 How to Supply a DC Bias Current 142
5.8 The Residual Charge Protection Function 143

5.9 9442 Printer (option) 144
5.9.1 Preparation 144
5.9.2 Connection Method 146
5.9.3 Control Screen Sequence 147
5.9.4 Returning from Comparator Operation to Normal Testing 148
5.9.5 Screen Copy Mode 149
5.9.6 Auto Print Mode 150
5.9.7 Manual Print Mode 150

Chapter 6 Maintenance, Adjustment, and Disposal 151

6.1 Maintenance and Servicing 151
⚠ 6.2 How to Change the Power Supply Fuse and Change the Power Supply Voltage 153
6.3 Shipping the Unit 155
6.4 Troubleshooting 156
6.5 Disposing of the Unit 157

Chapter 7 Specification and Options 159

7.1 General Specification 159
7.2 Testing Parameters and Calculation Equations 164
7.3 Time Taken for Testing 166
7.4 Options 169
7.5 Test Accuracy 172

Index ..... INDEX 1

Introduction

Thank you for purchasing the HIOKI "3532-50 LCR HiTESTER." To obtain maximum performance from the product, please read this manual first, and keep it handy for future reference.

This manual contains information and points for attention which are necessary for safe operation of the unit and for storing it safely in proper operational condition.

Shipping Check

When you receive the product, inspect it carefully to ensure that no damage occurred during shipping. In particular, check the accessories, panel switches, and connectors. If damage is evident, or if it fails to operate according to the specifications, contact your dealer or Hioki representative.

Check the 3532-50 unit and the supplied accessories

Main unit

3532-50 LCR HiTESTER

Supplied accessories

(1) Instruction manual ... 1

(2) Grounded power cord ... 1

(3) Spare fuse for power supply (according to voltage specification) ... 1
100 V, 120 V setting: 250 V F1.0AL 20 mm x 5 mm dia.
220 V, 240 V setting: 250 V F0.5AL 20 mm x 5 mm dia.

NOTE

No interface boards and no test cables are supplied with the unit as standard equipment. You should order them separately, according to requirements.

Safety

This manual contains information and warnings essential for safe operation of the product and for maintaining it in safe operating condition. Before using the product, be sure to carefully read the following safety notes.

⚠ WARNING

This product is designed to comply with IEC 61010 Safety Standards, and has been thoroughly tested for safety prior to shipment. However, mishandling during use could result in injury or death, as well as damage to the product. Be certain that you understand the instructions and precautions in the manual before use. We disclaim any responsibility for accidents or injuries not resulting directly from product defects.

The following symbols in this manual indicate the relative importance of cautions and warnings.

Safety symbols

	• The ⚠ symbol printed on the product indicates that the user should refer to a corresponding topic in the manual (marked with the ⚠ symbol) before using the relevant function. • In the manual, the ⚠ symbol indicates particularly important information that the user should read before using the product.
	Indicates a grounding terminal.
	Indicates AC (Alternating Current).
	Indicates a fuse.
	Indicates the ON side of the power switch.
	Indicates the OFF side of the power switch.

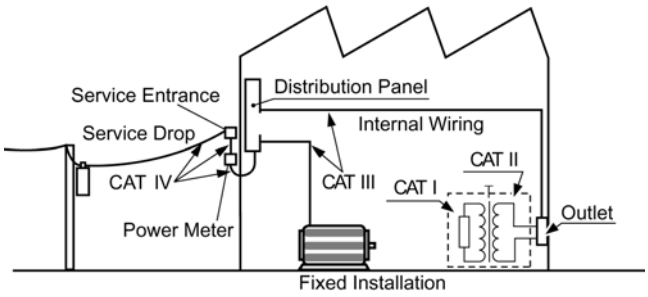
⚠ WARNING	Indicates that incorrect operation presents a significant hazard that could result in serious injury or death to the user.
⚠ CAUTION	Indicates that incorrect operation presents a possibility of injury to the user or damage to the product.
NOTE	Advisory items related to performance or correct operation of the product.

Measurement categories (Overvoltage categories)

This instrument complies with CAT I safety requirements.
To ensure safe operation of measurement instruments, IEC 61010 establishes safety standards for various electrical environments, categorized as CAT I to CAT IV, and called measurement categories. These are defined as follows.

CAT I Secondary electrical circuits connected to an AC electrical outlet through a transformer or similar device.
CAT II Primary electrical circuits in equipment connected to an AC electrical outlet by a power cord (portable tools, household appliances, etc.)
CAT III Primary electrical circuits of heavy equipment (fixed installations) connected directly to the distribution panel, and feeders from the distribution panel to outlets.
CAT IV The circuit from the service drop to the service entrance, and to the power meter and primary overcurrent protection device (distribution panel).

Higher-numbered categories correspond to electrical environments with greater momentary energy. So a measurement device designed for CAT III environments can endure greater momentary energy than a device designed for CAT II.
Using a measurement instrument in an environment designated with a higher-numbered category than that for which the instrument is rated could result in a severe accident, and must be carefully avoided.
Never use a CAT I measuring instrument in CAT II, III, or IV environments.
The measurement categories comply with the Overvoltage Categories of the IEC60664 Standards.



Points for Attention During Use

Follow these precautions to ensure safe operation and to obtain the full benefits of the various functions.

⚠ WARNING

- **Before turning the product on, make sure the source voltage matches that indicated on the product's power connector. Connection to an improper supply voltage may damage the product and present an electrical hazard.**
- **To avoid electric shock and ensure safe operation, connect the power cable to a grounded (3-contact) outlet.**
- **To avoid electric shock, do not remove the instrument's case. The internal components of the instrument carry high voltages and may become very hot during operation.**

⚠ CAUTION

- Various connectors are present on the outside of the 3532-50. Never connect any cable to any of these connectors without first turning off the power supply and removing the power cord. Moreover, check the connections carefully in order to avoid any chance of setting up a short circuit etc..
- If anything unusual happens during operation of the unit, turn off the power switch immediately and contact any HIOKI service facility for help, advice and service.
- This product should be installed and operated between 0℃ and 40℃ and 80% RH or less, and less than 2000 m height.
- The unit should always be stored in a range of temperature and humidity from -10℃ to 55℃, 80% RH or less.
- Do not store or use the product where it could be exposed to direct sunlight, high temperature or humidity, or condensation. Under such conditions, the product may be damaged and insulation may deteriorate so that it no longer meets specifications.
- To avoid damage to the product, protect it from vibration or shock during transport and handling, and be especially careful to avoid dropping.
- Do not use excessive force on the touch panel, and do not use sharp objects that could damage the touch screen.
- Before using the instrument, make sure that the insulation on the probes is undamaged and that no bare conductors are improperly exposed. Using the instrument in such conditions could cause an electric shock, so contact your dealer or Hioki representative for repair.
- Ventilation holes for heat radiation are provided on the side panels of the product. Leave sufficient space around the ventilation holes and install the product with the holes unobstructed. Installation of the product with the ventilation holes obstructed may cause a malfunction or fire.

About the guarantee

You should be aware that HIOKI cannot accept any responsibility directly or indirectly if the unit has been incorporated in some other system, or if it is resold to a third party.

Layout of This Manual

Chapter 1 Product Overview
Describes the product generally, and lists the parts and functions.

Chapter 2 Before Starting Measurement
How to connect the power cord etc., and important precautions before operation.

Chapter 3 Outline of Operation
Explains the touch panel and basic testing.

Chapter 4 Detailed Description of Functions
Detailed explanation of the functions.

Chapter 5 Detailed Description of Applications
Various testing applications.

Chapter 6 Maintenance, Adjustment, and Disposal

Chapter 7 Specification and Options

Index

Chapter 1
Product Overview

1.1 Product Overview

The HIOKI 3532-50 LCR HiTESTER is an impedance meter which uses a touch panel as the user interface. This interactive touch panel enables extremely easy operation. The test frequency can be set from 42 Hz to 5 MHz at high resolution.

The values of a maximum of any four of the fourteen test parameters, including not only impedance $|Z|$ and phase angle θ, but also L, C, and R etc., can be simultaneously displayed upon the screen.

Moreover, this widely applicable impedance meter can be set, not only to a floating voltage setting, but also to a constant voltage setting or a constant current setting.

1.2 Product Features

■ Wide range of test frequencies

The test frequency can be selected from a wide range - 42 Hz to 5 MHz - at high resolution (Three-digit resolution for not more than 100 Hz, and four-digit resolution for not more than 5 MHz). Frequency dependent assessment of electronic components and materials, etc., is possible.

■ Constant voltage and constant current testing

Assessment of dependence upon voltage or current is possible.

■ Outstanding operability

All control operations are initiated via a touch panel on the display. All the keys currently available for use are shown on the display, and can be operated interactively.

■ Simultaneous display of four parameters

Up to four of the test parameters (such as L,C,R, etc.) can be displayed simultaneously.

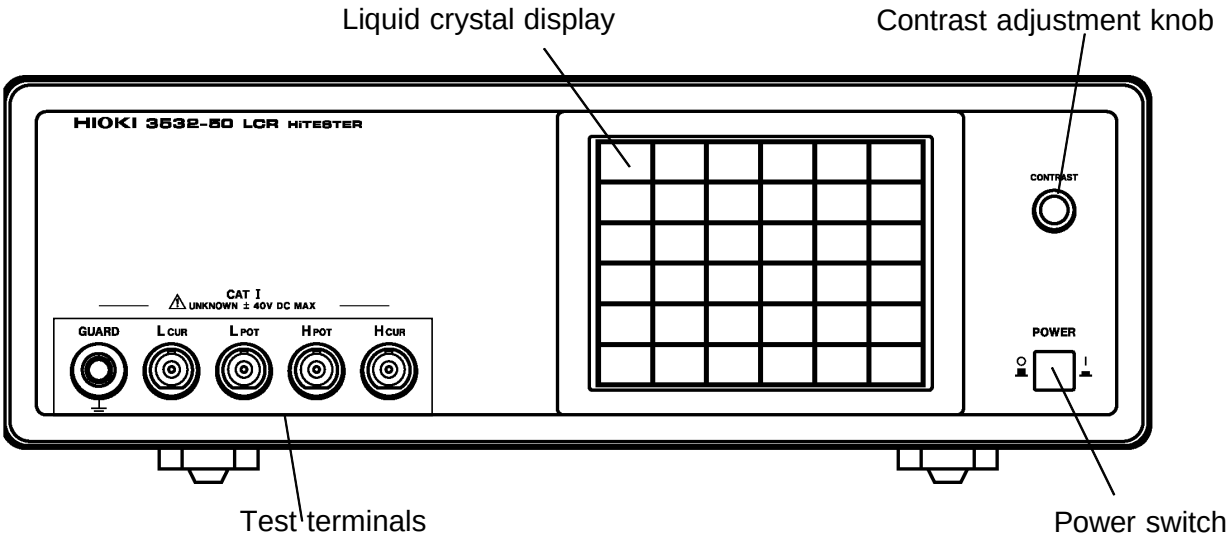
■ Interface

Using a computer, any required parameters can be captured

■ Changing settings without stopping measurement

Various background settings can be changed without stopping measurement (when an internal trigger is set).

1.3 Names and Functions of Parts



Front View

Liquid crystal display

This is a 5-inch liquid crystal display fitted with a touch panel. It also serves to provide input keys.

Power switch

Turns the power for the unit on and off.

Contrast adjustment knob

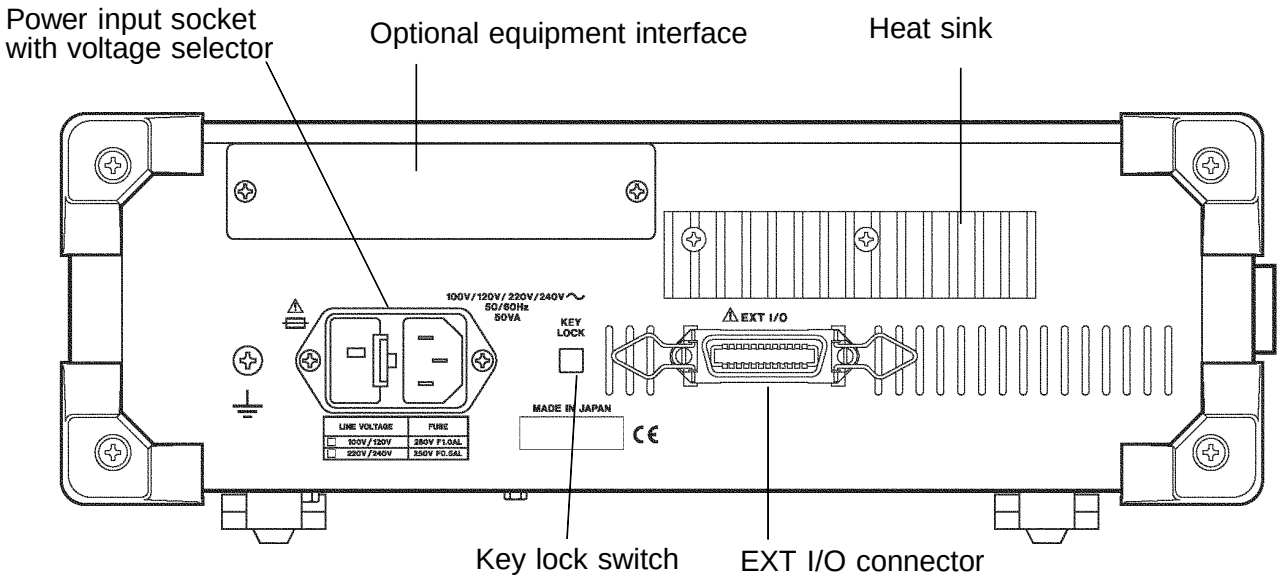
This knob adjusts the screen contrast. Turning it clockwise decreases the contrast, and vice versa.

Test terminals

There are five test terminals:

H_{CUR}	The test signal is supplied to this terminal.
H_{POT}	Detected voltage high terminal
L_{POT}	Detected voltage low terminal
L_{CUR}	Test current detected terminal
GUARD	Guard terminal

These test terminals are designed according to the safety standard; Pollution Degree 2, Measurement category I.



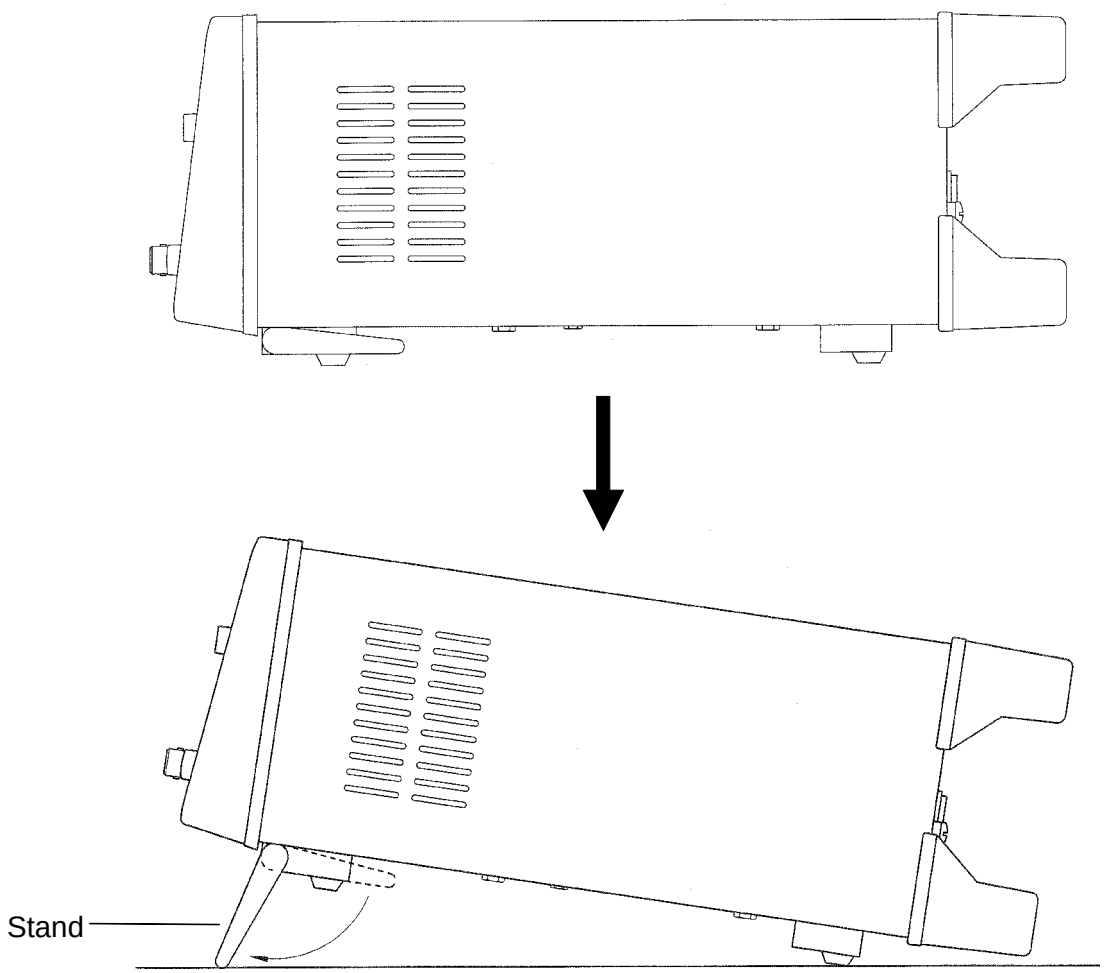
Rear View

Power input socket (internally fused type) with voltage selector
Connect the supplied power cord here.

Optional equipment interface
Optional interface boards are connected here.

EXT I/O connector
For input of an external trigger signal and output of comparator results. Compatible with sequencer connection.

Key lock switch
Puts the touch panel keys into the input-not-accepted state.

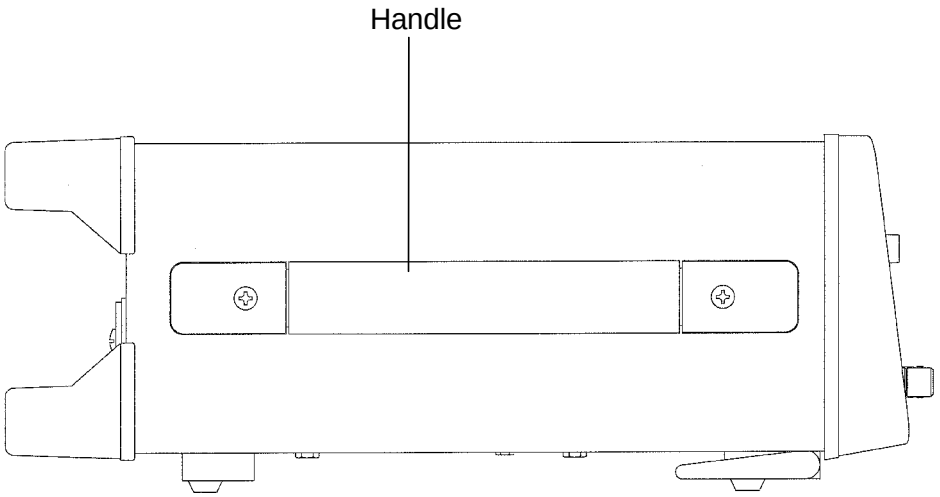


Right View

Stand
Can be opened to tilt the unit upwards.

⚠ CAUTION

Do not apply strong downward pressure with the stand extended.
Damage to the stand will result.



Left View

Handle
Used when carrying the unit.

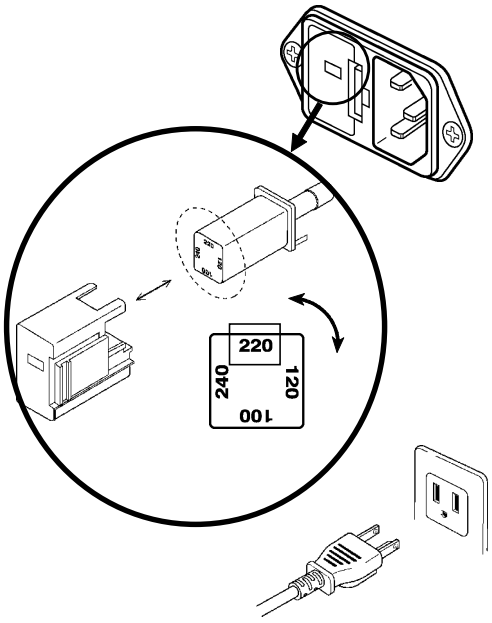
2

Chapter 2
Before Starting Measurement

2.1 Connecting the Power Cord

⚠ WARNING

- **When a 3532-50 unit is ordered, the supply voltage is set in the factory to the value specified, which can be 100 V, 120 V, 220 V, or 240 V.**
  The maximum rated power (with all options fitted) is 50 VA.
- **Before turning the product on, make sure the source voltage matches that indicated on the product's power connector. Connection to an improper supply voltage may damage the product and present an electrical hazard.**
- **The power supply voltage for this product is switchable. To avoid electrical accidents, check that the voltage selector is set correctly for the supply voltage you are using. (For details, refer to Section 6.2)**
- **To avoid electric shock and ensure safe operation, connect the power cable to a grounded (3-contact) outlet.**



The power cord is connected according to the following procedure.

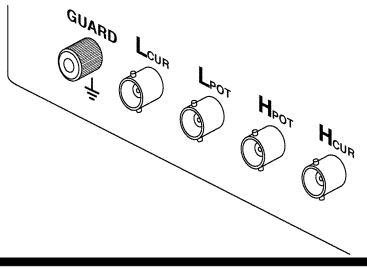
1. Check that the main power switch of the unit is off.
2. Check that the power supply voltage is correct, and connect the proper end of the power cord to the power input socket (with voltage selector) at the rear of the unit.
3. Plug the other end of the power cord into the power supply socket.

Grounding

Use the grounding type (three-wire) power cord supplied. The unit will be grounded automatically.

2.2 Connecting the Test Leads

The 3532-50 has five test terminals: H_{CUR} terminal (to which the test signal is supplied); H_{POT} terminal (detected voltage high terminal); L_{POT} terminal (detected voltage low terminal); L_{CUR} terminal (test current detected terminal), and GUARD terminal (connected to the chassis of the unit).

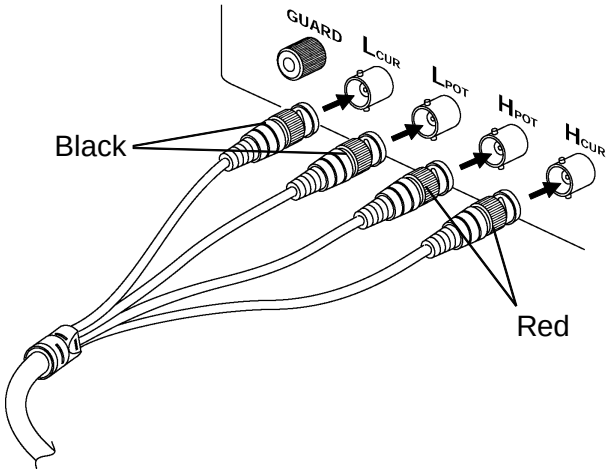


2.2.1 Establishing the Connections

⚠ CAUTION

- Using a low frequency to measure capacitors with a particular polarity (for example, electrolytic capacitors) results in a reverse bias being applied. In some cases this could damage or destroy the capacitor, and therefore a DC bias should always be applied while making the measurements. Also be sure that the positive terminal of the capacitor is connected to the Hcur terminal on this unit.
- The maximum voltage which can be applied to the test terminals of the 3532-50 unit is 40 V DC. If a DC voltage greater than this is applied continuously, the unit may be damaged. (For how to apply a DC bias voltage, refer to Section 5.7, "Supplying DC Bias")

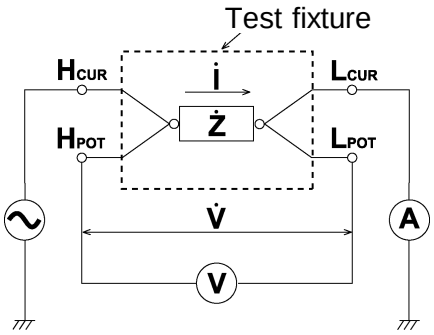
If using a test lead set supplied by HIOKI, connect the red leads to the H_{CUR} terminal and to the H_{POT} terminal, and connect the black leads to the L_{CUR} terminal and to the L_{POT} terminal.



The unit is designed and adjusted for 75 Ω coaxial cable test leads. It is best to use HIOKI test leads.

NOTE

- The connections to the article to be tested are as shown in the following figure.

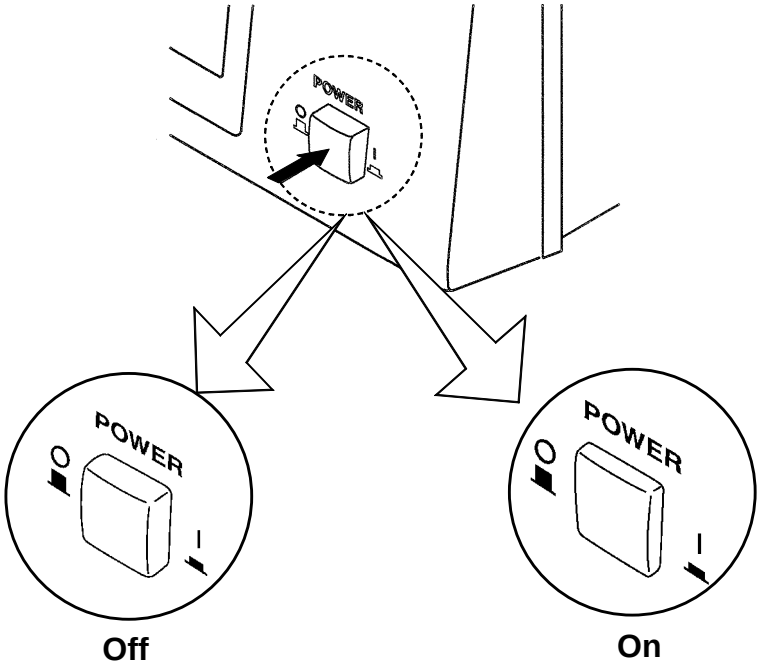


- No test cables are included with the 3532-50 unit. They must be purchased separately. (For details, refer to Section 7.4, "Options")
- If all four terminals are left floating, the numbers which appear on the display are completely meaningless.

2.3 Turning the Power On and Off

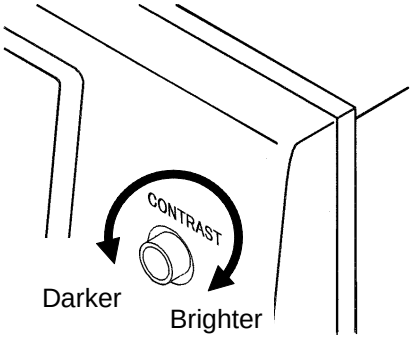
How to turn the power on

1. Turn on the power switch on the front panel. The Initial screen will be displayed on the liquid crystal display.



The test conditions will start off the same as they were when last the power was turned off.

2. Adjust the contrast knob so as to make the display as easy to see as possible.



3. Wait for 60 minutes after turning on the power before starting testing, so as to allow the unit to warm up fully.

How to turn the power off

Turn off the power switch on the front panel. The test conditions will be preserved.

NOTE

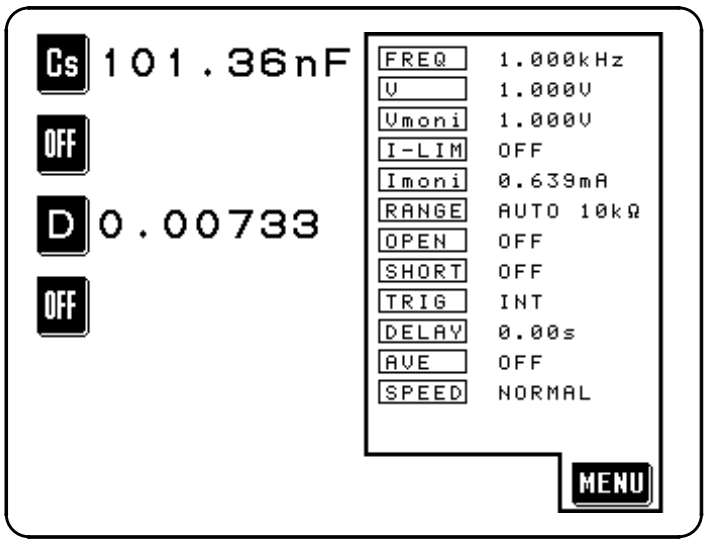
Even if the power supply is interrupted because of a power failure or the like, the test conditions (settings) will not be lost; when the power is turned on again, the unit will return to its state just before the interruption.

Chapter 3
Outline of Operation

3.1 About the Touch Panel

⚠ CAUTION Do not use excessive force on the touch panel, and do not use sharp objects that could damage the touch screen.

The 3532-50 uses a touch panel for setting and changing all of the test conditions. Simply by touching the LCD screen at certain areas - termed soft keys - which appear in reverse video, the items associated with these soft keys, and numerical values, can be selected.
In this manual, lightly touching a soft key area on the screen is termed "pressing" a key.

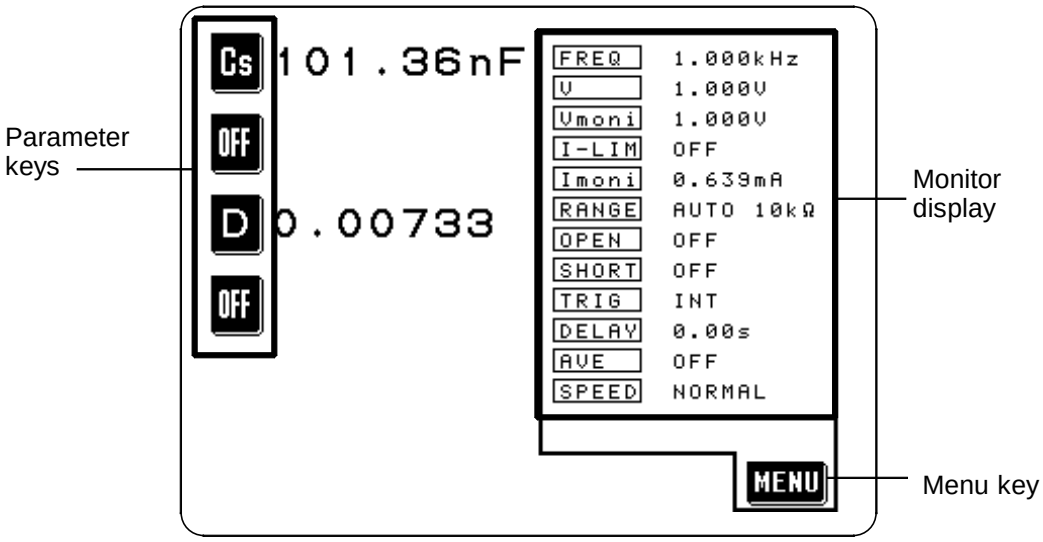


Initial Screen

3.2 About the Screen

(1) The Initial screen

- When the power is first turned on, the basic screen for controlling the 3532-50 immediately appears, called the "Initial screen". A maximum of four of the test parameters (L, C, *R*, etc.) can be set for display, and all of the test conditions can be checked, on this Initial screen.
- The Menu screen can be displayed by pressing the MENU key.
- The Parameter setting screen can be displayed by pressing a parameter key.

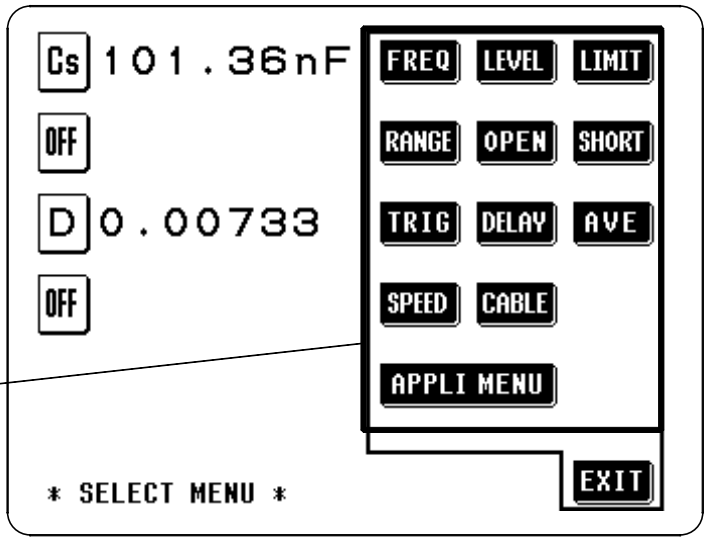


Initial Screen

For details, refer to Section 4.1.1, "The Initial Screen."

(2) The Menu screen

The Menu screen is used for selecting whichever of the test conditions you want to change. Pressing one of the keys on this screen changes over the display to the appropriate test condition setting screen.

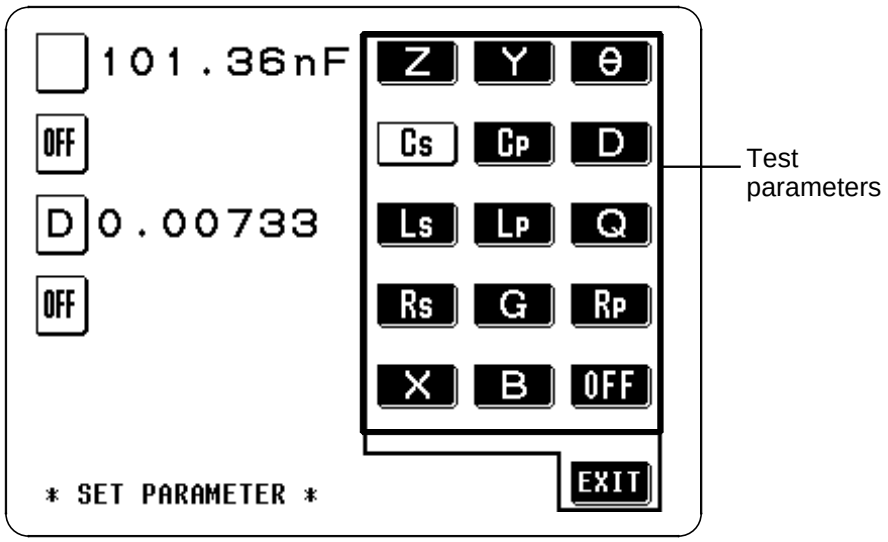


Menu Screen

For details, refer to Section 4.1.2, "The Menu Screen and Application Menu Screen"

(3) The Parameter setting screen

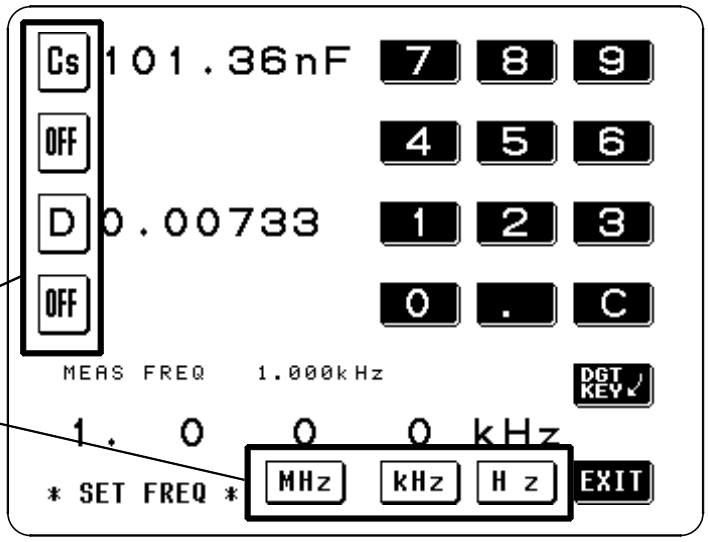
- Pressing a parameter key on the Initial screen causes the Parameter setting screen to be displayed, using which the test parameters to be displayed (up to a maximum of four) are selected.
- By pressing a key for any test parameter, that parameter is set to be displayed, and the unit automatically returns to displaying the Initial screen again.



Parameter Setting Screen

(4) The Test condition setting screen

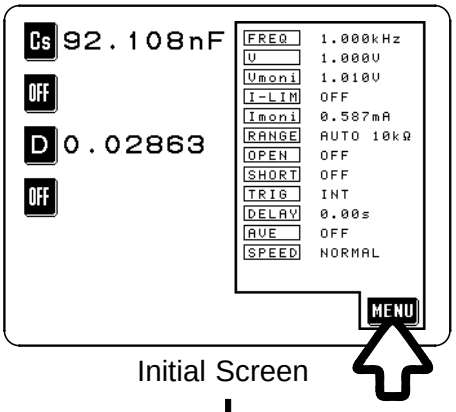
- This screen is for changing a test condition (for example, the test frequency).
- When you have finished setting the test condition, press the EXIT key, and the unit will return to displaying the Initial screen again.



Test Condition Setting Screen
(Test frequency setting screen)

3.2.1 Control Screen Sequence

- The basic flow for the change of screens as control operation is performed is as follows.
- The measurement values can be checked in real time on all of the screens.

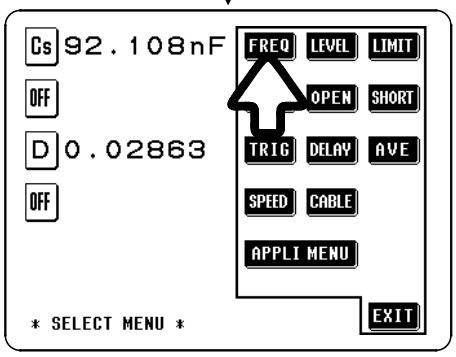


Initial Screen

The measured values of any of the test parameters can be displayed for checking (up to a maximum of four) and all of the test conditions can be checked on the Initial screen.

To make a change to the test conditions:

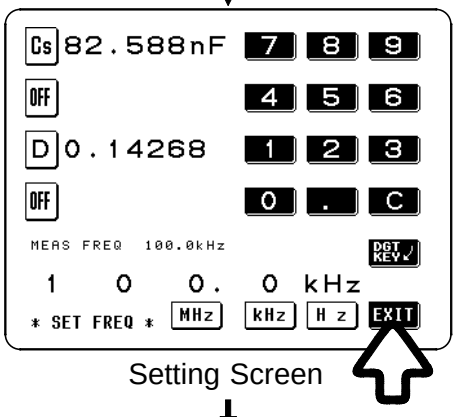
Press the MENU soft key, and the Menu screen will be displayed.



Menu Screen

Select the test condition to alter on the Menu screen (for example, when changing the test frequency).

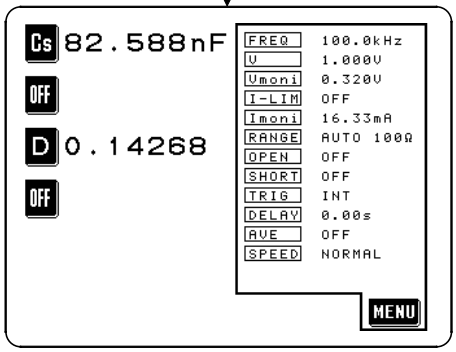
Press the FREQ soft key, and the Frequency setting screen will be displayed.



Setting Screen

Set or change that test condition on the appropriate Test condition setting screen.

When the test condition setting is complete, press the EXIT soft key, and the display will return to displaying the Initial screen.



Initial Screen

3.3 Basic Measurement

In order to explain the basic operation of the 3532-50 unit, as an example, the procedure will be shown for establishing the following settings:

Example

Sample to be tested
- Capacitor: 0.1 µF

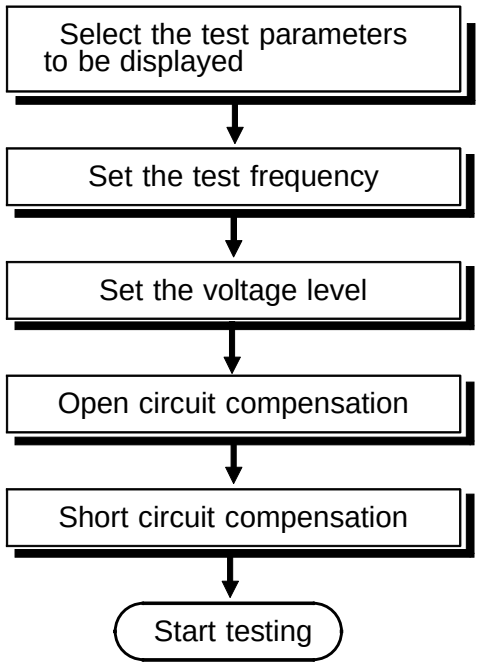
Test conditions
- Test frequency: 100 kHz
- Constant voltage level: 0.4 V
- Open circuit compensation setup: ALL compensation
- Short circuit compensation setup: ALL compensation

Parameters to be displayed
- Capacitance Cs, Loss coefficient D

NOTE The trigger is internal. The 3532-50 unit, when it is dispatched from the factory, is in the internal trigger state.

3.3.1 Basic Flow up to Testing of the Sample

The basic flow up to starting testing of the sample is as shown in the following chart in correspondence to the applicable reference sections:



Reference sections

3.3.2, "Setting the Test Parameters to be Displayed (Cs, D)"

3.3.3, "Setting the Test Frequency"

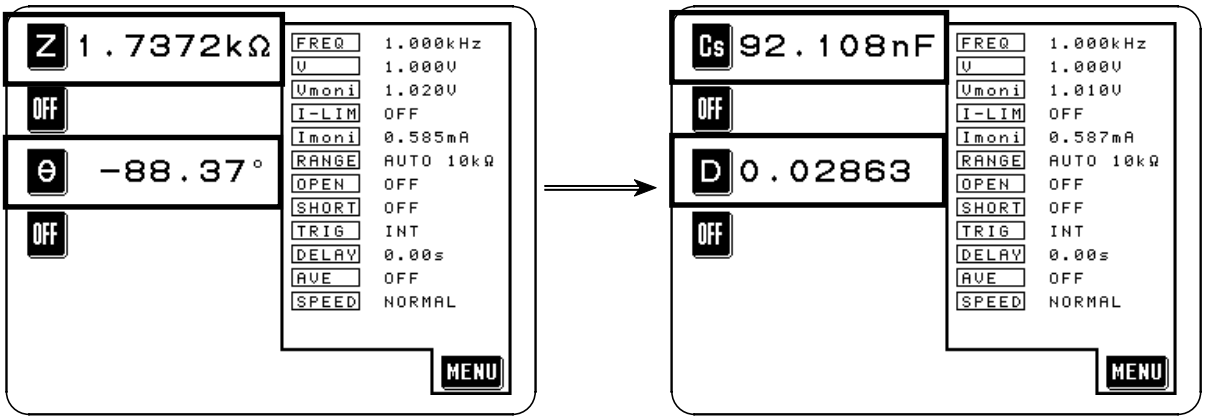
3.3.4, "Setting the Constant Voltage Level"

3.3.5, "Setting Open Circuit Compensation"

3.3.6, "Setting Short Circuit Compensation"

3.3.2 Setting the Test Parameters to be Displayed (Cs, D)

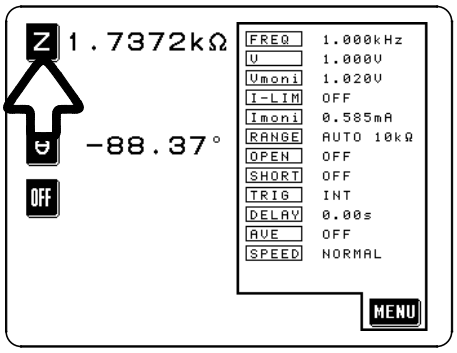
Here the first (i.e., the uppermost) parameter key will be set to capacitance Cs, and the third parameter key will be set to loss coefficient D.



Before Setting

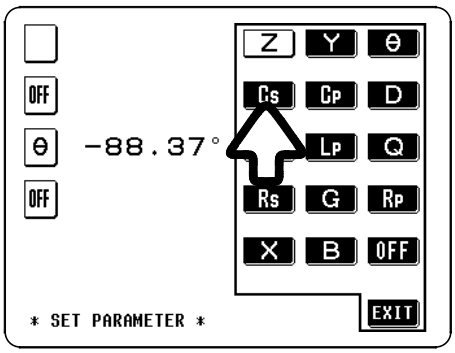
After Setting

Setting procedure



Initial Screen

1. In order to change the first parameter displayed on the Initial screen, press the first (uppermost) parameter key.



Parameter Setting Screen

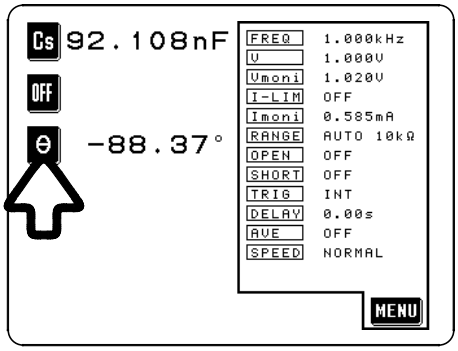
2. The Parameter setting screen is displayed. (The test parameter (currently *Z*) to which the pressed parameter key currently corresponds is shown in black characters on a white ground, i.e. in non-reversed video).

Press **Cs** on this screen, and the display will automatically return to displaying the Initial screen, with capacitance Cs being displayed as the first parameter.

If you press the **EXIT** key on this screen without pressing **Cs**, no new setting is performed, and the display just returns to displaying the Initial screen.

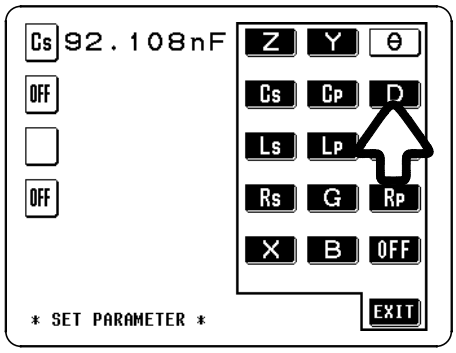
NOTE

Any of the test parameters (*Z*, L, C, *R*, etc.) (up to a maximum of four) can be set to correspond to any of the four parameter keys.



Initial Screen

3. In order to change the third parameter displayed on the Initial screen, press the third parameter key.

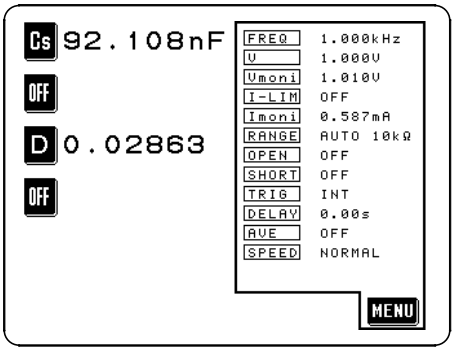


Parameter Setting Screen

4. The Parameter setting screen is displayed. Press D on this screen, and the display will automatically return to displaying the Initial screen, with the loss coefficient D being displayed as the third parameter.

NOTE

If you press the OFF key, instead of pressing a soft key corresponding to any one of the test parameters, then the display of the test parameter to which the third parameter key currently corresponds will be canceled.



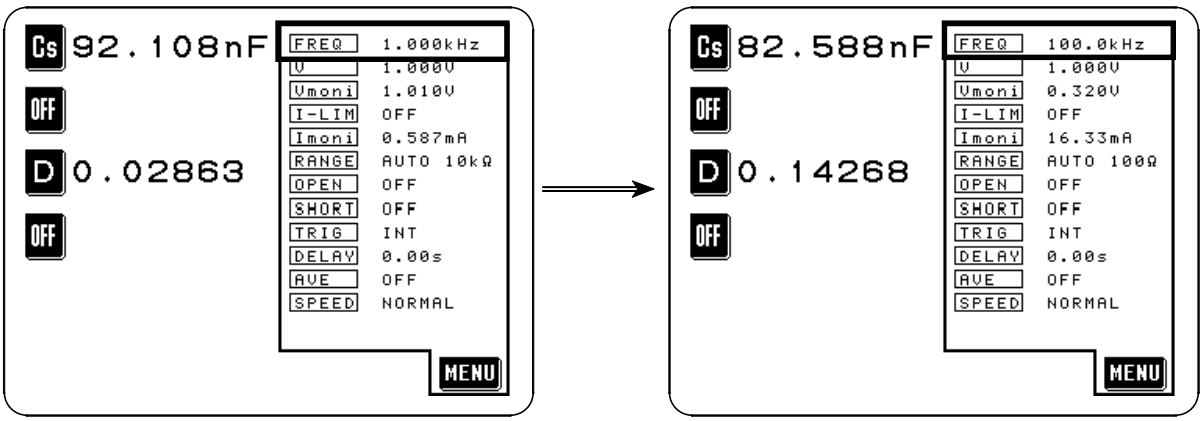
Initial Screen

5. Now the Initial screen is displaying the values of the parameters Cs and D.

For details, refer to Section 4.2, "Setting the Parameters to be Displayed".

3.3.3 Setting the Test Frequency

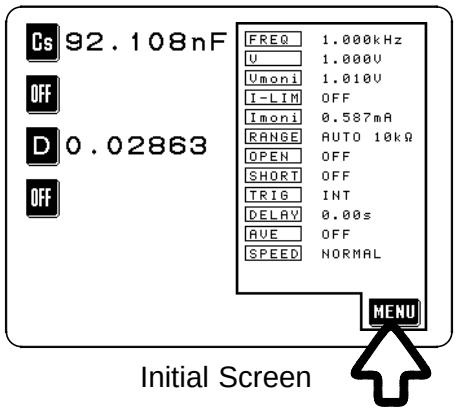
The following explanation shows how to set the test frequency to 100 kHz, as an example.



Before Setting

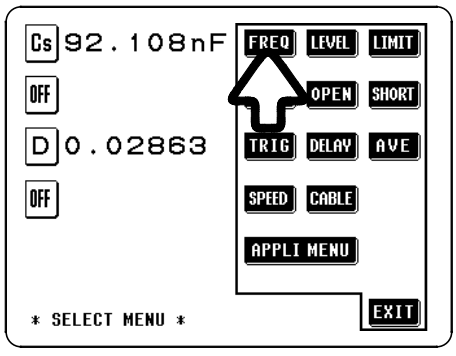
After Setting

Setting procedure



Initial Screen

1. On the Initial screen, press the MENU key, and the Menu screen will be displayed.



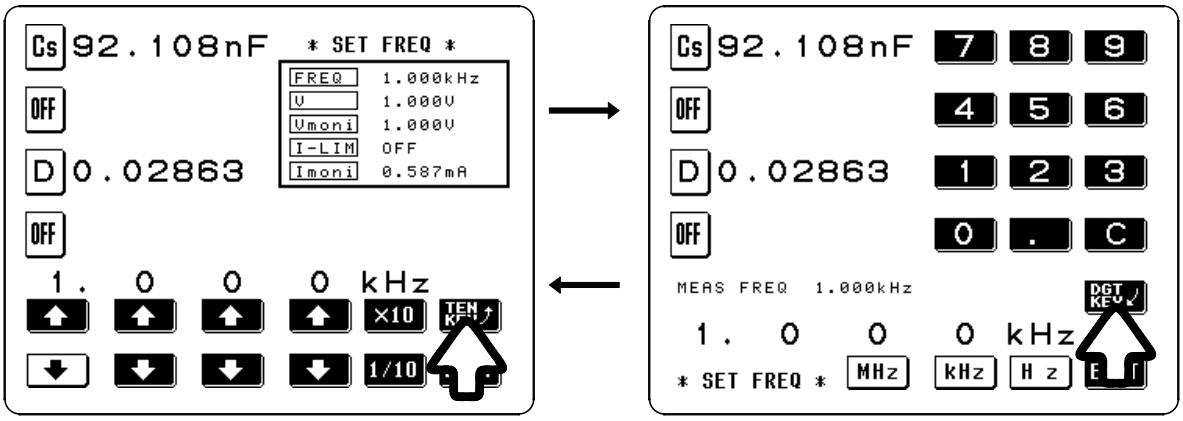
Menu Screen

2. Press the FREQ key on the Menu screen, and one of the frequency setting screens will be displayed.

There are actually two frequency setting screens. The display can be switched over between these two screens just by pressing a particular soft key.

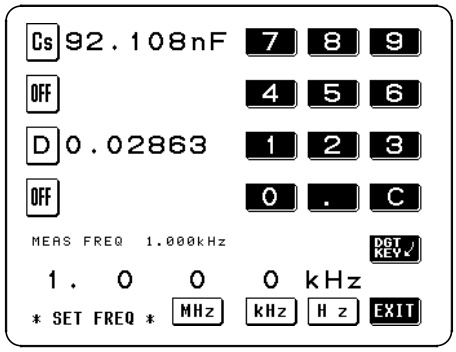
The Digit screen — The test frequency is input using the ▲ and ▼ digit keys.

The Ten key screen — A numerical value for the test frequency is input directly.



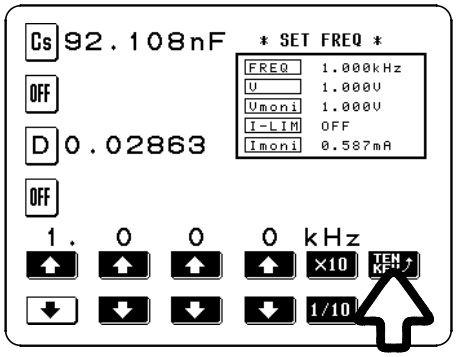
Digit Screen

Ten Key Screen



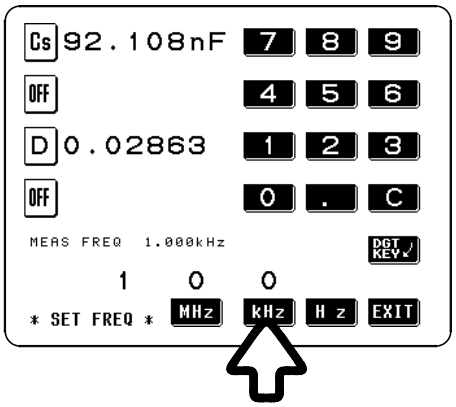
Ten Key Screen

- In this case, because it is desired to input the value 120 Hz for the test frequency directly as a numerical value, the Ten key screen is used.



Digit Screen

- When the Digit screen is being displayed, pressing the TEN KEY soft key causes the display to switch over to the Ten key screen.



Ten Key Screen

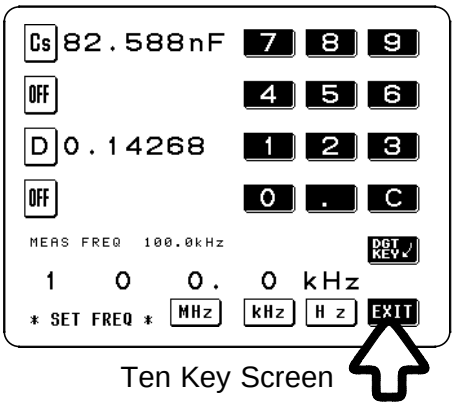
3. Press the keys 1, 0, and 0 in succession on the ten key pad.

If you make a mistake, press the C key to clear the value entered so far, and start again.

Then press the kHz key, and check that the test frequency value input is indeed 100 kHz.

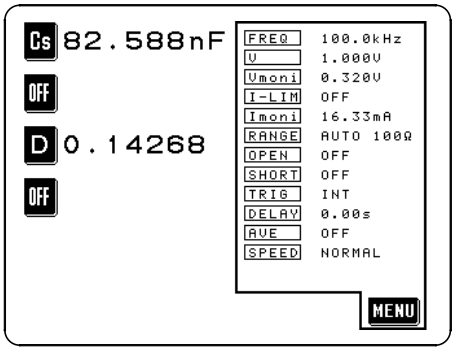
NOTE

The numerical value input for the test frequency cannot be checked until one of the keys MHz, kHz, and H z has been pressed.
If you press the EXIT key before pressing the H z key, the display will return to displaying the Initial screen with the previously set value for the test frequency still current.



Ten Key Screen

4. When the setting has been established as above, press the EXIT key, and the display will return to the Initial screen.

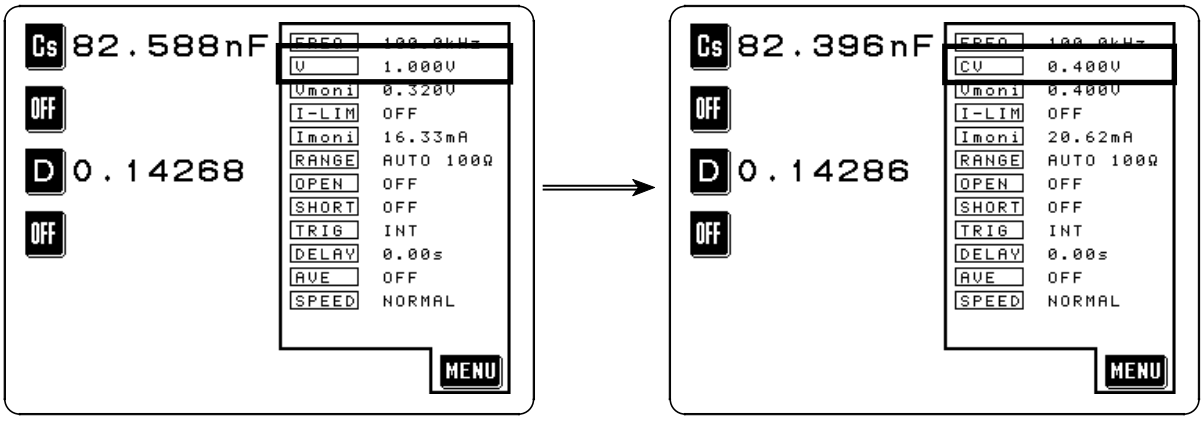


Initial Screen

For details, refer to Section 4.3, "Setting the Test Frequency".

3.3.4 Setting the Constant Voltage Level

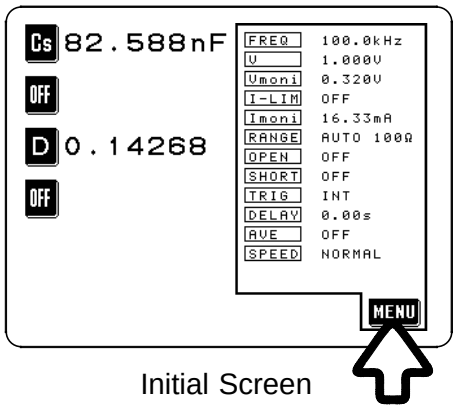
The following explanation shows, as an example, how to set the value for the constant voltage level to 0.4 V.



Before Setting

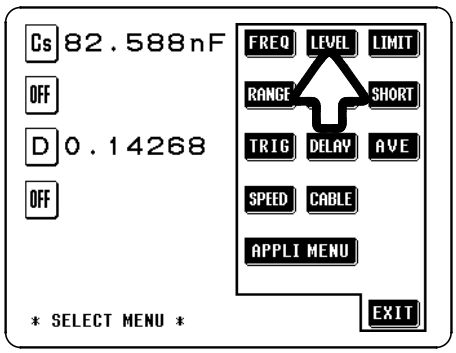
After Setting

Setting procedure



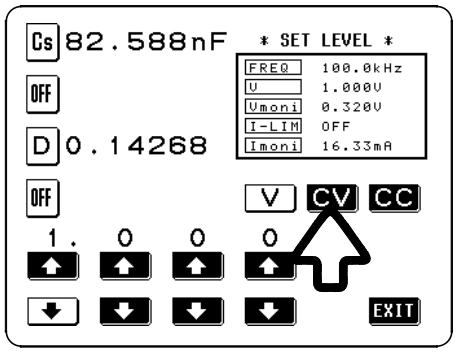
Initial Screen

1. On the Initial screen, press the MENU key, and the Menu screen will be displayed.



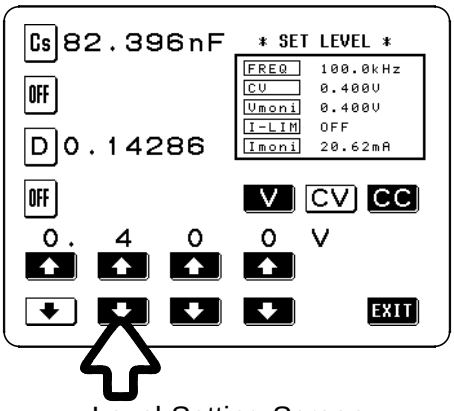
Menu Screen

2. Press the LEVEL key on the Menu screen, and the Level setting screen will be displayed.



Level Setting Screen

3. Because you for example want to set the value for the constant voltage (CV), press the CV key. Then check that the CV key changes to black figures on a white ground (i.e., in non-reversed video), which confirms that constant voltage has been properly selected.

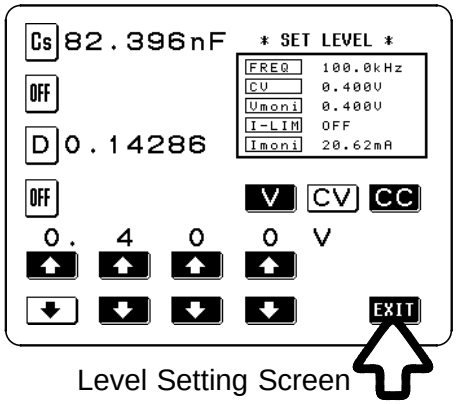


Level Setting Screen

4. Using the ▲ and ▼ keys, set the displayed constant voltage value to 0.400.

▲ The corresponding digit is increased. (If you hold this key down continuously, the corresponding digit increments continuously.)

▼ The corresponding digit is decreased. (If you hold this key down continuously, the corresponding digit decrements continuously.)

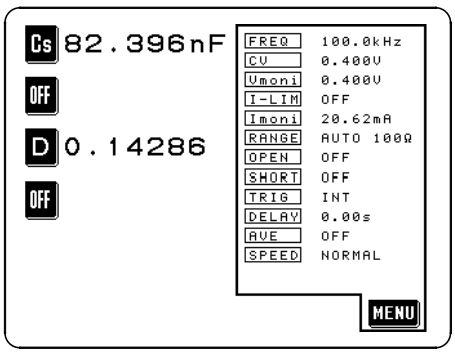


Level Setting Screen

5. When the setting has been established as above, press the EXIT key.

NOTE

- With this constant voltage (CV) setting, the testing will be performed with the voltage between the terminals of the sample being tested being kept constant at 0.400 V.
- The accuracy of this constant voltage:
  ±10%±10 mV (42 Hz to 1.000 MHz)
  ±20%±10 mV (1.001 MHz to 5.000 MHz)

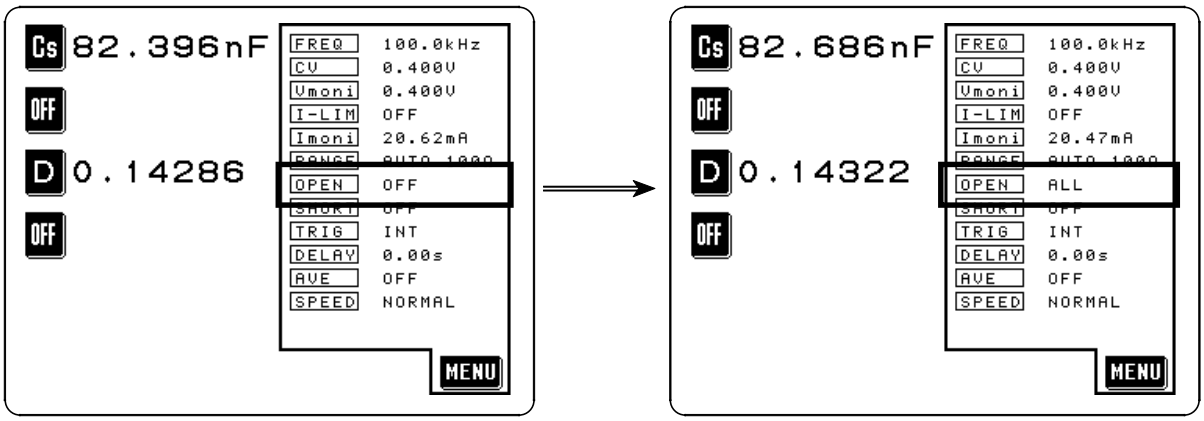


Initial Screen

For details, refer to Section 4.4, "Setting the Test Signal Level"

3.3.5 Setting Open Circuit Compensation

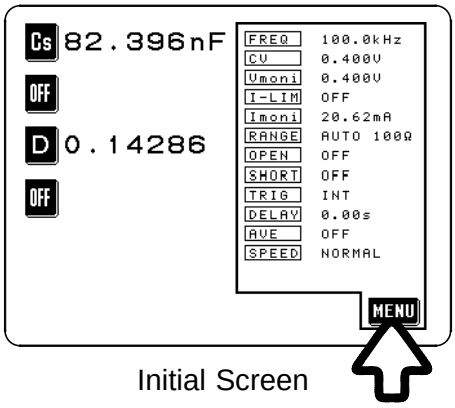
The following explanation shows, as an example, how to set up ALL open circuit compensation, with which open circuit compensation values for all of the test frequencies are determined and adjusted.



Before Setting

After Setting

Setting procedure

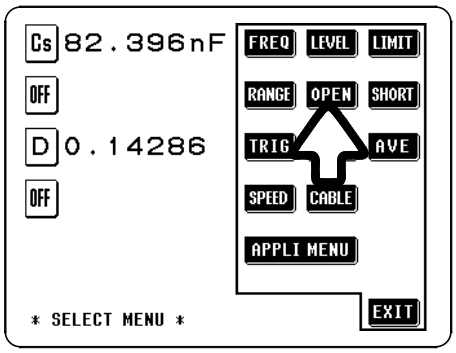


Initial Screen

1. Arrange the test leads as closely as possible to their configuration in which measurement will be performed, and make sure that the HIGH and LOW leads are not contacted together.

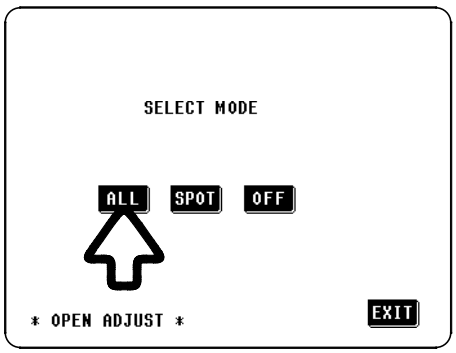
For details, refer to Section 4.7.2, "Selecting the Compensation Method".

2. On the Initial screen, press the MENU key, and the Menu screen will be displayed.



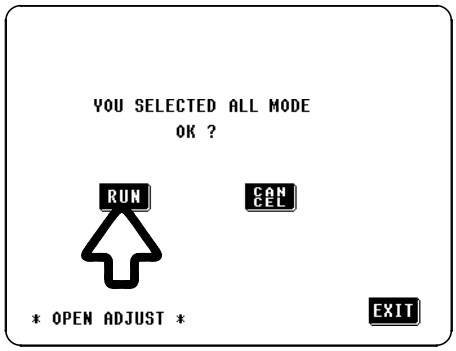
Menu Screen

3. Press the OPEN key on the Menu screen, and the Open circuit compensation screen will be displayed.



Open Circuit Compensation Screen

4. Press the ALL key so as to select ALL compensation, with which open circuit compensation values for all the test frequencies will be determined and adjusted.

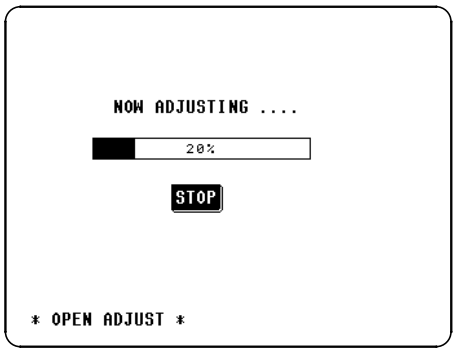


Confirmation Screen

5. A Confirmation screen will be displayed for confirmation of ALL open circuit compensation. If it is OK to proceed, press the RUN key.

NOTE

Check again - are the test leads definitely out of mutual contact ?

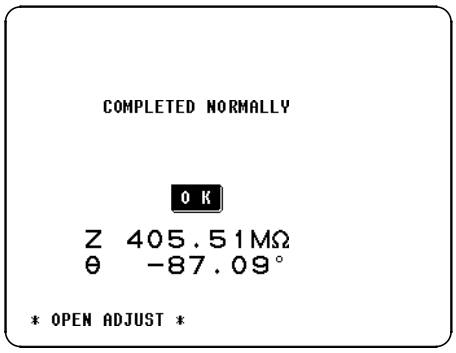


Data Determination Screen

6. When you press the RUN key, the ALL open circuit compensation process starts.

After about 2 minutes, the determination and adjustment of the open circuit compensation values is complete.

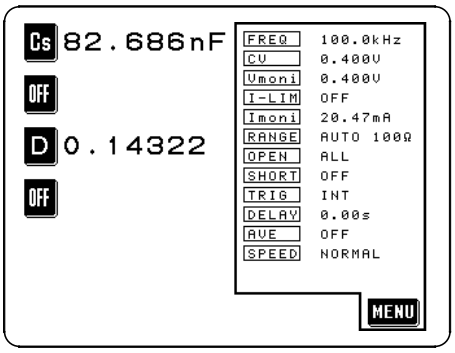
If an error message appears, refer to Section 4.7.5.



Confirmation Screen

7. If the compensation process has terminated satisfactorily, a Confirmation screen as shown to the left is displayed.

The residual component at the frequency of 5 MHz with the test cables separated (open circuited), and its phase angle, are shown on the screen. These values are required for use with the test range on HOLD.
(For details, refer to Section 4.9, "Open Circuit Compensation and Short Circuit Compensation".)



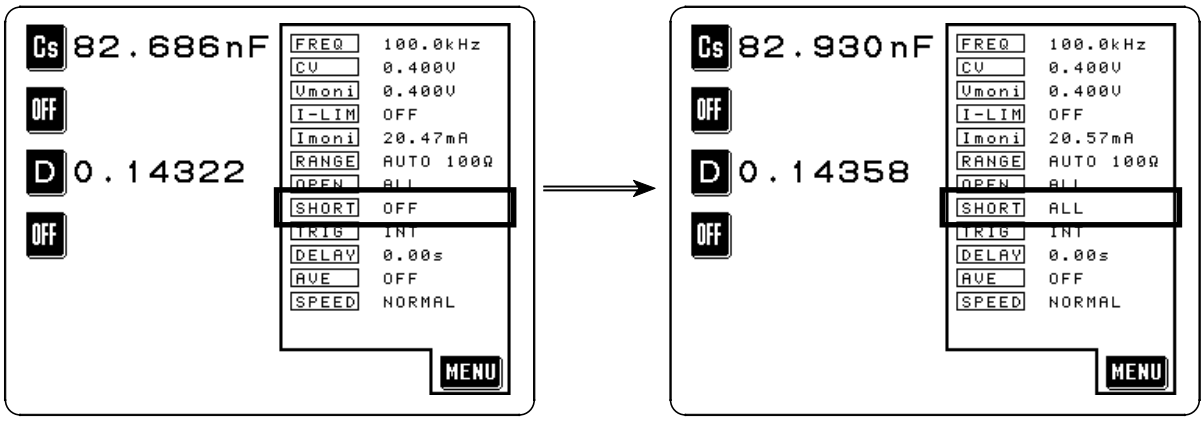
Initial Screen

8. After checking the open circuit residual component and its phase angle, press the O K key, and the display will return to the Initial screen.

For details, refer to Section 4.7, "Open Circuit Compensation".

3.3.6 Setting Short Circuit Compensation

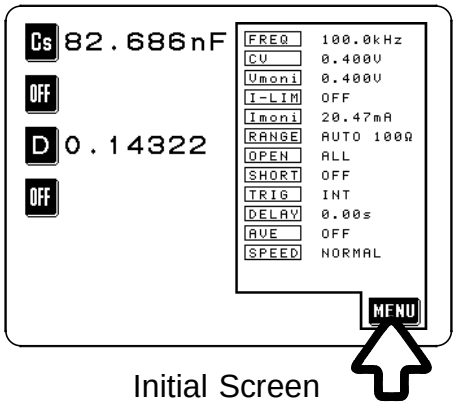
The following explanation shows, as an example, how to set up ALL short circuit compensation, with which short circuit compensation values for all of the test frequencies are determined and adjusted.



Before Setting

After Setting

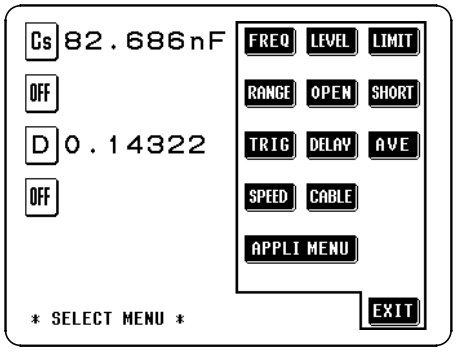
Setting procedure



Initial Screen

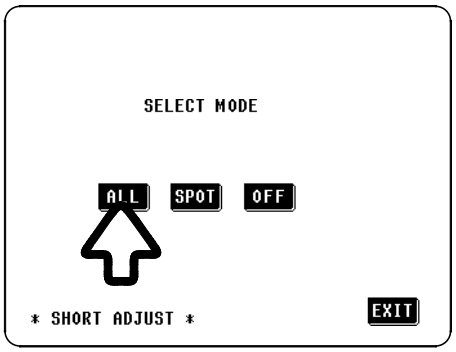
1. Arrange the test leads as closely as possible to their configuration in which measurement will be performed, and short circuit together the HIGH and LOW leads using a shorting bar.
(Refer to Section 4.8.2 for information about the shorting bar.)

2. On the Initial screen, press the MENU key, and the Menu screen will be displayed.



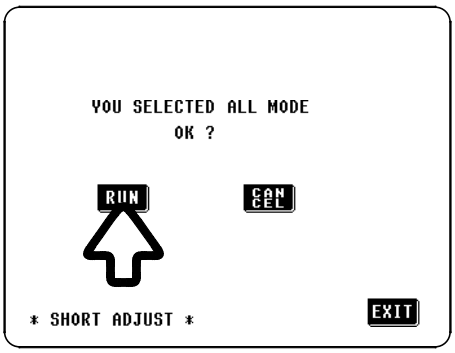
Menu Screen

3. Press the SHORT key on the Menu screen, and the Short circuit compensation screen will be displayed.



Short Circuit Compensation Screen

4. Press the ALL key so as for example to select ALL compensation, with which short circuit compensation values for all the test frequencies will be determined and adjusted.

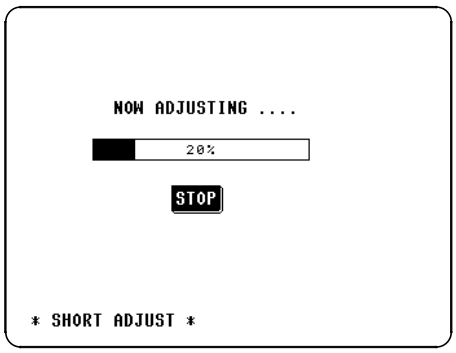


Confirmation Screen

5. A Confirmation screen will be displayed for confirmation of ALL short circuit compensation. If it is OK to proceed, press the RUN key.

NOTE

Check again - are the test leads properly short circuited together by the shorting bar?

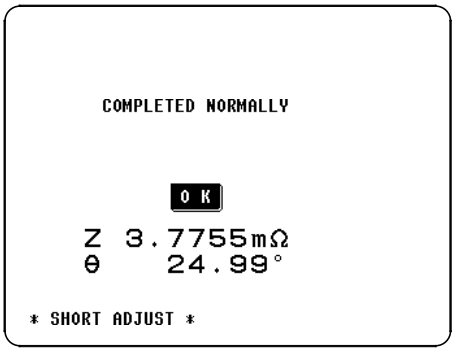


Data Determination Screen

6. When you press the RUN key, the ALL short circuit compensation process starts.

After about 2 minutes, the determination and adjustment of the short circuit compensation values is complete.

If an error message appears, refer to Section 4.8.5.

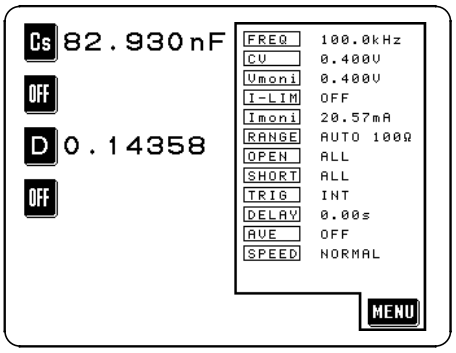


Confirmation Screen

7. If the compensation process has terminated satisfactorily, a Confirmation screen as shown to the left is displayed.

The residual component at the frequency of 5 MHz with the test cables connected together (short circuited), and its phase angle, are shown on the screen.

These values are required for use with the test range on HOLD. (For details, refer to Section 4.9, "Open Circuit Compensation and Short Circuit Compensation".)



Initial Screen

8. After checking the short circuit residual component and its phase angle, press the OK key, and the display will return to the Initial screen.

For details, refer to Section 4.8, "Short circuit compensation"

3.3.7 Starting Testing

When the operations described above have been completed, the test conditions have been for example set as follows:

Test conditions

Frequency	100 kHz
Constant voltage level	0.4 V
Open circuit compensation	ALL compensation
Short circuit compensation	ALL compensation

Parameters displayed

Capacitance Cs, Loss coefficient D

Connect the actual sample to be tested to the test cables, to start testing.

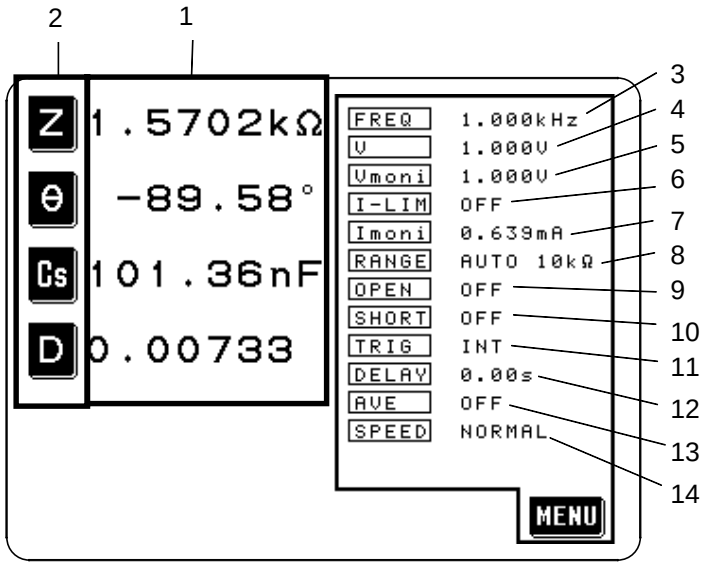
Chapter 4
Detailed Description of Functions

4.1 Description of the Screens

The Initial screen, Menu screen, Application menu screen will be explained.

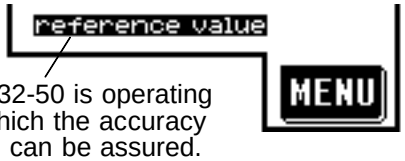
4.1.1 The Initial Screen

The Initial screen is the screen which is initially displayed when the power to the 3532-50 unit is turned on.
The monitor display on this screen enables the user to perform testing while checking the values of all the test conditions. (The monitor display varies according to the test signal level setting.)
When powering on again, the screen when the power has been turned off on the following screens is displayed.
Initial screen, Comparator screen, Scaling screen, Magnification screen, Continuous test screen



1. Measured values
2. Parameter keys
   (The parameters displayed can be selected using these keys.)
3. FREQ — Test frequency
4. V — Test signal control level
5. Vmoni — Voltage value between the terminals of the test sample
6. I-LIM — Measurement current limit value
7. Imoni — Current value flowing through the test sample
8. RANGE — Test range
9. OPEN — Open circuit compensation setup
10. SHORT — Short circuit compensation setup
11. TRIG — Trigger mode
12. DELAY — Set value for the trigger delay
13. AVE — Number of times for averaging
14. SPEED — Testing speed

NOTE Even if the 3532-50 unit is being used outside the limits of its specification, test values are sometimes displayed. In this case, the following type of indication appears on the display.



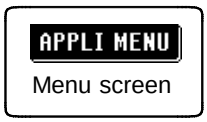
This means that the 3532-50 is operating outside the range for which the accuracy of the measured values can be assured.

- In this case, you should consider the following possible causes, and you should either change the test conditions while checking the accuracy assured ranges (with reference to Section 7.5, "Test Accuracy"), or you should consider the measured values as values for reference only, because their validity is somewhat doubtful.
- Perhaps the test signal controlled level is too low.
  Increase the test signal level.
- Perhaps the present test range (if ranging is set to HOLD) is not suitable.
  Either set the test range to the most suitable one by using AUTO ranging, or change the test range manually.

4.1.2 The Menu Screen and Application Menu Screen

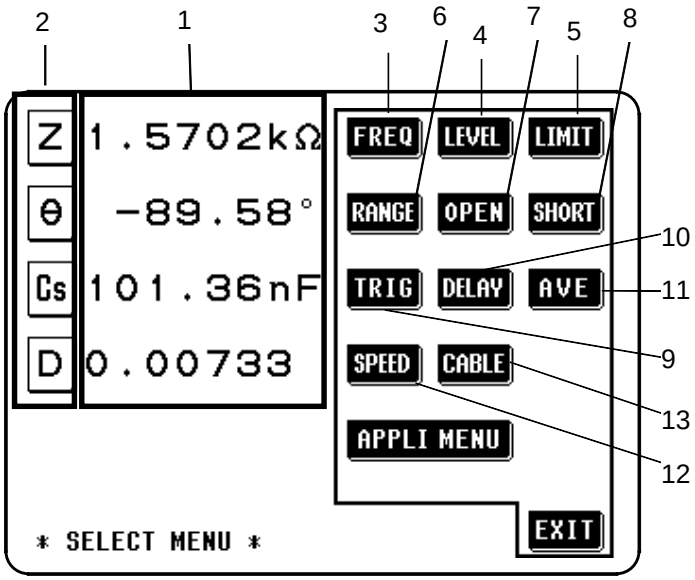
To display the Menu screen

Press this MENU key on the Initial screen.
It is possible to access various setting screens for changing the various test conditions from this screen.

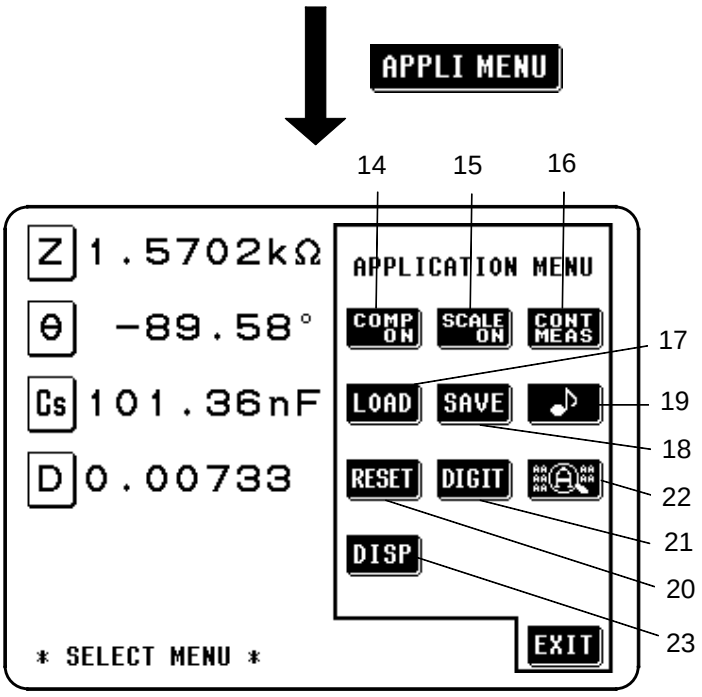


To display the Application screen

Press the APPLI MENU key on the Menu screen.
It is possible to access the various application function setting screens from this screen.



1. Measured values
2. Parameters displayed
3. FREQ — Test frequency setting
4. LEVEL — Test signal level setting
5. LIMIT — Limit setting
6. RANGE — Range setting
7. OPEN — Open circuit compensation setting
8. SHORT — Short circuit compensation setting
9. TRIG — Trigger setting
10. DELAY — Trigger delay function
11. AVE — Averaging setting
12. SPEED — Test speed setting
13. CABLE — Cable length setting

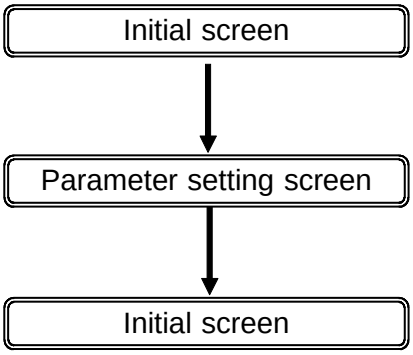


14. COMP ON — Comparator function
15. SCALE ON — Scaling function
16. CONT MEAS — Continuous test function
17. LOAD — Panel load function
18. SAVE — Panel save function
19. ♪ — Beep sound setting
20. RESET — System reset
21. DIGIT — Display digits setting
22. A — Magnification display function
23. DISP — Display setting

4.2 Setting the Parameters to be Displayed

From among the total of 14 different test parameters a maximum of four can be selected for their values to be simultaneously displayed on the screen, arranged in any desired order.

4.2.1 Control Screen Sequence



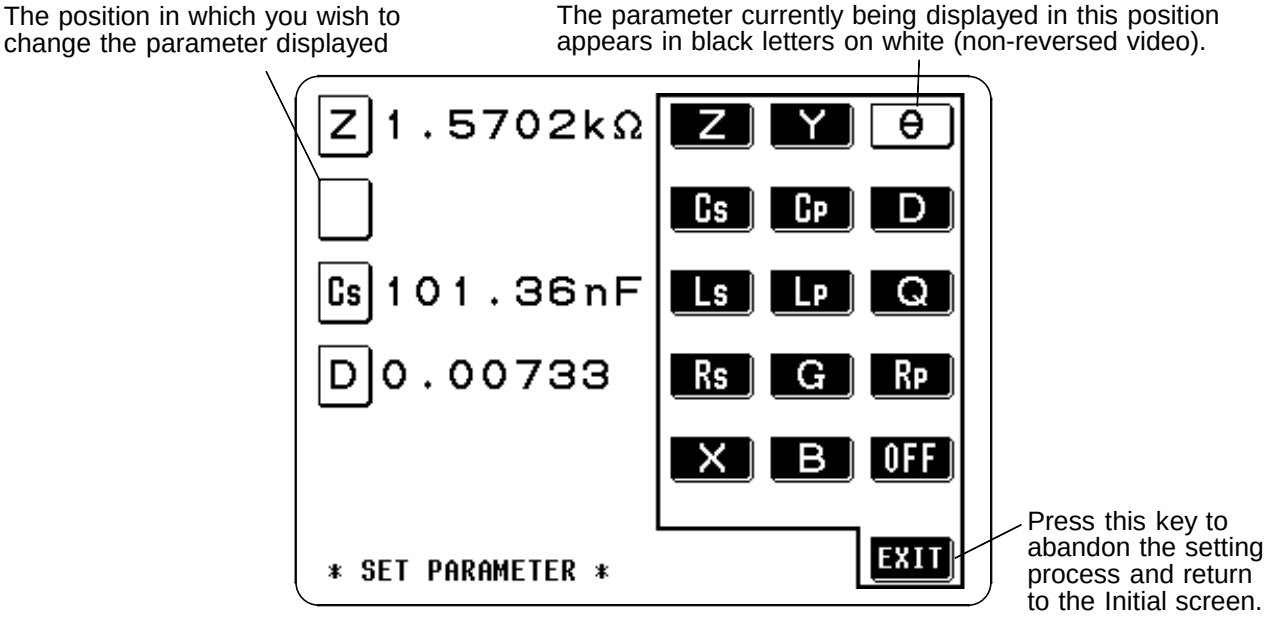
Press the parameter key for which you wish to make the change.

Press the key in the parameter list corresponding to the parameter which you wish to display in that position. The Initial screen will automatically be displayed again.

The parameter displayed in that position will now be the desired one.

4.2.2 Details of the Setting Process

1. Ensure that the Initial screen is being displayed.
2. Decide in which of the four positions on this Initial screen you wish to change the parameter which is being displayed, and then press the parameter key in the corresponding position.
   The Parameter setting screen will be displayed, as follows:



The parameters set to be displayed can only be changed by starting from the Initial screen.

3. The parameter which you wish to display in the chosen position can be chosen from the following list by pressing the corresponding key. The screen will then automatically revert to the Initial screen, with the desired new parameter being displayed in the appropriate position.

Z	impedance (Ω)
Y	admittance (S)
θ	impedance phase angle (°) *1
Cs	static capacitance in series equivalent circuit mode (F)
Cp	static capacitance in parallel equivalent circuit mode (F)
D	loss coefficient=tanδ
Ls	inductance in series equivalent circuit mode (H)
Lp	inductance in parallel equivalent circuit mode (H)
Q	Q factor
*R*s	effective resistance in series equivalent circuit mode (Ω)=ESR
*R*p	effective resistance in parallel equivalent circuit mode (Ω)
G	conductance (S)
X	reactance (Ω)
B	susceptance (S)
OFF	display no test parameter in the chosen position

*1 The phase angle *θ* is shown based on the impedance *Z*. When measuring based on the admittance, the sign of the phase angle *θ* must be reversed.

NOTE

All parameters excluding the impedance phase angle*θ* is displayed as absolute value. To check the polarity, confirm the impedance phase angle*θ*. For details, see Section 7.2, "Testing Parameters and Calculation Equations".

Press the EXIT key in order to cancel this setting process and return to the Initial screen with the original parameter still displayed as before.

4.2.3 Series Equivalent Circuit Mode and Parallel Equivalent Circuit Mode

The 3532-50 unit analyses the test sample in terms of a pure inductive component (L), an equivalent circuit construction composed of a pure capacitive component (C), and a pure resistive component (*R*), and calculates as though these components were connected in series, or alternatively connected in parallel. Therefore, it is possible for the user to select either a series equivalent circuit mode or a parallel equivalent circuit mode for this conceptual connection together of these L, C, and *R* components.

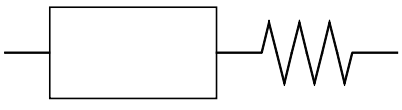
When the impedance of the sample being tested is relatively high, Lp, Cp, and *R*p for the parallel equivalent circuit mode should be selected manually, and when the impedance of the sample being tested is relatively low, Ls, Cs, and *R*s for the series equivalent circuit mode should be selected manually. Generally, for a device such as an electrolytic capacitor or the like with a high D value (i.e., a low Q value), the test values obtained when testing using series equivalent circuit mode differ from those obtained when testing using parallel equivalent circuit mode. The greater the resistance component in the sample being tested, the more this difference in the test values appears.
For example, the test values for capacitors of the same capacitance which have different values of D in series equivalent circuit mode and in parallel equivalent circuit mode may be as follows:

	Series equivalent circuit mode	Parallel equivalent circuit mode
D = 0	C	C
D = 0.1	1.005C	0.995C
D = 0.5	1.118C	0.8944C

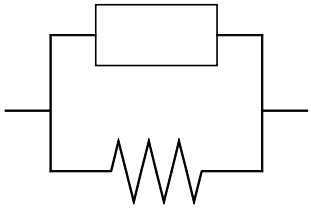
(Where C is the static capacitance)

Therefore it is necessary for the user clearly to understand the setting of this test mode, in order properly to assess test samples.

In general, parallel equivalent circuit mode should be used for elements which have relatively low capacitance and high impedance such as film capacitors and ceramic capacitors, since parallel resistance can cause great loss in this case; while series equivalent circuit mode should be used for elements which have relatively high capacitance and low impedance such as electrolytic capacitors, since series resistance can cause great loss in this case.



Series equivalent circuit



Parallel equivalent circuit

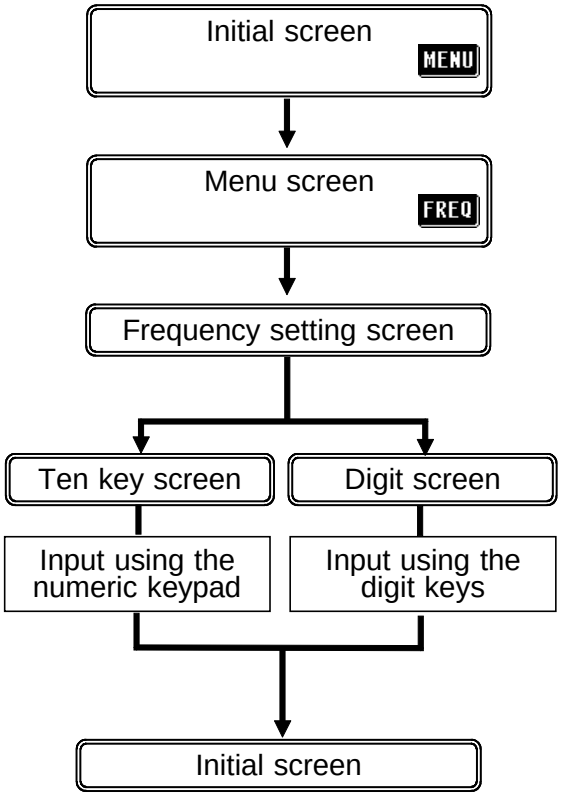
4.3 Setting the Test Frequency

Sometimes the value for the test frequency should be changed according to the type of sample being tested.

There are two types of method for inputting the frequency for testing. Either of two different screens can be selected, according to which of these two input methods is to be used. These two screens are called the Ten key screen and the Digit screen.

The Ten key screen	The numerical value for the test frequency is directly input using the numeric keypad (on the touch panel).
The Digit screen	Each digit of the test frequency can be varied by using the appropriate up and down keys.

4.3.1 Control Screen Sequence



Press the MENU key

Press the FREQ key

Select the type of input method for the test frequency (ten key input or digit variation input)

Input the test frequency

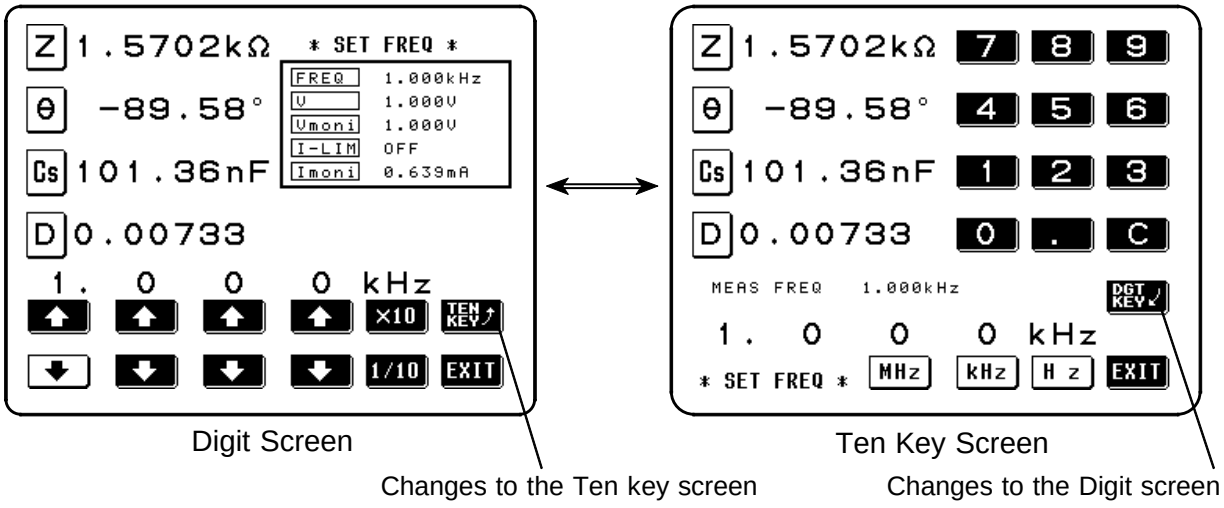
When setting has been completed, press the EXIT key to return to the Initial screen.

4.3.2 Selecting the Input Method

1. On the Initial screen, press the MENU key, and the Menu screen will be displayed.

2. Press the FREQ key on the Menu screen, and the display will change over to the one of the Frequency setting screens which was previously used.

3. The display can be switched over between these two Frequency setting screens just by pressing the soft keys shown in the figure.

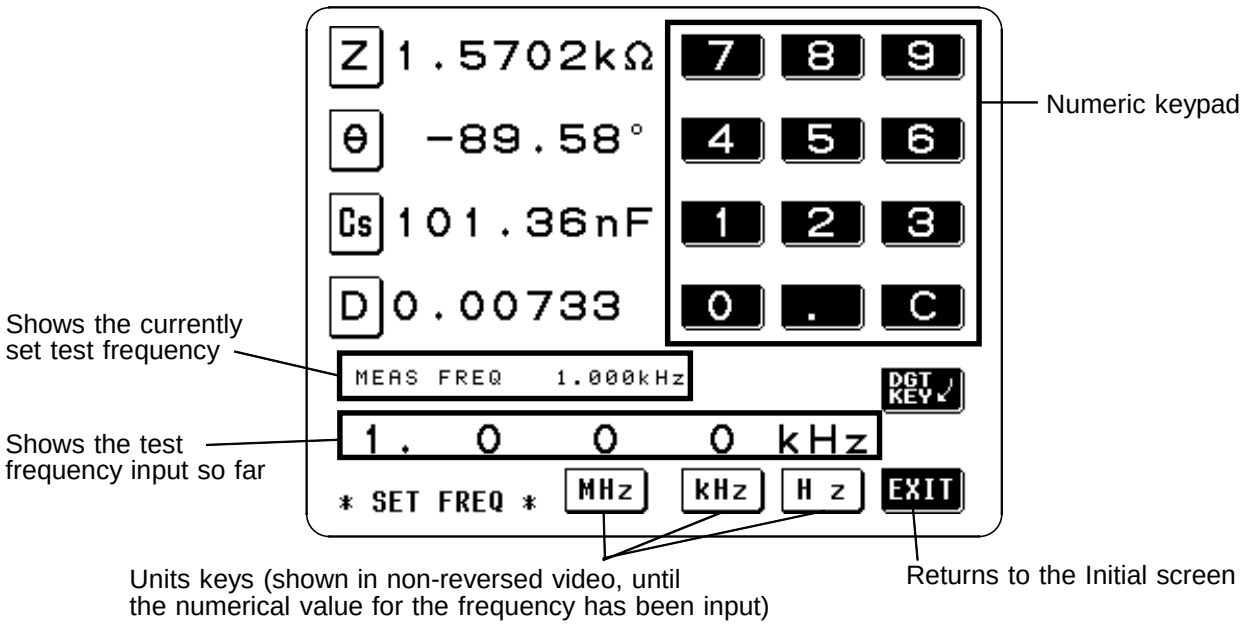


- Some test ranges and test signal levels are unavailable at certain test frequencies. These ranges and levels can be checked using the table below.
- If the test frequency is set to a specific value, the maximum values are automatically selected when the test range and test signal level settings exceed the values specified in the table below. For example, when the test frequency is set to 1.001 MHz in a test range of 1 MΩ and a test signal level of 1.5 V, the test range is automatically changed to 100 kΩ and the test signal level to 1 V.

Test frequency (Hz)	Setting range		
	Test range	Test voltage (V, CV)	Test current (CC)
42.0 - 100.0 k	0.1 Ω - 100 MΩ	0.010 V- 5.000 V	0.01 mA - 99.99 mA
100.1 k - 1.000 M	0.1 Ω - 1 MΩ		
1.001 M - 5.000 M	0.1 Ω - 100 kΩ	0.010 V - 1.000 V	0.01 mA - 20.00 mA

4.3.3 Input Using the Ten Key Screen

1. Access to the following Ten key screen.



2. Input the new test frequency directly using the numeric keypad.
Frequency range which can be set: 42.0 Hz to 5.000 MHz

NOTE

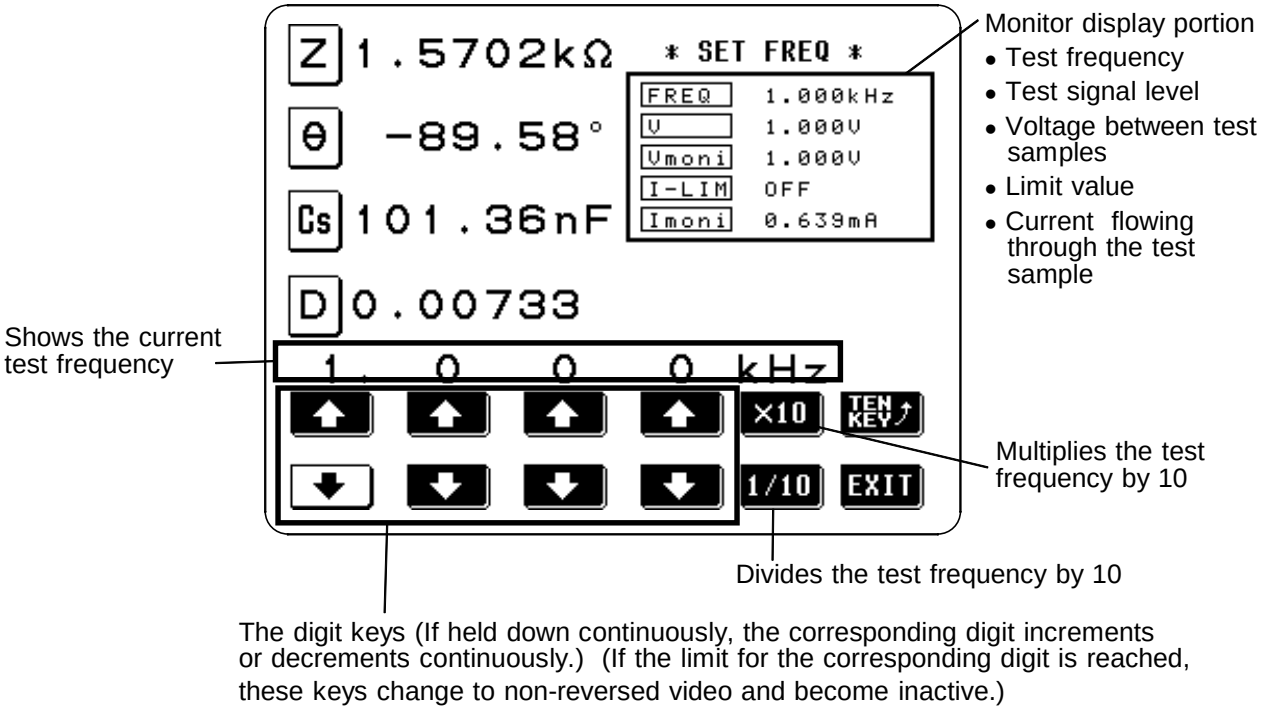
If you attempt to set a test frequency greater than 5 MHz, it will automatically be reduced to 5 MHz.
If you attempt to set a test frequency lower than 42 Hz, it will automatically be increased to 42 Hz.
If you make a mistake during input, press the C key to cancel the input so far, and start again.

3. When you have completed inputting the numerical value for the frequency, press the appropriate units key to confirm the displayed frequency.
If you change screens before confirming the frequency you have set, the frequency will not be changed.
Until the numerical value for the frequency has been input, the units keys cannot be used.

4. When the setting has been established as above, press the EXIT key to return to the Initial screen.

4.3.4 Input Using the Digit Screen

1. Access to the following Digit screen.



The current situation can be checked using the monitor display.

2. Change the test frequency using the digit keys.
Frequency range which can be set: 42.0 Hz to 5.000 MHz
If you try to go out of this range, the relevant digit key goes into non-reversed video and becomes inactive.

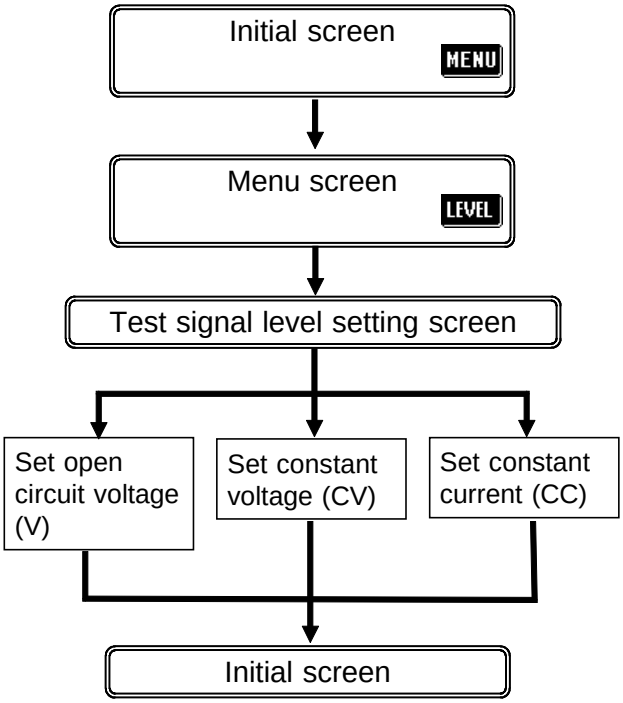
3. When the setting has been established as above, press the EXIT key to return to the Initial screen.

4.4 Setting the Test Signal Level

The value of the test signal level may change according to the sample which is being tested. With the 3532-50, it is possible to vary the level of the test signal applied to the object under test over a wide range using the following three methods:

Set open circuit voltage (V)	The value of the open circuit voltage is set.
Set constant voltage (CV)	The value of the voltage between the terminals of the object under test is set.
Set constant current (CC)	The value of the current flowing through the object under test is set.

4.4.1 Control Screen Sequence



Press the MENU key

Press the LEVEL key

Select the type of level for the test signal (open circuit voltage, constant voltage, or constant current) to be set.

Input the value for the test signal level.

When the setting process is completed, press the EXIT key to return to the Initial screen.

4.4.2 Selecting the Level Type

⚠ CAUTION

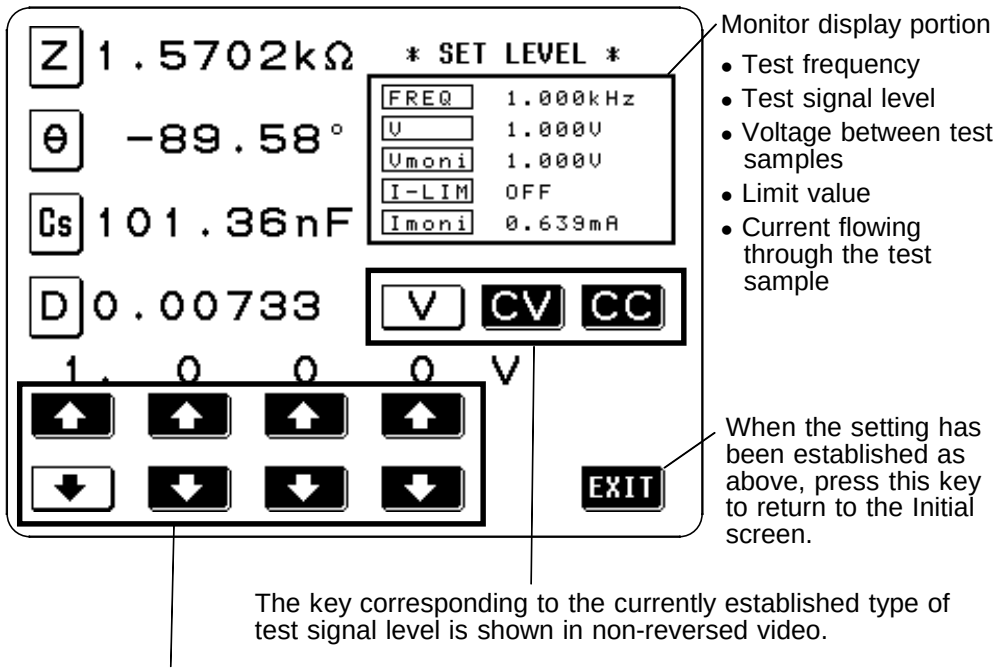
Be absolutely sure not to change over between constant current (CC) level and constant voltage (CV) level with the test terminals still connected to the sample to be tested. Doing so may damage the test sample.

MENU
Initial screen

LEVEL
Menu screen

1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the LEVEL key on the Menu screen to display the Test signal level setting screen.



The current situation can be checked using the monitor display.

3. The method of control for the test signal level can be selected from the following three:

- Set open circuit voltage (V) The value of the open circuit voltage is set.
- Set constant voltage (CV) The value of the voltage between the terminals of the object under test is set.
- Set constant current (CC) The value of the current flowing through the object under test is set.

NOTE

The accuracy of testing varies according to the test signal level. Check the accuracy table in Section 7.5.

NOTE

- Even if the 3532-50 unit is being used outside the limits of its specification, test values are sometimes displayed.

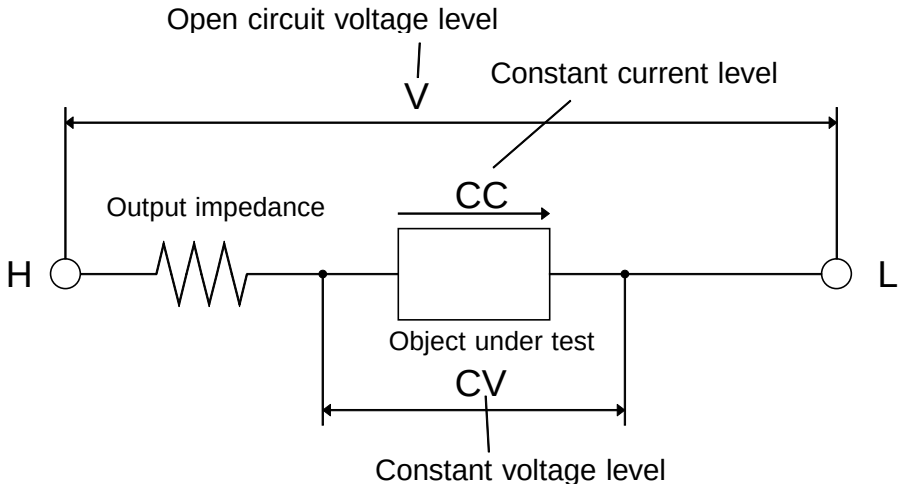
  In this case, the following type of indication appears on the display, indicating a value which is not guaranteed.

  In this case, you should consider the following possible causes, and you should either change the test conditions while checking the accuracy assured ranges (with reference to Section 7.5, "Test Accuracy"), or you should consider the measured values as values for reference only, because their validity is somewhat doubtful.

- Perhaps the test signal level is too low, increase the test signal level.
- If the current measurement range (during HOLD setting) is not appropriate, set again in the AUTO range, or change the range by manual.

About the test signal level

The relationship between the test signal level for the 3532-50 and the object to be tested is as follows:



Open circuit voltage level (V)

This voltage value is the value which is applied across the two terminals of the series combination of the object which is being tested and the output impedance. As for the voltage which is applied across the terminals of the object which is being tested (by itself), if required, you should either check the monitor voltage value, or select constant voltage (CV) and set a voltage value across these terminals.

Constant voltage level (CV)

You should select this if you wish to set the voltage across the terminals of the object to be tested to a constant value.

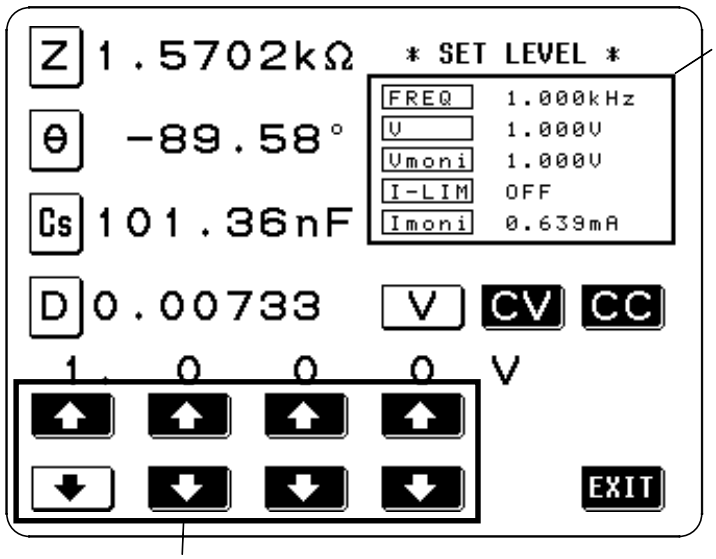
Constant current level (CC)

You should select this if you wish to set the current passing through the object to be tested to a constant value.

4.4.3 Setting the Open Circuit Voltage (V) Level

V
Test signal level setting screen

1. Press this key to set open circuit voltage (V), and the monitor display will change immediately.



Monitor display portion
- Test frequency
- Open circuit voltage
- Voltage between test samples
- Limit value for the current
- Current flowing through the test sample

The digit keys (If held down continuously, the corresponding digit increments or decrements continuously.) (If the limit for the corresponding digit is reached, these keys change to non-reversed video and become inactive.)

2. Change the open-circuited voltage value using the digit keys.
The definable open-circuit voltage depends on the frequency.

Test frequency (Hz)	Open-circuited voltage
42.0 - 1.000 M	0.010 V- 5.000 V
1.001 M - 5.000 M	0.010 V - 1.000 V

The accuracy of the open-circuit voltage is ±10%±10 mV for 42.0 Hz to 1.000 MHz, and ±20%±10 mV for 1.001 MHz to 5.000 MHz.

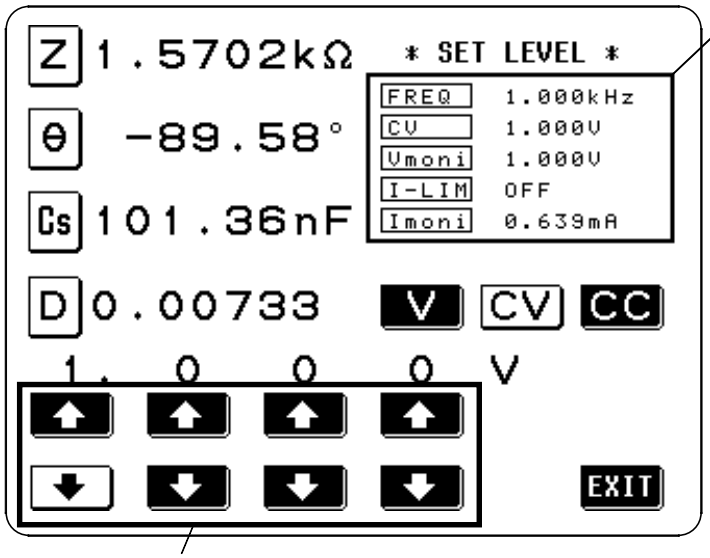
NOTE When the test frequency is higher than 1 MHz at an open-circuit voltage of more than 1 V, the voltage is automatically set to 1 V.

3. When the setting has been established as above, press the EXIT key to return to the Initial screen.

4.4.4 Setting the Constant Voltage (CV) Level

CV
Test signal level setting screen

1. Press this key to set constant voltage (CV), and the monitor display will change immediately.



Monitor display
- Test frequency
- Set value for constant voltage
- Voltage between test samples
- Limit value for the current
- Current flowing through the test sample

The digit keys (If held down continuously, the corresponding digit increments or decrements continuously.) (If the limit for the corresponding digit is reached, these keys change to non-reversed video and become inactive.)

2. Change the set constant voltage value using the digit keys.
The definable constant voltage depends on the frequency.

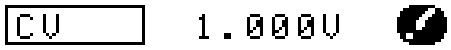
Test frequency (Hz)	Constant voltage
42.0 - 1.000 M	0.010 V- 5.000 V
1.001 M - 5.000 M	0.010 V - 1.000 V

The accuracy of the constant voltage is ±10%±10 mV for 42.0 Hz to 1.000 MHz, and ±20%±10 mV for 1.001 MHz to 5.000 MHz.

NOTE
When the test frequency is higher than 1 MHz at an open-circuit voltage of more than 1 V, the voltage is automatically set to 1 V.

3. When the setting has been established, press the EXIT key to return to the Initial screen.

NOTE
Testing some types of sample is not possible using constant voltage. In this case, the following symbol appears on the display:



In such a case, constant voltage testing is not performed. Change the constant voltage level to a value not more than the value being shown as Vmoni.

Reference

When a 1 µF capacitance is measured at 10 kHz, the CV operation range can be obtained as follows. Sample impedance Zm becomes as follows:

$Zm = Rm + jXm = 0\Omega - j15.9\Omega$ $Xm=-1/(2\pi fC)$

The impedance Zm' observed from the generator is as follows:

$Zm' = Ro + Zm = 50\Omega - j15.9\Omega$ Ro: Output resistance (50 Ω)

Accordingly, the voltage Vm across both leads of the sample is as follows:

$Vm = |Zm| \times Vo/|Zm'|$ Vo: generator output

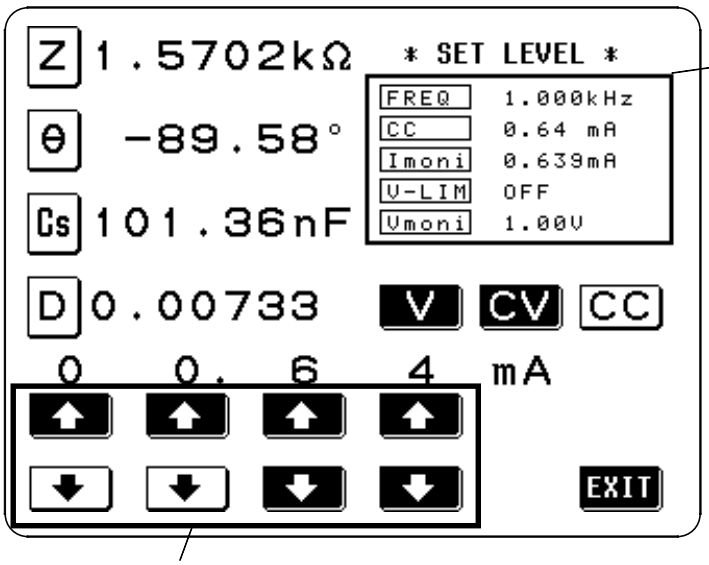
$= 15.9\Omega \times Vo/52.5\Omega$

Because the generator output voltage range is 10 mV to 5 V for 10 kHz, the CV operation range per the above expression is Vm = 3.03 mV to 1.51 V.

4.4.5 Setting the Constant Current (CC) Level

CC
Test signal level setting screen

1. Press this key to set constant current (CC), and the monitor display will change immediately.



Monitor display
- Test frequency
- Set value for constant current
- Current flowing through the test sample
- Limit value for the voltage
- Voltage between test samples

The digit keys (If held down continuously, the corresponding digit increments or decrements continuously.) (If the limit for the corresponding digit is reached, these keys change to non-reversed video and become inactive.)

2. Change the set constant current value using the digit keys.
The definable constant current depends on the frequency.

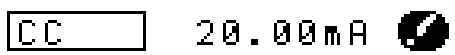
Test frequency (Hz)	Constant current
42.0 - 1.000 M	0.01 mA - 99.99 mA
1.001 M - 5.000 M	0.01 mA - 20.00 mA

The accuracy of the constant current is ±10%±10μA for 42.0 Hz to 1.000 MHz, and ±20%±10μA for 1.001 MHz to 5.000 MHz.

NOTE
When the test frequency is higher than 1 MHz at an constant current of more than 20 mA, the current is automatically set to 20 mA.

3. When the setting has been established, press the EXIT key to return to the Initial screen.

NOTE
Testing some types of sample is not possible using constant current. In this case, the following symbol appears on the display:



In such a case, constant current testing is not performed. Change the constant current level to a value not more than the value being shown as Imoni.

Reference

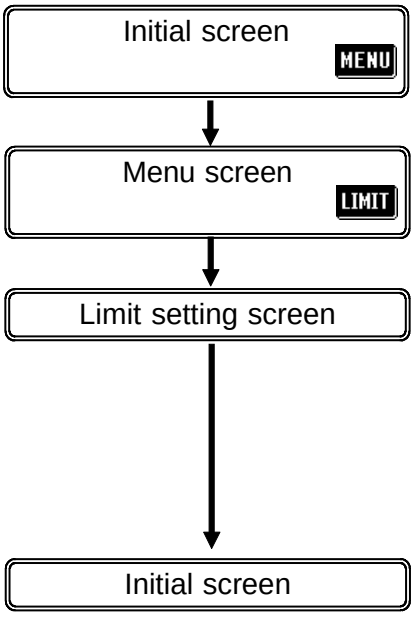
When a 10 mH impedance is measured at 1 kHz, the CC operation range can be obtained as follows. Sample impedance Zm becomes as follows:
Zm = Rm + jXm = 0Ω + j62.8Ω Xm: 2πfL
The impedance Zm' observed from the generator is as follows:
Zm' = Ro + Zm = 50Ω + j62.8Ω Ro: output resistance (50 Ω)
Accordingly, the current Im across both leads of the sample is as follows:
Im = Vo/|Zm'| = Vo/80.3Ω Vo: generator output
Because the generator output voltage range is 10 mV to 5 V for 1 kHz, the CC operation range per the above expression is Im = 125 μA to 62.3 mA.

4.5 Setting the Voltage/Current Limit

Depending on the test signal level, in some cases it is possible to damage the sample which is being tested by applying to it a voltage or a current greater than its rated value. Using the voltage/current limit function, it is possible to set a limit value which the voltage applied to the sample under test, or alternatively the current flowing through it, should not exceed; and thereafter the 3532-50 unit will limit the voltage, or current, so as keep it below this specified limit value.

When open circuit voltage (V) or constant voltage (CV) is set:
A current limit can be set.
When constant current (CC) is set:
A voltage limit can be set.

4.5.1 Control Screen Sequence



Press the MENU key.

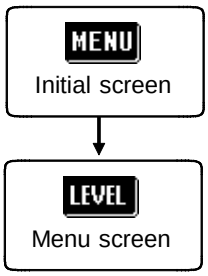
Press the LIMIT key.

Input a limit value.

(The 3532-50 will automatically switch between voltage limit and current limit according to the test signal level setting.)

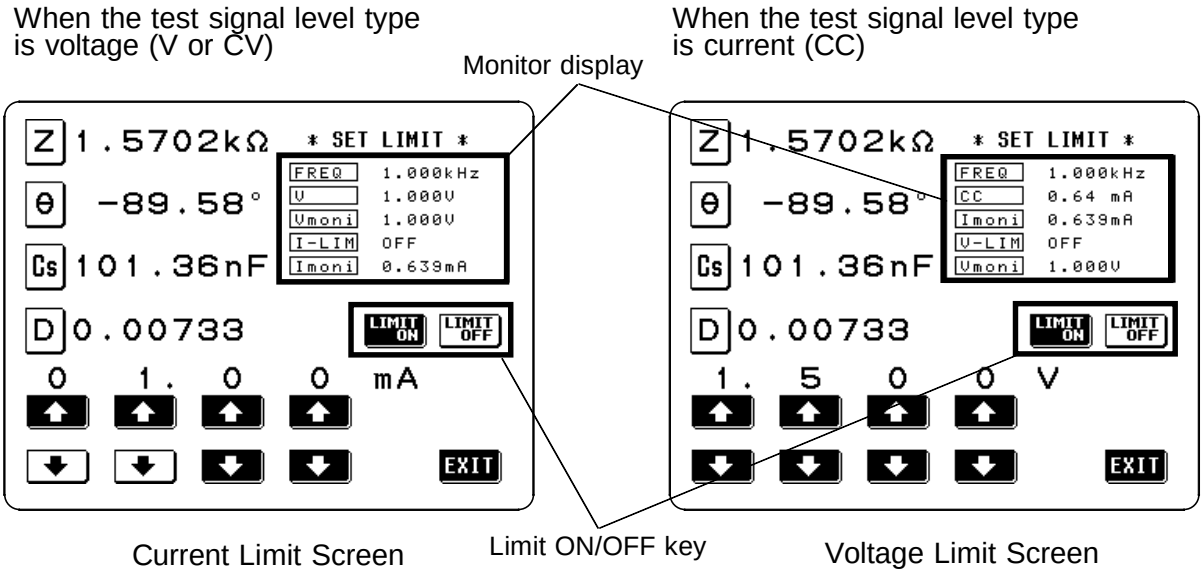
When the setting has been established, press the EXIT key to return to the Initial screen.

4.5.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the LIMIT key on the Menu screen to display the one of the Limit setting screens.



The present situation can be checked using the monitor display.
The monitor display is different for V, CV, and CC.

NOTE

The setting for voltage or current limit changes automatically to current or voltage limit, according to the present Test signal level setting. Therefore, first set the test signal level, and thereafter set the voltage or current limit. For details of the Test signal level setting, refer to Section 4.4.

3. Input the limit value using the digit keys. The ranges within which the limit values can be set are as follows.

Test signal control level	Limit set	Setting range
V, CV	Current limit	0.01 mA to 99.99 mA
CC	Voltage limit	0.01 V to 5 V

The accuracy of the current limit is ±10%±10μA for 42.0 Hz to 1.000 MHz, and ±20%±10μA for 1.001 MHz to 5.000 MHz.

The accuracy of the voltage limit is ±10%±10 mV for 42.0 Hz to 1.000 MHz, and ±20%±10 mV for 1.001 MHz to 5.000 MHz.
When any digit key would take the limit value outside these ranges, it changes to non-reversed video (black characters upon a white ground).

NOTE

The limit value is not made effective just by setting it, if the limit function is turned off.

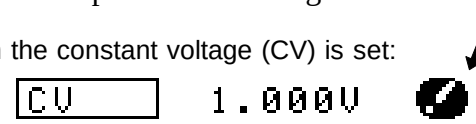
4. The limit function can be turned on and off by pressing the appropriate one of the following keys (The key which has been pressed changes to non-reversed video).
LIMIT ON : The limit function is turned on.
LIMIT OFF : The limit function is turned off.
Whether the limit function is on or off can be checked from the change on the monitor display.

NOTE

When the limit function is on in the following cases, " ◔ " or " limit " are displayed.

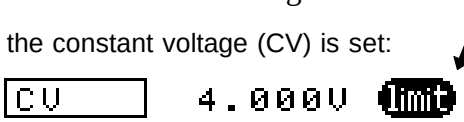
" ◔ " display
If the voltage or current which is applied to the sample under test exceeds the limit value (the current exceeding the limit value flows through the sample even when the open-circuit voltage is set to minimum value.)

When the constant voltage (CV) is set:



" limit " display
If the test signal level which is being applied to the sample under test exceeds the limit value. Then the test signal level is stopped changing .

When the constant voltage (CV) is set:



At this time, the voltage or current which exceeds the limit value is not being applied to the sample under test. You should change the test signal level so that it does not exceed the limit value.

5. When the setting has been established as above, press the EXIT key to return to the Initial screen.

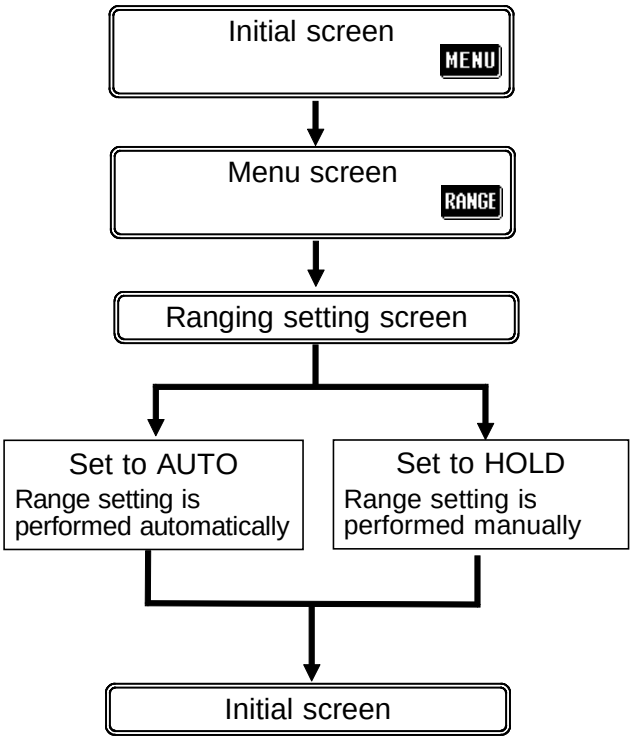
4.6 Setting the Ranging

Using AUTO, the 3532-50 unit can automatically select the most appropriate test range. This is useful when testing a sample whose impedance varies greatly with frequency, or whose nature is unknown. The test range can also be fixed using HOLD, which provides the quickest testing.
AUTO : The most suitable test range is set automatically.
HOLD : The test range is fixed, and may only be altered manually.

NOTE

The ranges are all defined in terms of impedance. Therefore, for a parameter other than impedance, the value is obtained by calculating from the measured values of $|Z|$ and θ.

4.6.1 Control Screen Sequence



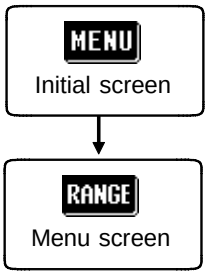
Press the MENU key.

Press the RANGE key.

Choose the manner in which the range will be set (AUTO or HOLD).

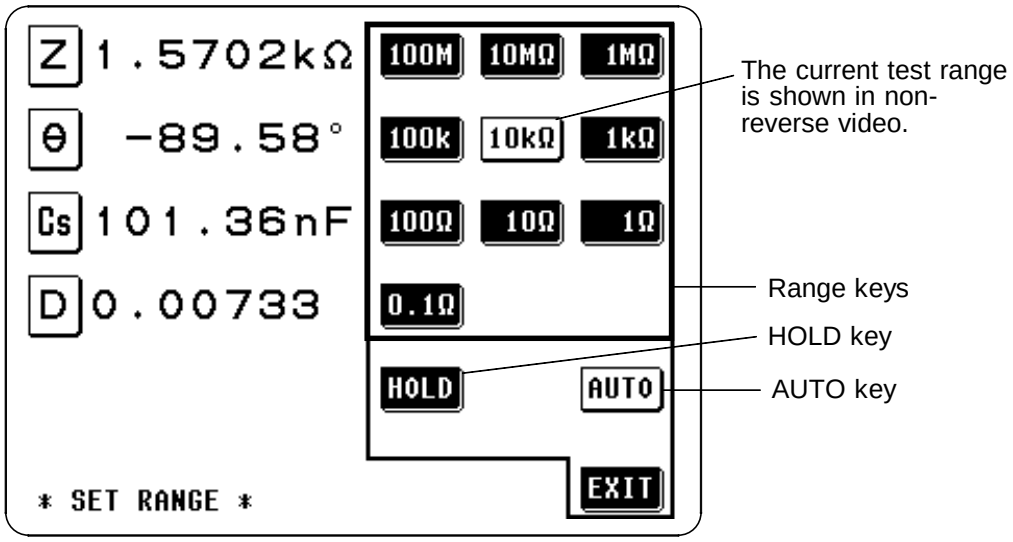
When the ranging setting has been established as above, press the EXIT key to return to the Initial screen.

4.6.2 Setting the Ranging



1. Press the MENU key on the Initial screen.
The Menu screen will be displayed.

2. Press the RANGE key on the Menu screen.
The Ranging setting screen will be displayed.



Ranging Setting Screen

3. The ranging setting can be either of the following:

AUTO : The most suitable test range is set automatically.

HOLD : The test range is fixed, and may only be altered manually.

4.6.3 Setting AUTO Ranging

1. Press this key, and the 3532-50 will automatically be set to the most suitable test range. At this time, the AUTO key and the key corresponding to the current test range will be shown in non-reverse video.

2. When the setting has been established as above, press the EXIT key to return to the Initial screen.

NOTE

If the 3532-50 unit is being used outside the limits of its specification, the suitable range may not be set in auto ranging function. In this case, check the accuracy assured ranges in Section 7.5, "Test Accuracy" and then change the test conditions.

4.6.4 Setting the Ranging to HOLD

HOLD
Ranging setting screen

1. There are two ways of setting the ranging to HOLD:

1) While AUTO ranging is set, press the HOLD key, and then this key will go into non-reverse video, and the currently most suitable range will be held fixed.

2) To select a desired test range directly, just press the key corresponding to that range. Then the HOLD key and also this range key will both go into non-reverse video.

Set the test range according to the combined impedance value of the sample to be tested and the test cables.

Test range [Ω]	Range of impedance which can be measured within the accuracy guaranteed [Ω]	- 100 k [Hz]	100.1 k - 1.000 M [Hz]	1.001 M - 5.000 M [Hz]
0.1	10.00 m to 99.99 m	●	●	●
1	80.00 m to 999.99 m	●	●	●
10	0.8000 to 9.9999	●	●	●
100	8.000 to 99.999	●	●	●
1 k	80.00 to 999.99	●	●	●
10 k	0.8000 k to 9.9999 k	●	●	●
100 k	8.000 k to 99.999 k	●	●	●
1 M	80.00 k to 999.99 k	●	●	--
10 M	0.8000 M to 9.9999 M	●	--	--
100 M	8.0000 M to 200.00M	●	--	--

●: settable/ -- cannot be set

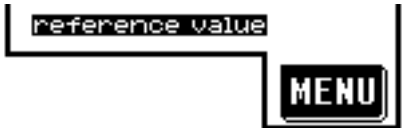
NOTE

- The accuracy assured ranges varies according to the measurement level. Check the accuracy assured ranges in Section 7.5, "Test Accuracy."
- The measurement range is determined according to the test range setting. If the display for the measured value shows "OVER FLOW" or "UNDER FLOW", that means that measurement cannot be performed using the currently set test range. Either you should set AUTO ranging so as to select the most suitable test range automatically, or you should set a more suitable test range manually.
- If the test frequency is set to a specific value, the maximum values are automatically selected when the test range setting exceeds the values specified in the table above. For example, when the test frequency is set to 1.001 MHz in a test range of 1 MΩ, the test range is automatically changed to 100 kΩ.

2. When the setting has been established as above, press the EXIT key to return to the Initial screen.

NOTE

- In the case of a test sample whose impedance changes according to the frequency, when testing is being performed with HOLD set, it may happen, when the frequency is changed over, that measurement cannot be continued to be performed upon the same test range. You should change the test range if this happens.
- The test range setting is made according to the combination of the impedances of the sample being tested and the test cables. Therefore it can happen that testing is not possible, if the test range is held with HOLD only upon the basis of the impedance of the sample under test. If this happens, you should change the test range, making reference to Section 4.9, "Open Circuit Compensation and Short Circuit Compensation".
- Even if the 3532-50 unit is being used outside the limits of its specification, test values are sometimes displayed.
  In this case, the following type of indication "reference value" appears on the display, indicating a value which is not guaranteed.



  In this case, you should consider the following possible cause, and you should either change the test conditions while checking the accuracy assured ranges (with reference to Section 7.5, "Test Accuracy"), or you should consider the measured values as values for reference only, because their validity is somewhat doubtful.
- Perhaps the test signal level is too low, increase the test signal level.
- When the present test range (when HOLD is set) is not suitable:
  Either you should set AUTO ranging so as to select the most suitable test range automatically, or you should set a more suitable test range manually.

4.7 Open Circuit Compensation

With open circuit compensation, it is possible to reduce the influence of the floating impedance of the test cables and thereby to enhance the accuracy of measurement. It is effective for test samples whose impedance is relatively high.

Open circuit compensation may be performed according to either of two methods:

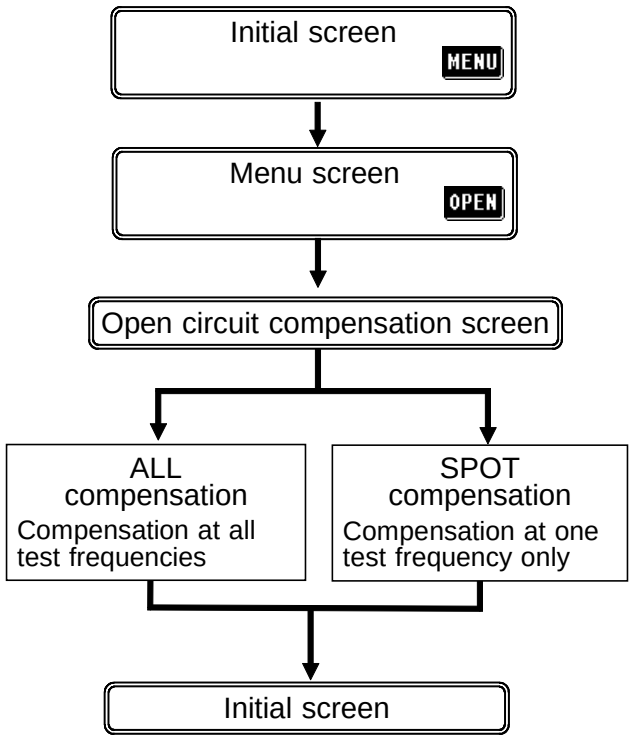
ALL compensation
Compensation is performed at all the test frequencies.

SPOT compensation
Compensation is performed for one specified test frequency only.

NOTE

- Before open circuit compensation, always set the cable length. For details, refer to Section 4.14.
- The testing accuracy specified in the specification of the 3532-50 unit assumes that open circuit compensation and short circuit compensation is being performed, as appropriate.
- When you have changed the test cables, be sure to perform compensation again. Correct test values will not be obtained if you go on testing using the same old compensation values which were obtained before the cable change.

4.7.1 Control Screen Sequence



Press the MENU key.

Press the OPEN key.

Select the compensation method (ALL compensation or SPOT compensation).

If setting has been completed normally, the open circuit residual component and its phase angle are displayed.

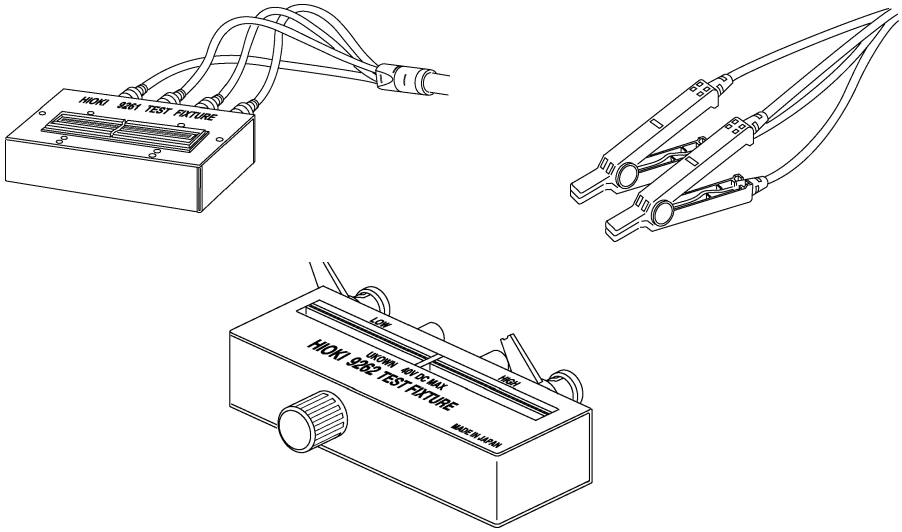
When compensation has been completed, press the O K key to return to the Initial screen.

Open circuit compensation has been set.

4.7.2 Setting the Compensation Method

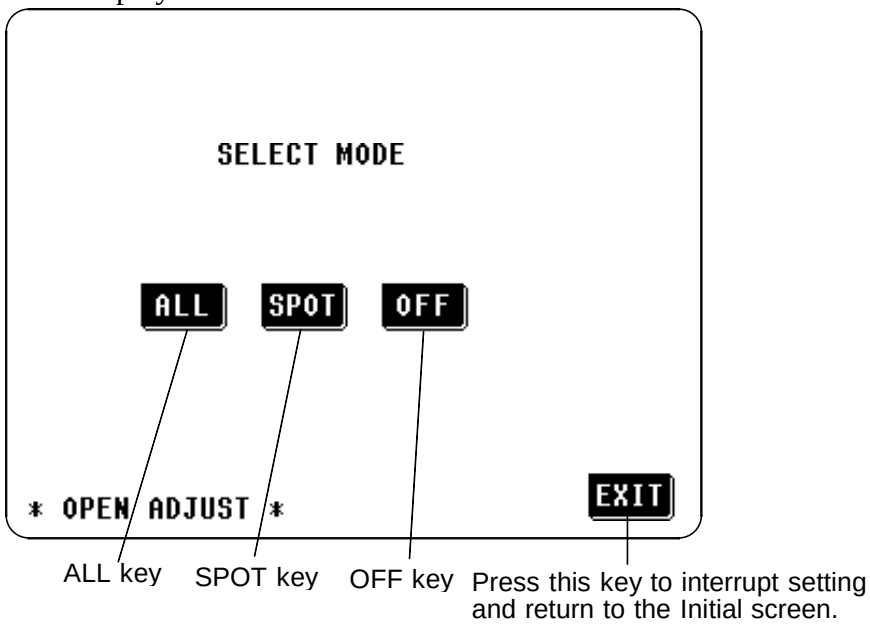
1. Arrange the test leads as closely as possible to their configuration in which measurement will be performed, and make sure that the HIGH and LOW leads are not contacted together.

2. When the open circuit compensation is performed, execute the guarding process. (For the guarding process, refer to Section 5.2.)



3. On the Initial screen, press the MENU key, and the Menu screen will be displayed.

4. Press the OPEN key on the Menu screen, and the Open circuit compensation screen will be displayed.



5. The OPEN circuit compensation method can be set to:

ALL : The compensation values are obtained for all test frequencies.

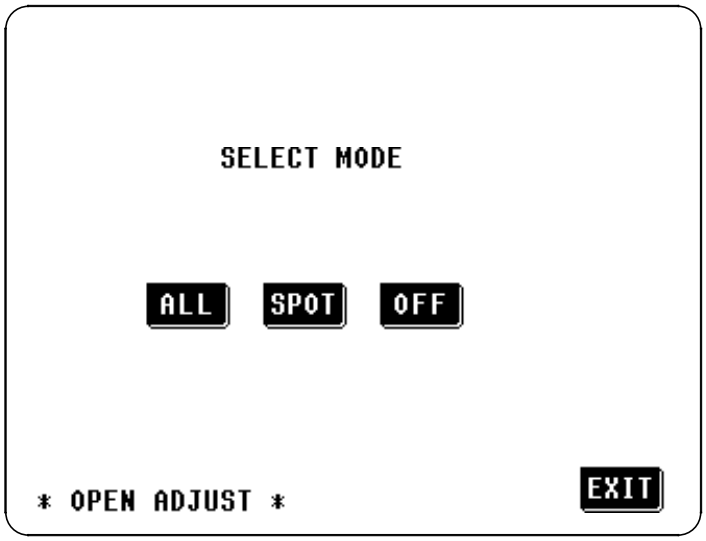
SPOT : The compensation values are obtained at the set test frequency only.

OFF : The open circuit compensation data are cleared.

4.7.3 ALL Compensation

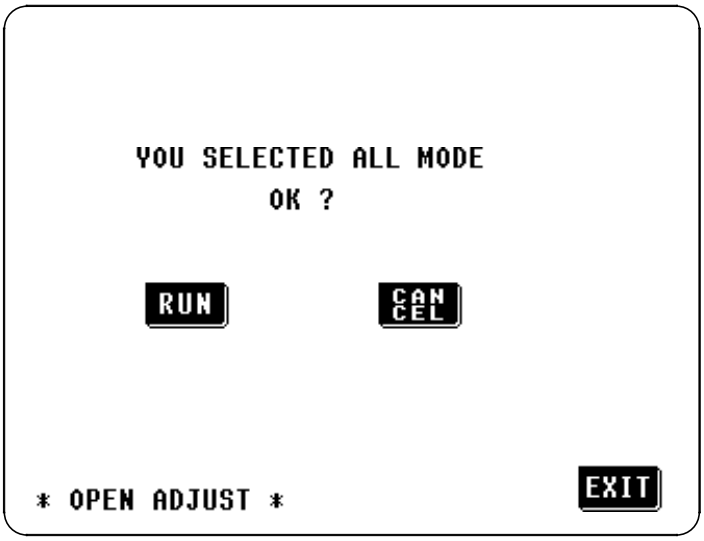
ALL
Open circuit compensation screen

1. To select ALL compensation, press this key with the Open circuit compensation screen displayed.



Open Circuit Compensation Screen

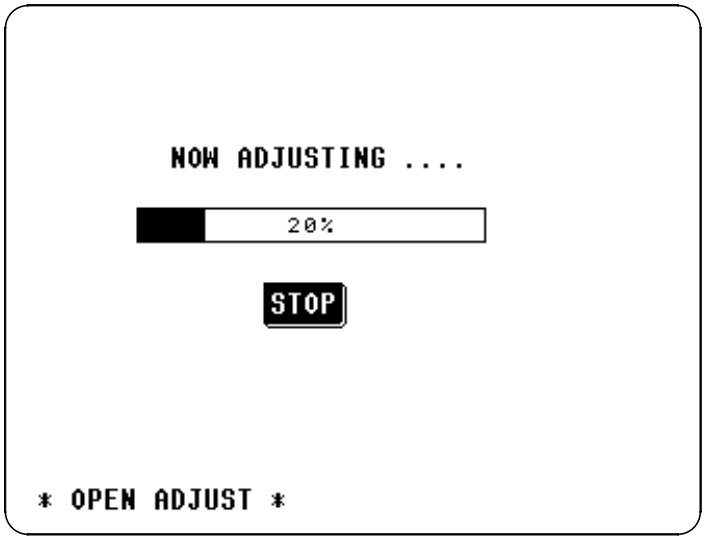
2. A Confirmation screen will appear for confirmation. If it is OK to proceed, press the RUN key; if not, press the CANCEL key to return to the Open circuit compensation screen.



NOTE

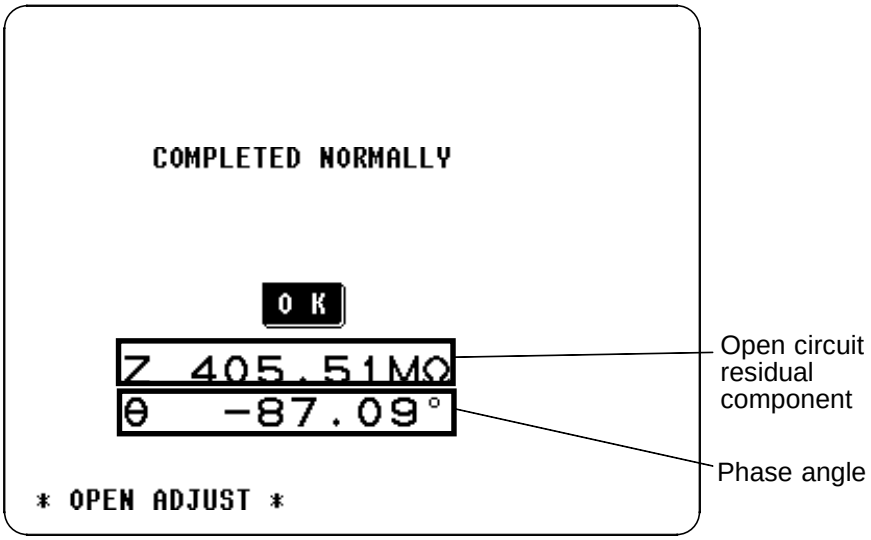
Check again - are the test leads definitely out of mutual contact?

3. When the RUN key is pressed, the ALL open circuit compensation process starts. After about 2 minutes, the determination and adjustment of the open circuit compensation values is complete.



Interrupting the ALL compensation process:
To interrupt the ALL compensation process, press the STOP key on this screen. The compensation process will stop and the display will revert to the Initial screen. At this time, the compensation values obtained in the previous episode of open circuit compensation will remain valid.

4. If the compensation process has terminated satisfactorily, the following Confirmation screen will be displayed.
The open circuit residual component for the test cables at the frequency of 5 MHz and its phase angle are shown on the screen. (If an error message appears, refer to Section 4.7.5.)



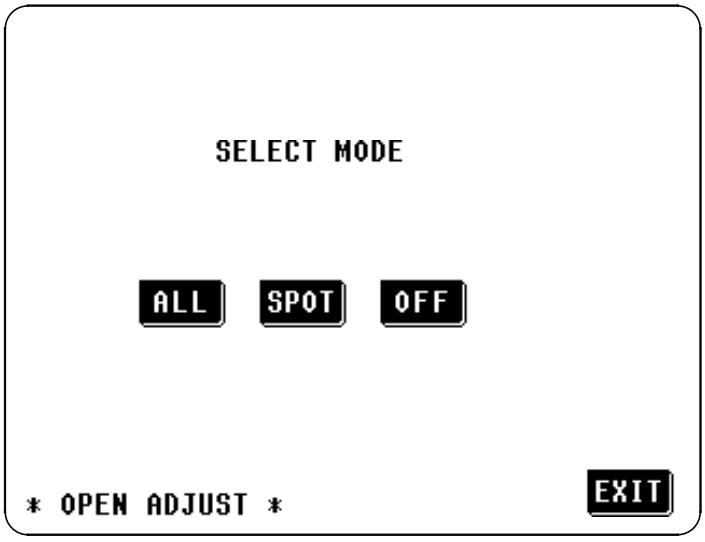
These values are required for use with the test range on HOLD. (For details, refer to Section 4.9, "Open Circuit Compensation and Short Circuit Compensation".)
After checking the open circuit residual component and its phase angle, press the O K key, and the display will return to the Initial screen.

NOTE Compensation can be performed for impedances of at least 1 kΩ.

4.7.4 Spot Compensation

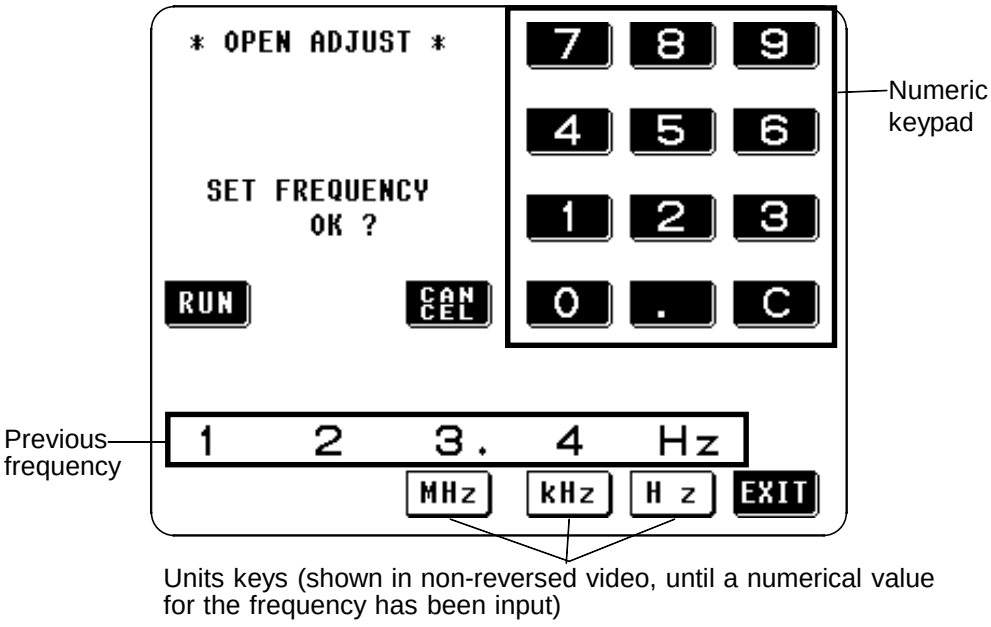
SPOT
Open circuit compensation screen

1. To select SPOT compensation, press this key with the Open circuit compensation screen displayed.



Open Circuit Compensation Screen

2. A numeric keypad is displayed for input of the frequency. Until one of these keys is pressed for input of a numerical value, the previous frequency for which SPOT compensation was performed is displayed.



SPOT compensation for the same frequency as previously
Just press the RUN key. SPOT compensation will be started using the same frequency which was used for the last episode of SPOT compensation.

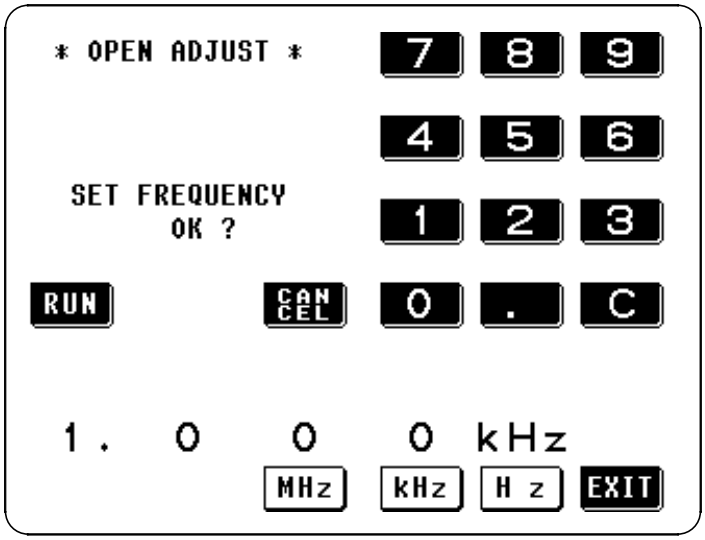
SPOT compensation for some new frequency
Input the frequency for compensation using the numeric keypad.
Frequency range which can be set : 42.0 Hz to 5.000 MHz

NOTE

If you attempt to set a test frequency greater than 5 MHz, it will automatically be reduced to 5 MHz.
If you attempt to set a test frequency lower than 42 Hz, it will automatically be set to 42 Hz.

- If you make a mistake during input of the numerical value, press the C key to cancel the input so far, and start again.
- When you have completed inputting the numerical value for the frequency, press the appropriate units key MHz, kHz, or H z so as to confirm the displayed frequency for compensation.
- Until the numerical value for the frequency has been input, the units keys cannot be used.

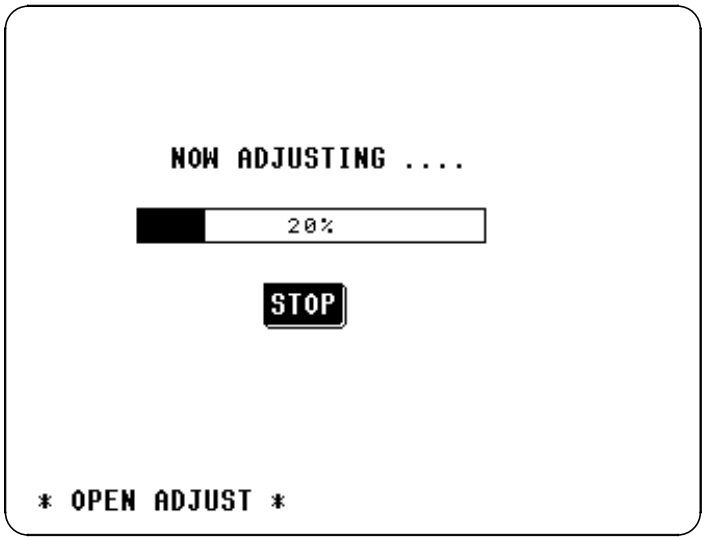
3. After the frequency for SPOT compensation has been input as above, press the RUN key.



NOTE

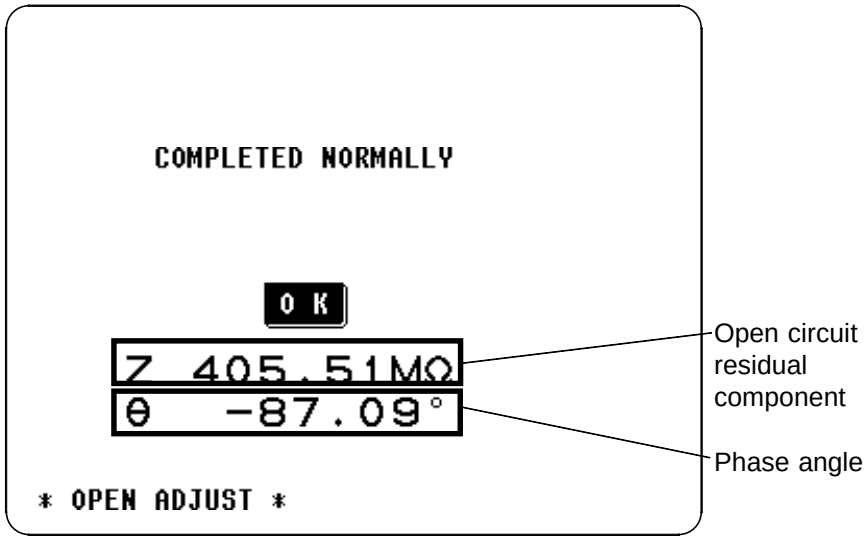
Check again - are the test leads definitely out of mutual contact?

4. When you press the RUN key, the SPOT open circuit compensation process starts.



Interrupting the SPOT compensation process:
To interrupt the SPOT compensation process, press the STOP key on this screen. The compensation process will stop and the display will revert to the Initial screen. At this time, the compensation values obtained in the previous episode of open circuit compensation will remain valid.

5. If the compensation process has terminated satisfactorily, the following Confirmation screen will be displayed.
The open circuit residual component for the test cables at the set frequency, and its phase angle, are shown on the screen. (If an error message appears, refer to Section 4.7.5.)

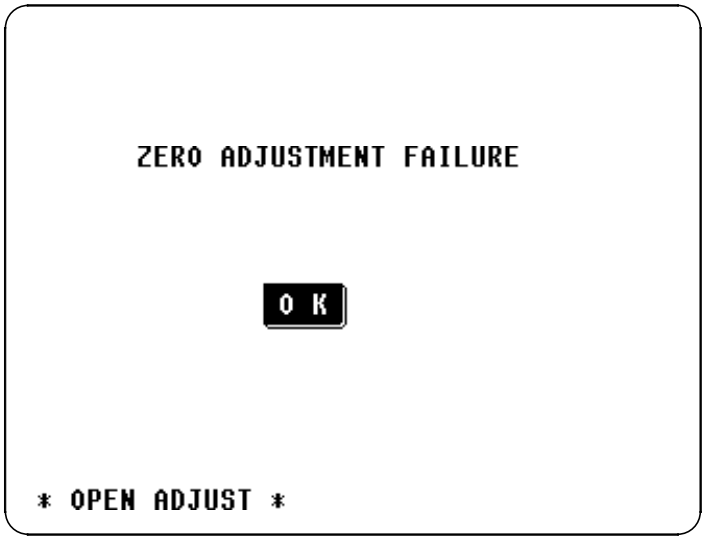


These values are required for use with the test range on HOLD. (For details, refer to Section 4.9, "Open Circuit Compensation and Short Circuit Compensation".)
After checking the open circuit residual component and its phase angle, press the O K key, and the display will return to the Initial screen.

NOTE Compensation can be performed for impedances of at least 1 kΩ.

4.7.5 When an Error Message Appears and Compensation Has Stopped

When an error message appears and compensation has stopped, open circuit compensation is turned OFF.



The open circuit compensation process is quite sensitive to noise - both noise originating externally and induced noise. Therefore, if open circuit compensation has been interrupted with a fault, you should check the following points before starting the compensation process again:

- Check that the test cables are properly connected.
- Check that nothing is connected to the test cables. (Open circuit compensation cannot be performed while any test sample is connected to the test cables.)
- Check that the test leads are arranged as closely as possible to their configuration in which measurement will be performed.
- During the compensation process, be sure not to disturb the test cables or to move your hand near them.
- Execute the guarding process. (For details, refer to Section 5.2, "Testing High Impedance Elements".)

4.7.6 Clearing Compensation Data

From the Open circuit compensation screen, press the OFF key, and the display will revert to the Initial screen with the compensation data cleared.

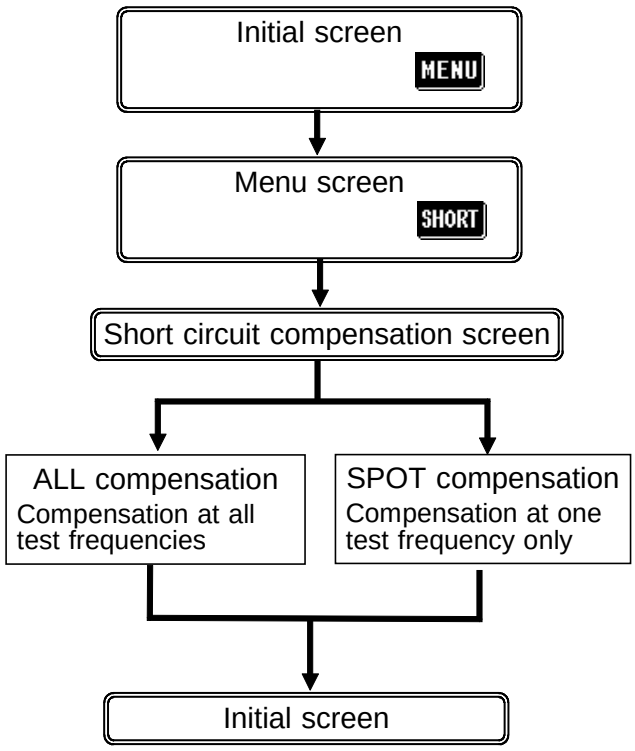
4.8 Short Circuit Compensation

With short circuit compensation, it is possible to reduce the influence of the residual impedance of the test cables and thereby to enhance the accuracy of measurement. It is effective for test samples whose impedance is relatively low.
Short circuit compensation may be performed according to either of two methods:
ALL compensation
Compensation is performed at all the test frequencies.
SPOT compensation
Compensation is performed for one specified test frequency only.

NOTE

- Before short circuit compensation, always set the cable length. For details, refer to Section 4.14.
- The testing accuracy specified in the specification of the 3532-50 unit assumes that open circuit compensation and short circuit compensation is being performed, as appropriate.
- When you have changed the test cables, be sure to perform compensation again. Correct test values will not be obtained if you go on testing using the same old compensation values which were obtained before the cable change.

4.8.1 Control Screen Sequence



Press the MENU key.

Press the SHORT key.

Select the compensation method
(ALL compensation or SPOT compensation).

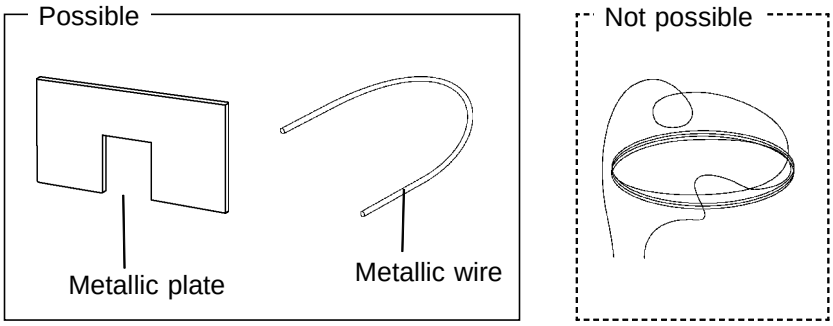
If setting has been completed normally, the short circuit residual component and its phase angle are displayed.

When compensation has been completed, press the O K key to return to the Initial screen.

Short circuit compensation has been set.

4.8.2 Setting the Compensation Method

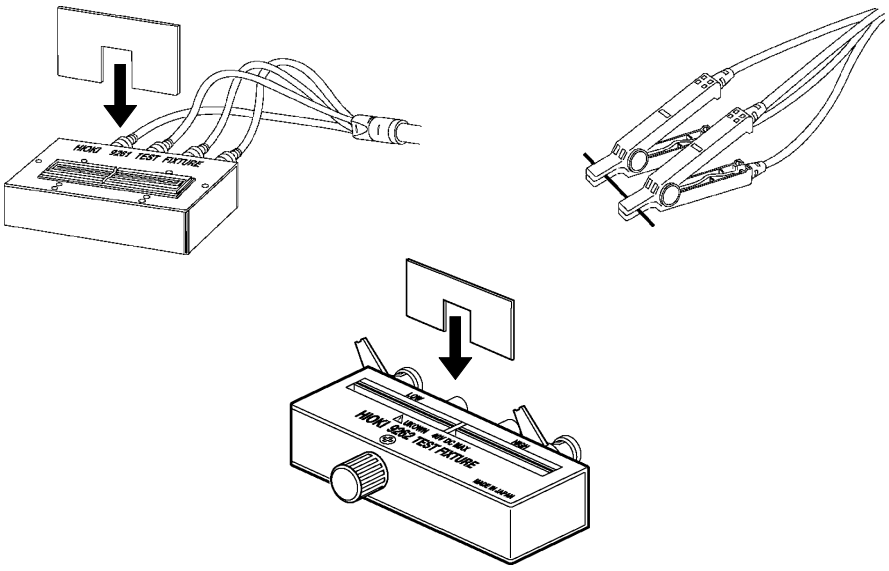
1. A shorting bar is used. This shorting bar is for short circuiting together the ends of the test leads. Use an object whose impedance is as low as possible.



NOTE

If you use a metallic wire or the like as a shorting bar, try to ensure that it is as thick and short as possible.

2. Arrange the test leads as closely as possible to their configuration in which measurement will be performed, and short circuit together the HIGH and LOW leads. In order to keep external influences as low as possible, be sure to thrust the shorting bar in all the way.

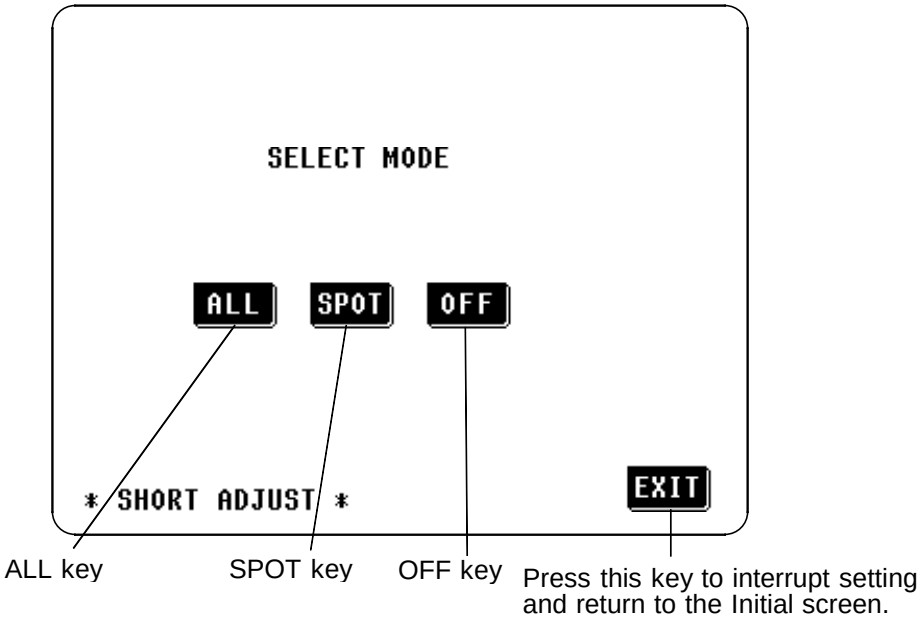


NOTE

If you intend to short circuit between the clamps at the ends of the test leads, clip both clamps onto a short piece of metallic wire as shown. If you clip the two clamps together directly, they will not be properly short circuited together.

3. On the Initial screen, press the MENU key, and the Menu screen will be displayed.

4. Press the SHORT key on the Menu screen, and the Short circuit compensation screen will be displayed.

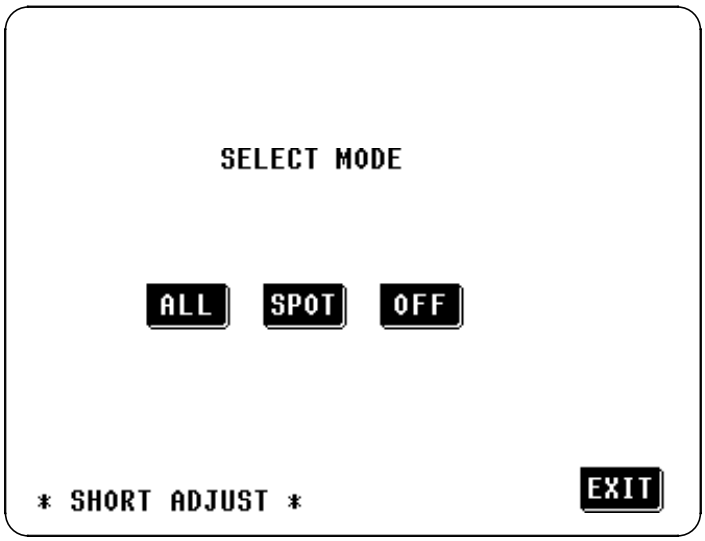


5. The SHORT circuit compensation method can be set to:
ALL : Compensation values are obtained for all test frequencies .
SPOT : Compensation values are obtained at the set test frequency only.
OFF : The short circuit compensation data are cleared.

4.8.3 ALL Compensation

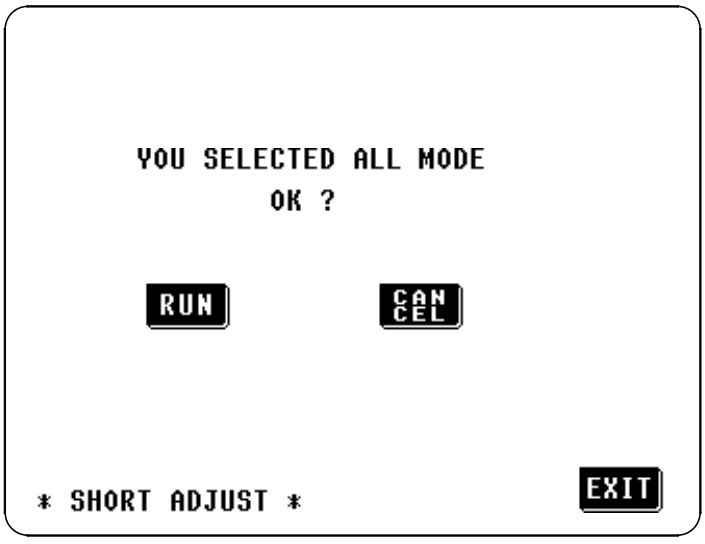
ALL
Short circuit compensation screen

1. To select ALL compensation, press this key with the Short circuit compensation screen displayed.



Short Circuit Compensation Screen

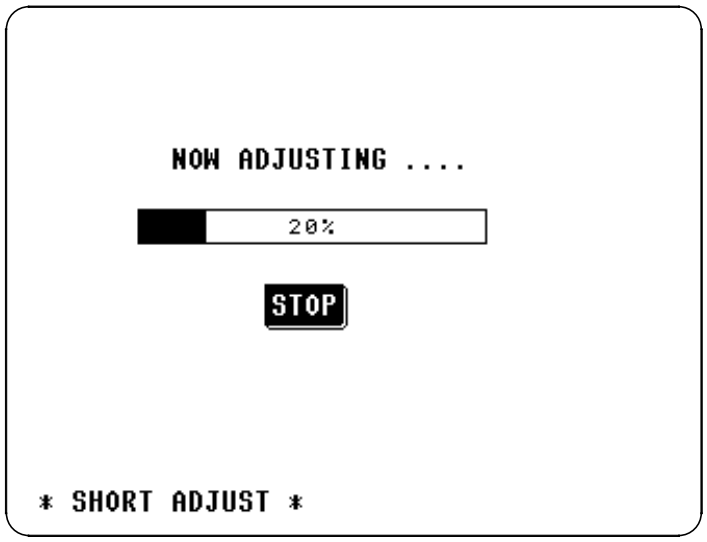
2. A Confirmation screen will appear for confirmation. To proceed, press the RUN key; if not, press the CANCEL key to return to the Short circuit compensation screen.



NOTE

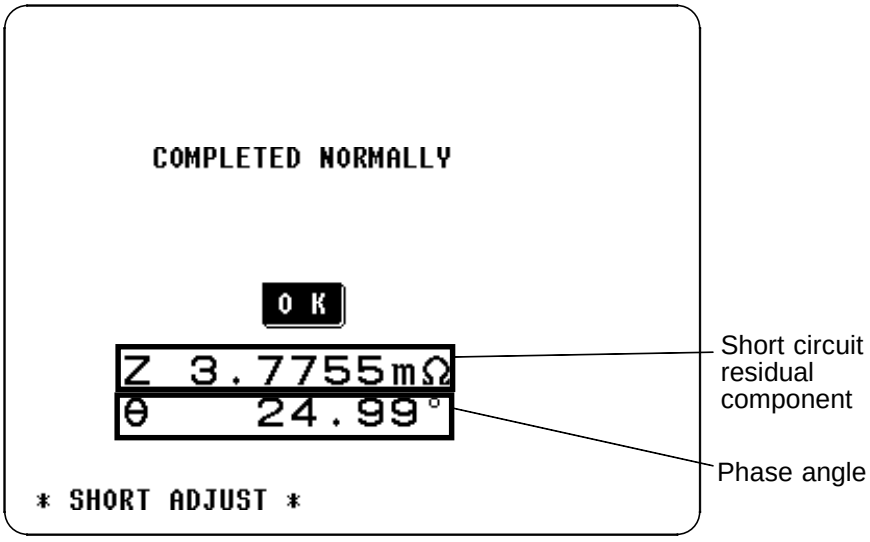
Check again - are the test leads properly shorted together with the shorting bar?

3. When you press the RUN key, the ALL short circuit compensation process starts. After about 2 minutes, the determination and adjustment of the short circuit compensation values is complete.



Interrupting the ALL compensation process:
To interrupt the ALL compensation process, press the STOP key on this screen. The compensation process will stop and the display will revert to the Initial screen. At this time, the compensation values obtained in the previous episode of short circuit compensation will remain valid.

4. If the compensation process has terminated satisfactorily, the following Confirmation screen will be displayed.
The short circuit residual component for the test cables at the frequency of 5 MHz and its phase angle are shown on the screen. (If an error message appears, refer to Section 4.8.5.)



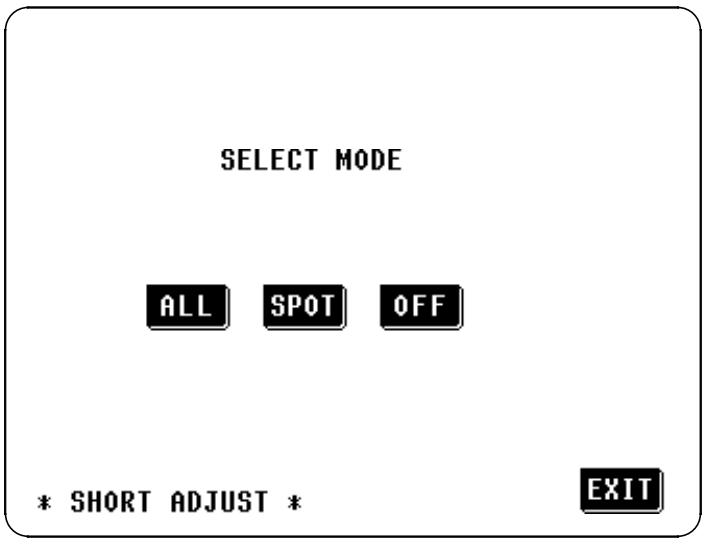
These values are required for use with the test range on HOLD. (For details, refer to Section 4.9, "Open Circuit Compensation and Short Circuit Compensation".)
After checking the short circuit residual component and its phase angle, press the O K key, and the display will return to the Initial screen.

NOTE Compensation can be performed for impedances less than 1 kΩ

4.8.4 Spot Compensation

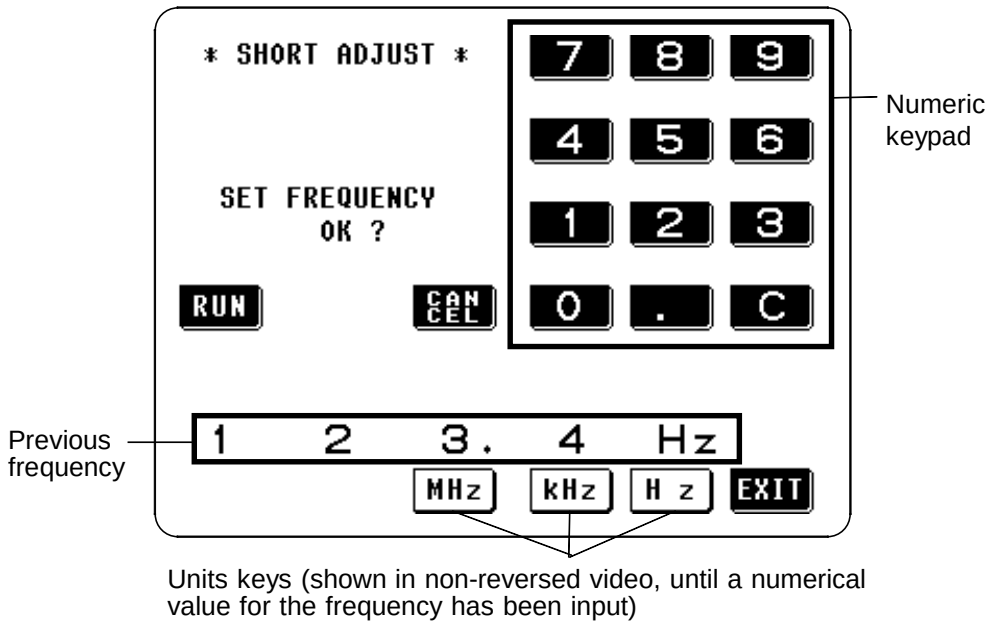
SPOT
Short circuit compensation screen

1. To select SPOT compensation, press this key with the Short circuit compensation screen displayed.



Short Circuit Compensation Screen

2. A numeric keypad is displayed for input of the frequency. Until one of these keys is pressed for input of a numerical value, the previous frequency for which SPOT compensation was performed is displayed.



SPOT compensation for the same frequency as previously:
Just press the RUN key. SPOT compensation will be started using the same frequency which was used for the last episode of SPOT compensation.

When compensation is to be performed for some new frequency:
Input the frequency for compensation using the numeric keypad.
Frequency range which can be set : 42.0 Hz to 5.000 MHz

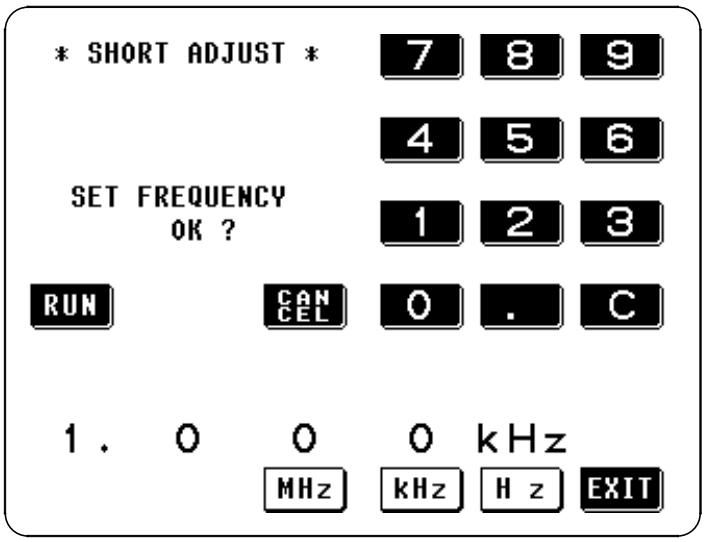
NOTE

If you attempt to set a test frequency greater than 5 MHz, it will automatically be reduced to 5 MHz.
If you attempt to set a test frequency lower than 42 Hz, it will automatically be increased to 42 Hz.

If you make a mistake during input of the numerical value, press the C key to cancel the input so far, and start again.

- When you have completed inputting the numerical value for the frequency, press the appropriate units key MHz, kHz, or Hz so as to confirm the displayed frequency for compensation.
- Until the numerical value for the frequency has been input, the units keys cannot be used.

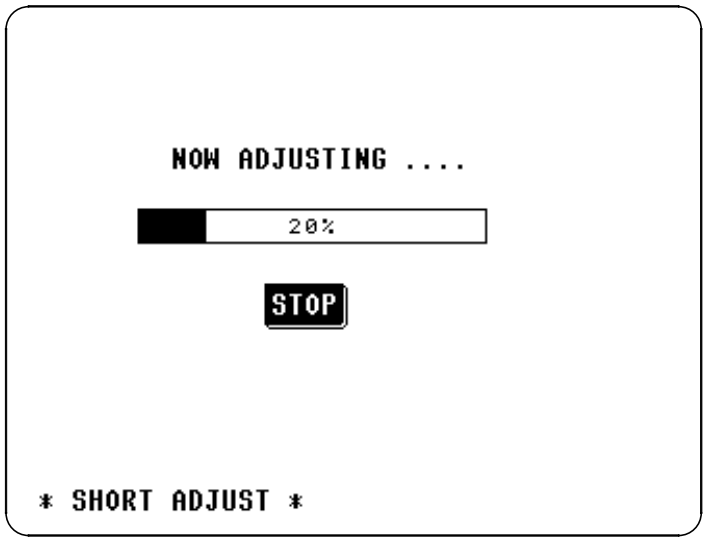
3. After the frequency for SPOT compensation has been input as above, press the RUN key.



NOTE

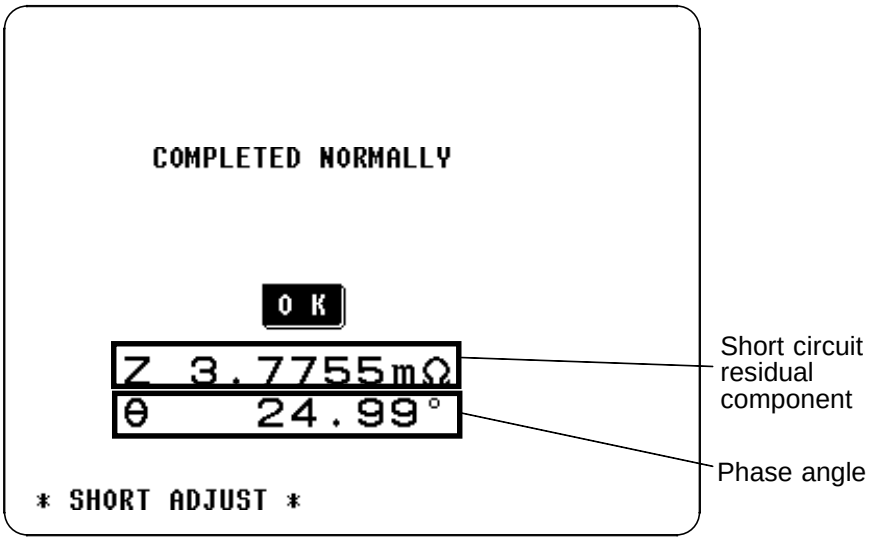
Check again - are the test leads properly shorted together with the shorting bar?

4. When you press the RUN key, the SPOT short circuit compensation process starts.



Interrupting the SPOT compensation process:
To interrupt the SPOT compensation process, press the STOP key on this screen. The compensation process will stop and the display will revert to the Initial screen. At this time, the compensation values obtained in the previous episode of short circuit compensation will remain valid.

5. If the compensation process has terminated satisfactorily, the following Confirmation screen will be displayed.
The short circuit residual component for the test cables at the set frequency, and its phase angle, are shown on the screen. (If an error message appears, refer to Section 4.8.5.)

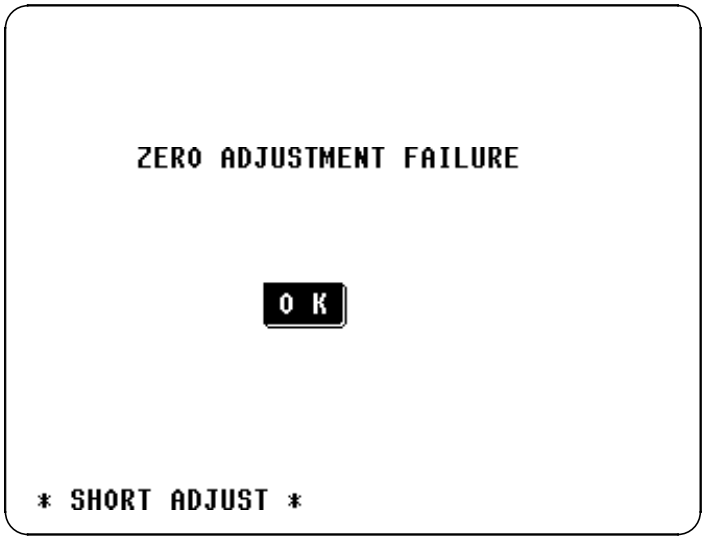


These values are required for use with the test range on HOLD. (For details, refer to Section 4.9, "Open Circuit Compensation and Short Circuit Compensation".)

After checking the short circuit residual component and its phase angle, press the O K key, and the display will return to the Initial screen.

4.8.5 When an Error Message Appears and Compensation Has Stopped

When an error message appears and compensation has stopped, short circuit compensation is turned off.



Check the following points before starting the short circuit compensation process again:

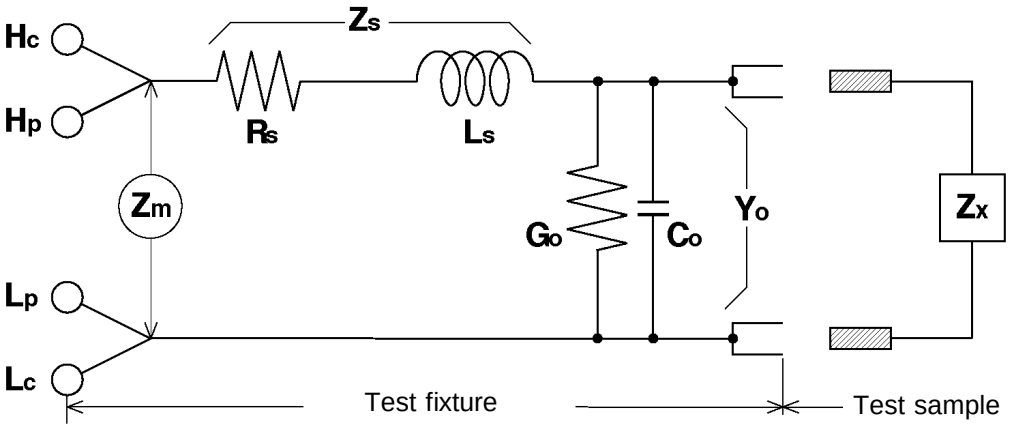
- Check that the test cables are properly connected.
- Check that the test cables are properly shorted together with the shorting bar. (Short circuit compensation cannot be performed while any test sample is connected to the test cables.)
- Check that the test leads are arranged as closely as possible to their configuration in which measurement will be performed.
- During the compensation process, be sure not to disturb the test cables or to move your hand near them.

4.8.6 Clearing Compensation Data

From the Short circuit compensation screen, press the OFF key, and the display will revert to the Initial screen with the compensation data cleared.

4.9 Open Circuit Compensation and Short Circuit Compensation

The residual impedance component of the test fixture can be considered in terms of an equivalent circuit as shown in the figure. Further, because the measured value Zm for impedance includes this residual component, therefore, in order to obtain the genuine impedance value, it is necessary to compensate the measured value in terms of the open circuit impedance residual component and the short circuit residual component, which accordingly must be obtained.



Zx : true value
Ls : residual inductance
Co : floating capacitance value
Yo : open circuit residual component
Rs : residual resistance
Go : residual conductance
Zs : short circuit residual component
Zm : measured value

In this case, for the measured value Zm:

$$Zm = Zs + 1/(Yo + 1/Zx)$$

The residual components can be determined in the following manner:

Open circuit compensation

The terminals of the test fixture are left separated (open circuited). Because the short circuit residual component Zs is now zero, therefore the open circuit residual component Yo can be determined.

Short circuit compensation

The terminals of the test fixture are connected together (short circuited). Because the open circuit residual component Yo is now zero, therefore the short circuit residual component Zs can be determined.

These residual components thus obtained are recorded as compensation values, and the compensation process may then be performed by substituting them into the above equation.

NOTE

The determination of test range is performed according to the measured value Zm for impedance. Therefore it may happen that testing cannot be performed, when HOLD is on, if the test range is determined merely according to the value of impedance of the sample under test. In this case, you should set the test range in consideration both of the impedance of the test sample and also of the residual impedance components of the test fixture.

Deviations in the measured values can become comparatively large in the following cases:

- If only short circuit compensation has been performed.
  With short circuit compensation only having been performed, since no compensation can be performed in terms of the open circuit residual component Yo (which is not available), thereby deviation in the resultant values will become large if the value of that open circuit residual component Yo is relatively large.

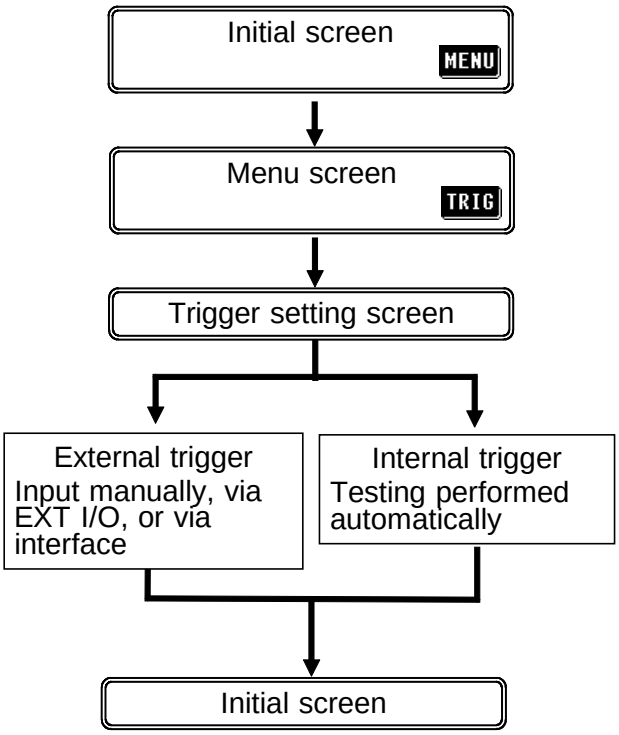
- If only open circuit compensation has been performed.
  With open circuit compensation only having been performed, since no compensation can be performed in terms of the short circuit residual component Zs (which is not available), thereby deviation in the resultant values will become large if the value of that short circuit residual component Zs is relatively large.

  In order to avoid this sort of thing, be sure always to perform both short circuit compensation and also open circuit compensation.

4.10 Setting the Trigger

The trigger can either be set to internal trigger, when continuous testing is performed while automatically generating an internal trigger signal, or external trigger, when a trigger signal is input from the outside either manually or automatically.

4.10.1 Control Screen Sequence



Press the MENU key.

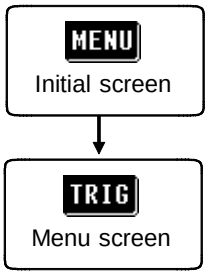
Press the TRIG key.

Select the type of trigger (external trigger or internal trigger).

When the setting has been established as above, press the EXIT key to return to the Initial screen.

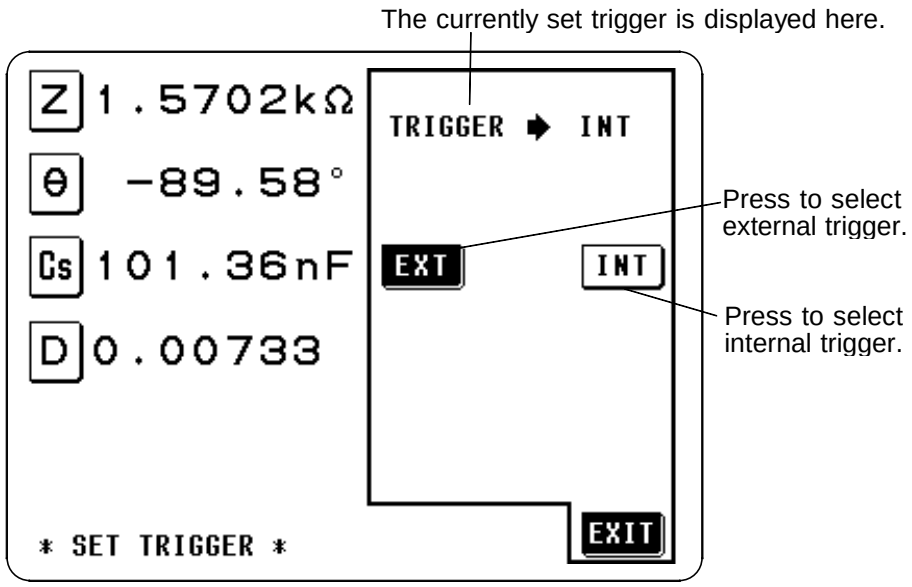
The trigger has been set.

4.10.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the TRIG key on the Menu screen to display the Trigger setting screen.

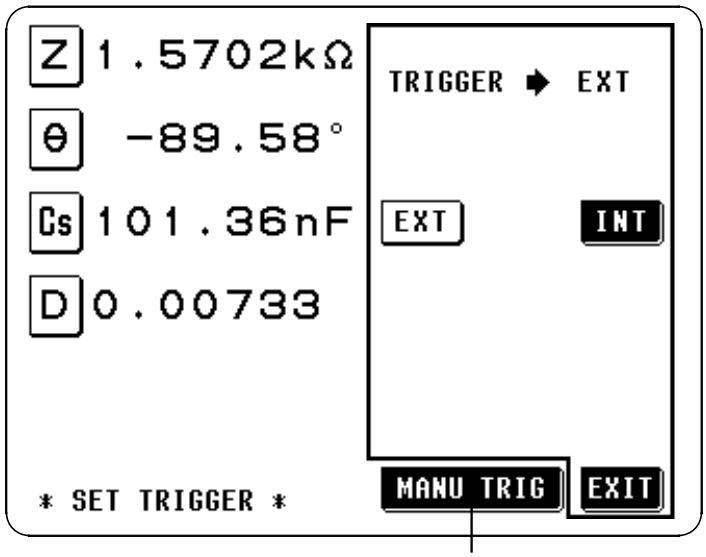


Trigger Setting Screen

INT (internal trigger)
Testing is performed continuously.

EXT (external trigger)
The trigger is input manually, via EXT I/O, or via interface.

The external trigger can be input manually, via the EXT I/O connector, or via interface.
When external trigger is selected, MANU TRIG appears as shown in the following figure, and a manual trigger signal can be input by pressing this key.



When inputting the trigger signal through the EXT I/O connector:
Testing is performed once, each time a negative sense pulse signal is supplied to the EXT I/O connector on the rear panel of the 3532-50. (For details, refer to Section 5.5, "The EXT I/O Connector")

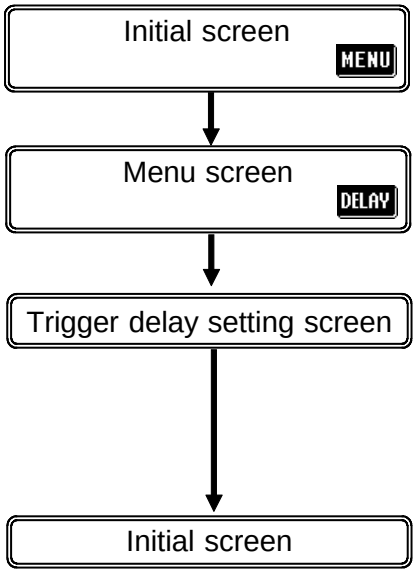
When inputting the trigger signal through the interface:
Testing is performed once, when the "*TRG" command is transferred from the interface. (For details, see the "Command Reference" of the Instruction Manuals for the interface.

3. When the setting has been established as above, press the EXIT key to return to the Initial screen.

4.11 Setting the Trigger Delay

The delay time period from input of the trigger signal to reading of the test data can be set. The value of the trigger delay period can be set from 10 ms to 9.99 s, with a resolution of 10 ms. With this function it is possible to ensure that testing is started after the connection condition of the object being tested and the test cables has stabilized.

4.11.1 Control Screen Sequence



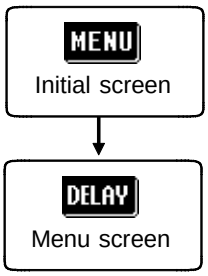
Press the MENU key.

Press the DELAY key.

Set the trigger delay time.
When the setting has been established, press the EXIT key to return to the Initial screen.

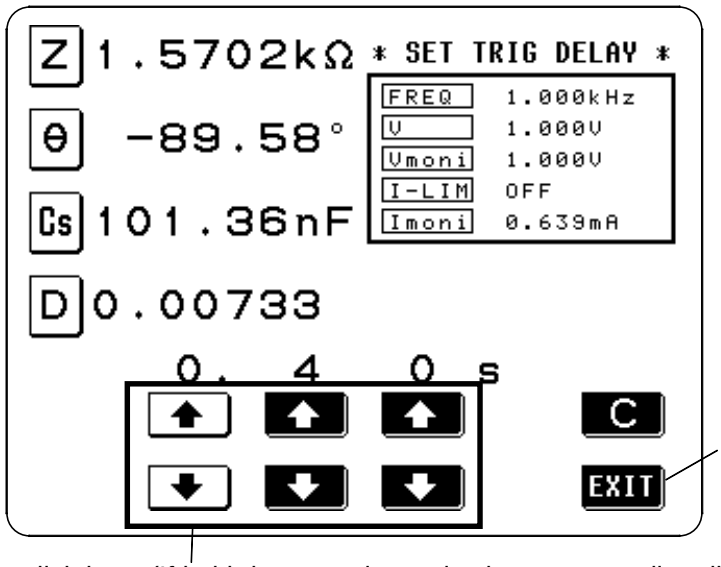
The setting has been performed.

4.11.2 Details of the Setting Process



1. Press the MENU key on the Initial screen.
The Menu screen will be displayed.

2. Press the DELAY key on the Menu screen.
The Trigger delay setting screen will be displayed.



Press this key when setting is completed to return to the Initial screen.

The digit keys (If held down continuously, the corresponding digit increments or decrements continuously.) (If the limit for the corresponding digit is reached, these keys change to non-reversed video and become inactive.)

3. Set the desired value for the delay time period using the digit keys.

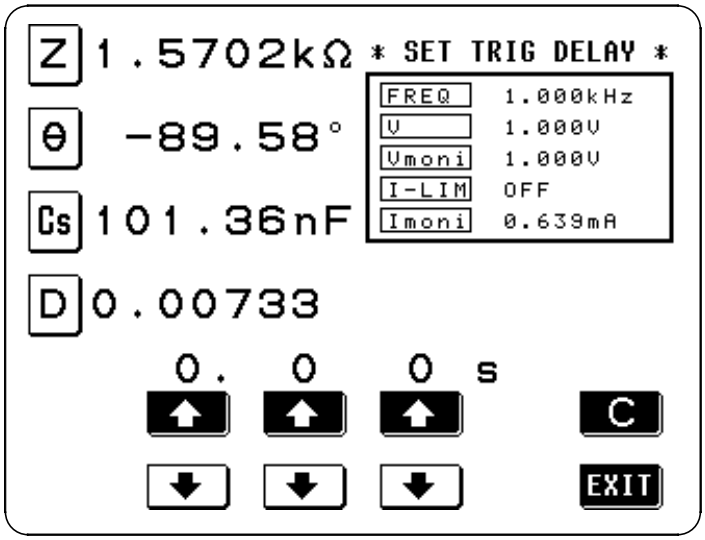
The range over which the delay time period can be set :
10 ms to 9.99 s, with a resolution of 10 ms

The other keys, which cannot be used, are shown in non-reversed video.

4. When the setting has been established as above, press the EXIT key to return to the Initial screen.

Canceling the trigger delay function

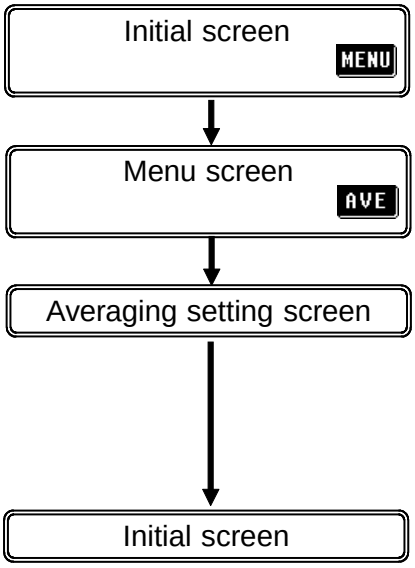
Press the C key to set the trigger delay period to 0.00 s. This will cancel the trigger delay function.



4.12 Setting Averaging

With the averaging function, the measured values can be averaged. Using this function, it is possible to reduce fluctuations in the measured value display.
The averaging can be performed over 2, 4, 8, 16, 32, or 64 times that measurement is performed.

4.12.1 Control Screen Sequence



Press the MENU key.

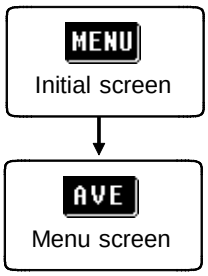
Press the AVE key.

Set the number of measurement times for averaging.

When the setting has been established, press the EXIT key to return to the Initial screen.

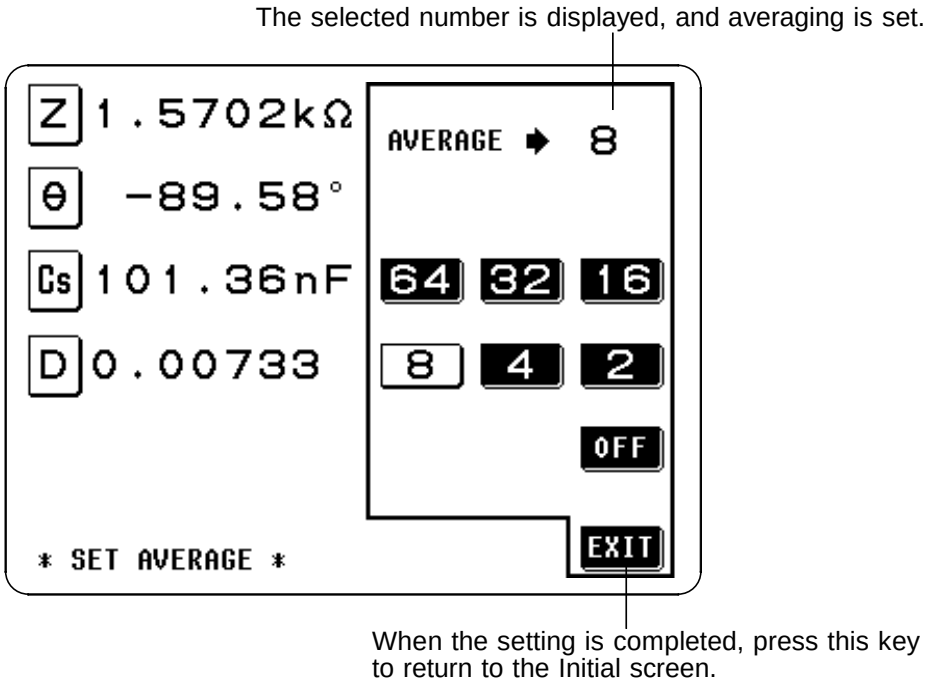
The setting has been made.

4.12.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the AVE key on the Menu screen to display the Averaging setting screen.



Averaging Setting Screen

3. Press the key corresponding to the desired number of times for averaging.
The number of times for averaging which can be selected : 2, 4, 8, 16, 32, or 64.
The key which is pressed goes into non-reversed video, and this number is set as the number of times for averaging.

NOTE

The way in which averaging is performed varies, depending upon the trigger setting.

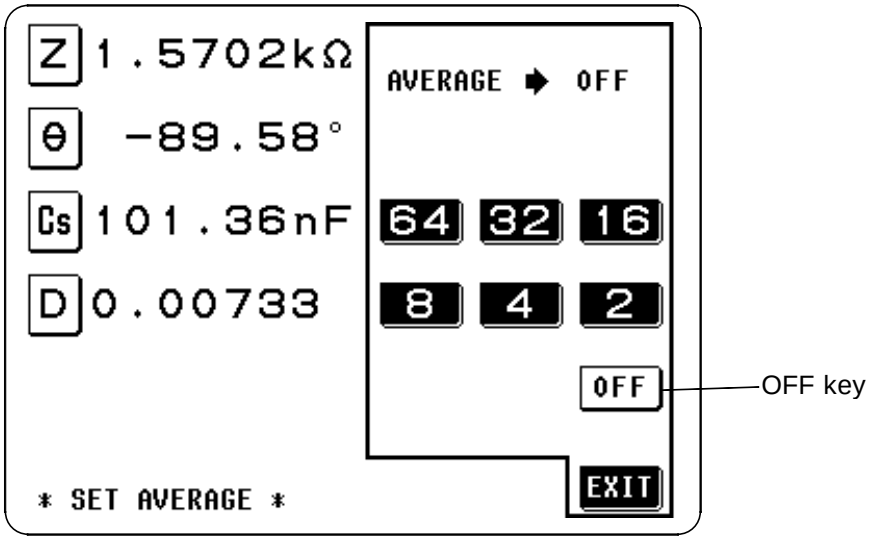
With internal trigger:
A rolling average of the tested values over the set number of times for averaging is always calculated backwards from the present.
When the sample to be tested is changed over, it takes a little time for a certain stabilization time period until the results is reliable.

With external trigger:
An average of the test values is calculated over the set number of times for averaging forwards from when the trigger is input.

4. When the setting has been established as above, press the EXIT key to return to the Initial screen.

Stopping the averaging function

On the Averaging setting screen, press the OFF key. This key will go into non-reversed video, and the averaging function will be terminated.

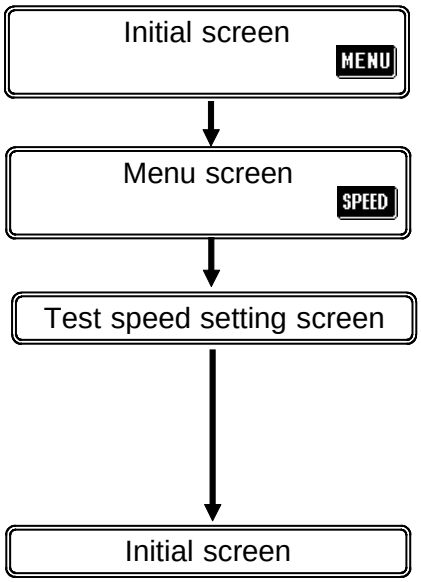


4.13 Setting the Testing Speed

The testing speed can be set. The slower the testing speed is, the more accurate are the results.
The testing speed can be set to one of three values:

FAST	low accuracy testing is performed at high speed
NORM	the speed used for normal testing
SLOW	high accuracy testing is performed slowly
SLOW2	high accuracy testing is performed slowly

4.13.1 Control Screen Sequence



Press the MENU key.

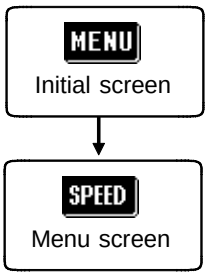
Press the SPEED key.

Select the speed for testing.

When the setting has been established, press the EXIT key to return to the Initial screen.

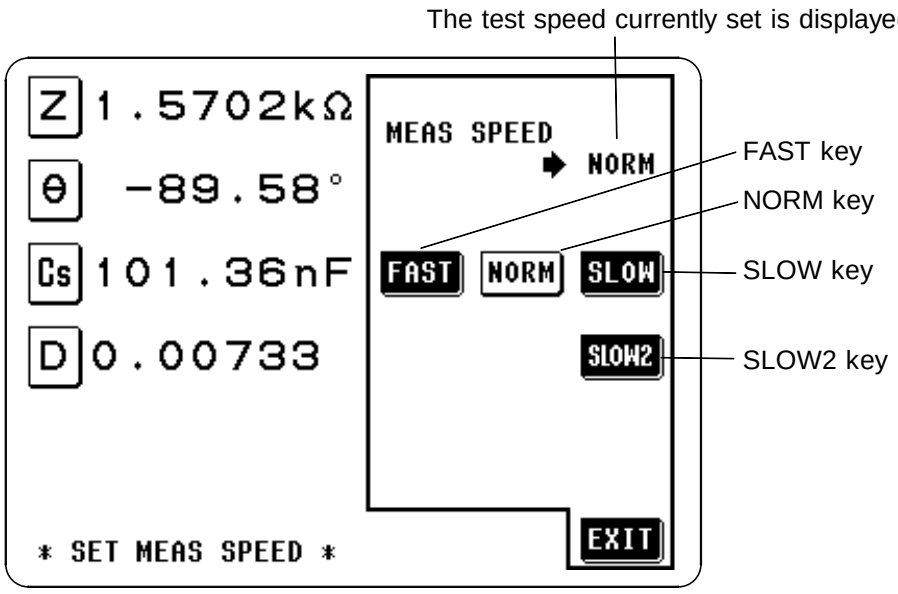
The setting has been made.

4.13.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the SPEED key on the Menu screen to display the Test speed setting screen.



Test Speed Setting Screen

3. Select the desired new speed for testing from among the following options. The key corresponding to the currently selected testing speed appears in non-reversed video (black letters upon a white ground).

Testing speeds (typical)

FAST	5 ms ±2 ms	Low accuracy testing at high speed
NORM	21 ms ±2 ms	This speed used for normal testing
SLOW	72 ms ±2 ms	High accuracy slow testing
SLOW2	140 ms ±2 ms	High accuracy slow testing

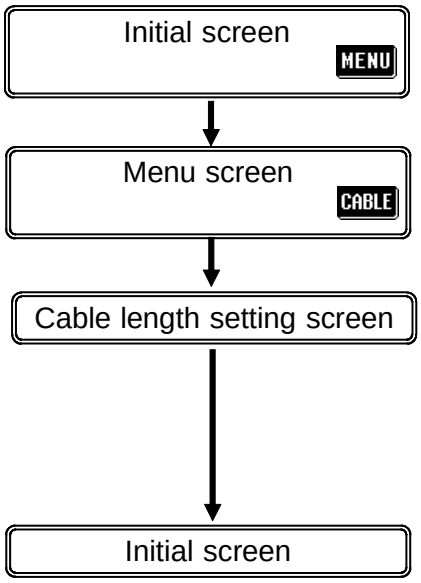
The testing speed varies according to the number of parameters being displayed, and according to their type. The speeds given in the table relate to the case of $|Z|$ only being displayed. For details, refer to Section 7.3, "Time Taken for Testing."

4. When the setting has been established as above, press the EXIT key to return to the Initial screen.

4.14 Setting the Measurement Cable Length

In measuring harmonics, the cable has a large influence on the measurement error. Making the cable length setting enables the measurement error to be reduced.

4.14.1 Control Screen Sequence



Press the MENU key.

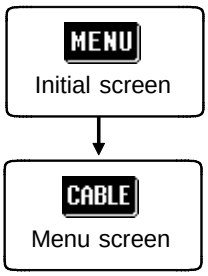
Press the CABLE key.

Set the cable length.

When the setting has been established, press the EXIT key to return to the Initial screen.

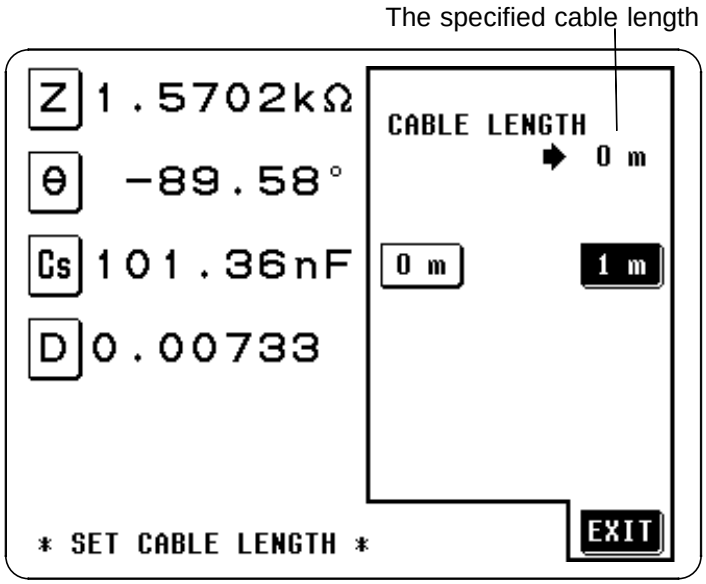
The setting has been made.

4.14.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the CABLE key on the Menu screen to display the Cable length setting screen.



Cable Length Setting Screen

3. Select the desired cable length.
When the following test fixture probe is used, set the cable length shown below.

0 m : When using the 9262 TEST FIXTURE or 9263 SMD TEST FIXTURE

1 m : When using the 9140 4-TERMINAL PROBE, 9143 PINCHER PROBE, or 9261 TEST FIXTURE

4. When the setting has been established, press the EXIT key to return to the Initial screen.

4.15 Setting and Activating the Comparator

Using the comparator function an upper limit value and a lower limit value can be set, and the result of measurement then can be compared with these two limit values, so as to give a result expressed as HI (greater than the upper limit value), IN (between the lower limit value and the upper limit value), or LO (less than the lower limit value). Moreover, a corresponding signal can be output via the EXT I/O connector on the rear panel of the 3532-50 unit.
The following setting methods are available on the comparator:

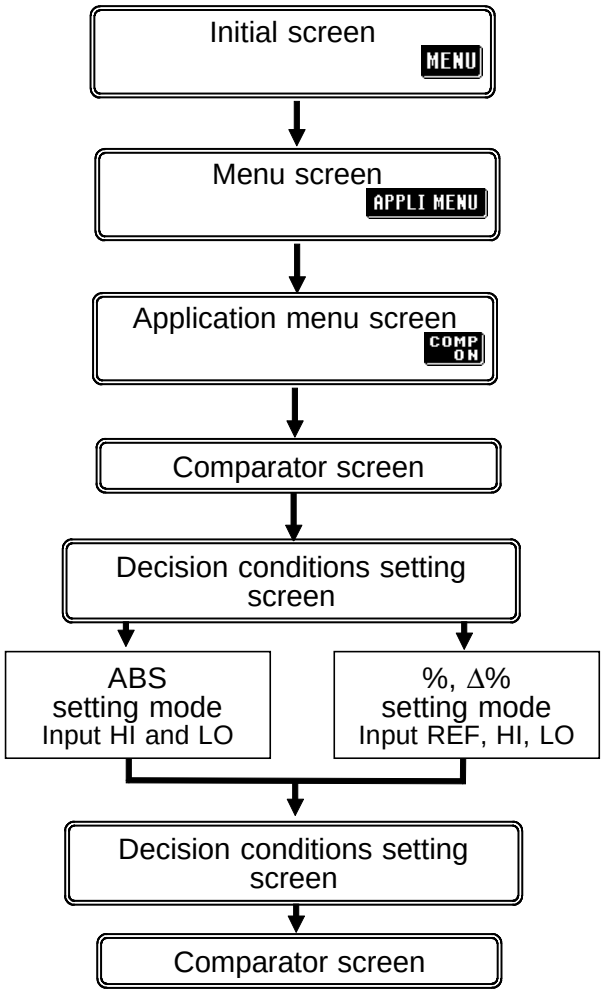
Absolute value setting method (ABS)
The upper limit value and the lower limit value are set as absolute numerical values. The measurement values displayed are the same as those of the measurement parameters.

Percentage setting method (%)
A reference value is input, and the upper-limit and lower-limit values are set as percentages relative to the reference value. The measurement values displayed are the same as those of the measurement parameters.

Setting of the deviation percentage (Δ%)
A reference value is input, and the upper-limit and lower-limit values are set as percentages relative to the reference value. The measurement values are displayed in deviations (Δ%) from the reference value.

The comparator can deal with two test values at the most. "ABS", "%", and "Δ%" can be selected for each of these values individually.
After powering off on the Comparator setting screen, the screen is displayed when the power is turned on again.

4.15.1 Control Screen Sequence



Press the MENU key.

Press the APPLI MENU key.

Press the COMP ON key.

Activate the comparator.

To change the comparator settings, press the LMT key.

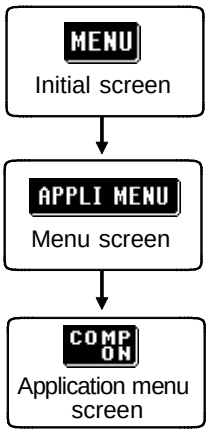
Choose the comparator setting method (ABS, %, or Δ%)

Input the decision conditions.

When the input is complete, press the ENTER key to return to the Decision conditions setting screen.

When the setting has been established as above, press the EXIT key to return to the Comparator screen.

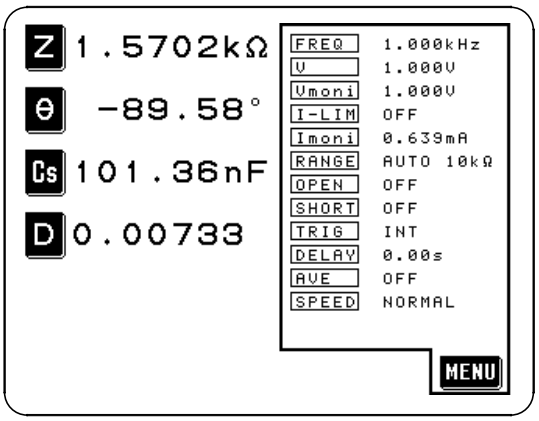
4.15.2 Setting the Comparator



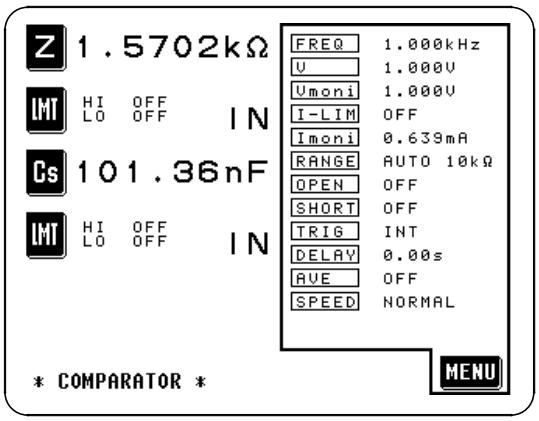
1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

3. Press the COMP ON key on the Application menu screen to display the Comparator screen. At the same time, the comparator will be started.



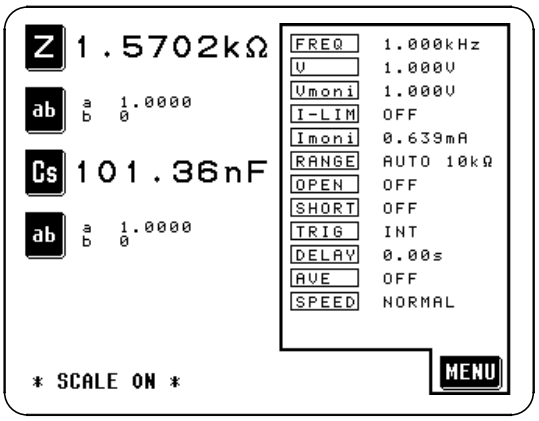
Initial Screen



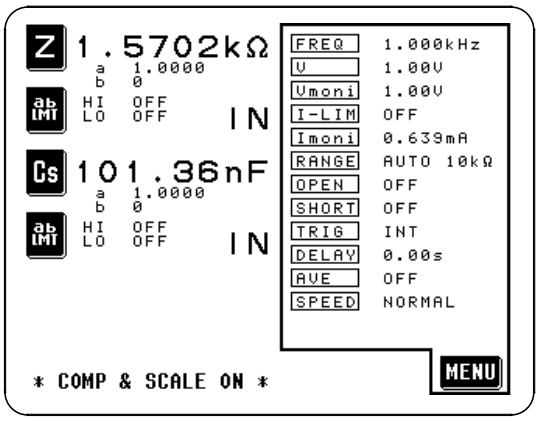
Comparator Screen

NOTE

On the Scaling screen, the Comparator scaling screen can be also accessed by same key operations. The comparator is activated for the scaling measured value.
For the scaling function, refer to Section 4.16.

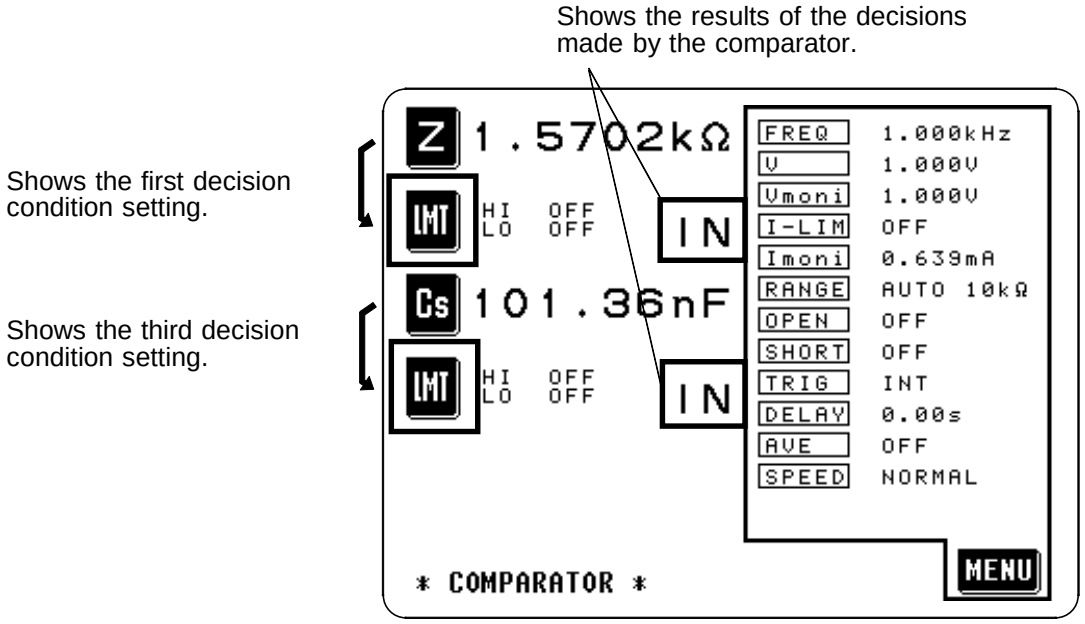


Scaling Screen



Comparator Scaling Screen

4. Set the first and third parameters to be the two parameters which you wish to measure. (Refer to the section on display parameter setting for details upon how to make the setting.)



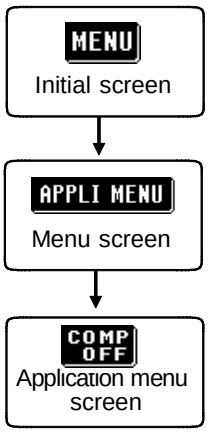
The Conditions setting screen is accessed by pressing the LMT key.

5. The Menu screen can be displayed from the Comparator screen display by pressing the MENU key, in the same manner as from the Initial screen, and then the values for the various test conditions can be changed. (For details, refer to the explanation of setting the appropriate test condition.)

NOTE

- When the trigger is internal, testing starts at the time point at which the comparator mode is started, and the results of the decisions will be output through the EXT I/O terminal.
- The test conditions during comparator operation and normal operation are compatible.

4.15.3 Returning from Comparator Operation to Normal Testing



1. Press the MENU key on the Comparator screen or the Comparator scaling screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

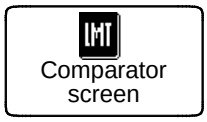
3. Press the COMP OFF key on the Application menu screen to return the Initial screen or the Scaling screen.

- The test conditions during comparator operation and normal operation are compatible.
- On the Initial screen, the second and fourth display parameter positions LMT will revert to displaying the parameters which they were displaying before the comparator mode was started. On the Scaling screen, they will revert to displaying ab .

NOTE

The comparator is active until the display returns to showing the Initial screen or Scaling screen.

4.15.4 Choosing How to Set the Upper and Lower Limit Values

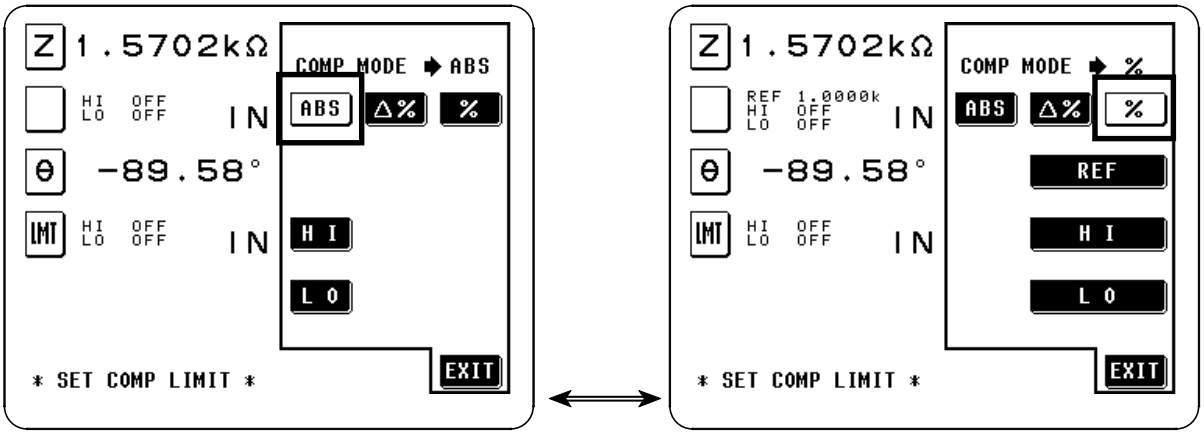


1. Access the Comparator screen.

2. On this screen, press the LMT key which corresponds to the upper or lower limit value to set or change. The Conditions setting screen is displayed.

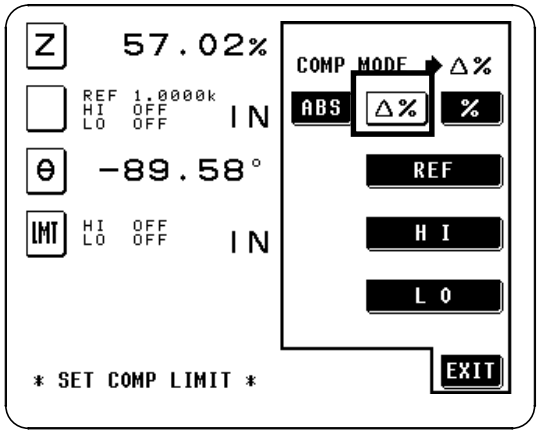
3. Select the method for setting the limit value and press the following corresponding key ABS or % :

- Absolute value setting method (ABS)
  The upper limit value and the lower limit value for the test parameter are set as absolute numerical values. The measurement values displayed are the same as those of the measurement parameters.
- Percentage setting method (%)
  A reference value is input, and the upper-limit and lower-limit values are set as percentages relative to the reference value. The measurement values displayed are the same as those of the measurement parameters.
- Setting of the deviation percentage (Δ%)
  A reference value is input, and the upper-limit and lower-limit values are set as percentages relative to the reference value. The measurement values are displayed in deviations (Δ%) from the reference value.



Absolute Value (ABS) Setting Screen

Percentage (%) Setting Screen



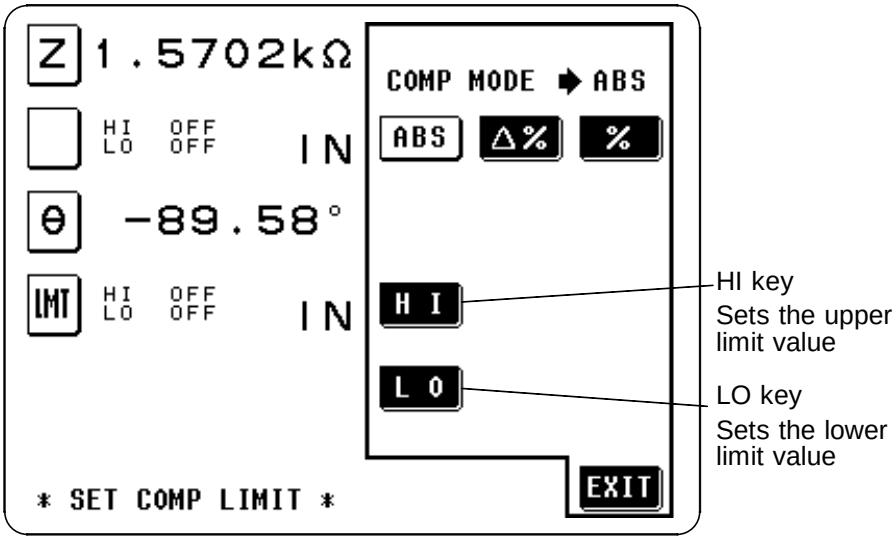
Deviation Percentage (Δ%) Setting Screen

4.15.5 Setting the Upper or Lower Limit Value as an Absolute Value (ABS)

ABS
Condition setting screen

1. Press this key on the Conditions setting screen displayed to select the absolute value setting mode.

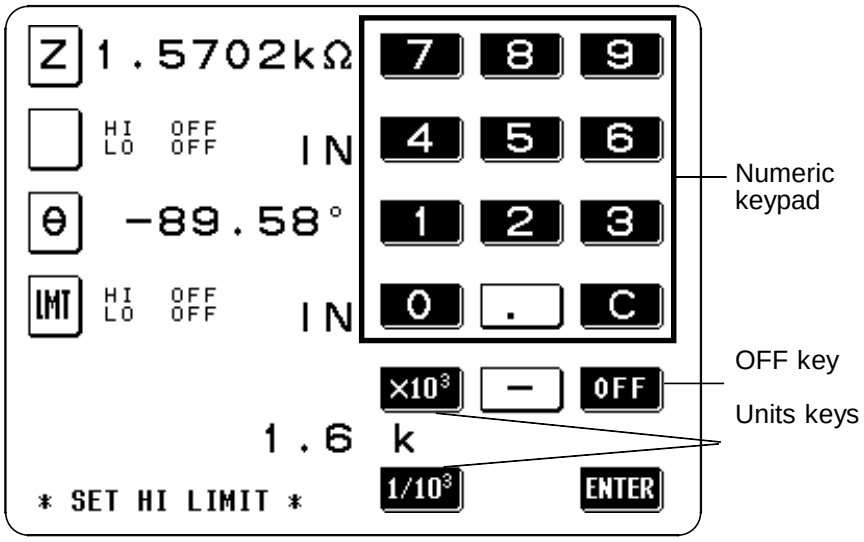
At this time the ABS key will go into non-reversed video, and simultaneously HI and LO keys will appear for setting the upper and lower limit values.



Absolute Value Setting Mode

2. To set the upper limit value (for example), press the HI key, and a screen will appear for upper limit value setting. Use the numeric keypad to input the desired value for the upper limit.

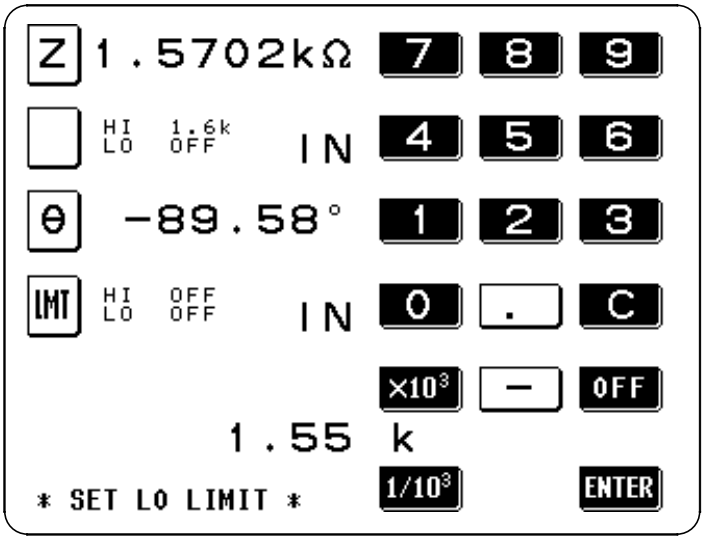
In order to set no upper limit value, press the OFF key.



The setting can be made in the range : -200.00M to +200.00M
To return to the previous screen without making any change to the set value, press the ENTER key when the screen is in the state with nothing being displayed (the state after pressing the C key).

3. Select the units using one of the units keys:
[×10³] : step the units up
[1/10³] : step the units down
p -- n -- μ -- m -- (none) -- k -- M
<= Units down Units up =>
Pressing the [ENTER] key causes the upper limit value to be set and the screen display to return to the Conditions setting screen.

4. The lower limit value is set in a manner identical to the upper limit value, mutatis mutandis.



The setting can be made in the range : -200.00M to +200.00M

5. When the setting for the upper or lower limit value has been established as above, press the [EXIT] key on the Condition setting screen to return to the Comparator screen.

NOTE

The comparator decisions are made in the following order:
1) If the measured value is "OVER FLOW", HI is displayed, and the value is "UNDER FLOW", LO is displayed.
2) Is the measured value greater than the lower limit value or not?
If not (NG decision result), then LO is displayed.
3) Is the measured value lower than the upper limit value or not?
If not (NG decision result), then HI is displayed.
4) If both 2) and 3) give an affirmative result, then IN is displayed.
No test is performed in order to ensure that the upper limit value is greater than the lower limit value. Therefore no error message will be displayed even if you mistakenly interchange the settings for the desired upper limit value and the desired lower limit value. However, be careful that the decision process will not operate properly.

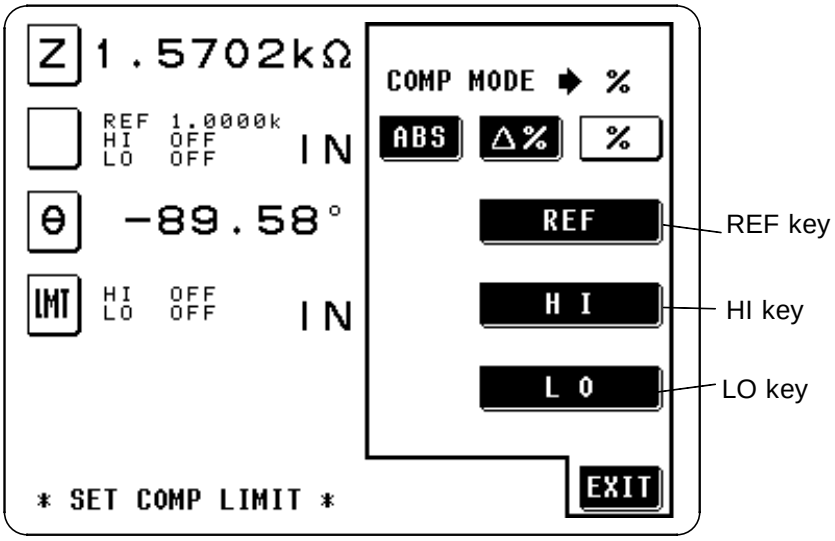
4.15.6 Setting the Upper or Lower Limit Value as a Percentage (%) Relative to a Standard Value

[%] Condition setting screen

1. Press this key on the Conditions setting screen to select the percentage value setting mode.

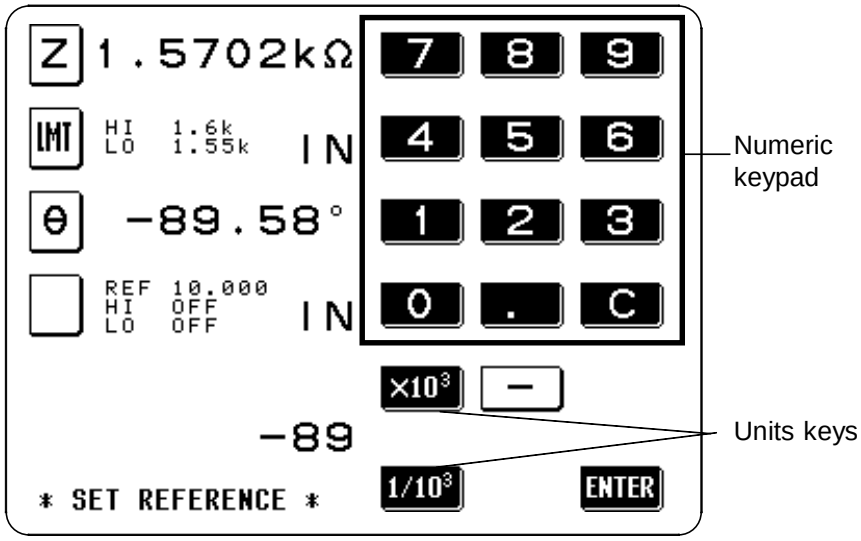
At this time the [%] key will go into non-reversed video, and simultaneously a [REF] key will appear for inputting the reference value, and [HI] and [LO] keys will appear for the upper and lower limit values.

NOTE The settings of the reference value and the upper- and lower-limit values are common to both the percentage mode and deviation percentage mode.



Percentage Value Setting Mode

2. Press the [REF] key, and a screen will appear for setting the reference value. This reference value is necessary for setting the limit values in terms of percentages.

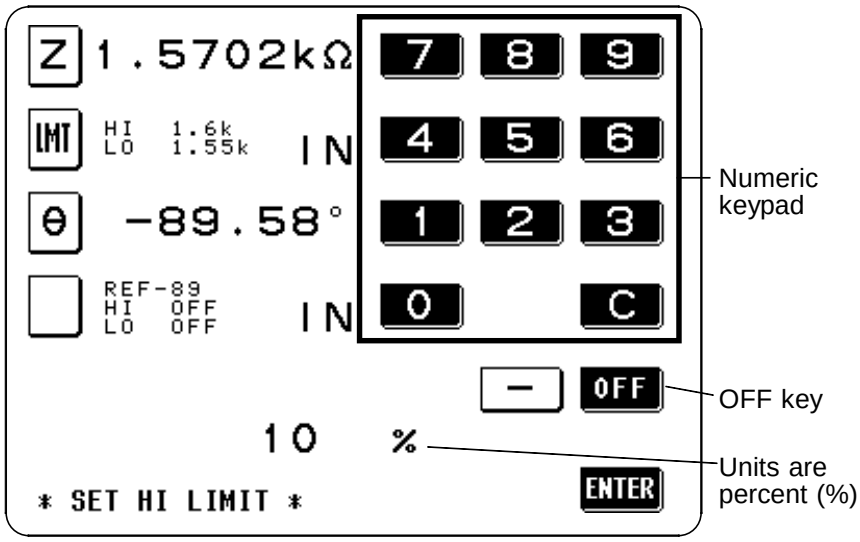


The setting can be made in the range : -200.00M to +200.00M

To return to the previous screen without making any change to the set reference value, press the [ENTER] key when the screen is in the state with nothing being displayed (the state after pressing the [C] key).

3. Select the units using one of the units keys:
[×10³] : step the units up
[1/10³] : step the units down
p -- n -- μ -- m -- (none) -- k -- M
<= Units down Units up =>
Pressing the [ENTER] key causes the upper limit value to be set and the screen display to return to the Conditions setting screen.

4. When the [H I] key is pressed, a screen for setting the upper limit value will appear. Use the numeric keypad to input the upper limit value as a percentage relative to the reference value.
In order to set no upper limit value, press the [OFF] key.



The setting can be made in the range : -999.99% to +999.99%

When the setting has been established as above, press the [ENTER] key to return to the Conditions setting screen with the upper limit value set.

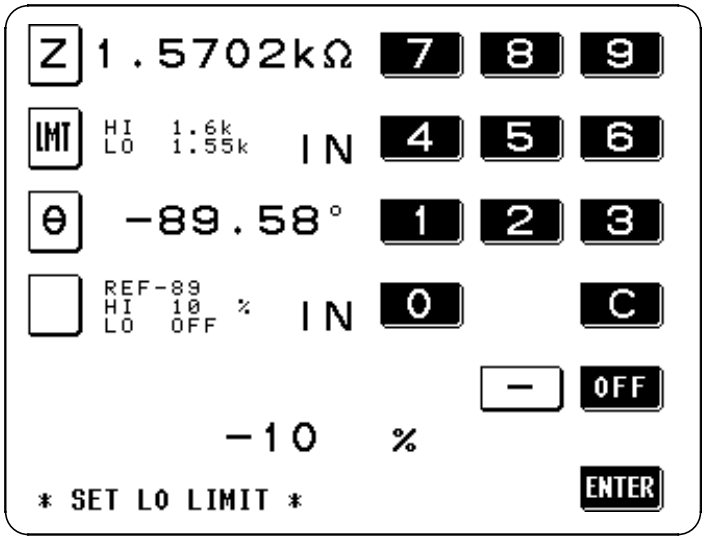
NOTE

The actual internal operation consists of calculating the upper-limit value of comparison using the equation given below, and comparing it to the measurement value to enable a decision to be made.

$$\text{Upper-limit comparison value} = \text{Reference value} + |\text{Reference value}| \times \frac{\text{Percentage set value}}{100}$$

| |: Denotes an absolute value

5. The lower limit value is set in a manner identical to the upper limit value, mutatis mutandis.



The setting can be made in the range : -999.99% to +999.99%

NOTE

The actual internal operation consists of calculating the lower-limit value of comparison using the equation given below, and comparing it to the measurement value to enable a decision to be made.
If a value smaller than the reference value is to be set, the percentage set value must be an absolute value.

$$\text{Lower-limit comparison value} = \text{Reference value} + |\text{Reference value}| \times \frac{\text{Percentage set value}}{100}$$

| |: Denotes an absolute value

If the value is lower than the reference value, a minus sign is necessary.

6. When the setting for the upper or lower limit value has been established as above, press the EXIT key on the Condition setting screen to return to the Comparator screen.

NOTE

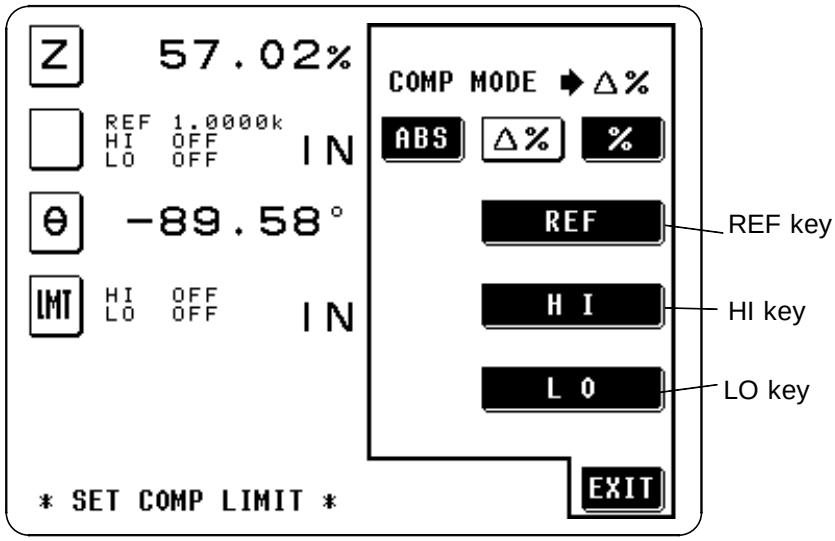
The comparator decisions are made in the following order:
1) If the measured value is "OVER FLOW", HI is displayed, and the value is "UNDER FLOW", LO is displayed.
2) Is the measured value greater than the lower limit value or not?
If not (NG decision result), then LO is displayed.
3) Is the measured value lower than the upper limit value or not?
If not (NG decision result), then HI is displayed.
4) If both 2) and 3) give an affirmative result, then IN is displayed.
No test is performed in order to ensure that the upper limit value is greater than the lower limit value. Therefore no error message will be displayed even if you mistakenly interchange the settings for the desired upper limit value and the desired lower limit value. However, be careful that the decision process will not operate properly.

4.15.7 Displaying Measurement Values as Deviations from the Reference Value (Δ%)

[Δ%] Condition setting screen

1. Press this key on the Conditions setting screen to select the deviation percentage mode.

At this time the [Δ%] key will go into non-reversed video, and simultaneously a [REF] key will appear for inputting the reference value, and [HI] and [LO] keys will appear for the upper and lower limit values.



Deviation Percentage Mode

The setting can be made in the range : -999.99% to +999.99%
In the deviation percentage mode, the measurement value is displayed as a deviation (Δ%) from the reference value. The reference value and upper- and lower-limit values are set in the same manner as in the percentage mode. For the setting method, refer to "4.15.6."

NOTE

The settings of the reference value and the upper- and lower-limit values are common to both the percentage mode and deviation percentage mode.

The Δ% value is calculated using the following equation:

$$\Delta\% = \frac{\text{Measurement value - Reference value}}{|\text{Reference value}|} \times 100$$

| |: Denotes an absolute value

If the result of the calculation exceeds 999.99, "999.99" will be indicated, and if the result is less than -999.99, "-999.99" will be displayed.

NOTE

The comparator decisions are made in the following order:

1) If the measured value is "OVER FLOW", HI is displayed, and the value is "UNDER FLOW", LO is displayed.
2) Is the measured value greater than the lower limit value or not? If not (NG decision result), then LO is displayed.
3) Is the measured value lower than the upper limit value or not? If not (NG decision result), then HI is displayed.
4) If both 2) and 3) give an affirmative result, then IN is displayed.

No test is performed in order to ensure that the upper limit value is greater than the lower limit value. Therefore no error message will be displayed even if you mistakenly interchange the settings for the desired upper limit value and the desired lower limit value. However, be careful that the decision process will not operate properly.

4.16 Setting and Activating the Scaling

Scaling applies a correction function to the measurement value. This function can be used to provide compatibility among measurement devices. Set the compensation coefficient a and b for the measurement values of the first and third parameters to compensate by the following expression.

$Y = a \times X + b$

X: the first or third parameter measurement value
Y: the last measurement value
a: integration value of the measured value X
b: the value added to measured value X

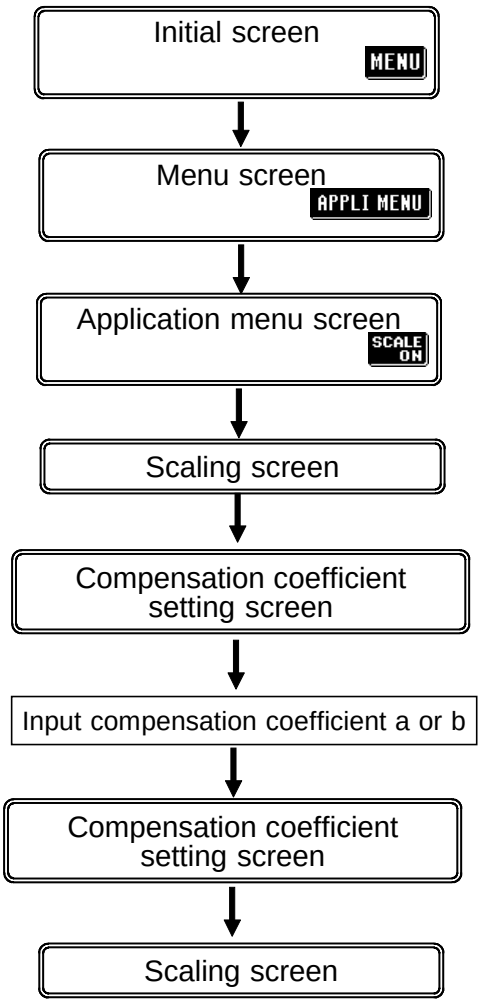
Here, when the parameter corresponding to X is either D or Q, the scaling is applied to θ as follows:

$\theta' = a \times \theta + b$

This gives a new value θ', from which D or Q is obtained.

After powering off on the Scaling screen, the same screen is displayed when the power is turned on again.

4.16.1 Control Screen Sequence



Press the MENU key.

Press the APPLI MENU key.

Press the SCALE ON key.

Activate the scaling function.

To change the compensation coefficient, press the ab key.

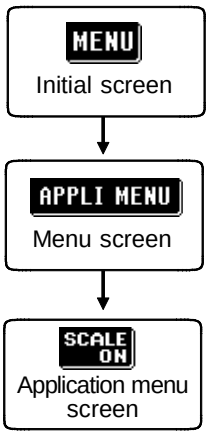
Choose the compensation coefficient (a or b).

Input the compensation coefficients.

When the input is complete, press the ENTER key to return to the Decision conditions setting screen.

When the setting has been established as above, press the EXIT key to return to the Scaling screen.

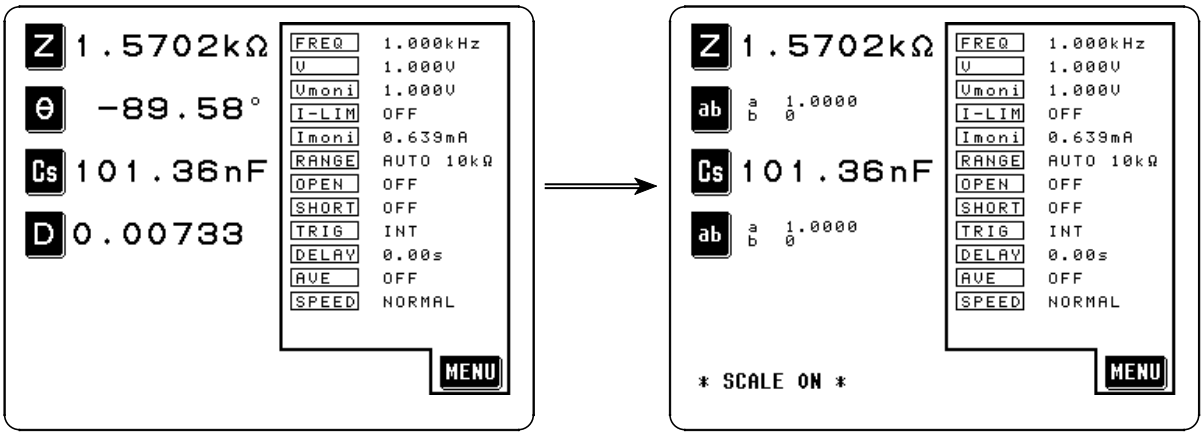
4.16.2 Setting Scaling



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

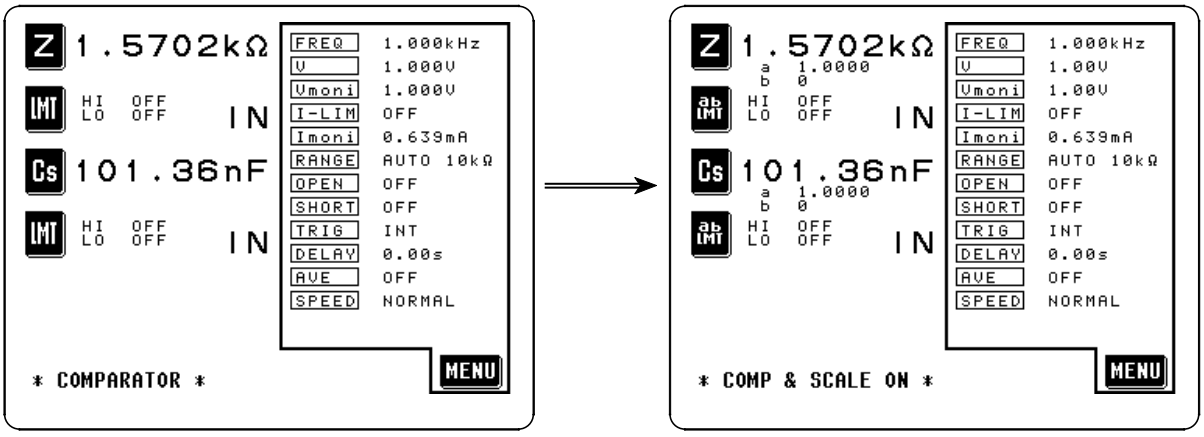
3. Press the SCALE ON key on the Application menu screen to display the Scaling screen. At the same time, the comparator will be started.



Initial Screen　　Scaling Screen

NOTE

On the Comparator screen, the Comparator scaling screen can be also accessed by the same key operations. For details on the comparator, see Section 4.15.

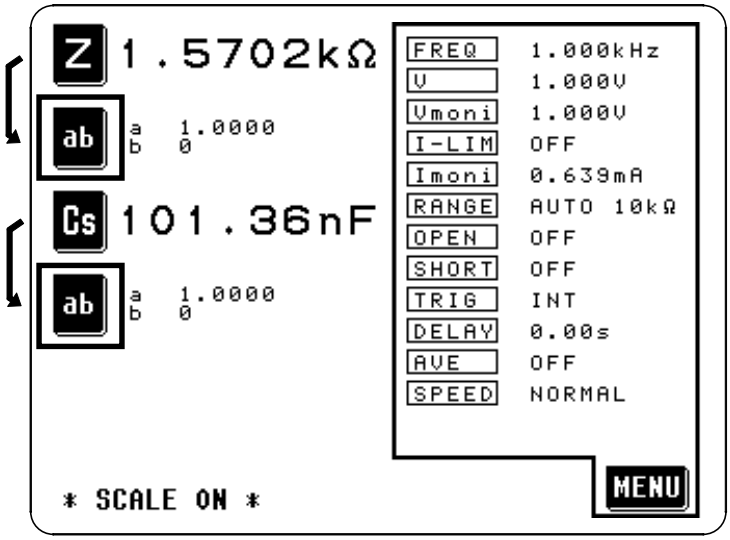


Comparator Screen　　Comparator Scaling Screen

4. Set the first and third parameters to be the two parameters which you wish to measure. (Refer to the section on display parameter setting for details upon how to make the setting.)

Shows the first compensation coefficient setting.

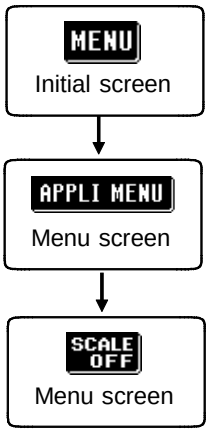
Shows the third compensation coefficient setting.



The Conditions setting screen is accessed by pressing the ab key.

5. The Menu screen can be displayed from the Comparator screen display by pressing the MENU key, in the same manner as from the Initial screen, and then the values for the various test conditions can be changed. (For details, refer to the explanation of setting the appropriate test condition.)

4.16.3 Canceling the Scaling Function



1. Press the MENU key on the Scaling screen or the Comparator scaling screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

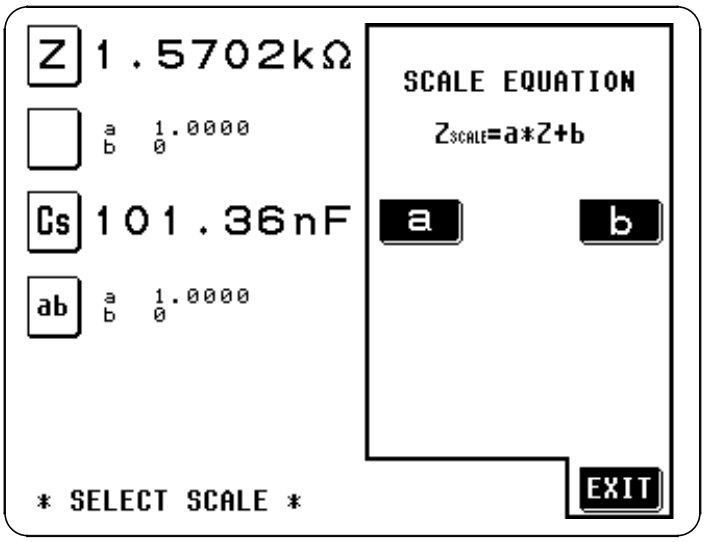
3. Press the SCALE OFF key on the Application menu screen to return the Initial screen or the Scaling screen.

On the Initial screen, the second and fourth display parameter positions ab will revert to displaying the parameters which they were displaying before the comparator mode was started. On the Comparator screen, they will revert to displaying LMT .

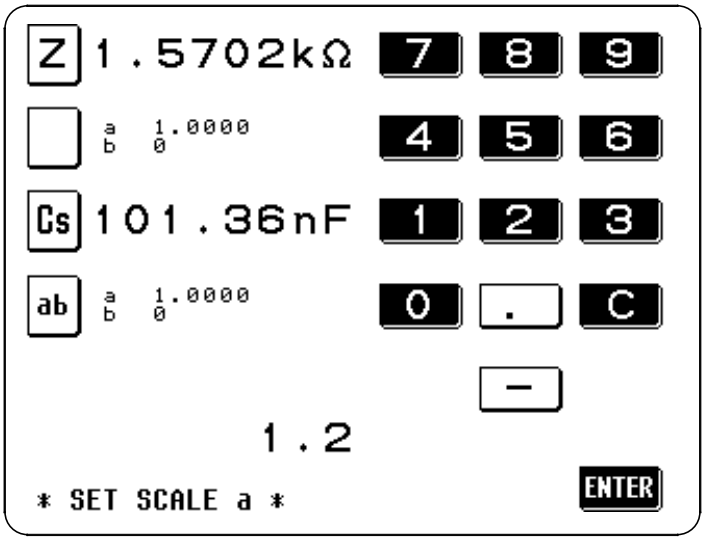
4.16.4 Setting the Compensation Coefficient (a, b)

1. Access the Scaling screen.

2. On the Scaling screen, press the [ab] key which you wish to change. The Conditions setting screen will be displayed.

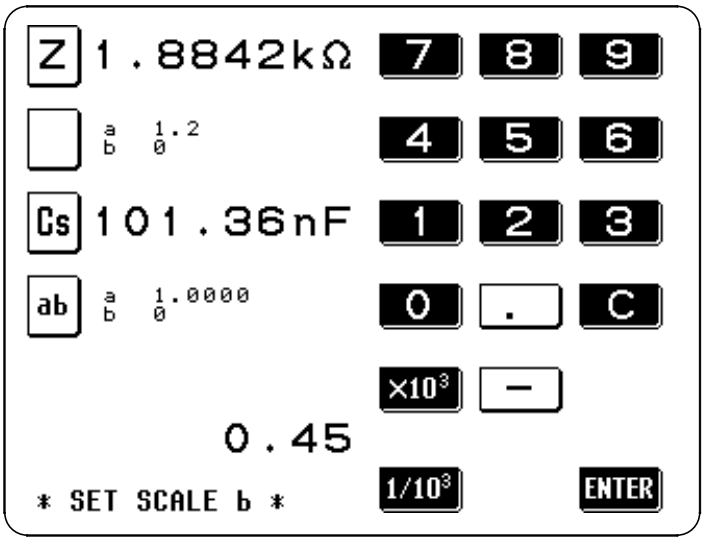


3. Press the [a] key, and a screen will appear for setting the compensation coefficient a. Use the numeric keypad to input the desired value.



The setting can be made in the range : -999.99 to +999.99
To return to the previous screen without making any change to the set value, press the [ENTER] key when the screen is in the state with nothing being displayed (the state after pressing the [C] key).

4. Set the compensation coefficient b as the same way.



The setting can be made in the range : -200.00M to +200.00M
×10³ : step the units up
1/10³ : step the units down
p -- n -- μ -- m -- (none) -- k -- M
<= Units down Units up =>

5. When the compensation coefficient setting has been established, press the EXIT key on the Compensation coefficient setting screen to return to the Scaling screen.

NOTE

- The scaled measurement value has no effect on other measurement values. Therefore, even if the same parameter is set for the first and third parameters, the scaling is carried out with the respective compensation coefficients.
- The calculation result of scaling for θ is as follows.
  When exceeding 180°, "180.00° " is displayed.
  When below -180°, "-180.00° " is displayed.

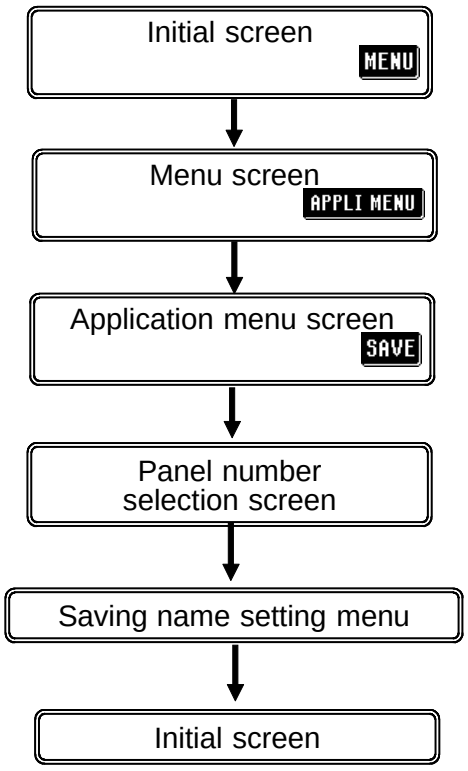
4.17 Panel Save Function

All of the test conditions can be saved as a "panel", up to a maximum of 30 such stored panels (i.e., sets of stored test conditions).

The test conditions which are saved are:

- Display parameters
- Test range
- Set value for averaging
- Test frequency
- Open and short circuit compensation values
- Set value for test speed
- Test signal level
- Setting for trigger value
- Beep sound setting
- Voltage and current limit values
- Set value for trigger delay
- Comparator setting
- Scaling setting
- Display digits setting
- Cable length setting
- Display setting

4.17.1 Control Screen Sequence



Press the MENU key.

Press the APPLI MENU key.

Press the SAVE key.

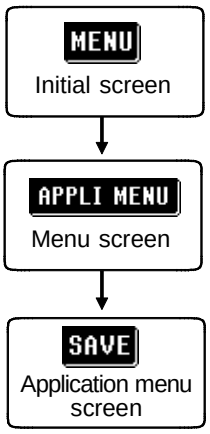
Select the panel number under which settings will be saved.

Set the saving name.

When the saving has been completed, the system returns automatically to the Initial screen.

The saving has been performed.

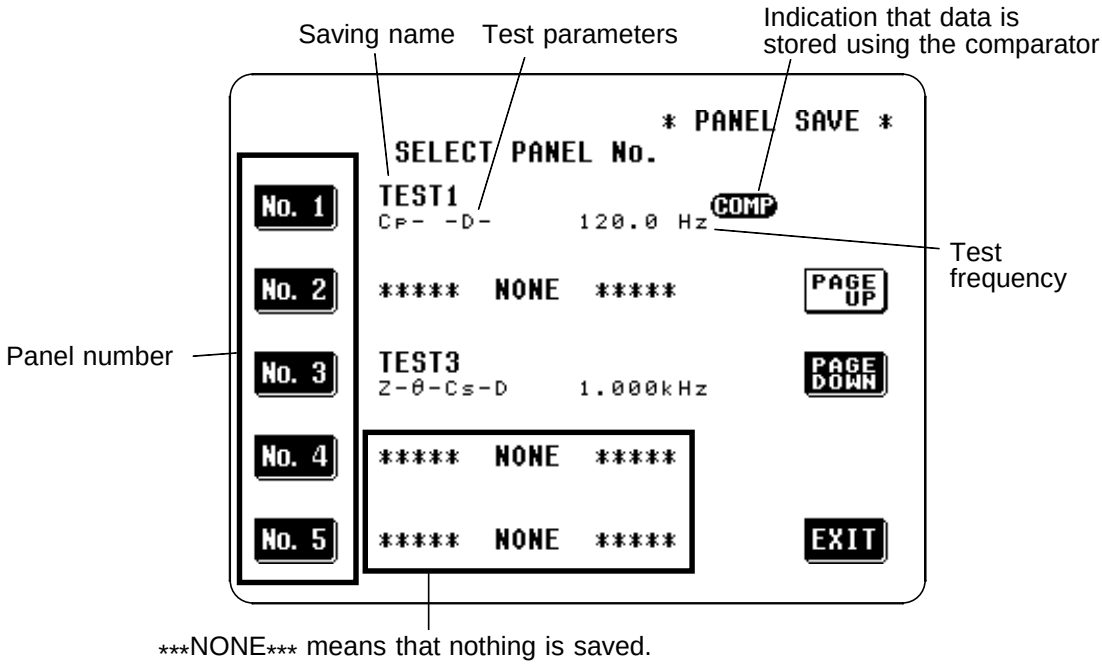
4.17.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

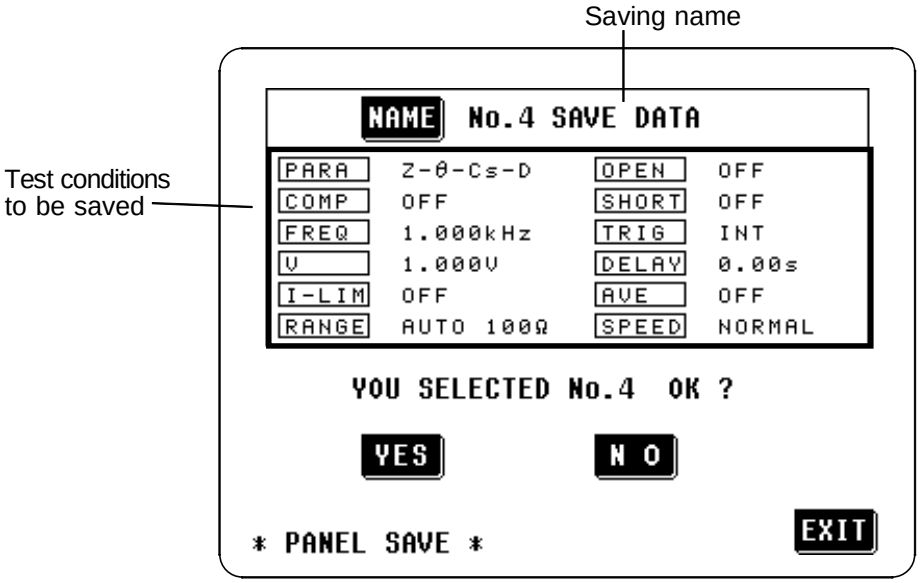
3. Press the SAVE key on the Application menu screen to display the Panel number selection screen.



Panel Number Selection Screen

EXIT : cancel the saving, and the display reverts to the Initial screen.
PAGE UP, PAGE DOWN : change the position of the panel number

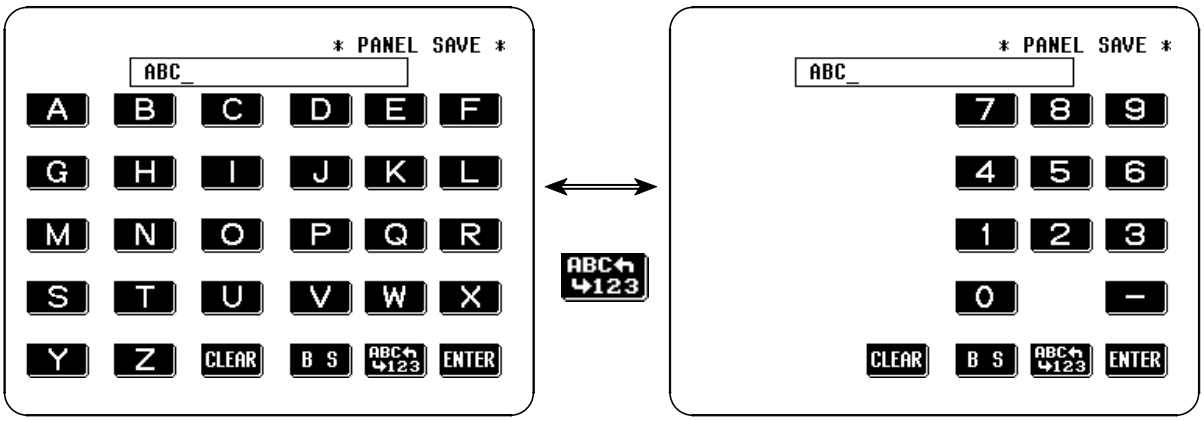
4. When you have decided upon the panel number under which the present test conditions will be saved, press the corresponding panel number key to select it.



YES : save the current test conditions with the saving name, and the display automatically reverts to the Initial screen.

NO : change the panel number, and the previous screen will be displayed again.

5. To change the saving name, press the NAME key, and the screen for name input will be displayed. Input the saving name (up to 20 characters).



ABC↵123 : Toggles between the alphabet input screen and numerical input screen.

B S : Back space

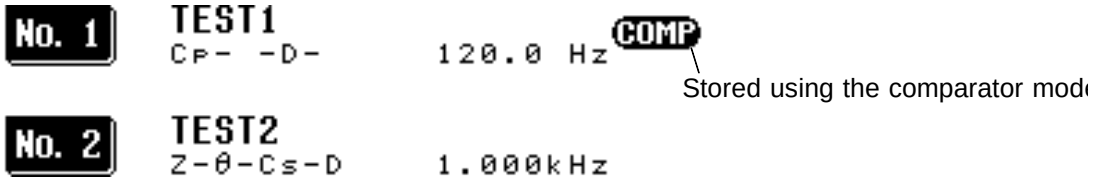
CLEAR : Clears the input character.

6. After input, press the ENTER key to return the Saving confirmation screen.

7. Press the YES key on the Saving confirmation screen to save the test conditions. The display automatically reverts to the Initial screen.

NOTE

- If the comparator mode is set, then when the test conditions are saved, as well as the saved test conditions, the following mark is displayed:



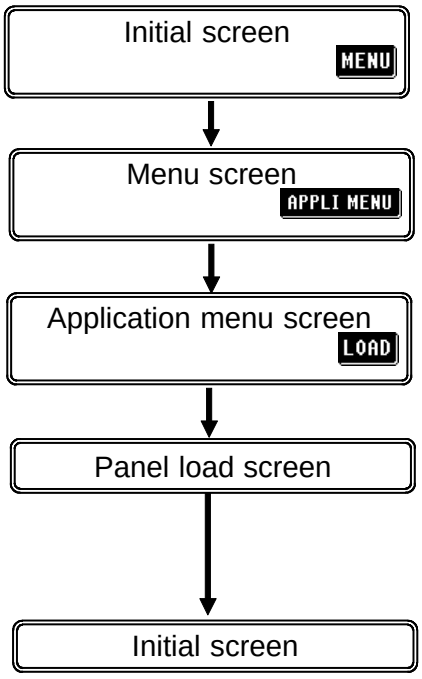
- Under normal conditions of use, the average life of the backup battery is about 10 years.
- If the internal battery becomes exhausted, it is no longer possible to save the test conditions. You should have the battery changed by an approved HIOKI service facility (which is chargeable).

4.18 Panel Load Function

Using the panel load function, saved test conditions can be loaded.

The test conditions which are saved:
- Display parameters
- Test range
- Set value for averaging
- Test frequency
- Open and short circuit compensation values
- Set value for test speed
- Test signal level
- Setting for trigger value
- Beep sound setting
- Voltage and current limit values
- Set value for trigger delay
- Comparator setting
- Scaling setting
- Display digits setting
- Cable length setting
- Display setting

4.18.1 Control Screen Sequence



Press the MENU key.

Press the APPLI MENU key.

Press the LOAD key.

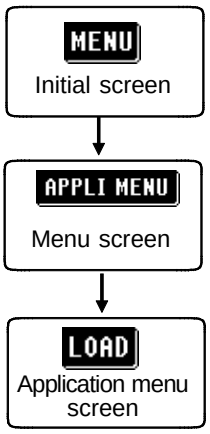
Select the panel number which you wish to load.

When the loading has been completed, the system returns automatically to the Initial screen.

The loading has been performed.

Testing starts with the new test conditions.

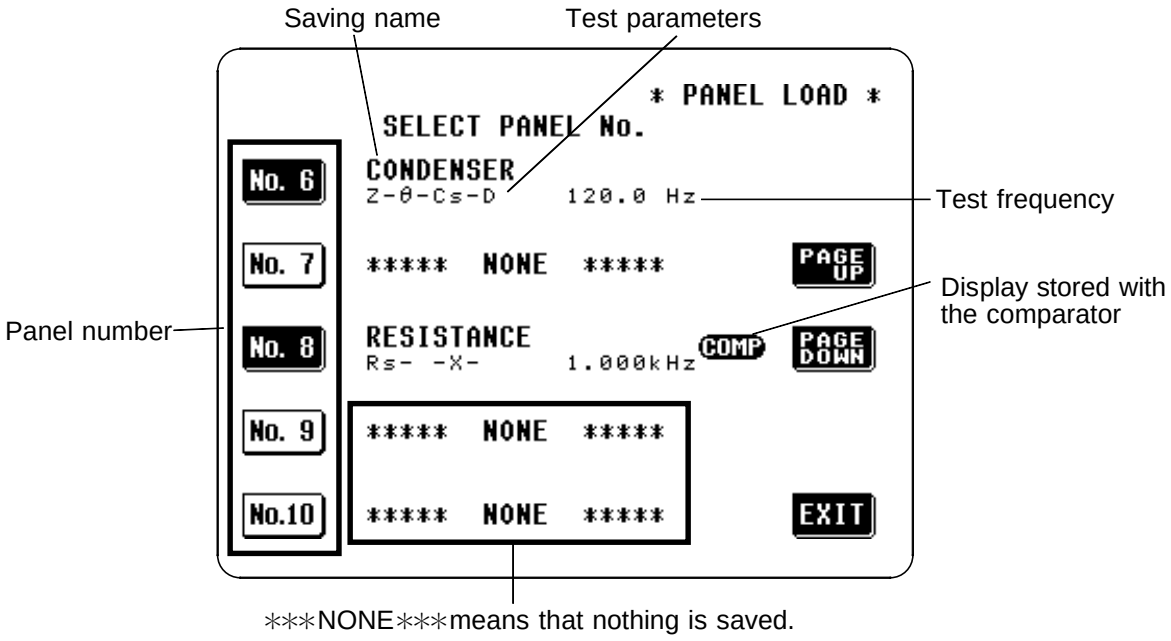
4.18.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

3. Press the LOAD key on the Application menu screen to display the Panel load screen.



Panel Load Screen

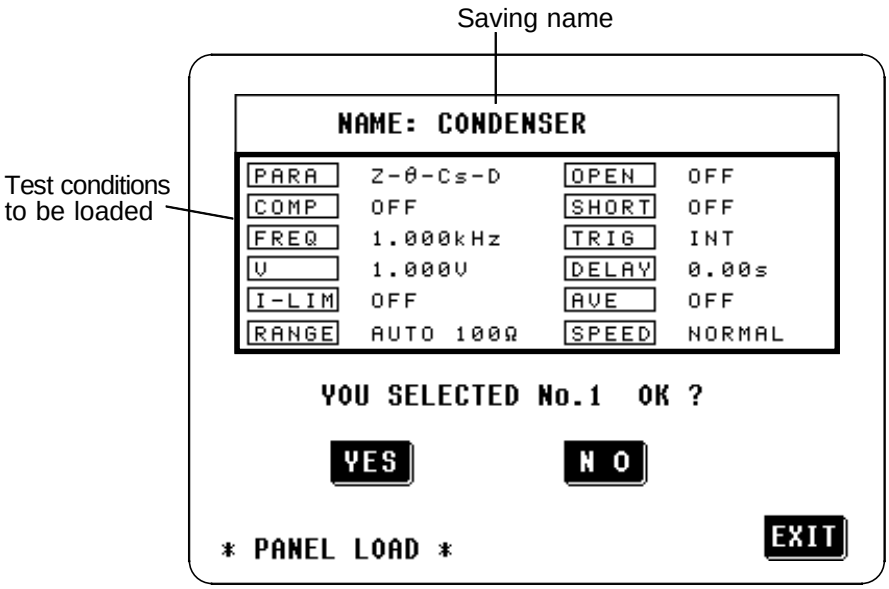
4. For each panel number, some of the values currently saved are shown on the Panel load screen. Check these stored values and then select the panel number for which the stored test conditions will be loaded.

PAGE UP, PAGE DOWN : change the position of the panel number

5. When you have decided upon the panel number for which the stored test conditions will be loaded, press the corresponding panel number key to select it.

To cancel the panel load process, press the EXIT key. The present test conditions will not be altered, and the display will revert to the Initial screen.

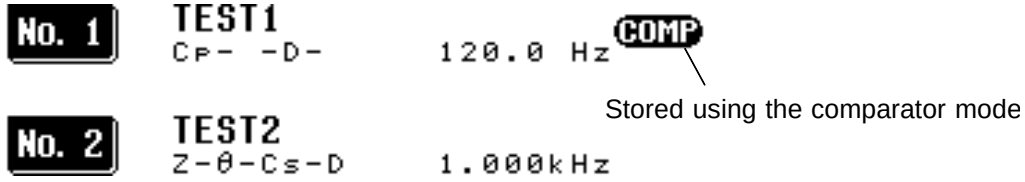
6. A message requesting confirmation will be displayed. To continue, press the YES key. The test conditions saved under the panel number which was selected will be loaded in place of the present test conditions.



To change the panel number for the load, press the NO key, and the previous screen will be displayed again.
When the new test conditions have been loaded, the display automatically reverts to the Initial screen, on which the panel number from which the newly loaded test conditions just came is displayed.

NOTE

- For test conditions saved with the comparator mode, the following mark is displayed:

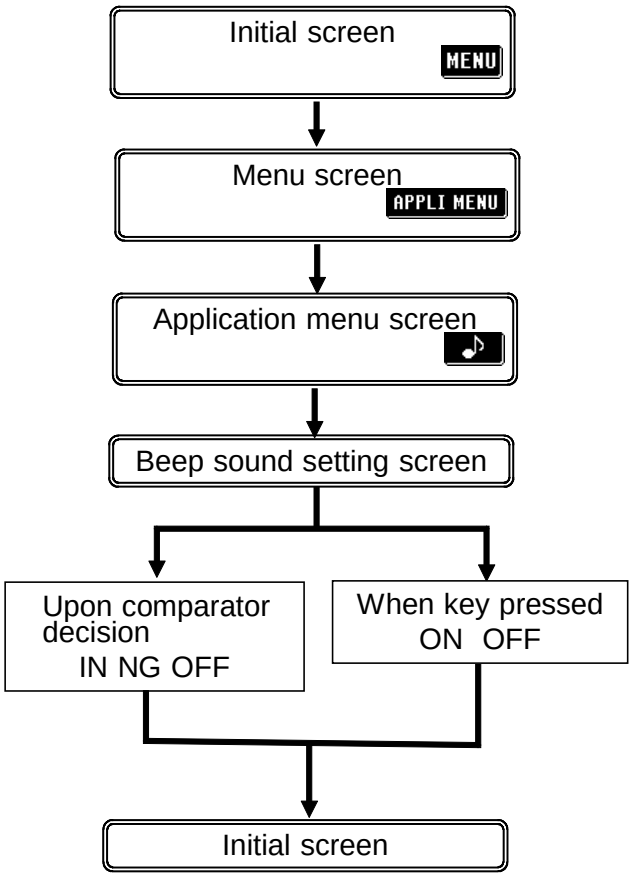


- Under normal conditions of use, the average life of the backup battery is about 10 years.
- If the internal battery becomes exhausted, it is no longer possible to save the test conditions. You should have the battery changed by an approved HIOKI service facility (which is chargeable).

4.19 Setting the Beep Sound

The beep sound which is produced each time that a soft key is pressed, and the beep sound which is produced when the comparator makes decisions, can be turned on and off individually.

4.19.1 Control Screen Sequence



Press the MENU key.

Press the APPLI MENU key.

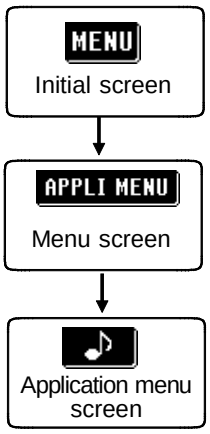
Press the ♪ key.

Set the beep sound for the comparator and for key input.

When the setting has been established, press the EXIT key to return to the Initial screen.

The setting has been performed.

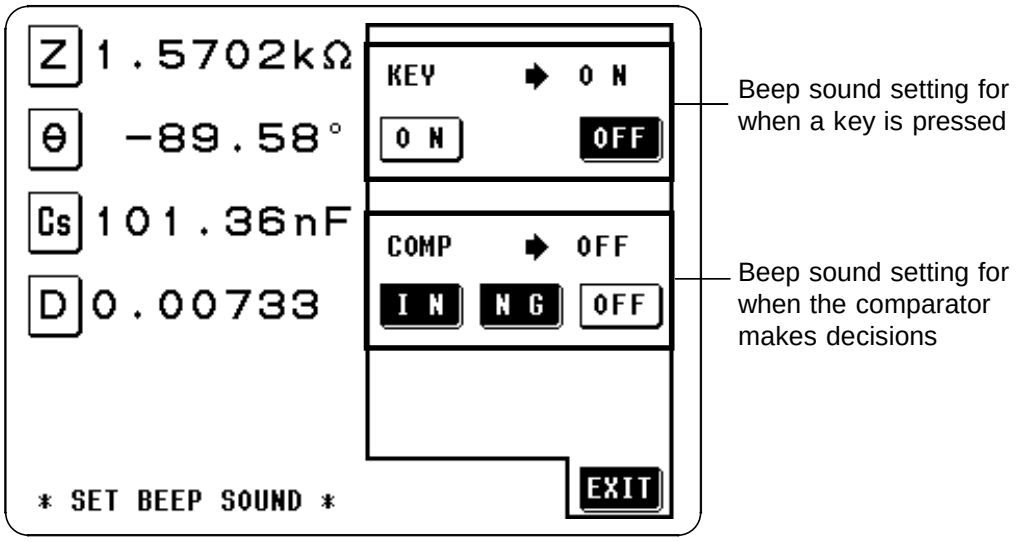
4.19.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

3. Press the ♪ key on the Application menu screen to display the Beep sound setting screen.



Setting the beep sound produced each time a key is pressed:

ON : A beep sound for key input is emitted.
OFF : No beep sound for key input is emitted.

Setting the beep sound produced when the comparator makes decisions:

- When the comparator makes a single decision:
  - IN : When the comparator result is IN, a beep sound is emitted.
  - NG : When the comparator result is LO or HI, a beep sound is emitted.
  - OFF : No beep sound is emitted when the comparator operates.
- When the comparator makes two decisions:
  - IN : When both of these comparator results are IN, a beep sound is emitted.
  - NG : When either of these comparator result is LO or HI, a beep sound is emitted.
  - OFF : No beep sound is emitted when the comparator operates.

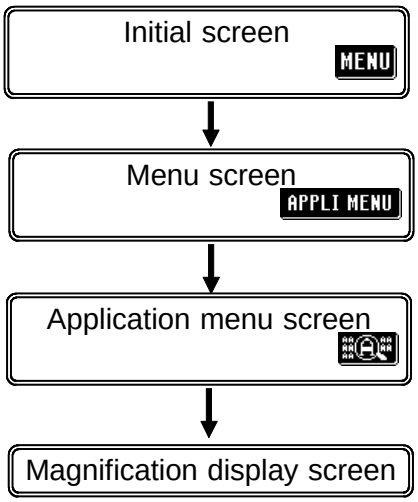
3. When the setting has been established as above, press the EXIT key to return to the Initial screen.

4.20 Enlarged Display of Measurement Values

The measurement values and comparator decision results can be displayed in enlarged form. This function is convenient when the unit is used under constant measurement conditions.

After powering off on the Magnification display screen, the same screen is displayed when the power is turned on again.

4.20.1 Control Screen Sequence

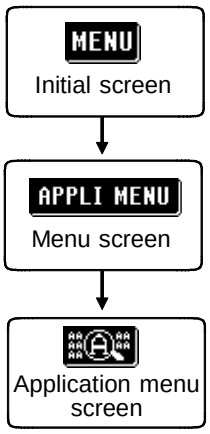


Press the MENU key.

Press the APPLI MENU key.

Press the key.

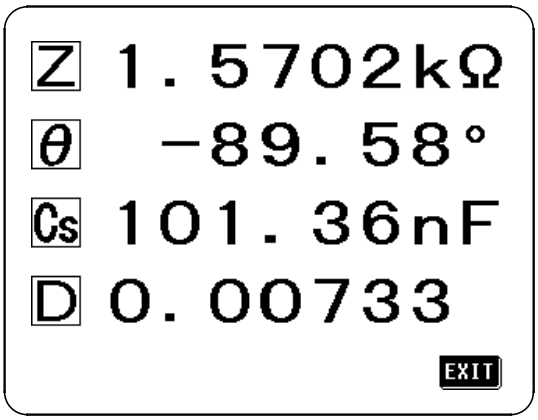
4.20.2 Details of the Setting Process



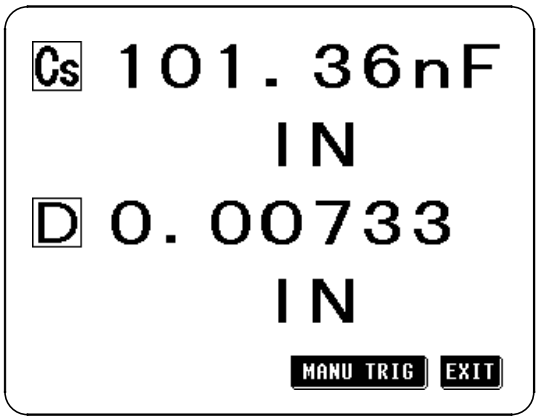
1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

3. Press the key on the Application menu screen to display the Magnification display screen.



Normal Screen



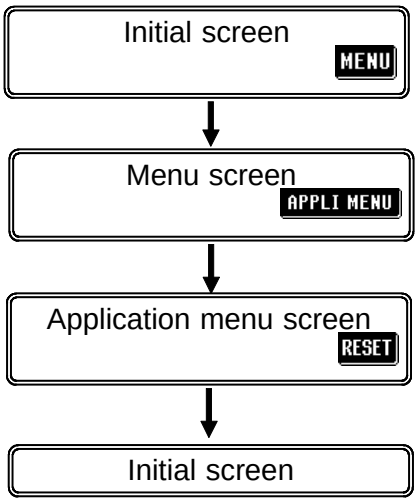
Comparator Screen

EXIT : return the Initial screen
MANU TRIG (during the external trigger setting): measure once
On the Magnification display screen, only EXIT and MANU TRIG keys are displayed.

4.21 System Reset

All of the settings will revert to the factory original settings.

4.21.1 Control Screen Sequence

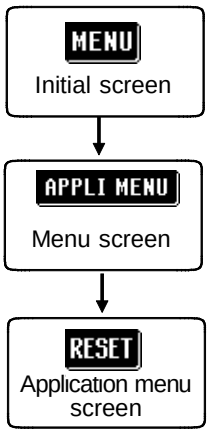


Press the MENU key.

Press the APPLI MENU key.

Press the RESET key.

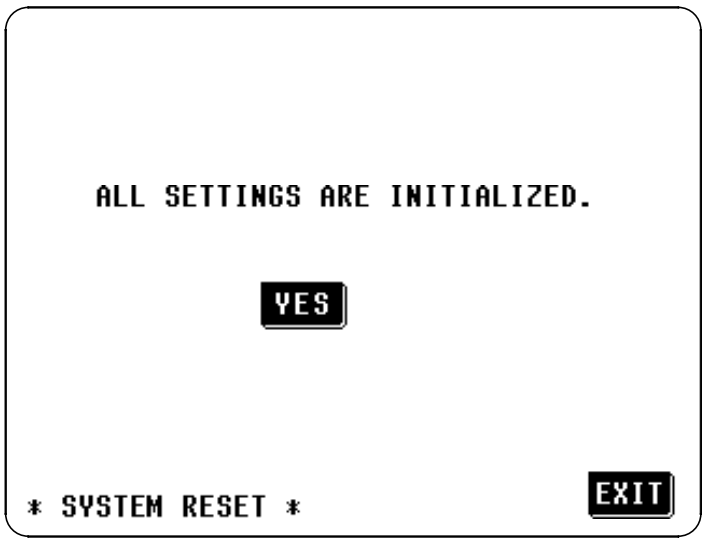
4.21.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

3. Press the RESET key on the Application menu screen to display the System reset screen.



YES : reverts to the factory settings and the Initial screen is displayed.
EXIT : halts settings and reverts to the Initial screen.

The settings established at the factory are as follows:

Test parameters	$\|Z\|$, θ
Test frequency	1 kHz
Test signal level	Open circuit voltage (V) setting
Open circuit voltage (V) set value	1.000 V
Constant voltage (CV) set value	1.000 V
Constant current (CC) set value	10.00 mA
Limit function	OFF
Voltage limit set value	5.000 V
Current limit set value	50.00 mA
Test range	AUTO range
Open circuit compensation	OFF
Short circuit compensation	OFF
Trigger setting	Internal trigger
Trigger delay setting	0 s
Averaging	OFF
Test speed setting	NORMAL
Cable length setting	0 m
Beep sound setting	ON for key input, OFF for comparator
Panel save, panel load	All contents clear
Comparator	
Comparator setting	Both first and third parameters set to absolute value.
Absolute value set values	Upper and lower limit values for the first and third parameters both OFF
Percent set values	First parameter reference value: 1000 Upper and lower limit values for first parameter both OFF Third parameter reference value: 10 Upper and lower limit values for third parameter both OFF
Scaling setting value	Compensation coefficient a for the first and third parameters: 1.0000 Compensation coefficient b for the first and third parameters: 0
Display digits setting	All five digits for first to 4th parameters
Display setting	LCD display: ON Voltage and Current monitor: ON

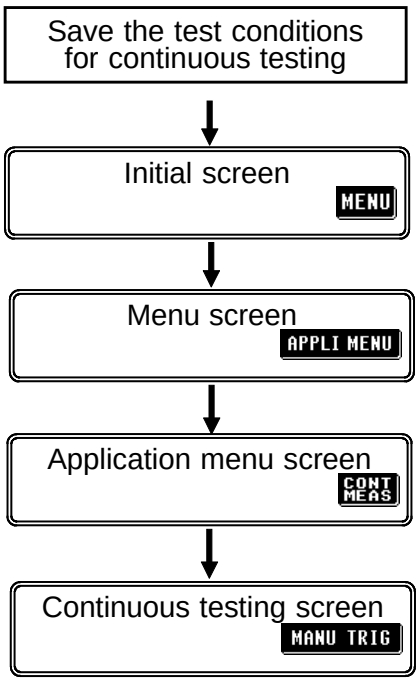
4.22 Continuous Test Function

It is possible to read in order test conditions which have been saved using the panel save function, and to perform continuous testing.
Up to five panel numbers can be selected in a page for the continuous testing.

Page	Panel numbers
1	1 - 5
2	6 - 10
3	11 - 15
4	16 - 20
5	21 - 25
6	26 - 30

After powering off on the Continuous test screen, the same screen is displayed when the power is turned on again.

4.22.1 Control Screen Sequence



Section 4.17, "Panel Save Function"

Press the MENU key.

Press the APPLI MENU key.

Press the CONT MEAS key.

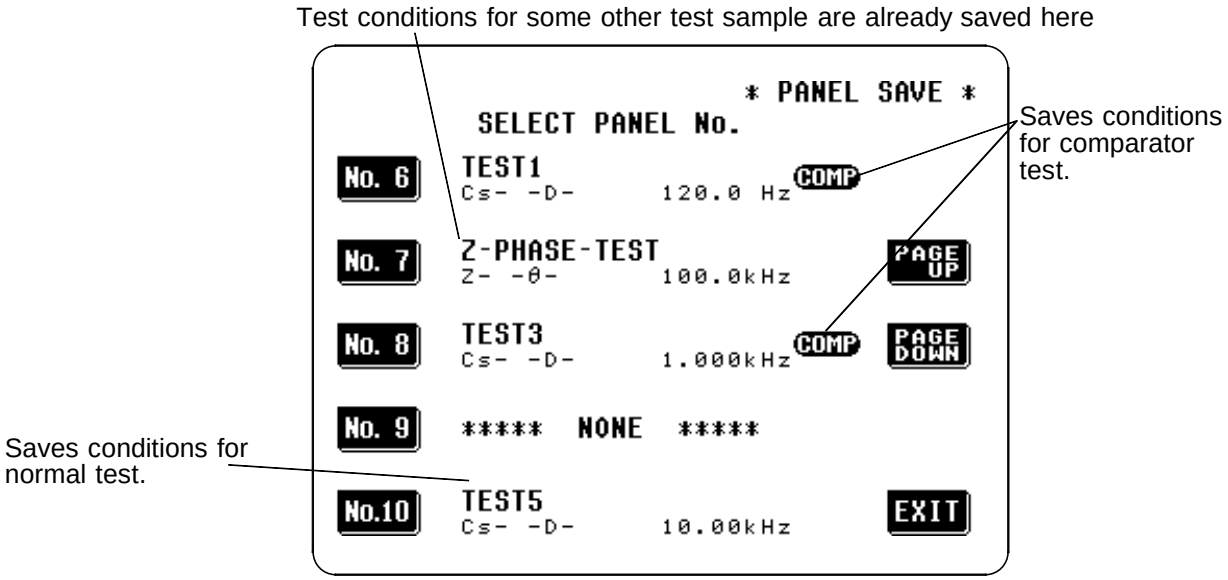
Select the panel number which you wish to test.
Press the MANU TRIG key to start test.

4.22.2 Details of the Setting Process

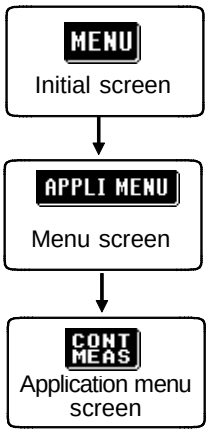
This section describes procedure when performing continuous testing with panel numbers 6, 8, and 10 for example.

1. Save the continuous testing conditions on panel numbers 6, 8, and 10 using the panel save function. The continuous testing is performed for the first and third parameters which have been saved.

For details on panel save function, see Section 4.17.



Panel Save Screen

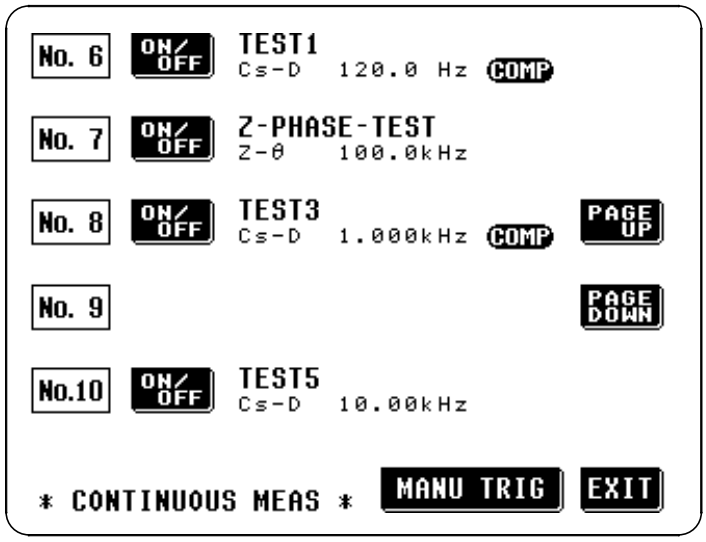


2. Press the MENU key on the Initial screen to display the Menu screen.

3. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

4. Press the CONT MEAS key on the Application menu screen to display the Continuous test screen.

5. Using the PAGE UP and PAGE DOWN keys, make a display of panel numbers which are previously saved.

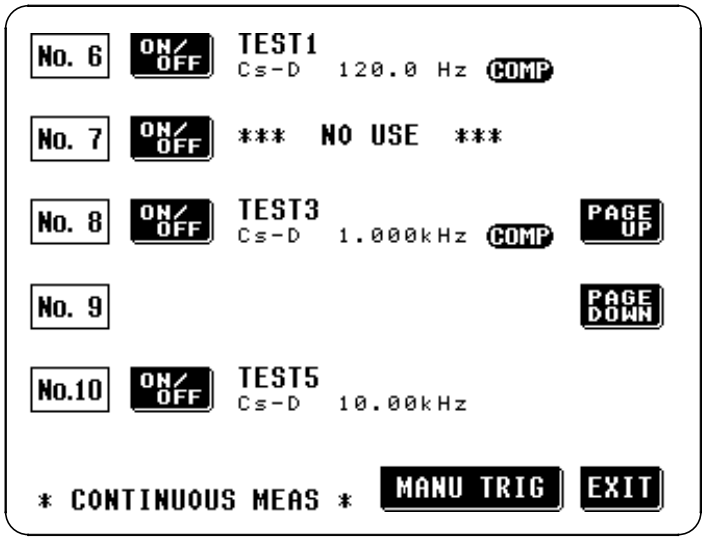


Continuous Test Screen

NOTE The panel numbers which are not saved or which are invalid even if saved (when the both first and third parameters are off) are not displayed.

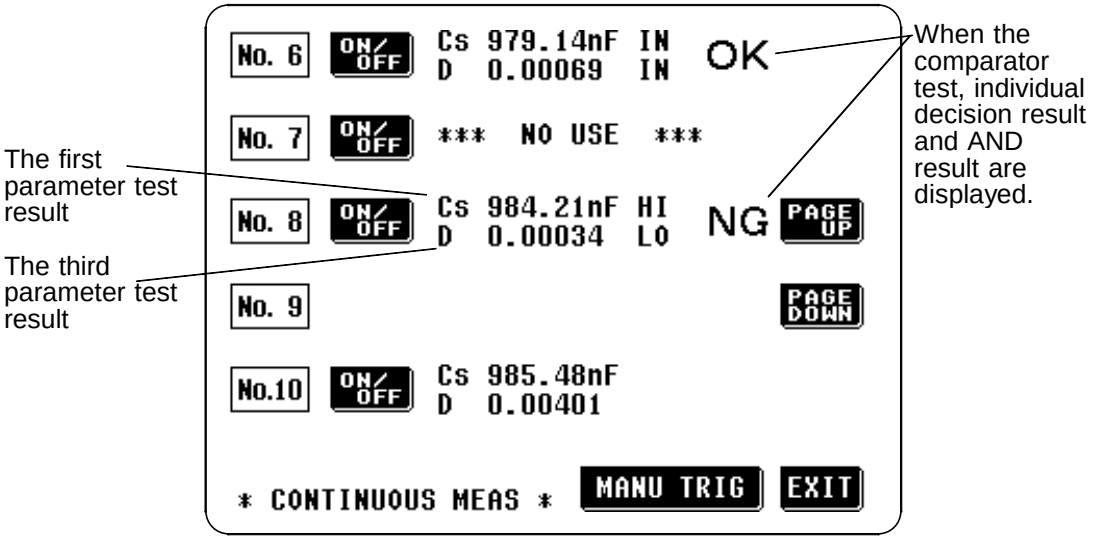
6. Set whether testing of each panel number is executed or not.

When the saving conditions of the panel or previous test result is displayed, the testing is executed. However, when "*** NO USE ***" is displayed, the testing is not executed. In this example, make a setting not to test for the panel number 7.



NOTE When changing a page, the all panel number displayed will be tested.

7. Press the MANU TRIG to start test. The test result is displayed when the tests of each panel numbers are terminated.



NOTE

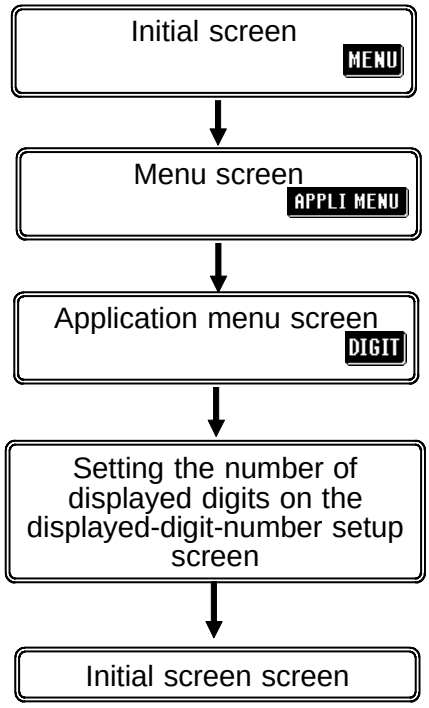
If the displaying page is switched to other page after test completed, the displays of the test result are disappear.

8. To exit from the continuous test, press the EXIT key to return the Initial screen.
The continuous test can be executed from the EXT I/O connector. For details, see Section 5.6, "Testing Using EXT I/O."

4.23 Setting the Number of Displayed Digits

The number of effective digits for measurement can be set on a parameter-by-parameter basis.

4.23.1 Control Screen Sequence



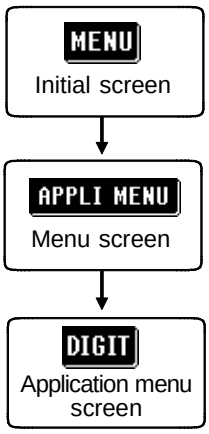
Press the MENU key.

Press the APPLI MENU key.

Press the DIGIT key.

Set the number of digits to be displayed.
When the setting is completed, press the EXIT key to return to the Initial screen.

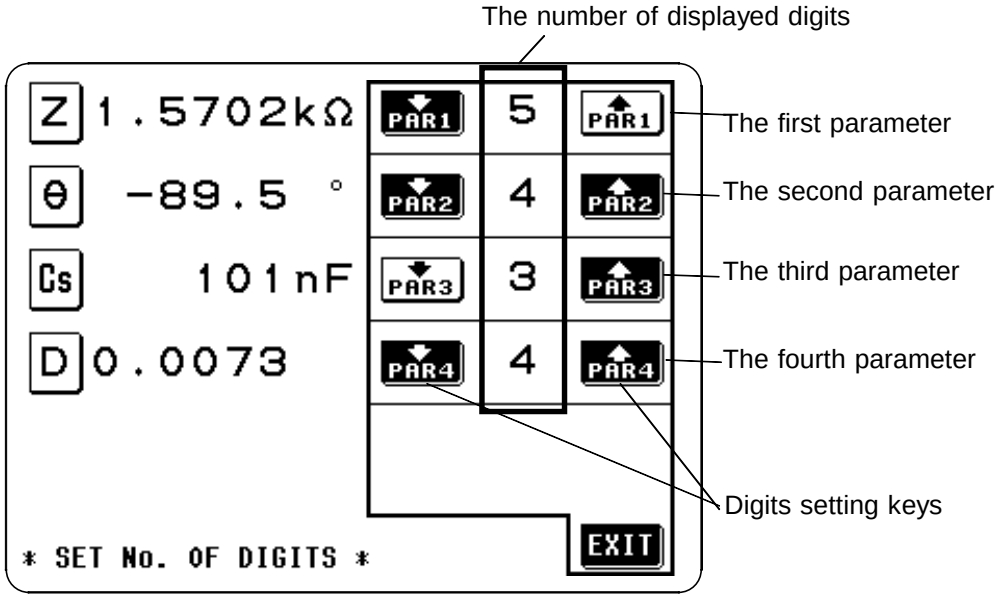
4.23.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

3. Press the DIGIT key on the Application menu screen to display the Setting the displayed digits screen.



Press PAR and PAR for each parameter to set the number of displayed digits. While the definable set values are 3, 4, and 5, the value is actually selected according to the parameter type, as shown in the table below.

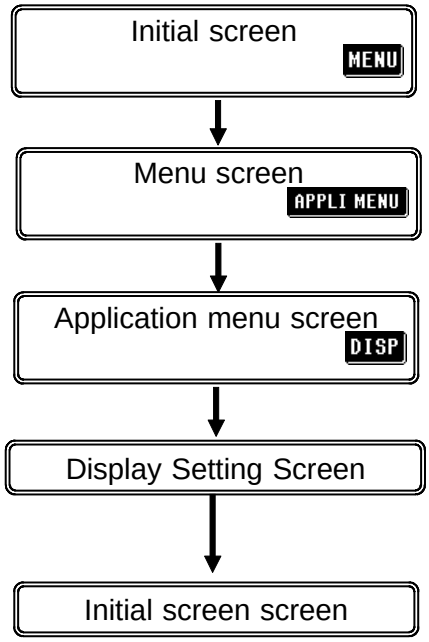
Parameter / Setting value	θ, Q Comparator Δ% setting	D	Others
5	Up to the second decimal place	Up to the fifth decimal place	Up to 5 digits
4	Up to the first decimal place	Up to the fourth decimal place	Up to 4 digits
3	No decimal place	Up to the third decimal place	Up to 3 digits

4. To exit from this mode, press the EXIT key to return the Initial screen.

4.24 Setting for Display

In some applications, such as on a production line or where EXT I/O or interfaces are used, it may not be necessary to display measurement values. This unit allows ON/OFF settings of the display and voltage/current monitors (Vmoni, Imoni) to be made.
Turning off the LCD display helps save power, as the LCD display and backlight remain off. Moreover, the measurement time is reduced due to the fact that measurement values and Vmoni and Imoni indications need not be displayed. When the voltage and current monitors are turned off, the measuring time is also reduced due to the fact that the Vmoni and Imoni indications are not required.

4.24.1 Control Screen Sequence



Press the MENU key.

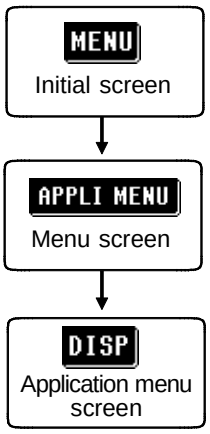
Press the APPLI MENU key.

Press the DISP key.

Set ON or OFF of the display.

When the setting is completed, press the EXIT key to return to the Initial screen.

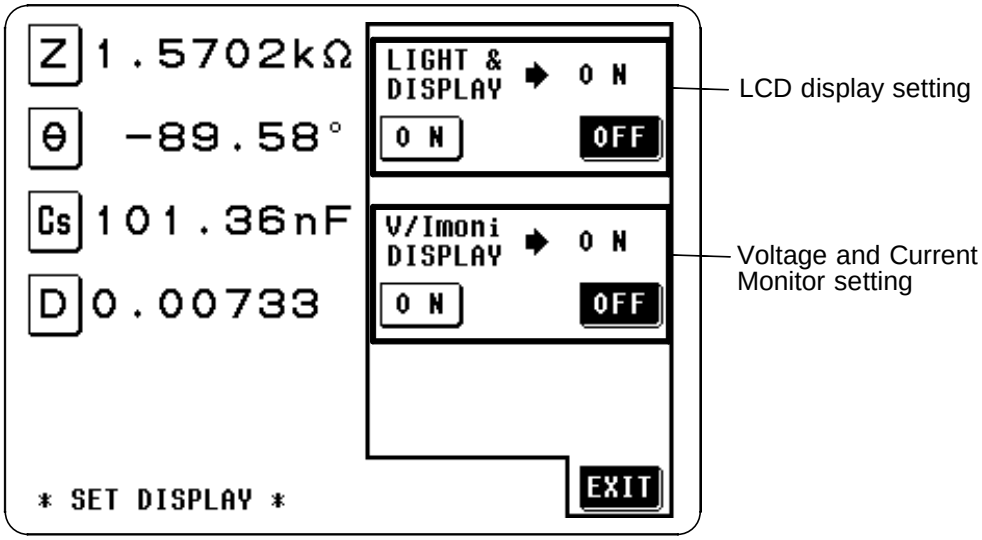
4.24.2 Details of the Setting Process



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

3. Press the DISP key on the Application menu screen to display the Display Setting Screen.



Setting for LCD Display

ON :The LCD display and backlight remain on permanently.
OFF :The LCD display and backlight remain off permanently.

When OFF is selected, the LCD display and backlight go out approximately 10 seconds after the touch panel is last touched. When the touch panel is touched after the display and backlight have gone out, they will come on again. When the display and backlight are off, the measurement time is reduced, as Vmoni and Imoni do not display indications.

Setting for Voltage and Current Monitors (Vmoni, Imoni)

ON :The voltage and current monitors display indications.
OFF :The voltage and current monitors do not display indications.

When OFF is selected, the measurement time is reduced, as Vmoni and Imoni do not display indications. For the measurement time, refer to "7.3 Time Taken for Testing."

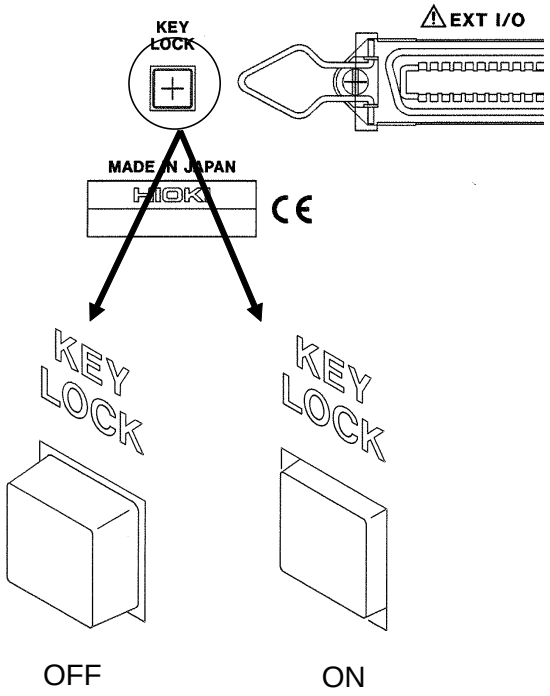
4. To exit from this mode, press the EXIT key to return the Initial screen.

4.25 Key Lock Function

When the key lock function is turned on, all of the keys become inoperative, so that no control via the touch panel is possible, and the values of the settings are all frozen and preserved.

4.25.1 Turning the Key Lock On and Off

- This function is activated using the key lock switch on the rear panel of the 3532-50 unit.
- The key lock function can only be used when the screen is displaying the Initial screen, Comparator screen, Scaling screen, Magnification display screen, or Continuous test screen.



NOTE

- In the case of external triggering, the key lock does not apply to the MANU TRIG button.
- Even if the power supply is interrupted, the key lock function is not canceled.
- The key lock function can be turned on and off via the EXT I/O connector. For details, see Section 5.5, "The EXT I/O Connector."

Chapter 5
Applications

5.1 Example of Comparator Application

Making decisions for two items simultaneously (ABS and % settings).

Example

First parameter: static capacitance Cp and third parameter: phase angle θ will be set as follows:

First parameter (ABS setting)
Upper limit value 110 nF
Lower limit value 100 nF

Third parameter (% setting)
Reference value -85°
Upper limit value 5% (i.e., -80.75°)
Lower limit value -5% (i.e., -89.25°)

The results of the decisions with these settings are as shown in the following table:

Comparator decisions

First parameter \ Third parameter	Lower limit value LO	IN	Upper limit value HI
HI (Upper limit value)	HI/LO	HI/IN	HI/HI
IN	IN/LO	IN/IN	IN/HI
LO (Lower limit value)	LO/LO	LO/IN	LO/HI

In this manner, two decisions can be made simultaneously. Further, it is possible to check the decision results for two different parameters at the same time, and thereby to determine what quality zone the object which is being tested falls into.

Sorting a single item into five bands (% setting).
Two decisions can be made relating to the same item, so as to obtain five different combinations of results.

Example

First parameter and third parameter: impedance *Z*, will be set as follows:

First parameter
Reference value 3.0 kΩ
Upper limit value 10%
Lower limit value 5%

Third parameter
Reference value 3.0 kΩ
Upper limit value -5%
Lower limit value -10%

The results of the decisions with these settings are as shown in the following table:

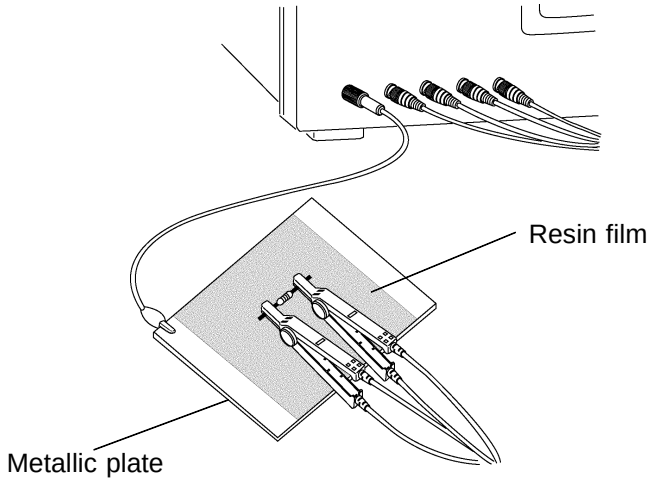
	Comparator decisions	
	Parameter 1 result	Parameter 3 result
Band 1 First parameter upper limit value 10% (3.3 kΩ)	HI	HI
Band 2 First parameter lower limit value 5% (3.15 kΩ)	IN	HI
Band 3 Third parameter upper limit value -5% (2.85 kΩ)	LO	HI
Band 4 Third parameter lower limit value -10% (2.7 kΩ)	LO	IN
Band 5	LO	LO

It is possible to sort the objects under test into five bands according to the results of the decisions relating to the first and the third parameter. (This can also be done using the ABS setting.)

Various other possibilities can be used for the settings, according to requirements.

5.2 Testing High Impedance Elements

The measured value obtained when testing a high impedance element (such as, for example, a resistor with resistance higher than 100 kΩ) is sometimes unreliable, because such an element is vulnerable to the effects of external interference and the like. In this case, reliable testing can be performed by the use of guarding, that is, connecting a metallic plate to the GUARD terminal and carrying out the measurement on the metallic plate.



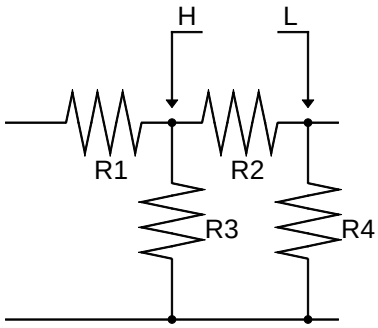
When testing against a metallic plate, the surface of the plate should be covered by a film of resin or the like, in order to prevent short circuiting together the terminals.

NOTE When the open circuit compensation is performed always execute the guarding process because of high impedance elements testing. If not, the compensation values do not stabilize. It is not possible to obtain the reliable measured value.

5.3 Testing an Element in a Circuit

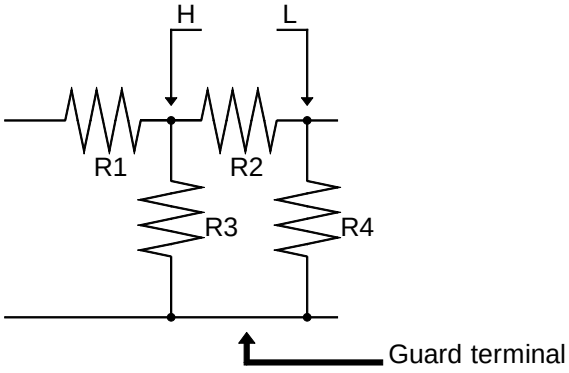
Testing an element in a circuit is not possible without guarding.

- Referring to the following figure, when measuring a resistance value for the resistor R_2, even if the tips of the two probes are contacted against the ends of the resistor R_2, considering the sum of the current flowing through the resistor R_2 and the current flowing through the resistors R_3 and R_4, what is obtained is the resistance value for the parallel combination:



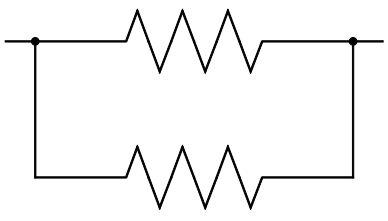
$$R = R_2 \cdot \frac{R_3 + R_4}{R_2 + R_3 + R_4}$$

- If as shown in the next figure a guard terminal is used, the current flowing through the resistors R_3 (not flowing through R_4) is absorbed by this guard terminal, so that the resistance value for the resistor R_2 is accurately measured.

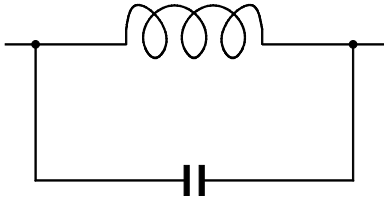


NOTE

The accuracy of measurement will not be improved in cases where for example
$R_2 >> R_3$ and R_3 is close to zero.
As shown in the figure below, it is not possible to use this type of separation process for testing of the impedance values of two resistors or other elements of identical types which are connected in parallel, or for testing of the impedance values of a coil and a capacitor which are connected in parallel.



Two resistors in parallel



Coil and capacitor in parallel

5.4 External Interference

The 3532-50 is designed to be resistant to errors caused by interference from the test cables or the power supply line. However, if the level of the interference is particularly large, this can cause measurement errors or faulty operation.
Refer to the examples given below for examples of countermeasures which can be taken against interference which has caused faulty operation etc.

5.4.1 Countermeasures Against Interference from the Power Supply Line

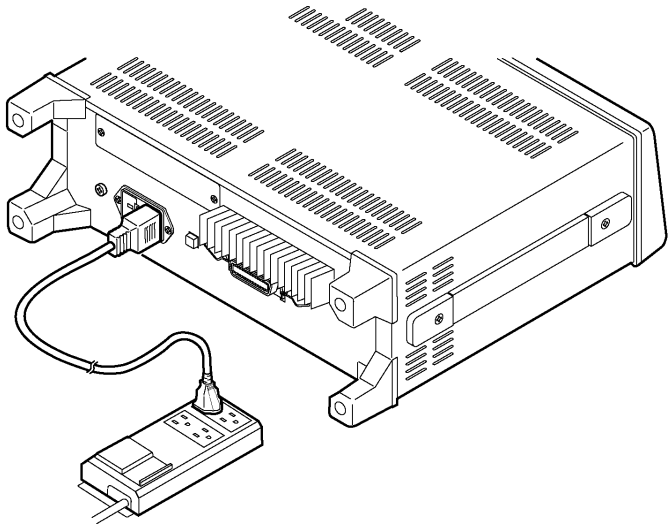
If noise is present in the power supply line, its influence can be moderated by the following countermeasures:

Grounding by using a protective ground wire
The 3532-50 unit is constructed so as to be provided with protective grounding via the ground lead in the power cord.

This protective grounding serves the important function, not only of avoiding the possibility of electric shock to the operator, but also of eliminating noise from the power supply line by the provision of an internal filter.

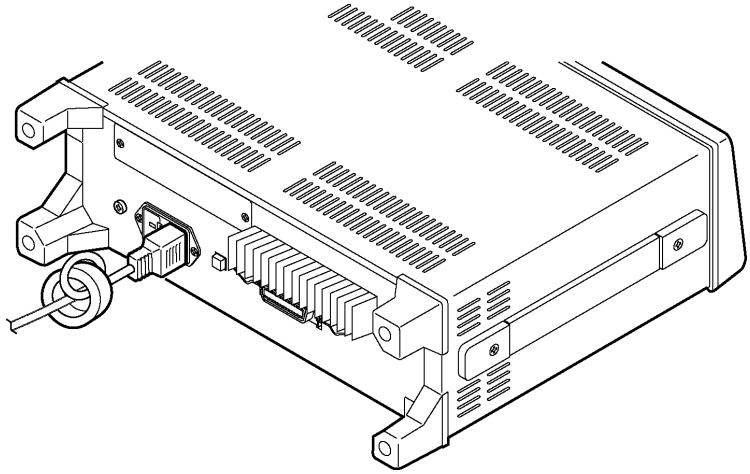
Be sure to connect the 3532-50 unit to a properly 3-wire power supply socket, using the grounded power cord which is supplied with the unit.

Inserting a noise filter in the power supply line
Any excessive noise present in the power supply line can be suppressed by purchasing a socket type noise filter (generally available commercially) which can be inserted into the power supply socket, with the 3532-50 unit connected to the output of the noise filter.
Various types of such socket type noise filters are readily available from specialist manufacturers.



Fitting an anti-interference ferrite core on the power cord

Pass the power cord through a commercially available anti-interference ferrite core, and fix it on the power cord as close as possible to the AC power inlet of the 3532-50 unit, so as to suppress noise from the power supply line. Further benefit can often be obtained by fitting another anti-interference ferrite core on to the power cord at its other end, as close as possible to the plug which connects to the power supply outlet.
Moreover, if the internal diameter of the ferrite core allows, winding the power cord several times around the ferrite core may further reduce the amount of noise. Various types of such anti-interference ferrite cores or ferrite beads are readily available in the market from specialist manufacturers.

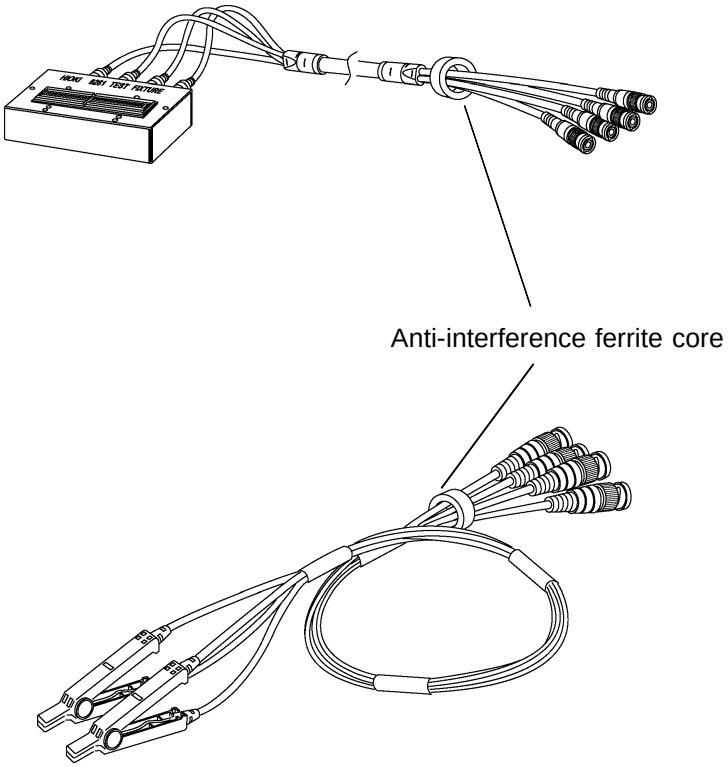


5.4.2 Countermeasures Against Noise from the Test Cables

If interference is producing noise in the test cables, its influence can be moderated by the following countermeasure.

Fitting an anti-interference ferrite core on the test cables
Pass the test cables through a commercially available anti-interference ferrite core, and fix it close to the test terminals, so as to suppress noise from the test cables.

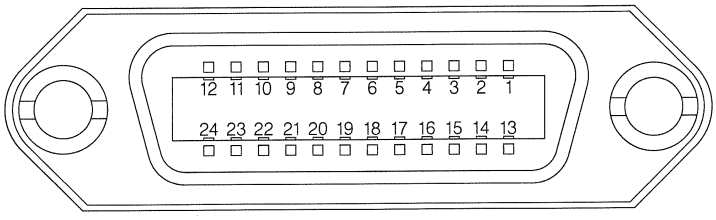
Moreover, if the internal diameter of the ferrite core allows, winding the test cables several times around the ferrite core (as with the power cord as described above) may further reduce the amount of noise.



5.5 The EXT I/O Connector

This is a connector for output of comparator result signals, of a measurement finished signal (EOM), and of an analog measurement finished signal (INDEX), and for input of an external trigger signal, and a signal for performing selection of the number of the panel to be loaded.

Connector used	Hirose type RC10(F)-24R-LW 24-pin receptacle
Compatible connector	Hirose type RC30-24P 24-pin receptacle



EXT I/O Connector Pin Numbering
(seen from 3532-50)

5.5.1 Pinouts for the EXT I/O Connector

Pin number	Signal line name	Input/output	Pin number	Signal line name	Input/output
1	INT.DCV	Output	13	INT.GND	Output
2	EXT.DCV	Input	14	EXT.COM	Input
3	EXT.DCV	Input	15	EXT.COM	Input
4	$\overline{\text{TRIG}}$	Input	16	$\overline{\text{M-HI}}$	Output
5	$\overline{\text{LOCK}}$	Input	17	$\overline{\text{M-IN}}$	Output
6	$\overline{\text{LD1}}$	Input	18	$\overline{\text{M-LO}}$	Output
7	$\overline{\text{LD2}}$	Input	19	$\overline{\text{S-HI}}$	Output
8	$\overline{\text{LD3}}$	Input	20	$\overline{\text{S-IN}}$	Output
9	$\overline{\text{LD4}}$	Input	21	$\overline{\text{S-LO}}$	Output
10	$\overline{\text{LD5}}$	Input	22	$\overline{\text{AND}}$	Output
11	Unused	———	23	$\overline{\text{INDEX}}$	Output
12	Unused	———	24	$\overline{\text{EOM}}$	Output

All input and output terminals excluding the power supply are all negative logic.

5.5.2 Signal Lines for the EXT I/O Connector

NOTE All input signals are all negative logic.

(1) $\overline{\text{M-HI}}$, $\overline{\text{M-IN}}$, $\overline{\text{M-LO}}$ (Output signal of comparator result)

These lines output the comparator result for the first parameter.

(2) $\overline{\text{S-HI}}$, $\overline{\text{S-IN}}$, $\overline{\text{S-LO}}$ (Output signal of comparator result)

These lines output the comparator result for the third parameter.

(3) $\overline{\text{AND}}$ (Output signal of comparator result)

This signal is used to comprehensively evaluate the decision results for the first and third parameters.

This signal is output only if both the first parameter comparator result and the third parameter comparator result are IN.

(4) $\overline{\text{EOM}}$ (End of measurement signal)

This signal is continuously output during measurement. When this signal is HI, the most recent comparator result is used for the evaluation. The next trigger signal can also be input.

(5) $\overline{\text{INDEX}}$ (Signal during analog measurement)

Output during analog measurement. When this signal is HI, the object under test can be changed.

NOTE $\overline{\text{INDEX}}$ signal is output at each time of retest. Therefore, when the object under test is changed, the settings of the test signal level, current and voltage limits, test range, and average are specified as followings.

Test signal level	Open-circuit voltage (V) setting
Current and voltage limits	OFF
Test range	HOLD range
Average	OFF

For the settings other than above, change the object under test referring to $\overline{\text{EOM}}$.

(6) EXT.DCV, EXT.COM

These are terminals for supplying a power supply voltage from an external device. This enables the 3532-50 unit to be connected to an external device while maintaining the isolation. The range of power voltage which can be connected is from +5 to +24 volts DC.

(7) INT.DCV, INT.GND

These lines output +5 VDC and COM from the 3532-50 unit.

(8) $\overline{\text{TRIG}}$

When the external trigger is enabled for the 3532-50, measurement is begun when this signal is input.

(9) $\overline{\text{LD1}}$ to $\overline{\text{LD5}}$

This signal is used to select panel numbers stored using the panel save function. When a panel number has been selected using this signal at the input of a trigger signal, the 3532-50 loads the measurement conditions for the panel number and then begins measurement. The table below shows the selectable panel numbers.

L: low level input, H: high level input

Panel number	$\overline{\text{LD}}$					Panel number	$\overline{\text{LD}}$					Panel number	$\overline{\text{LD}}$				
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
1	L	H	H	H	H	11	L	L	H	L	H	21	L	H	L	H	L
2	H	L	H	H	H	12	H	H	L	L	H	22	H	L	L	H	L
3	L	L	H	H	H	13	L	H	L	L	H	23	L	L	L	H	L
4	H	H	L	H	H	14	H	L	L	L	H	24	H	H	H	L	L
5	L	H	L	H	H	15	L	L	L	L	H	25	L	H	H	L	L
6	H	L	L	H	H	16	H	H	H	H	L	26	H	L	H	L	L
7	L	L	L	H	H	17	L	H	H	H	L	27	L	L	H	L	L
8	H	H	H	L	H	18	H	L	H	H	L	28	H	H	L	L	L
9	L	H	H	L	H	19	L	L	H	H	L	29	L	H	L	L	L
10	H	L	H	L	H	20	H	H	L	H	L	30	H	L	L	L	L
												Invalid	H	H	H	H	H
													L	L	L	L	L

(10) LOCK (Key lock signal)

This signal activates the key lock function. If the key lock switch of the 3532-50 has been turned on, the key lock is not deactivated even if the key lock function is turned off using this signal.

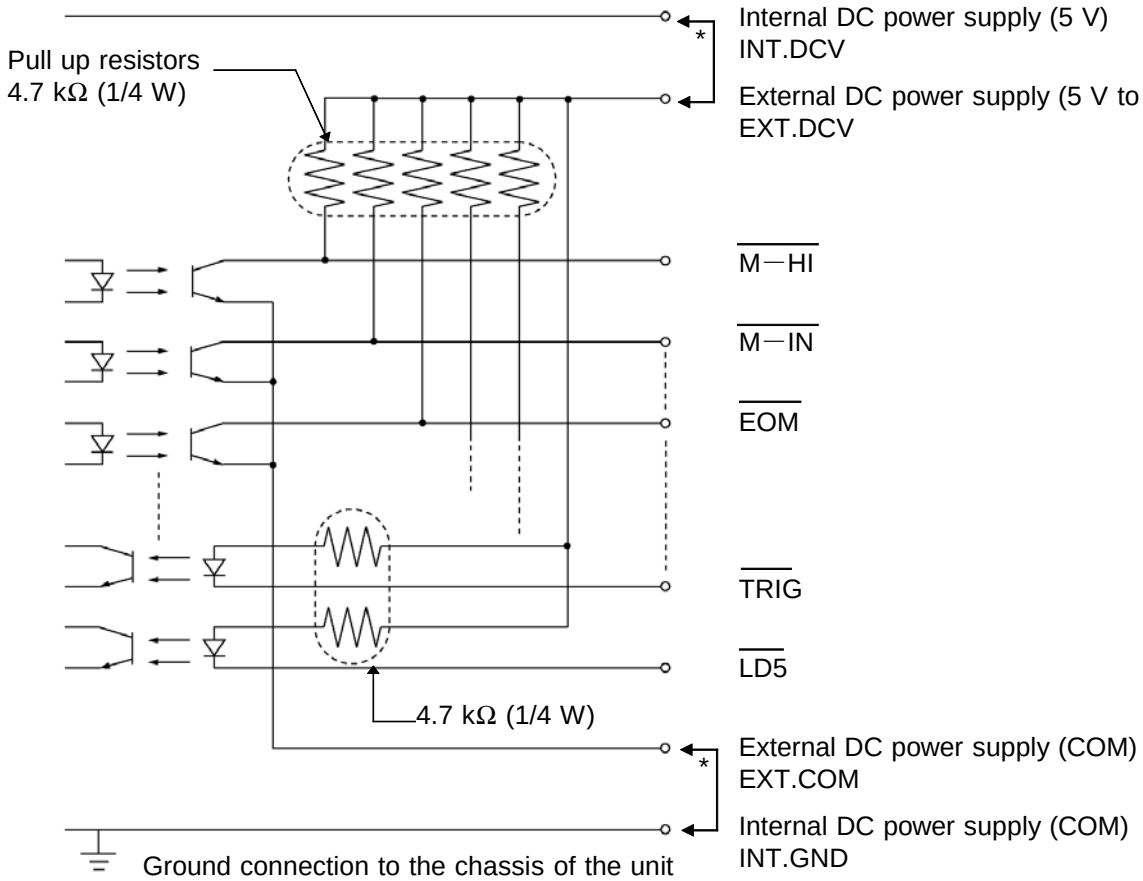
5.5.3 Circuit Construction and Connections for the EXT I/O Connector

⚠ CAUTION

- The insulation of the signal lines is for eliminating mutual influences between the signals. Any device which is connected to the 3532-50 unit should always be properly protectively grounded. If proper connection to a protective ground is not established, there is a danger of damage to the insulation.
- The voltage of the external DC power supply to be connected to the EXT DCV and EXT COM terminals should be from 5 V to 24 V. Do not supply DC voltage greater than 24 V. If you do, there is a danger of damage to the unit.
  Moreover, for driving the circuitry, connect any device which is capable of providing an output current of more than 200 mA.

The circuit construction for the EXT I/O connector is shown in the figure.

Except for the power supply lines, all of the input and output signal lines are insulated by photocouplers.



Circuit Construction

* Connect when using the internal 5V power supply.

NOTE

- The internal DC power supply of 5 VDC is provided between INT DCV and INT GND. The maximum current capacity is 100 mA. Do not connect any external circuit whose current consumption is greater than 100 mA.
- INT GND is grounded to the chassis of the 3532-50 unit.
- When using the EXT I/O connector, be sure always to supply power to the external DC power supply.
- The output signal low level output current is a maximum of 60 mA. If a current greater than this is required, you should connect a transistor circuit using a current amplifier driven by an external power source or the like externally.

5.5.4 Electrical Characteristics of the Output Signals

The output signals are the collector outputs of the photocouplers, and are connected to the external DC power supply (EXT. DCV) via 4.7 kΩ pull-up resistors provided internally to the 3532-50 unit.

The relationship between the external DC power supply voltage, the voltage of the output signals, and the current, is as shown in the following table:

External DC power supply voltage	Output signals (internal pull-up resistors 4.7 kΩ)			
	High level	Low level (Output current)		
		10 mA	40 mA	60 mA (max.)
5 V	5V	0.9 V	1.1 V	1.2 V
12 V	12 V	0.9 V	1.1 V	1.2 V
24 V	24 V	0.9 V	1.1 V	1.2 V

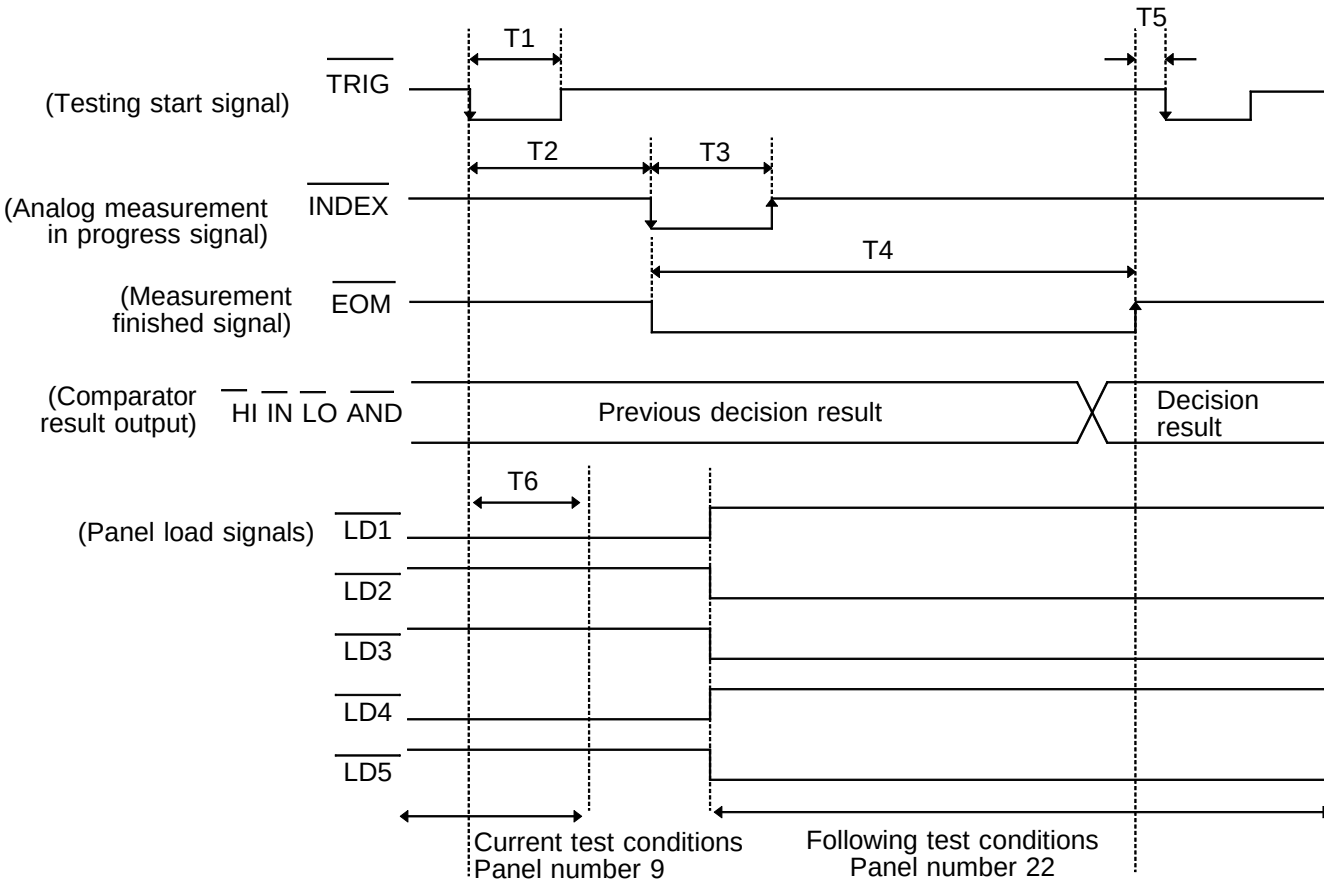
Direct connection of a circuit whose input voltage V_{IL} is regulated to a maximum of 0.8 V or the like is not possible.

In such a case, keep V_{IL} below 0.8 V by incorporating a transistor or a drive capable buffer circuit or the like.

5.6 Testing Using EXT I/O

5.6.1 Normal Testing

With the test conditions for testing by the comparator having been set (with the trigger setting set to external trigger), when in this state a trigger signal is input via the EXT I/O connector, or when on the screen the MANU TRIG soft key is pressed, then the decision result is output on the comparator result output signal line of the EXT I/O connector.
When a panel number has been selected using the panel load signal at the input of a trigger signal via the EXT I/O connector, the 3532-50 loads the measurement conditions for the panel number and then begins measurement.
An example of testing timing is as follows:



	Meaning	Timing (approximate)
T1	Minimum time period for trigger signal recognition	100 µs
T2	Time period from trigger to circuit response	300 µs + α (α depends on the sample under test and the trigger delay)
T3	Analog measurement time; chucking switching on INDEX (HIGH) possible (Note 1)	1 ms (Note 2)
T4	Time period for testing	5 ms (Note 2)
T5	Minimum time period from end of testing to next trigger	0 s
T6	Time period from trigger input to panel load signal recognition. After this length of time has elapsed, the LD signal can be changed.	300 µs

Note1: The chuck can be switched using the INDEX signal only when the test signal level, current and voltage limits, test range, and average are set as specified below:
Test signal level: Open circuit voltage (V) setting
Current and voltage limits: OFF
Test range: HOLD range
Average: OFF

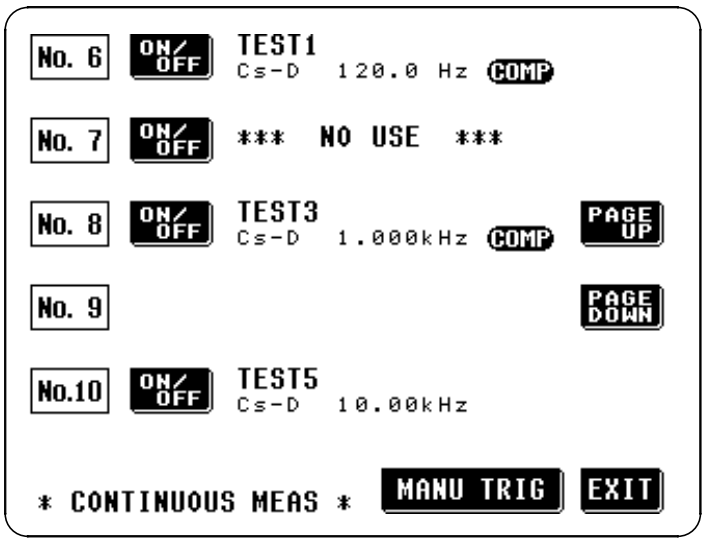
Note2: Reference value with the following conditions; test frequency:1 kHz, testing speed:FAST, averaging:OFF, and when measuring |*Z*|.
For the test time, refer to Section 7.3, "Time Taken for Testing."

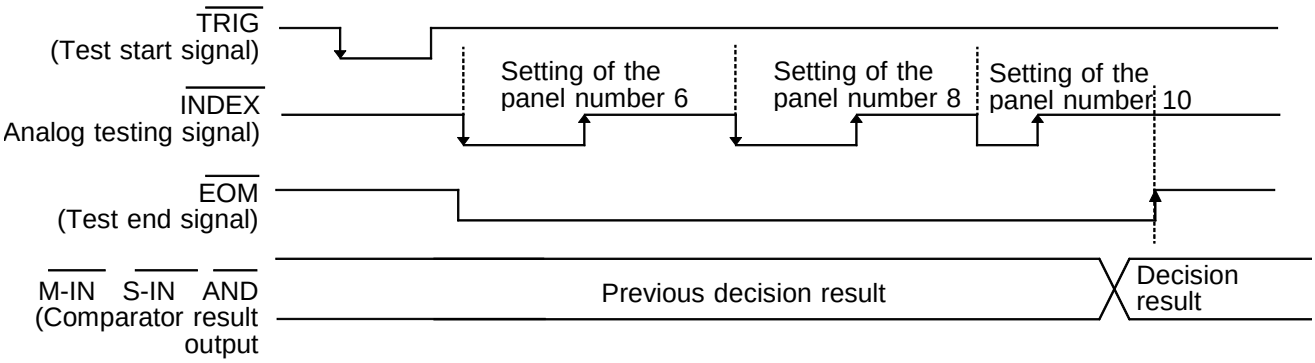
NOTE

- When the selected panel number is not stored, the 3532-50 begins measurement without loading the measurement conditions.
- When the measurement conditions are loaded, the external trigger is always set.

5.6.2 Test on the Continuous Test Screen

On the Continuous test screen, when a trigger signal is input via the EXT I/O connector, or when on the screen the MANU TRIG soft key is pressed, then the decision result is output on the comparator result output signal line of the EXT I/O connector after testing is completed for all the panel numbers that must be tested on the screen according to the setting.
When performing continuous testing with panel numbers 6, 8, and 10 for example.





AND If all of the decision results are IN, then LO is output.

M-IN If all of the decision results of the first parameters are IN, then LO is output.

S-IN If all of the decision results of the third parameters are IN, then LO is output.

M-HI, M-LO, S-HI, S-LO: No output

NOTE On the continuous testing screen, the panel load signals (LD1 to LD5) cannot be used.

For details on continuous testing, see Section 4.22, "Continuous Test Function."

5.7 Supplying DC Bias

⚠ CAUTION

The maximum voltage which can be applied to the test terminals of the 3532-50 unit is 40 V DC. If a DC voltage greater than this is applied continuously, the unit may be damaged.

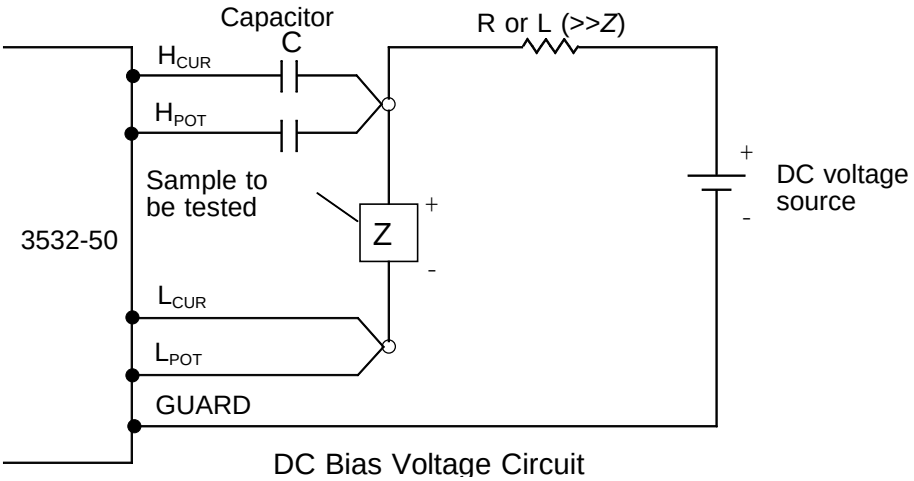
Supplying DC bias means that a DC voltage is supplied as a bias to a sample for test whose characteristics are voltage dependent, such as an electrolytic capacitor or a ceramic capacitor.
Further, a DC current can be supplied as a bias to a sample for test whose characteristics are current dependent, such as a choke coil.
Since the 3532-50 unit has no DC bias input terminals, a DC bias must be supplied in the manner described in the following sections.

5.7.1 How to Supply a DC Bias Voltage

⚠ CAUTION

- In order to avoid electric shock accident, be absolutely sure not to touch the test terminals while the DC bias voltage is being supplied to them.
- If you disconnect the sample under test from the test terminals with the DC bias voltage still being supplied, then the test sample is left charged, which is very dangerous. In order to avoid electric shock accident, be absolutely sure to discharge the test sample.
- Do not short circuit between the clips of the test probes with the DC bias voltage still being supplied. Doing so may damage the probes or cause a short circuit accident.

To supply a DC bias voltage to a capacitor or the like, proceed as follows.
Use the optional 9268 DC BIAS VOLTAGE UNIT.
For details on using the 9268, refer to the Instruction Manual of the 9268.
(Depending on the test frequency, test signal level, and test range, the 9268 cannot be used.)
If the 9268 is not used, refer to the following.



DC Bias Voltage Circuit

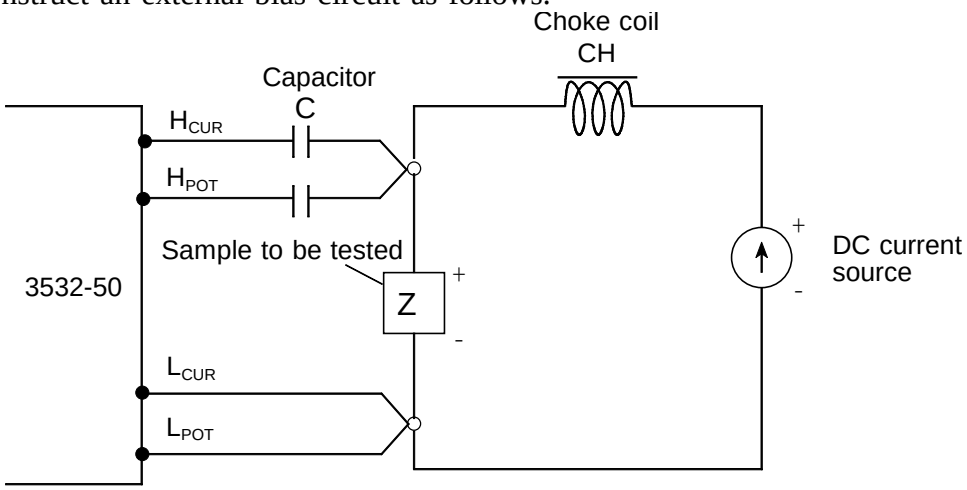
- Use a resistance (*R*) or inductance (L) which has a large enough impedance with reference to the sample under test (*Z*).
- Use a capacitor (C) which has a small enough impedance (i.e., a large enough capacitance) with reference to the sample under test (*Z*).
- Be careful about the polarity when connecting together the probes, the sample to be tested, and the DC voltage source.
- It takes a little time for the DC voltage which is being supplied to the sample under test to reach the set voltage, so you should wait for a certain stabilization time period (which depends upon the sample) before performing testing. Be careful, because if you perform testing before this stabilization time period has elapsed, the results will not be reliable.
- After testing is completed, drop the voltage of the DC voltage source to zero, and remove the sample under test from the probes after having discharged any electric charge which may have built up.
- If you have removed the sample under test from the probes without first having discharged the accumulated electric charge, you should be careful to do so immediately.

5.7.2 How to Supply a DC Bias Current

⚠ CAUTION

- In order to avoid electric shock accident, be absolutely sure not to touch the test terminals while the DC bias is being supplied to them.
- Due to the inductance of the coil and the sample, counter electromotive force is generated when the sample is removed or inserted with the DC bias supplied. This may result in damage to the 3532-50 or to the DC source.

To supply a DC bias, use the optional 9269 DC BIAS CURRENT UNIT. For details on using the 9269, refer to the Instruction Manual of the 9269. (Depending on the test frequency, test signal level, and test range, the 9269 cannot be used.)
If the 9269 is not used, refer to the followings.
To supply a DC bias current to a transformer or a choke coil or the like, construct an external bias circuit as follows.



DC Bias Current Circuit

- Connect the sample to the measuring probe and then gradually raise the voltage of the DC source to the specified DC bias level. To disconnect the sample, gradually reduce the voltage of the DC source until the DC bias supplied to the sample is decreased to zero. You may disconnect the sample after this is achieved.
- Use a choke coil (CH) which has a large enough impedance with reference to the sample under test (*Z*).
- Use a capacitor (C) which has a small enough impedance (i.e., a large enough capacitance) with reference to the sample under test (*Z*).
- Be careful about the polarity when connecting together the probes, the sample to be tested, and the DC current source.
- Be careful not to magnetically saturate the choke coil (CH) with the DC bias current.
- It takes a little time for the DC current which is being supplied to the sample under test to reach the set value, so you should wait for a certain stabilization time period (which depends upon the sample) before performing testing. Be careful, because if you perform testing before this stabilization time period has elapsed, the results will not be reliable.

5.8 The Residual Charge Protection Function

⚠ CAUTION

- The quoted maximum voltage from which the unit can be protected by this function is for reference purposes only, and is not a guaranteed value. There may be danger of damage to the 3532-50 unit, depending upon the operational circumstances and upon how often such charged capacitors are connected. In general, you should not rely upon this protection function; be sure to discharge charged capacitors properly before connecting them to the test terminals.
- The residual charge protection function is for protection of the 3532-50 unit against the discharge of voltage present in charged capacitors, and is not capable of protecting the unit against DC voltage which is constantly applied such as a superimposed DC voltage. (The maximum voltage for supply to the test terminals of the 3532-50 unit is 40 VDC.) If this is done, there is a danger of damage to the unit. (For how to supply a DC bias voltage, refer to Section 5.7, "Supplying DC Bias".)

The 3532-50 has been enhanced by the incorporation of a residual charge protection function. If by mistake a charged capacitor is connected to the test terminals, this function protects the internal circuitry of the unit from discharge of such residual charge.
The maximum voltage from which the unit can be protected by this function is determined from the capacitance value of the sample under test by the following equation:

$$V = \sqrt{\frac{1}{C}}$$

V: voltage (volts) (maximum 400 VDC)
C: capacitance (farads)

5.9 9442 Printer (option)

Using with the optional 9593-01 RS-232C INTERFACE, 9442 PRINTER, and 9446 CONNECTION CABLE, the test values and screen display copy can be printed out.

5.9.1 Preparation

(1) Using of the printer

Use the 9442 PRINTER, the 9443-01 AC ADAPTER, and the 1196 RECORDING PAPER.
To connect the main unit and printer, use the 9593-01 RS-232C INTERFACE and the 9446 CONNECTION CABLE. (All are options)

9442	DPU-414	Seiko Instruments Inc.
9443-01	PW-4007-J1	Seiko Instruments Inc. (for Japan)
9443-02	PW-4007-E1	Seiko Instruments Inc. (for EU)
9443-03	PW-4007-U1	Seiko Instruments Inc. (for America)

(2) Setting of the 9442 PRINTER communication condition

Change the settings of the software dip switches (DIP SW) to use the 9442 for the 3532-50.

⚠ CAUTION

- The 9442 is shipped with the function settings for use with the HIOKI 3166 CLAMP ON POWER HiTESTER. Before using, always change the settings of the DIP switches.
- For details on the operations and handling of the printer, refer to the operation manual supplied to the printer.
- For the printer, use the 1196 RECORDING PAPER (thermal paper, 10 rolls) or an equivalent.

1. Turn off the power.
2. Turn on the power while pressing the ON LINE button. Release the button after a list of the current settings starts printing out.
3. The print out of the current settings is followed by the prompt: "Continue? :Push 'On-line SW'", "Write?:Push 'Paper feed SW'". Press the ON LINE button to change the settings.

4. "Dip SW-1" is printed to make a settings for switch number 1 to 8 of DIP SW 1. Refer to the next table.

Software DIP SW1
Use these settings for the 3532-50

Switch No.	Function	ON (ON LINE)	OFF (FEED)
1	Input method	Parallel	Serial
2	Printing speed	High	Low
3	Auto loading	Enable	Off
4	CR function	Carriage return and line feed	Carriage return
5	DIP SW setting command	Enable	Disable
6	Printing density (set to 100%)		OFF
7		ON	
8		ON	

To set to ON, press the ON LINE button once and to set to OFF, press the FEED button once.
The setting is printed out after the ON LINE or FEED button is pressed to allow to confirm the new setting. To change the settings, repeat from step 1. When the setting for switch number 8 is made, the printer once again prompts with "Continue? :Push 'On-line SW'", "Write?:Push 'Paper feed SW'".

5. Set the switch number 1 to 8 of DIP SW 2 and 3 in the same way from step 3 referring to the following tables.

Software DIP SW2

Switch No.	Function	ON (ON LINE)	OFF (FEED)
1	Print mode	Normal printing (40 columns)	Condensed printing (80 columns)
2	User-defined characters back-up	Enable	Disable
3	Character type	Ordinary characters	Special characters
4	Zero font	0	Ø
5	International character set	ON	
6		ON	
7		ON	
8		ON	

Software DIP SW3

Switch No.	Function	ON	OFF
1	Data bit length	Eight bits	Seven bits
2	Parity permission	Without	With
3	Parity condition	Odd	Even
4	Flow control	H/W BUSY	XON/XOFF
5	Baud rate (19200bps)		OFF
6		ON	
7		ON	
8			OFF

6. After setting for the switch number 8 of DIP SW 3 is made, press the ON LINE or FEED switch to complete settings.
   "Dip SW setting complete!!" is printed out.

(3) Setting of the 9593-01 RS-232C INTERFACE

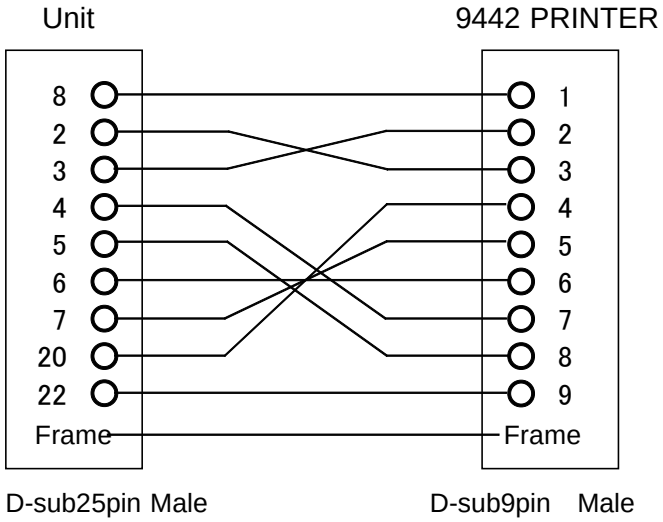
Set the communication setting switch on the left of the RS-232C connector to ON.

5.9.2 Connection Method

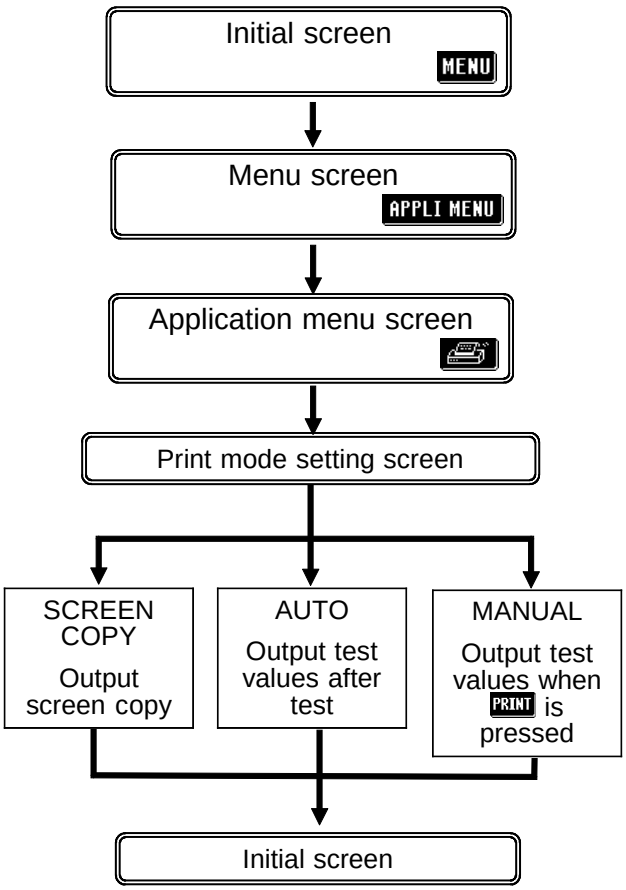
⚠ WARNING **To avoid electrocution, turn off the power to all devices before plugging or unplugging any cables or peripherals.**

Set the 9442 PRINTER and the 9593-01 RS-232C INTERFACE referring to Section 5.9.1.

1. Turn off the power of the main unit and printer.
2. Install the 9593-01 RS-232C INTERFACE to the main unit.
(For details on installing, see the 9593-01 Instruction Manual.)
3. Connect the 9446 CONNECTION CABLE between the main unit and the printer.



5.9.3 Control Screen Sequence



Press the MENU key.

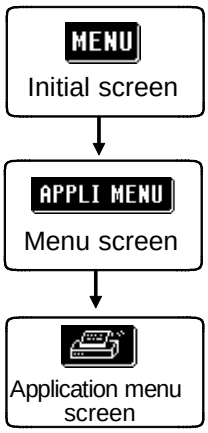
Press the APPLI MENU key.

Press the key.

Select the print type.

When the setting has been established as above, press the EXIT key to return to the Initial screen.

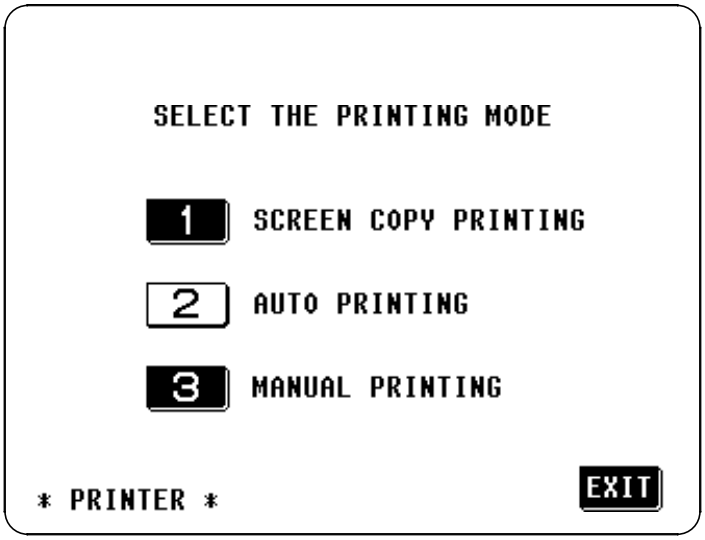
5.9.4 Returning from Comparator Operation to Normal Testing



1. Press the MENU key on the Initial screen to display the Menu screen.

2. Press the APPLI MENU key on the Menu screen to display the Application menu screen.

3. Press the key on the Application menu screen to display the Print mode setting screen.



Print mode setting screen

4. Select the one of the following print mode. The key selected changes to non-reversed video. For details on print mode, see Section 5.9.5 to 5.9.7.

1: Screen copy printing	Prints out the Initial screen copy.
2: Auto printing	Prints out the test values after test.
3: Manual printing	Prints out the test values only when the PRINT key key on the Initial screen is pressed.

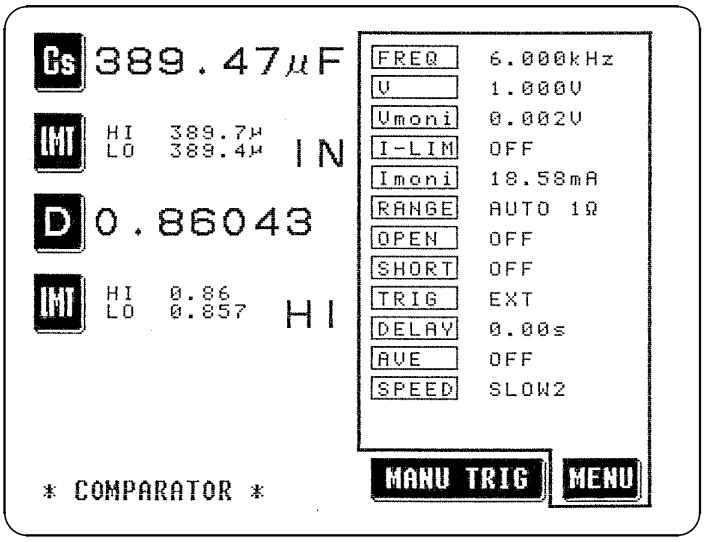
5. When the setting is completed, press the EXIT key to return the Initial screen.

5.9.5 Screen Copy Mode

Prints out the screen copy of the Initial screen.

- Pressing the PRINT key on the Initial screen starts printing.
- During printing, the PRINT key is not displayed, and all keys are invalid.
- When the printer is not operated for 10 seconds or more after pressing the key, such as case of disconnecting the printer, it stops printing after beep sounds.

Example of printing



5.9.6 Auto Print Mode

The test values are printed out when the test is completed.
When the continuous test is performed, the test values are printed out when each test for the panel number is completed.

Example of printing

Normal test

```
Z  413.49m ohm ; PH -79.68  deg
Cs 391.24u F   ; D  0.18210
```

Comparator executing

```
Cs 391.34u F   HI ; D  0.18174      HI
```

Continuous test

```
PANEL No.1: No.1 SAVE DATA
Cs 385.12u F   IN ; D  0.31376      IN

PANEL No.2: No.2 SAVE DATA
Cs 383.24u F   IN ; D  0.44627      IN

PANEL No.3: No.3 SAVE DATA
Cs 383.56u F   IN ; D  0.57990      LO

PANEL No.4: No.4 SAVE DATA
Cs 385.70u F   IN ; D  0.71671      IN

PANEL No.5: No.5 SAVE DATA
Cs 389.56u F   IN ; D  0.85801      IN
```

5.9.7 Manual Print Mode

Regardless of the trigger settings, the test values are printed out when the PRINT key on the Initial screen is pressed.

- When the test value is not stabilized because of changing the range by auto-ranging, "OVER FLOW" may be printed out.
  Press the PRINT key after the test value is stabilized.
- The examples of the output results are same as a and b of the auto print mode.

Chapter 6
Maintenance, Adjustment, and Disposal

6.1 Maintenance and Servicing

In order to use the 3532-50 safely, the following maintenance and checking procedures should be executed at the proper intervals.

- Be sure to read assiduously the various items highlighted in this manual for attention, in order to use the unit correctly.
- If damage is suspected, check the "Troubleshooting" section before contacting your dealer or Hioki representative.
- Getting the 3532-50 unit wet or letting oil or dust enter inside its casing will certainly damage it, and is quite likely to cause an electric shock accident or a dangerous conflagration. If the unit has gotten seriously wet, oily, or dusty, stop using it and send it for service at an approved HIOKI service facility.
- Periodic calibration is necessary in order to maintain and authenticate the accuracy of this testing device. When such calibration is necessary, you should utilize the services of an approved HIOKI calibration facility.
- A lithium battery is used in the 3532-50 for powering the backup memory. When this battery becomes unfit for service, it is no longer possible to preserve the testing conditions. Therefore, when it is not possible to preserve the testing conditions, you should dispatch the unit to an approved HIOKI service facility for the lithium battery to be changed.

NOTE HIOKI intend to maintain the supply of spare parts for maintenance and service of the 3532-50 unit for a minimum of seven years after the cessation of production.

Cleaning the unit

- To clean the product, wipe it gently with a soft cloth moistened with water or mild detergent. Never use solvents such as benzene, alcohol, acetone, ether, ketones, thinners or gasoline, as they can deform and discolor the case.
- Wipe the LCD gently with a soft, dry cloth.

6.2 How to Change the Power Supply Fuse and Change the Power Supply Voltage

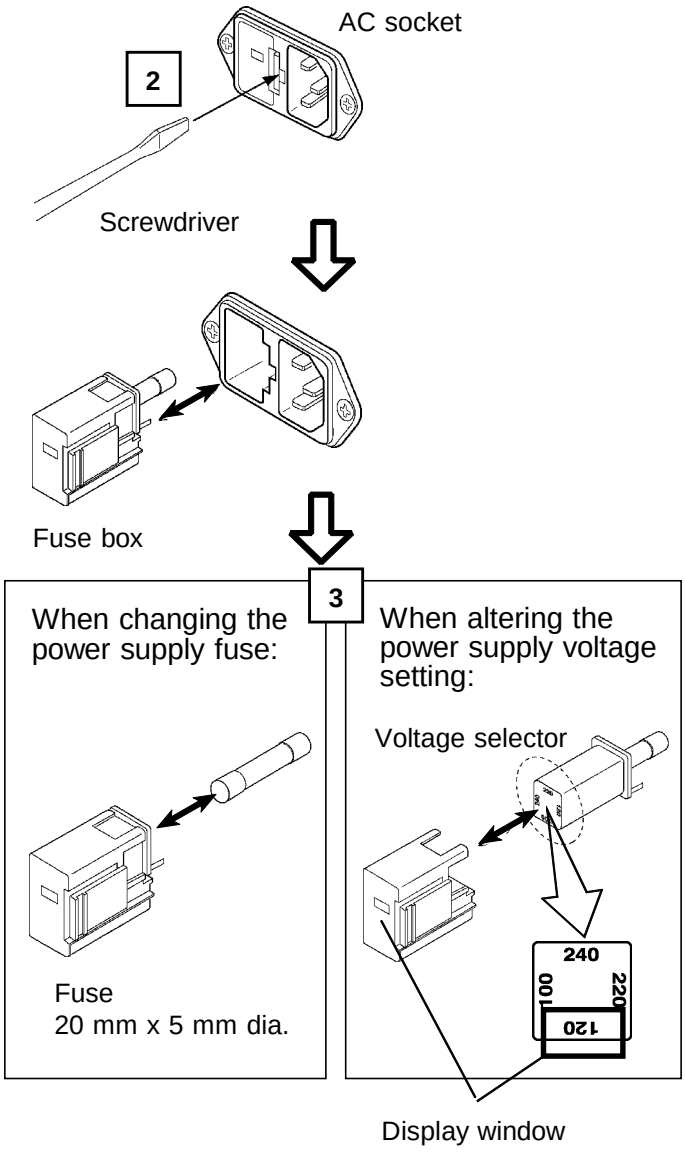
The power supply fuse for the 3532-50 unit, and the power supply voltage selector, are housed in the power input socket on the rear panel.

⚠ WARNING

- **When changing the power supply fuse or changing the power supply voltage, in order to avoid the risk of electric shock accident, be quite sure first to turn the main switch of the 3532-50 unit off, and then to remove the power cord.**
  Moreover, after finishing any operation, before reconnecting the power cord to the unit, be sure to check that the power supply voltage value indicated on the voltage selector housed in the power input socket on the rear panel is in agreement with the actual voltage value of the power supply line to which you intend to connect the unit.
  (The voltage indication is upside down.)
- **Replace the fuse only with one of the specified characteristics and voltage and current ratings. Using a non-specified fuse or shorting the fuse holder may cause a life-threatening hazard.**
  Fuse type:
  100 V, 120 V settings: 250 V F1.0 AL 20 mm × 5 mm dia.
  220 V, 240 V settings: 250 V F0.5 AL 20 mm × 5 mm dia.
- **Before the 3532-50 is dispatched from the factory, it is set to the power supply voltage used at the destination specified for shipping, and the specified fuse for that power supply voltage is fitted, along with an identical spare fuse. If for any reason you intend to power the unit from a power supply whose voltage is different, be sure to change the fuse as well as altering the voltage selector setting.**
- **If you intend to use a power supply of a voltage other than the specified ones for powering the unit, use a fuse and voltage selector setting as follows:**

  Actual power supply voltage 110 V : use settings for 120 V
  Actual power supply voltage 200 V : use settings for 220 V
  Actual power supply voltage 230 V : use settings for 240 V

Changing the power supply fuse and the power supply voltage:



1. Turn the power switch off, and then remove the power cord.

2. Using a slot head screwdriver or the like, bias sideways the catch which holds the fuse box into the power input socket as shown in the figure, and then remove the fuse box.

3. When changing the power supply fuse:
Change the power supply fuse for a new one of the same rating and specification.

When altering the power supply voltage setting:

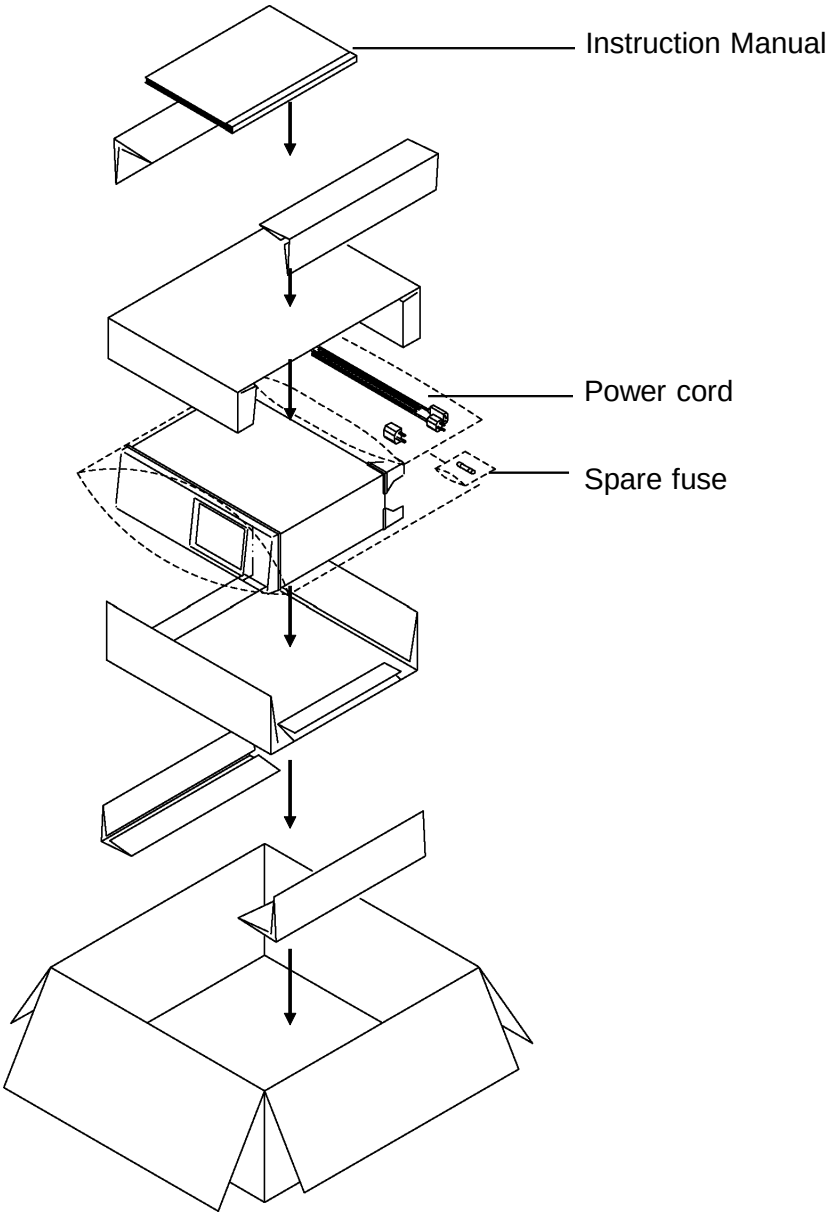
1) Remove the voltage selector from the fuse box, and reinsert it after having rotated it so that the desired new power supply voltage setting appears in the display window as shown in the figure.
Then recheck the setting value shown in the window. (The voltage display is upside down and backwards.).

2) Change the power supply fuse for a new one whose rating and specification are appropriate for the new power supply setting.

4. Replace the fuse box by reinserting it into the power input socket.

6.3 Shipping the Unit

Use the original packing materials when reshipping the product, if possible.



6.4 Troubleshooting

If the 3532-50 unit appears to be faulty, check the following possibilities before sending the unit for service:

Symptom	Cause	Treatment
Although you have turned on the power switch, the screen display does not appear.	Is the power cord disconnected?	Reconnect the power cord.
	Is the contrast on the LCD panel turned down to minimum?	Adjust the LCD panel contrast.
	Has the fuse blown?	Change the fuse.
Key input is not effective.	Is the unit in the key locked state?	Release the key lock state.
	If both GP-IB and RS-232C are in use, has remote been externally set?	Set both GP-IB and RS-232C to local.

If none of these is applicable, or if you have no idea of the problem, try resetting the system.
All of the settings will revert to the factory original settings. You must reset them again.
For the method of system reset, see Section 4.21 "System Reset."

If operation is interrupted in the following kinds of situation, remove the power cord and the input cables, and get into contact with an approved Hioki service facility:

- The unit is clearly damaged.
- Even when you try, testing is not possible.
- The unit has remained subject to high temperature or high humidity conditions for a long time period.
- The unit has been subjected to stress due to rough transportation.

6.5 Disposing of the Unit

A lithium battery is used in the 3532-50 as a power source for recording test conditions.

⚠ WARNING

- **To avoid electrocution, turn off the power switch and disconnect the power cord and measurement cables before removing the lithium battery.**
- **When disposing of this product, remove the lithium battery and dispose of battery and product in accordance with local regulations.**

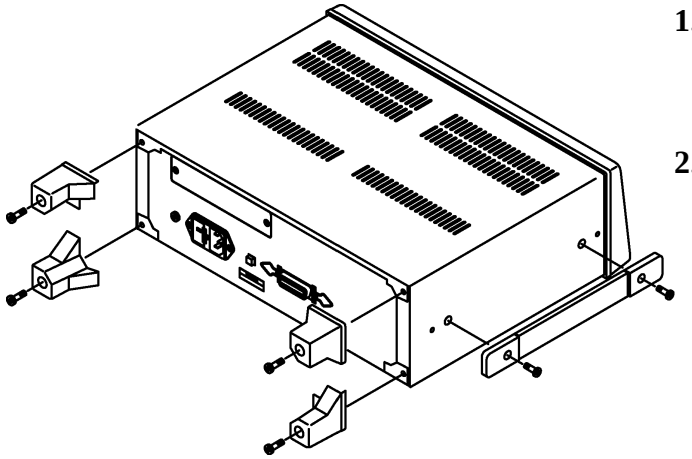
⚠ CAUTION

If the protective functions of the instrument are damaged, either remove it from service or mark it clearly so that others do not use it inadvertently.

Tools required for dismantling

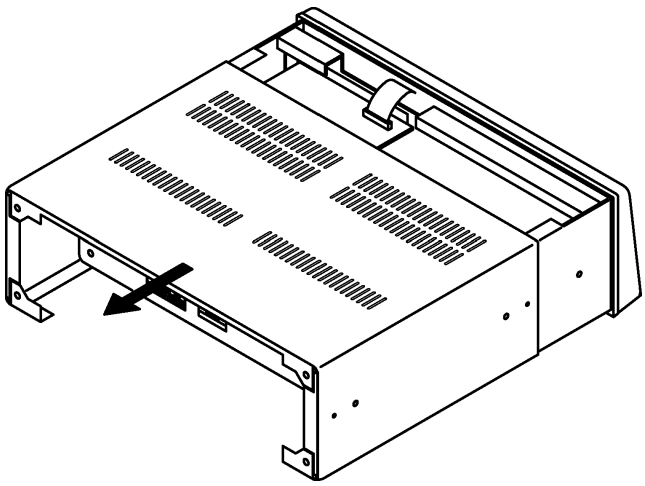
- Phillips screwdriver 1
- Pair of tweezers 1

How to dismantle the unit

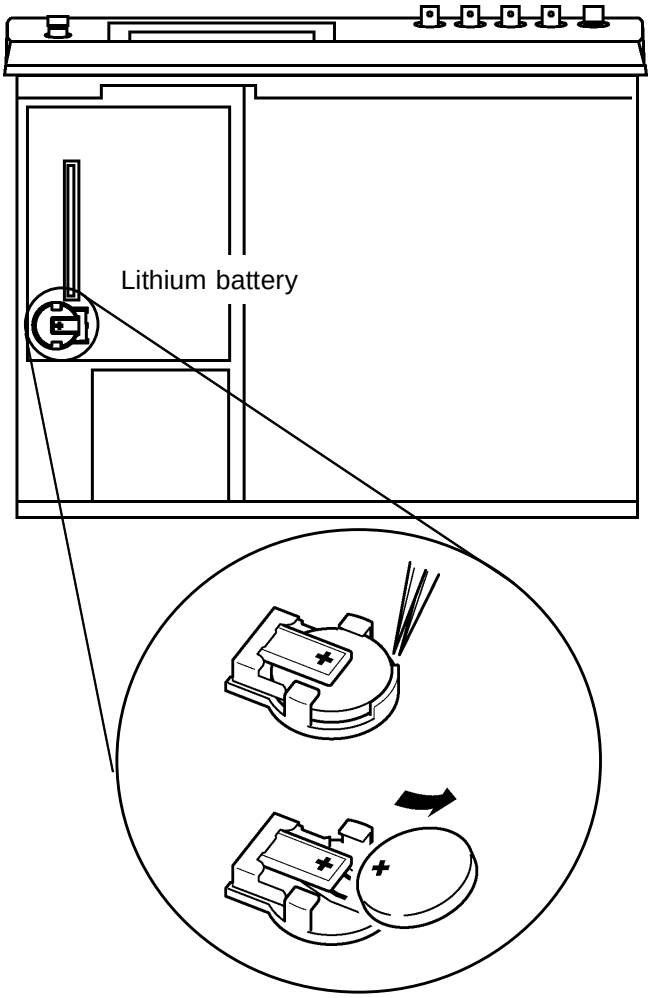


1. Turn off the power switch, and disconnect the power cord and other cables.

2. Remove the four screws at the back of the unit and the two screws which hold on the carrying handle, as shown.



3. Pull off the case in the direction shown by the arrows in the figure.



4. The battery holder is located in the position illustrated on the left. Insert a pointed tool, such as the tip of a tweezers, between the battery and the battery holder, and lift the battery to remove it.

Chapter 7
Specification and Options

7.1 General Specification

1. Test parameters	|*Z*|	Impedance
	|*Y*|	Admittance
	θ	Phase angle
	Cs	Series-equivalent static capacitance
	Cp	Parallel-equivalent static capacitance
	D	Loss coefficient = tan δ (δ = delta)
	Ls	Series-equivalent impedance
	Lp	Parallel-equivalent impedance
	Q	Q factor (Q = 1/D)
	*R*s	Series-equivalent resistance = ESR
	*R*p	Parallel-equivalent resistance
	G	Conductance
	X	Reactance
	B	Susceptance

2. Test frequencies 42 Hz to 5.000 MHz

Setting resolution

Frequency (Hz)	Step (Hz)
42.0 to 999.9	0.1
1.000 k to 9.999 k	1
10.00 k to 99.99	10
100.0 k to 999.9	100
1.000 M to 5.000 M	1 k

Test frequency accuracy ±0.005% or less

3. Output impedance 50 Ω±10 Ω

4. Test signal levels		
Open circuit voltage (V) mode and Constant voltage (CV) mode	Range	10 mV to 5 V, 100 mA max. (1.000 MHz or less) 10 mV to 1 V, 20 mA max. (1.001 MHz or more)
	Resolution	1 mV steps
	Accuracy	±10%±10 mV (1.000 MHz or less) ±20%±10 mV (1.001 MHz or more)
Constant current (CC) mode	Range	10 µA to 100 mA, 5 V max. (1.000 MHz or less) 10 µA to 20 mA, 1 V max. (1.001 MHz or more)
	Resolution	10 µA steps
	Accuracy	±10%±10 µA (1.000 MHz or less) ±20%±10 µA (1.001 MHz or more)
Monitor function Voltage monitor (Vmoni)	Range	0.000 V to 5.000 V
	Accuracy	±10%±10 mV (1.000 MHz or less) ±20%±10 mV (1.001 MHz or more)
Current monitor (Imoni)	Range	0.000 mA to 100.0 mA
	Accuracy	±10%±10 µA (1.000 MHz or less) ±20%±10 µA (1.001 MHz or more)
Limit function Current limit (I-LIM) (V, CV mode)	Range	0.01 mA to 99.99 mA
	Accuracy	±10%±10 µA (1.000 MHz or less) ±20%±10 µA (1.001 MHz or more)
Voltage limit (V-LIM) (CC mode)	Range	0.010 V to 5.000 V
	Accuracy	±10%±10 mV (1.000 MHz or less) ±20%±10 mV (1.001 MHz or more)
5. Residual charge protection	400 V max (for reference only) Where: $V = \sqrt{\frac{1}{C}}$ {C: capacitance of the sample under test in farads}	
6. Test ranges (RANGE)	The test range is determined according to impedance and phase angle. The values of the other test parameters are calculated from |*Z*|.	
Ranges	100 mΩ, 1 Ω, 10 Ω, 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, 1 MΩ, 10 MΩ, and 100 MΩ (10 ranges, can be set either automatically or manually)	
|*Z*| display range	10.00 mΩ to 200.00 MΩ (5 digits)	
θ display range	+180.00° to -180.00° (5 digits)	

7. Display ranges

The measurement range varies according to the test frequency.
( ): impedance

Y, G, B	99.999 S (100 mΩ) to 5.0000 nS (200 MΩ)	5 digits
R, X	10.00 mΩ to 200.00 MΩ	5 digits
L	38.000 µH(100mΩ) to 750.00 kH(200MΩ) (at 42 Hz, θ =90°) 32.000 nH(10Ω) to 3.2000 mH(100kΩ) (at 5 MHz, θ =90°)	5 digits 5 digits
C	19.000 pF(200MΩ) to 370.00 mF(100mΩ) (at 42 Hz, θ = 90°) 0.3200 pF(100kΩ) to 32.000 nF(10Ω) (at 5 MHz, θ =90°)	5 digits 5 digits
D	0.00001 to 9.99999	6 digits
Q	0.01 to 999.99	5 digits

NOTE: The test range of L and C varies depending on the test frequency and value of θ.

8. Display

78.4 mm x 107.2 mm LCD display with backlight

9. Testing speed

Processing method: taken as the average of the waveform detected by the measurement circuit.

When measuring open-circuit terminal voltage (V) (minimum times with test frequency 1 kHz, Z display, initial screen)

The values depend on the measurement frequency, display parameter types, open-circuit and short-circuit compensation, and whether or not the comparator is being used.

FAST 5 ms ±2 ms
NORMAL 21 ms ±2 ms
SLOW 72 ms ±2 ms
SLOW2 140 ms ±2 ms

Constant voltage (CV) and constant current (CC) settings

Constant voltage/constant current measurement after connecting a measurement sample

Maximum of 5 times measurement speed setting

10. Averaging function

Setting of the number of averaging

OFF, 2, 4, 8, 16, 32, or 64

Processing

Internal trigger moving average of setting times
External trigger moving average of setting times

11. Trigger function

Manual setting of the Internal trigger (INT) or external trigger (EXT)
Trigger delay function (DELAY): 0.01 s to 9.99 s, setting resolution 0.01 s

12. Zero compensation

Open circuit compensation (OPEN)

Correction of residual admittance between the measurement terminals of the fixture
Operation is possible when, with the terminals open-circuit, the impedance is at least 1 kΩ.

Short circuit compensation (SHORT)

Correction of residual impedance between the measurement terminals of the fixture
Operation is possible when, with the terminals short-circuit, the impedance is less than 1 kΩ.

Spot compensation (SPOT)/Continuous correction (ALL)

For both open-circuit and short-circuit correction, a selection can be made for correction either at the set frequency only, or correction to be made over the entire frequency range.

13. Cable length setting function

Can be set to 0 m or 1 m

14. Comparator function (COMP)

Comparator function setting and using	For the touch panel, GP-IB, and/or RS-232C, comparator settings can be made and execution carried out for two parameters.
Upper and lower limit value settings (LIM)	For ABS (absolute values) setting Upper and lower limit values (HI, LO) are set. For % (percentages) setting Set a reference value (REF) and upper- and lower-limit values (HI, LO). For Δ% (deviation percentages) setting Set a reference value (REF) and upper- and lower-limit values (HI, LO). The measurement values are displayed as deviations from the reference value (Δ%).
Comparator result output (HI, IN, LO)	EXT I/O connector (HI, IN, LO, AND output of two parameters, INDEX, EOM signal outputs, TRIG, LOCK, LOAD signal inputs, internal 5 V, GND output, external power supply, GND input)

15. Scaling function

Test value compensation is possible by setting the compensation coefficients a and b to the following equation.

[test value after compensation] = a×[test value] + b

When the parameter is D or Q, calculate from compensation value for θ.

16. Magnification display function

The test values and comparator decision results can be displayed in enlarged form

17. Continuous test function

Continuous testing of the conditions which have been saved

18. Display digits

The values 3, 4, and 5 can be set as the number of displayed digits. The actual number of displayed digits, however, depends on the parameter used.

Parameter / Setting value	θ, Q Comparator Δ% setting	D	Others
5	Up to the second decimal place	Up to the fifth decimal place	Up to 5 digits
4	Up to the first decimal place	Up to the fourth decimal place	Up to 4 digits
3	No decimal place	Up to the third decimal place	Up to 3 digits

19. Display-setting function

A setting can be made to turn on/off the indications of the LCD display and voltage/current monitors.

20. System reset

All of the settings will revert to the factory settings.

21. Key lock function (KEY LOCK)

This disables the operation of keys on the panel, by means of either the special-purpose switch or EXT I/O connector on the rear panel.

22. Panel save (SAVE) and load (LOAD) function

A maximum of 30 sets of complete measurement conditions can be saved and recalled.

23. Beep sound setting (BEEP)

There are settings corresponding to key input and to the comparator results.

24. Interfaces

Touch panel settings

9518-01 GP-IB INTERFACE or 9593-01 RS-232C INTERFACE options can be selected (separate package)

EXT I/O connector (standard)

25. Temperature range for use

0 to 40℃ (32 to 104℉), up to 80% relative humidity, no condensation.

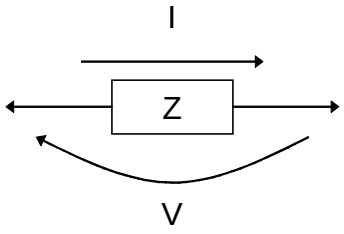
26. Temperature range for storage

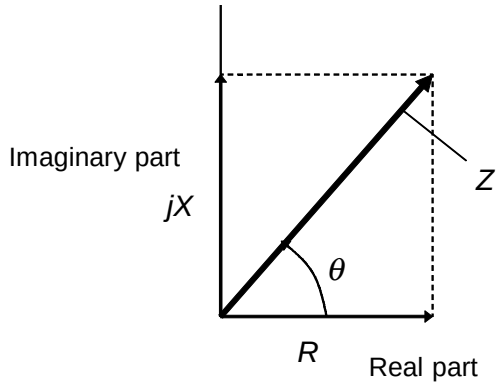
-10 to 55℃ (14 to 131℉), up to 80%RH, no condensation.

27. Operating environment	Indoors, altitude up to 2000 m (6562 feet)
28. Power supply	Rated supply voltage 100/120/220/240 V AC (switchable)(Voltage fluctuations of ±10% from the rated supply voltage are taken into account.) Rated supply frequency 50/60 Hz Maximum rated power 50 VA (with options installed)
29. Dimensions and mass	Approx. 348W mm x 113H mm x 273D mm (13.70"W x 4.45"H x 10.75"D), Approx. 5.7 kg (201.1 oz.)
30. Accessories supplied	Instruction Manual 1 Power cord 1 (selected according to shipping destination) Spare fuse for power supply 1 (selected according to shipping destination) (100/120 V: 250 V F1.0 AL, 200/240 V: 250 V F1.0 AL)
31. Component replacement	Power supply fuse (refer to above)
32. Options	9140 4-TERMINAL PROBE 9143 PINCHER PROBE 9261 TEST FIXTURE 9262 TEST FIXTURE (direct connection type) 9263 SMD TEST FIXTURE (direct connection type) 9268 DC BIAS VOLTAGE UNIT 9269 DC BIAS CURRENT UNIT 9165 CONNECTION CORD (for 9268, 9269/ BNC-BNC/ 1.5 m) 9166 CONNECTION CORD (for 9268, 9269/ BNC-clip/ 1.5 m) 9518-01 GP-IB INTERFACE 9151-02 GP-IB CONNECTOR CABLE (2 m) 9151-04 GP-IB CONNECTOR CABLE (4 m) 9593-01 RS-232C INTERFACE 9442 PRINTER(DPU-414 Seiko Instruments Inc.) 9443-01 AC ADAPTER (for printer, for Japan)(PW-4007-J1 Seiko Instruments Inc.) 9443-02 AC ADAPTER (for printer, for EU)(PW-4007-E1 Seiko Instruments Inc.) 9443-03 AC ADAPTER (for printer, for America)(PW-4007-U1 Seiko Instruments Inc.) 9446 CONNECTION CABLE (for printer) 1196 RECORDING PAPER (for printer) Note: Only one of the 9518-01 GP-IB INTERFACE and the 9593-01 RS-232C INTERFACE can be installed. To use the 9442 printer, 9593-01 is necessary.
33. Applicable Standards	EMC EN61326:1997+A1:1998+A2:2001+A3:2003 EN61000-3-2:2000 EN61000-3-3:1995+A1:2001 Safety EN61010-1:2001 Pollution Degree 2 Measurement Category I (anticipated transient overvoltage 330 V)
34. Withstand voltage	1.39 kV AC for 15s, between power and ground

7.2 Testing Parameters and Calculation Equations

Normal circuit elements etc. are assessed with regard to their characteristics in terms of their impedance *Z*. The 3532-50 for subjects such circuit components to an alternating current signal at a certain test frequency, measures their voltage and current vectors, and from these values obtains the impedance *Z* and the phase angle *θ*. It is then possible to obtain the following quantities from the impedance *Z* by displaying it upon the complex plane.



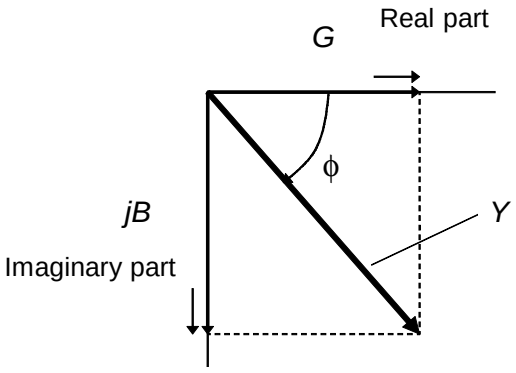


$Z = R + jX$
$\theta = \tan^{-1}(X/R)$
$|Z| = \sqrt{R^2 + X^2}$

Z : impedance (Ω)
θ: phase angle (degrees)
R : resistance (Ω)
X : reactance (Ω)
|*Z*| : absolute value of impedance (Ω)

Moreover, it is possible to use the admittance *Y*, which as a characteristic of a circuit component is the reciprocal of the impedance *Z*.

By displaying the admittance *Y* upon the complex plane (just as was done for the impedance *Z*) the following quantities can be obtained:



$Y = G + jB$
$\phi = \tan^{-1}(B/G)$

Y : admittance (S)
G : conductance (S)
B : susceptance (S)
|*Y*|: absolute value of admittance (S)

From the voltage V which is applied between the terminals of the sample under test, the current I which flows through the test sample at this time, the phase angle θ between this voltage V and this current I, and the angular velocity ω which corresponds to the test frequency, the 3532-50 can calculate the following components by using the calculation equations shown:

NOTE

The phase angle θ is shown based on the impedance *Z*. When measuring based on the admittance, the sign of the phase angle θ must be reversed.

Quantit	Series equivalent circuit mode	Parallel equivalent circuit mode
Z	$\|Z\| = \frac{V}{I}\left(= \sqrt{R^2 + X^2}\right)$	
Y	$\|Y\| = \frac{1}{\|Z\|}\left(= \sqrt{G^2 + B^2}\right)$	
R	Rs = ESR = $\|Z\| \cos\theta\|$	Rp = $\left\|\frac{1}{\|Y\|\cos\phi}\right\|$ $(= \frac{1}{G})$*
X	$X = \|Z\| \sin\theta\|$	_____
G	_____	$G = \|Y\|\cos\phi\ \|$ *
B	_____	$B = \|Y\|\sin\phi\ \|$ *
L	$L_s = \frac{X}{\omega}$	$L_p = \frac{1}{\omega B}$
C	$C_s = \frac{1}{\omega X}$	$C_p = \frac{B}{\omega}$
D	$D = \left\|\frac{1}{\tan\theta}\right\|$	
Q	$Q = \|\tan\theta\|\left(= \frac{1}{D}\right)$	

* ϕ: phase angle of admittance *Y* ($\phi = -\theta$)

Ls, *R*s, Cs : The measured values of L, C, and *R* in series equivalent circuit mode.

Lp, *R*p, Cp : The measured values of L, C, and *R* in parallel equivalent circuit mode.

7.3 Time Taken for Testing

The time taken for testing varies according to the test conditions.
The following values may be used for reference.

NOTE

These values are all for reference only. Do not rely upon them absolutely, because the actual time taken for testing depends upon many operational conditions.

Analog testing signal (INDEX)

The output time (T3) of the analog testing signal (INDEX) taken according to the testing speed:

Tf(s) = 1/ test frequency

Test frequency [Hz]	Calculation time (Allowance ±2 ms)			
	FAST	NORM	SLOW	SLOW2
42.0 to 99.9	Tf	Tf x 4	Tf x 8	Tf x 16
100.0 to 300.0	Tf	Tf x 16	Tf x 32	Tf x 64
300.1 to 1.000 k	Tf	Tf x 16	Tf x 64	Tf x 128
1.001 k to 3.000 k	Tf	Tf x 32	Tf x 128	Tf x 256
3.001 k to 30.00 k	10 ms	160 ms	320 ms	640 ms
30.01 k to 5.000 M	1 ms	16 ms	64 ms	128 ms

Testing finished signal (EOM)

For the output time (T4) of the testing finished signal (EOM), the following time periods A through E should be added to the output time of the analog testing signal <T3>:

T4 = T3+A+B+C+D+E

The time taken for calculation varies according to A to E.

<A>

The time taken for calculation varies according to the display parameters:

Test frequency [Hz]	Calculation time (Allowance ±2 ms)			
	FAST	NORM	SLOW	SLOW2
42.0 to 99.9	8 ms	10 ms	12 ms	16 ms
100.0 to 300.0	5 ms	7 ms	9 ms	14 ms
300.1 to 1.000 k	4 ms	5 ms	8 ms	12 ms
1.001 k to 3.000 k	4 ms	5 ms	7 ms	10 ms
3.001 k to 30.00 k	5 ms	7 ms	9 ms	14 ms
30.01 k to 5.000 M	5 ms	6 ms	8 ms	12 ms

<B>
The time taken for test varies according to the display state (display ON/OFF):

Display setting	Test time
LCD display and backlight :OFF	-2.3 ms
Voltage and current monitors:OFF	-1.4 ms
LCD display and backlight :ON Voltage and current monitors:ON	0 ms

(Allowance ±1 ms)

<C>
The time taken for calculation varies according as to whether or not both open circuit compensation and also short circuit compensation are performed:

Open/short circuit compensation	Calculation time
Open and/or short circuit compensation performed	1.5 ms
Not performed	0 ms

(Allowance ±1 ms)

<D>
The time taken for calculation varies according as to whether or not the comparator is operating:

Comparator operating	Calculation time
Normal testing	0 ms
When the comparator is operating	0.7 ms

(Allowance ±1 ms)

<E>
The time taken for calculation varies according as to whether or not the comparator is operating:

Scaling execution	Calculation time
Normal testing	0 ms
When the scaling is executed	0.8 ms for a parameter

(Allowance ±1 ms)

Wait time for changing test conditions

When the test conditions are changed, the time taken for the internal processing is necessary according to the following factors (1) to (3), before testing.

(1) When the test frequency is changed:
Changing to the frequency in another range Wait time: 300 ms

Range	Frequency
1	42 Hz to 99.9 Hz
2	100.0 Hz to 300.0 Hz
3	300.1 Hz to 1.000 kHz
4	1.001 kHz to 3.000 kHz
5	3.001 kHz to 10.00 kHz
6	10.01 kHz to 30.00 kHz
7	30.01 kHz to 100.0 kHz
8	100.1 kHz to 1.000 MHz
9	1.001 MHz to 5.000 MHz

(2) When the test signal level is changed:
Changing to the test signal level in another range Wait time: 300 ms

Range	Test signal level
1	0.010 V to 0.100 V
2	0.101 V to 0.500 V
3	0.501 V to 1.000 V
4	1.001 V to 5.000 V

Note When the test signal level setting is CV/CC or the setting of voltage and current limit is ON, the test signal level is automatically changed.

(3) When the test range is changed:
Wait time: 300 ms

7.4 Options

9518-01 GP-IB INTERFACE

Compliance standard: IEEE-488.1 (1987)

Reference standard: IEEE-488.2 (1987)

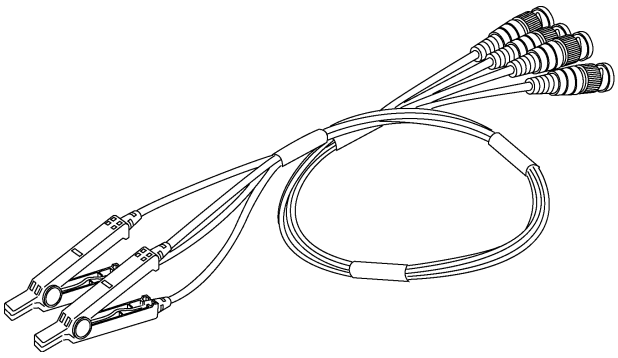
For explanation of how to fit the 9518-01 GP-IB INTERFACE BOARD and for a detailed description of its commands etc., reference should be made to the user manual supplied with the 9518-01.

9593-01 RS-232C INTERFACE

Compliance standard: EIA RS-232C

For explanation of how to fit the 9593-01 RS-232C INTERFACE BOARD and for a detailed description of its commands etc., reference should be made to the user manual supplied with the 9593-01.

9140 4-TERMINAL PROBE

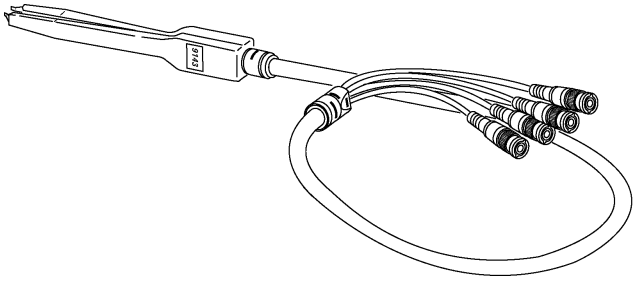


This is a crocodile clip type of test probe.

This type of probe is very convenient for connection to a wide range of wires, from comparatively thin wires to comparatively thick ones.

Range of frequencies which can be used is from DC to 100 kHz

9143 PINCHER PROBE



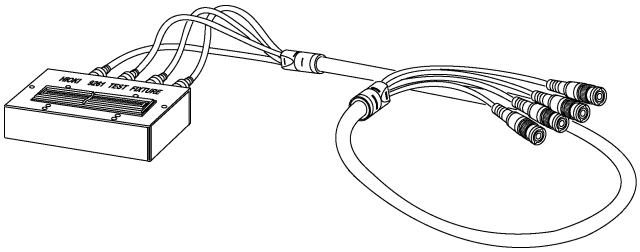
This tweezer type probe is very convenient for testing samples such as chips. The impedance range which can be measured by the 3532-50 using this probe varies according to the frequencies.

The range of test frequency which can be used is from DC to 5 MHz.

NOTE

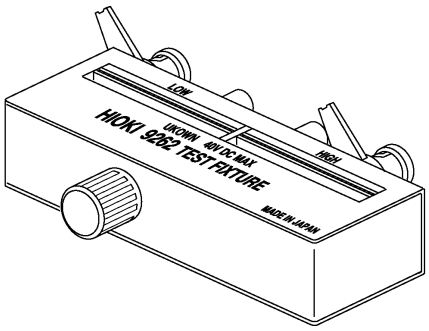
When using a probe, it may happen that the values obtained vary because the contact resistance is altering due to alterations in the pinch pressure exerted. Therefore it is necessary to keep the pinch pressure as constant as possible.

9261 TEST FIXTURE

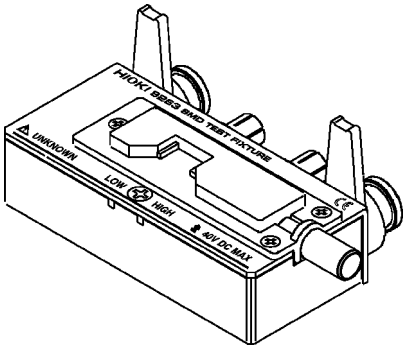


Samples to be tested can be comparatively easily loaded into and removed from this type of fixture. The range of test frequency which can be used is from DC to 5 MHz.

9262 TEST FIXTURE

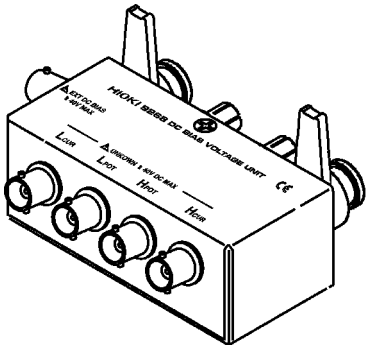


9263 SMD TEST FIXTURE



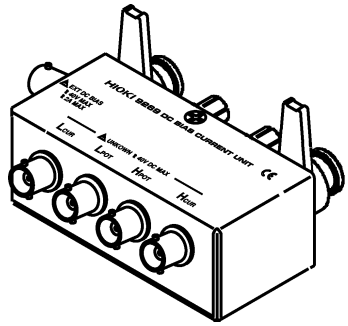
This is very convenient for testing samples such as chips.
The range of test frequency which can be used is from DC to 5 MHz.

9268 DC BIAS VOLTAGE UNIT



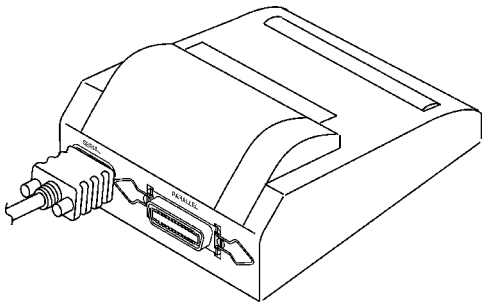
Maximum input voltage: 40 VDC

9269 DC BIAS CURRENT UNIT



Maximum input current: 2 A

9442 PRINTER



The screen copy and test values can be printed out. To use the printer, the following optional unit is necessary.

9593-01 RS-232C INTERFACE
9443 AC ADAPTER
9446 CONNECTION CABLE
1196 RECORDING PAPER

7.5 Test Accuracy

The test accuracy is calculated from a basic accuracy, which is based on the accuracy for impedance Z (%) and phase angle θ (°), and the following coefficients.

Test accuracy = Basic accuracy x C x D + E

C: Test speed coefficient
D: Cable length coefficient
E: Temperature coefficient

1. Basic accuracy

The basic accuracy is calculated from a value A and B from the accuracy coefficient table, which is based on the measurement frequency (*1), the measurement range, and the measurement signal level (*2).

(*1): When the measurement frequency is 1.001 MHz or more, (f [MHz] +3)/4 must be multiplied to the basic accuracy.

(*2): In CV or CC mode, the accuracy varies according to the test signal level.

(1 kΩ range or more)

$$\text{Basic accuracy Z(\%) or } \theta(^\circ) = \pm\left(A + \frac{B \times |10 \times Zx[\Omega] - \text{Range}[\Omega]|}{\text{Range}[\Omega]}\right)$$

(100 Ω range or less)

$$\text{Basic accuracy Z(\%) or } \theta(^\circ) = \pm\left(A + \frac{B \times |\text{Range}[\Omega] - Zx[\Omega]| \times 10}{\text{Range}[\Omega]}\right)$$

*Z*x: sample of |*Z*|

The impedance of the measurement sample (Zx) is taken to be either the measured value, or the value calculated from the following expressions (refer to "Conversion Table from C and L to |*Z*|").

$$|Zx|\ (\Omega) \fallingdotseq \omega L\ (H)\ (\theta \fallingdotseq 90^\circ)$$
$$\fallingdotseq 1/\omega C\ (F)\ (\theta \fallingdotseq -90^\circ)$$
$$\fallingdotseq R\ (\Omega)\ (\theta \fallingdotseq 0^\circ)$$

Basic accuracy conditions:

- Using the 9262 TEST FIXTURE
- Test speed: SLOW2
- Cable length coefficient: 0 m
- Temperature and humidity: 23±5℃, 80 %RH or less
- Operation 60 minutes after the power is turned on
- Open circuit compensation and short circuit compensation both being performed

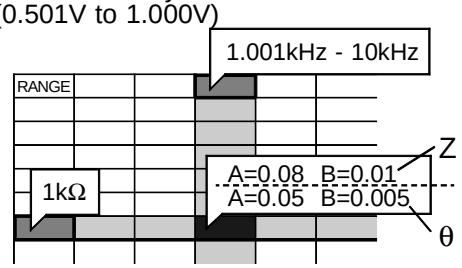
If the test condition is different from above, the coefficients corresponding to the following settings are calculated from each table and must be multiplied (C, D) or added (E) to the basic accuracy.

Example calculation

1. Impedance (Z=500 Ω) basic accuracy

Measurement conditions: test frequency = 10 kHz, signal level = 1 V, speed = SLOW2, range = 1 kΩ

Basic Accuracy Coefficient Table (0.501V to 1.000V)



From Basic Accuracy Coefficient Table (0.501V to 1.000V) on the following pages), basic Z accuracy coefficients A=0.08, B=0.01.

Inserting these in the calculation expression yields:

$$\text{Z accuracy} = \pm\left(0.08 + \frac{0.01 \times |10 \times 500 - 1 \times 10^3|}{1 \times 10^3}\right) = \pm 0.12\%$$

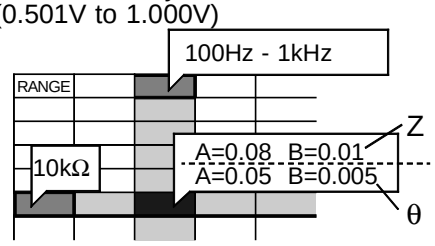
Similarly for θ basic accuracy coefficients A = 0.05, B=0.005, and thus:

$$\theta \text{ accuracy} = \pm\left(0.05 + \frac{0.005 \times |10 \times 500 - 1 \times 10^3|}{1 \times 10^3}\right) = \pm 0.07^\circ$$

2. Capacitance(Cs=160 nF) basic accuracy

Measurement conditions: test frequency = 1 kHz, signal level = 1 V, speed = SLOW2

Basic Accuracy Coefficient Table (0.501V to 1.000V)



Test Z and θ.
Measurement range: AUTO

When Z = 1.0144 kΩ, θ = -78.69° , test range is 10 kΩ

From Basic Accuracy Coefficient Table (0.501V to 1.000V) on the following pages), basic Z accuracy coefficients A=0.08, B=0.01.

Inserting these in the calculation expression yields:

$$\text{Z accuracy} = \pm\left(0.08 + \frac{0.01 \times |10 \times 1.0144 \times 10^3 - 10 \times 10^3|}{10 \times 10^3}\right) \fallingdotseq \pm 0.08\%$$

Similarly for θ basic accuracy coefficients A = 0.05, B=0.005, and thus:

$$\theta \text{ accuracy} = \pm\left(0.05 + \frac{0.005 \times |10 \times 1.0144 \times 10^3 - 10 \times 10^3|}{10 \times 10^3}\right) \fallingdotseq \pm 0.05^\circ$$

From the basic accuracy, find ranges that each of Z and θ can take.

Zmin = 1.0144 kΩ × (1 - 0.08/100) ≒ 1.0136kΩ
Zmax = 1.0144 kΩ × (1 + 0.08/100) ≒ 1.0152kΩ
θmin = 78.69 - 0.05 = 78.64 ° (θ: |θ| absolute value)
θmax = 78.69 + 0.05 = 78.74 °

From the ranges of Z and θ, determine ranges of Cs can take.

Csmin = 1/(Zmax x ω x sinθmax) ≒ 159.85 nF ..... -0.09%
Csmax = 1/(Zmin x ω x sinθmin) ≒ 160.15 nF ..... +0.09%
ω = 2 x π x f
f: frequency [Hz]

Hence the accuracy of Cs is ±0.009

2. Test speed coefficient (C)

Test speed	FAST	NORMAL	SLOW	SLOW2
C	5	2	1.5	1

3. Test cable length coefficient (D)

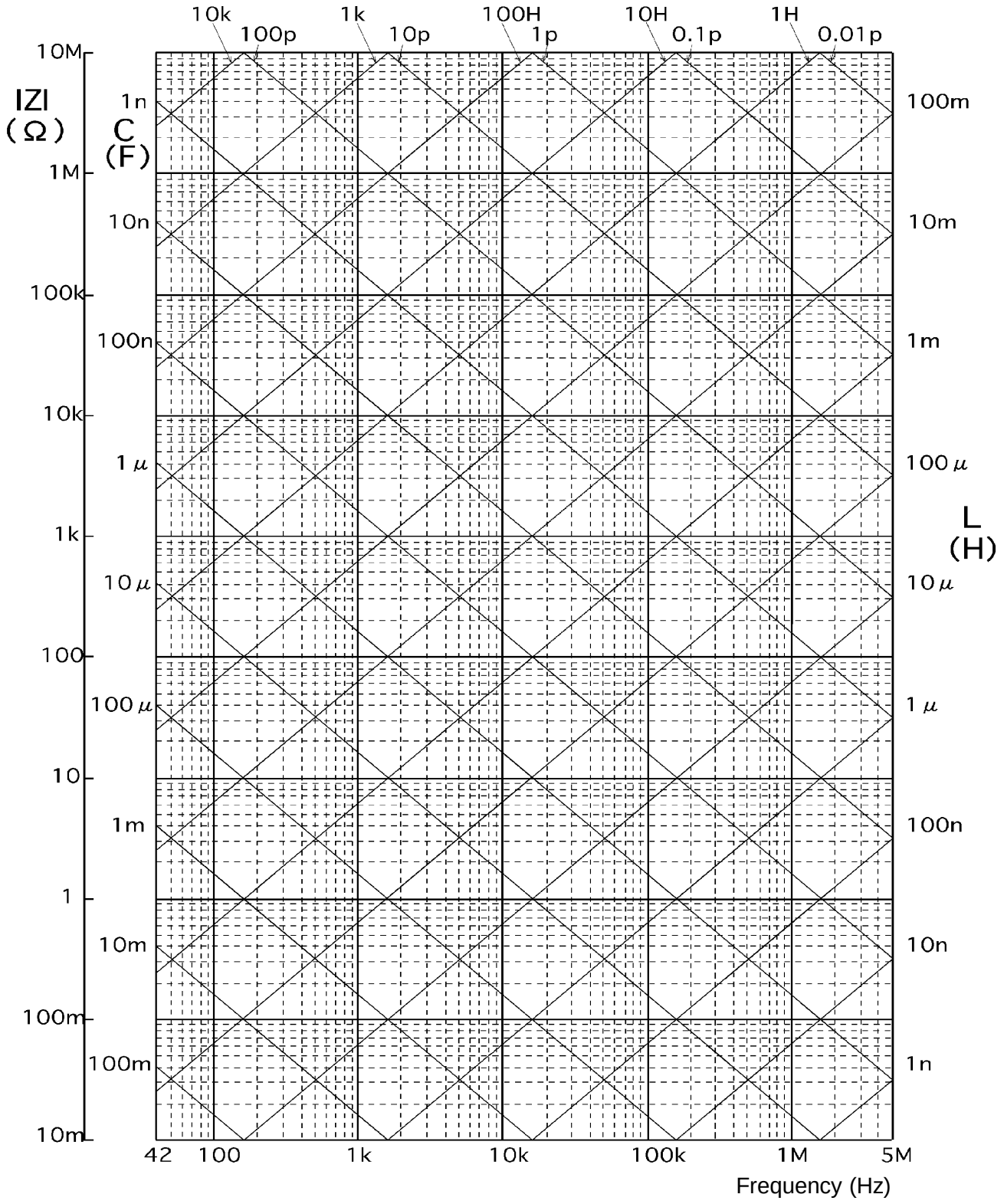
Cable length	0 m	1 m
D	1	(100 kHz max) 1.5 + 0.015×f [kHz]
		(100.1 kHz min) 1.5 + 0.3×f [MHz]

f: measurement frequency

4. Temperature coefficient (E)

Temperature	Operating temperature = T ℃
E	0.1× basic accuracy× (T-23)

Conversion Table from C and L to |*Z*|



Basic Accuracy Coefficient Table 1 (0.010 V to 0.049 V)

1 kΩ range or more

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |10 \times Zx[\Omega] - \text{Range}[\Omega]|}{\text{Range}[\Omega]}\right)$$

100 Ω range or less

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |\text{Range}[\Omega] - Zx[\Omega]| \times 10}{\text{Range}[\Omega]}\right)$$

Zx: sample of impedance
A, B: basic accuracy coefficient
Accuracy coefficient for Z (%): upper values in the following table
Accuracy coefficient for θ (°): lower values in the following table

When the frequency is 1.001 MHz or more, (f [MHz] +3)/4 must be multiplied to the basic accuracy.

*1: Guaranteed accuracy period

*1	Range	42Hz to 99.9Hz	100Hz to 1kHz	1.001kHz to 10kHz	10.01kHz to 100kHz	100.1kHz to 1MHz	1.001MHz to 5MHz
6 months	100MΩ						
	10MΩ						
	1MΩ	A= 1.5 B= 1 A= 2 B= 0.3	A= 1 B= 0.5 A= 0.5 B= 0.1	A= 1 B= 0.5 A= 0.5 B= 0.1			
	100kΩ	A= 0.8 B= 0.5 A= 0.5 B= 0.01	A= 0.5 B= 0.2 A= 0.2 B= 0.02	A= 0.5 B= 0.2 A= 0.2 B= 0.02	A= 1.5 B= 0.5 A= 0.6 B= 0.05		
	10kΩ	A= 0.6 B= 0.05 A= 0.5 B= 0.01	A= 0.25 B= 0.01 A= 0.15 B= 0.01	A= 0.25 B= 0.01 A= 0.15 B= 0.01	A= 1 B= 0.2 A= 0.5 B= 0.02		
	1kΩ	A= 0.6 B= 0.05 A= 0.5 B= 0.01	A= 0.25 B= 0.01 A= 0.15 B= 0.01	A= 0.25 B= 0.01 A= 0.15 B= 0.01	A= 0.5 B= 0.02 A= 0.5 B= 0.02	A= 2 B= 0.5 A= 2 B= 0.5	
	100Ω	A= 0.6 B= 0.05 A= 0.5 B= 0.02	A= 0.25 B= 0.02 A= 0.15 B= 0.02	A= 0.25 B= 0.02 A= 0.15 B= 0.02	A= 0.5 B= 0.02 A= 0.5 B= 0.02	A= 2 B= 0.5 A= 2 B= 0.5	
	10Ω	A= 1 B= 0.2 A= 0.5 B= 0.5	A= 0.4 B= 0.2 A= 0.3 B= 0.05	A= 0.4 B= 0.2 A= 0.3 B= 0.05	A= 1 B= 0.2 A= 0.6 B= 0.1	A= 3 B= 1 A= 3 B= 1	
	1Ω	A= 2.5 B= 1 A= 3 B= 2	A= 2 B= 1 A= 0.7 B= 0.5	A= 2 B= 1 A= 0.7 B= 0.5	A= 2 B= 1 A= 1 B= 1		
	100mΩ						

*1	Range	42Hz to 99.9Hz	100Hz to 1kHz	1.001kHz to 10kHz	10.01kHz to 100kHz	100.1kHz to 1MHz	1.001MHz to 5MHz
1 year	100MΩ						
	10MΩ						
	1MΩ	A= 2.25 B= 1.5 A= 3 B= 0.45	A= 1.5 B= 0.75 A= 0.75 B= 0.15	A= 1.5 B= 0.75 A= 0.75 B= 0.15			
	100kΩ	A= 1.2 B= 0.75 A= 0.75 B= 0.015	A= 0.75 B= 0.3 A= 0.3 B= 0.03	A= 0.75 B= 0.3 A= 0.3 B= 0.03	A= 2.25 B= 0.75 A= 0.9 B= 0.075		
	10kΩ	A= 0.9 B= 0.075 A= 0.75 B= 0.015	A= 0.375 B= 0.015 A= 0.225 B= 0.015	A= 0.375 B= 0.015 A= 0.225 B= 0.015	A= 1.5 B= 0.3 A= 0.75 B= 0.03		
	1kΩ	A= 0.9 B= 0.075 A= 0.75 B= 0.015	A= 0.375 B= 0.015 A= 0.225 B= 0.015	A= 0.375 B= 0.015 A= 0.225 B= 0.015	A= 0.75 B= 0.03 A= 0.75 B= 0.03	A= 3 B= 0.75 A= 3 B= 0.75	
	100Ω	A= 0.9 B= 0.075 A= 0.75 B= 0.03	A= 0.375 B= 0.03 A= 0.225 B= 0.03	A= 0.375 B= 0.03 A= 0.225 B= 0.03	A= 0.75 B= 0.03 A= 0.75 B= 0.03	A= 3 B= 0.75 A= 3 B= 0.75	
	10Ω	A= 1.5 B= 0.3 A= 0.75 B= 0.75	A= 0.6 B= 0.3 A= 0.45 B= 0.075	A= 0.6 B= 0.3 A= 0.45 B= 0.075	A= 1.5 B= 0.3 A= 0.9 B= 0.15	A= 4.5 B= 1.5 A= 4.5 B= 1.5	
	1Ω	A= 3.75 B= 1.5 A= 4.5 B= 3	A= 3 B= 1.5 A= 1.05 B= 0.75	A= 3 B= 1.5 A= 1.05 B= 0.75	A= 3 B= 1.5 A= 1.5 B= 1.5		
	100mΩ						

Basic Accuracy Table 2 (0.050 V to 0.100 V)

1 kΩ range or more

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |10 \times Zx[\Omega] - \text{Range}[\Omega]|}{\text{Range}[\Omega]}\right)$$

100 Ω range or less

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |\text{Range}[\Omega] - Zx[\Omega]| \times 10}{\text{Range}[\Omega]}\right)$$

Zx: sample of impedance
A, B: basic accuracy coefficient
Accuracy coefficient for Z (%): upper values in the following table
Accuracy coefficient for θ (°): lower values in the following table

When the frequency is 1.001 MHz or more, (f [MHz] +3)/4 must be multiplied to the basic accuracy.

*1: Guaranteed accuracy period

*1	Range	42Hz to 99.9Hz	100Hz to 1kHz	1.001kHz to 10kHz	10.01kHz to 100kHz	100.1kHz to 1MHz	1.001MHz to 5MHz
6 months	100MΩ						
	10MΩ						
	1MΩ	A= 1 B= 0.2 A= 1.5 B= 0.2	A= 0.5 B= 0.05 A= 0.25 B= 0.05	A= 0.5 B= 0.05 A= 0.25 B= 0.05	A= 1 B= 0.2 A= 1 B= 0.1		
	100kΩ	A= 0.5 B= 0.01 A= 0.35 B= 0.01	A= 0.2 B= 0.01 A= 0.15 B= 0.01	A= 0.25 B= 0.01 A= 0.15 B= 0.01	A= 0.5 B= 0.05 A= 0.3 B= 0.05	A= 3.5 B= 2 A= 1.5 B= 1	
	10kΩ	A= 0.5 B= 0.01 A= 0.35 B= 0.01	A= 0.2 B= 0.01 A= 0.1 B= 0.01	A= 0.2 B= 0.01 A= 0.1 B= 0.01	A= 0.3 B= 0.02 A= 0.2 B= 0.02	A= 0.8 B= 0.2 A= 1 B= 0.3	
	1kΩ	A= 0.5 B= 0.01 A= 0.35 B= 0.01	A= 0.2 B= 0.01 A= 0.1 B= 0.01	A= 0.2 B= 0.01 A= 0.1 B= 0.01	A= 0.3 B= 0.02 A= 0.2 B= 0.02	A= 0.6 B= 0.05 A= 0.4 B= 0.05	A= 2.5 B= 0.4 A= 2 B= 0.2
	100Ω	A= 0.5 B= 0.02 A= 0.35 B= 0.02	A= 0.2 B= 0.02 A= 0.1 B= 0.02	A= 0.2 B= 0.02 A= 0.1 B= 0.02	A= 0.3 B= 0.02 A= 0.2 B= 0.02	A= 0.6 B= 0.05 A= 0.4 B= 0.05	A= 2.5 B= 0.2 A= 2 B= 0.2
	10Ω	A= 0.6 B= 0.1 A= 0.4 B= 0.2	A= 0.35 B= 0.04 A= 0.2 B= 0.05	A= 0.35 B= 0.04 A= 0.2 B= 0.05	A= 0.35 B= 0.04 A= 0.3 B= 0.05	A= 1 B= 0.5 A= 1 B= 0.3	A= 4 B= 1.5 A= 3.5 B= 1
	1Ω	A= 1.5 B= 1 A= 2.2 B= 0.5	A= 0.7 B= 0.5 A= 0.5 B= 0.3	A= 0.7 B= 0.5 A= 0.5 B= 0.3	A= 1 B= 1 A= 0.8 B= 0.5		
	100mΩ						

*1	Range	42Hz to 99.9Hz	100Hz to 1kHz	1.001kHz to 10kHz	10.01kHz to 100kHz	100.1kHz to 1MHz	1.001MHz to 5MHz
1 year	100MΩ						
	10MΩ						
	1MΩ	A= 1.5 B= 0.3 A= 2.25 B= 0.3	A= 0.75 B= 0.075 A= 0.375 B= 0.075	A= 0.75 B= 0.075 A= 0.375 B= 0.075	A= 1.5 B= 0.3 A= 1.5 B= 0.15		
	100kΩ	A= 0.75 B= 0.015 A= 0.525 B= 0.015	A= 0.3 B= 0.015 A= 0.225 B= 0.015	A= 0.375 B= 0.015 A= 0.225 B= 0.015	A= 0.75 B= 0.075 A= 0.45 B= 0.075	A= 5.25 B= 3 A= 2.25 B= 1.5	
	10kΩ	A= 0.75 B= 0.015 A= 0.525 B= 0.015	A= 0.3 B= 0.015 A= 0.15 B= 0.015	A= 0.3 B= 0.015 A= 0.15 B= 0.015	A= 0.45 B= 0.03 A= 0.3 B= 0.03	A= 1.2 B= 0.3 A= 1.5 B= 0.45	
	1kΩ	A= 0.75 B= 0.015 A= 0.525 B= 0.015	A= 0.3 B= 0.015 A= 0.15 B= 0.015	A= 0.3 B= 0.015 A= 0.15 B= 0.015	A= 0.45 B= 0.03 A= 0.3 B= 0.03	A= 0.9 B= 0.075 A= 0.6 B= 0.075	A= 3.75 B= 0.6 A= 3 B= 0.3
	100Ω	A= 0.75 B= 0.03 A= 0.525 B= 0.03	A= 0.3 B= 0.03 A= 0.15 B= 0.03	A= 0.3 B= 0.03 A= 0.15 B= 0.03	A= 0.45 B= 0.03 A= 0.3 B= 0.03	A= 0.9 B= 0.075 A= 0.6 B= 0.075	A= 3.75 B= 0.3 A= 3 B= 0.3
	10Ω	A= 0.9 B= 0.15 A= 0.6 B= 0.3	A= 0.525 B= 0.06 A= 0.3 B= 0.075	A= 0.525 B= 0.06 A= 0.3 B= 0.075	A= 0.525 B= 0.06 A= 0.45 B= 0.075	A= 1.5 B= 0.75 A= 1.5 B= 0.45	A= 6 B= 2.25 A= 5.25 B= 1.5
	1Ω	A= 2.25 B= 1.5 A= 3.3 B= 0.75	A= 1.05 B= 0.75 A= 0.75 B= 0.45	A= 1.05 B= 0.75 A= 0.75 B= 0.45	A= 1.5 B= 1.5 A= 1.2 B= 0.75		
	100mΩ						

Basic Accuracy Table 3 (0.101 V to 0.500 V)

1 kΩ range or more

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |10 \times Zx[\Omega] - \text{Range}[\Omega]|}{\text{Range}[\Omega]}\right)$$

100 Ω range or less

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |\text{Range}[\Omega] - Zx[\Omega]| \times 10}{\text{Range}[\Omega]}\right)$$

Zx: sample of impedance
A, B: basic accuracy coefficient
Accuracy coefficient for Z (%): upper values in the following table
Accuracy coefficient for θ (°): lower values in the following table

When the frequency is 1.001 MHz or more, (f [MHz] +3)/4 must be multiplied to the basic accuracy.

*1: Guaranteed accuracy period

*1	Range	42Hz to 99.9Hz		100Hz to 1kHz		1.001kHz to 10kHz		10.01kHz to 100kHz		100.1kHz to 1MHz		1.001MHz to 5MHz	
6 months	100MΩ	A= 4.5	B= 4	A= 2.5	B= 2	A= 2.5	B= 2						
		A= 3.5	B= 2	A= 2	B= 1.5	A= 2	B= 1.5						
	10MΩ	A= 1	B= 1	A= 0.7	B= 0.5	A= 0.7	B= 0.5	A= 1.2	B= 1				
		A= 2	B= 0.2	A= 0.3	B= 0.2	A= 0.3	B= 0.2	A= 1.2	B= 0.5				
	1MΩ	A= 0.45	B= 0.05	A= 0.3	B= 0.05	A= 0.3	B= 0.05	A= 0.5	B= 0.08				
		A= 0.35	B= 0.2	A= 0.2	B= 0.02	A= 0.2	B= 0.02	A= 0.5	B= 0.08				
	100kΩ	A= 0.4	B= 0.01	A= 0.15	B= 0.01	A= 0.2	B= 0.01	A= 0.3	B= 0.04	A= 2	B= 1.5		
		A= 0.3	B= 0.01	A= 0.08	B= 0.01	A= 0.1	B= 0.01	A= 0.25	B= 0.03	A= 1	B= 0.5		
	10kΩ	A= 0.4	B= 0.01	A= 0.15	B= 0.01	A= 0.15	B= 0.01	A= 0.25	B= 0.02	A= 0.5	B= 0.05	A= 2	B= 1
		A= 0.3	B= 0.01	A= 0.08	B= 0.01	A= 0.08	B= 0.01	A= 0.1	B= 0.02	A= 0.7	B= 0.3	A= 1.5	B= 0.5
	1kΩ	A= 0.4	B= 0.01	A= 0.15	B= 0.01	A= 0.15	B= 0.01	A= 0.25	B= 0.02	A= 0.5	B= 0.03	A= 2	B= 0.2
		A= 0.3	B= 0.01	A= 0.08	B= 0.01	A= 0.08	B= 0.01	A= 0.1	B= 0.02	A= 0.2	B= 0.05	A= 1.5	B= 0.2
	100Ω	A= 0.4	B= 0.02	A= 0.15	B= 0.02	A= 0.15	B= 0.02	A= 0.25	B= 0.02	A= 0.5	B= 0.03	A= 2	B= 0.2
		A= 0.3	B= 0.01	A= 0.08	B= 0.01	A= 0.08	B= 0.01	A= 0.1	B= 0.02	A= 0.2	B= 0.05	A= 1.5	B= 0.2
	10Ω	A= 0.5	B= 0.1	A= 0.3	B= 0.04	A= 0.3	B= 0.04	A= 0.3	B= 0.04	A= 0.6	B= 0.1	A= 2.5	B= 1.5
		A= 0.35	B= 0.2	A= 0.15	B= 0.03	A= 0.15	B= 0.03	A= 0.2	B= 0.03	A= 0.6	B= 0.1	A= 3	B= 1
	1Ω	A= 1.4	B= 1	A= 0.5	B= 0.3	A= 0.5	B= 0.3	A= 0.5	B= 0.3				
		A= 2	B= 0.5	A= 0.4	B= 0.2	A= 0.4	B= 0.2	A= 0.4	B= 0.2				
	100mΩ												

*1	Range	42Hz to 99.9Hz		100Hz to 1kHz		1.001kHz to 10kHz		10.01kHz to 100kHz		100.1kHz to 1MHz		1.001MHz to 5MHz	
1 year	100MΩ	A= 6.75	B= 6	A= 3.75	B= 3	A= 3.75	B= 3						
		A= 5.25	B= 3	A= 3	B= 2.25	A= 3	B= 2.25						
	10MΩ	A= 1.5	B= 1.5	A= 1.05	B= 0.75	A= 1.05	B= 0.75	A= 1.8	B= 1.5				
		A= 3	B= 0.3	A= 0.45	B= 0.3	A= 0.45	B= 0.3	A= 1.8	B= 0.75				
	1MΩ	A= 0.675	B= 0.075	A= 0.45	B= 0.075	A= 0.45	B= 0.075	A= 0.75	B= 0.12				
		A= 0.525	B= 0.3	A= 0.3	B= 0.03	A= 0.3	B= 0.03	A= 0.75	B= 0.12				
	100kΩ	A= 0.6	B= 0.015	A= 0.225	B= 0.015	A= 0.3	B= 0.015	A= 0.45	B= 0.06	A= 3	B= 2.25		
		A= 0.45	B= 0.015	A= 0.12	B= 0.015	A= 0.15	B= 0.015	A= 0.375	B= 0.045	A= 1.5	B= 0.75		
	10kΩ	A= 0.6	B= 0.015	A= 0.225	B= 0.015	A= 0.225	B= 0.015	A= 0.375	B= 0.03	A= 0.75	B= 0.075	A= 3	B= 1.5
		A= 0.45	B= 0.015	A= 0.12	B= 0.015	A= 0.12	B= 0.015	A= 0.15	B= 0.03	A= 1.05	B= 0.45	A= 2.25	B= 0.75
	1kΩ	A= 0.6	B= 0.015	A= 0.225	B= 0.015	A= 0.225	B= 0.015	A= 0.375	B= 0.03	A= 0.75	B= 0.045	A= 3	B= 0.3
		A= 0.45	B= 0.015	A= 0.12	B= 0.015	A= 0.12	B= 0.015	A= 0.15	B= 0.03	A= 0.3	B= 0.075	A= 2.25	B= 0.3
	100Ω	A= 0.6	B= 0.03	A= 0.225	B= 0.03	A= 0.225	B= 0.03	A= 0.375	B= 0.03	A= 0.75	B= 0.045	A= 3	B= 0.3
		A= 0.45	B= 0.015	A= 0.12	B= 0.015	A= 0.12	B= 0.015	A= 0.15	B= 0.03	A= 0.3	B= 0.075	A= 2.25	B= 0.3
	10Ω	A= 0.75	B= 0.15	A= 0.45	B= 0.06	A= 0.45	B= 0.06	A= 0.45	B= 0.06	A= 0.9	B= 0.15	A= 3.75	B= 2.25
		A= 0.525	B= 0.3	A= 0.225	B= 0.045	A= 0.225	B= 0.045	A= 0.3	B= 0.045	A= 0.9	B= 0.15	A= 4.5	B= 1.5
	1Ω	A= 2.1	B= 1.5	A= 0.75	B= 0.45	A= 0.75	B= 0.45	A= 0.75	B= 0.45				
		A= 3	B= 0.75	A= 0.6	B= 0.3	A= 0.6	B= 0.3	A= 0.6	B= 0.3				
	100mΩ												

Basic Accuracy Table 4 (0.501 V to 1.000 V)

1 kΩ range or more

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |10 \times Zx[\Omega] - \text{Range}[\Omega]|}{\text{Range}[\Omega]}\right)$$

100 Ω range or less

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |\text{Range}[\Omega] - Zx[\Omega]| \times 10}{\text{Range}[\Omega]}\right)$$

Zx: sample of impedance
A, B: basic accuracy coefficient
Accuracy coefficient for Z (%): upper values in the following table
Accuracy coefficient for θ (°): lower values in the following table

When the frequency is 1.001 MHz or more, (f [MHz] +3)/4 must be multiplied to the basic accuracy.

*1: Guaranteed accuracy period

*1	Range	42Hz to 99.9Hz		100Hz to 1kHz		1.001kHz to 10kHz		10.01kHz to 100kHz		100.1kHz to 1MHz		1.001MHz to 5MHz	
6 months	100MΩ	A= 4	B= 4	A= 2	B= 2	A= 2	B= 2						
		A= 2.5	B= 2	A= 1	B= 1.5	A= 1	B= 1.5						
	10MΩ	A= 0.8	B= 0.4	A= 0.4	B= 0.2	A= 0.4	B= 0.2	A= 1	B= 0.5				
		A= 1	B= 0.2	A= 0.25	B= 0.1	A= 0.25	B= 0.1	A= 1	B= 0.5				
	1MΩ	A= 0.4	B= 0.05	A= 0.15	B= 0.05	A= 0.15	B= 0.05	A= 0.3	B= 0.08	A= 3	B= 1		
		A= 0.3	B= 0.1	A= 0.15	B= 0.02	A= 0.15	B= 0.02	A= 0.3	B= 0.08	A= 3	B= 0.5		
	100kΩ	A= 0.35	B= 0.01	A= 0.08	B= 0.01	A= 0.15	B= 0.01	A= 0.25	B= 0.04	A= 0.4	B= 0.3	A= 2	B= 0.5
		A= 0.25	B= 0.01	A= 0.05	B= 0.01	A= 0.08	B= 0.01	A= 0.15	B= 0.02	A= 0.3	B= 0.3	A= 2	B= 0.3
	10kΩ	A= 0.35	B= 0.01	A= 0.08	B= 0.01	A= 0.08	B= 0.01	A= 0.2	B= 0.02	A= 0.3	B= 0.03	A= 1.5	B= 0.2
		A= 0.25	B= 0.005	A= 0.05	B= 0.005	A= 0.05	B= 0.005	A= 0.08	B= 0.02	A= 0.15	B= 0.02	A= 1	B= 0.2
	1kΩ	A= 0.35	B= 0.01	A= 0.08	B= 0.01	A= 0.08	B= 0.01	A= 0.2	B= 0.02	A= 0.3	B= 0.03	A= 1.5	B= 0.2
		A= 0.25	B= 0.005	A= 0.05	B= 0.005	A= 0.05	B= 0.005	A= 0.08	B= 0.02	A= 0.15	B= 0.02	A= 1	B= 0.2
	100Ω	A= 0.35	B= 0.02	A= 0.08	B= 0.02	A= 0.08	B= 0.02	A= 0.2	B= 0.02	A= 0.3	B= 0.03	A= 1.5	B= 0.2
		A= 0.25	B= 0.01	A= 0.05	B= 0.01	A= 0.05	B= 0.01	A= 0.08	B= 0.02	A= 0.15	B= 0.02	A= 1	B= 0.2
	10Ω	A= 0.4	B= 0.04	A= 0.2	B= 0.03	A= 0.2	B= 0.03	A= 0.2	B= 0.03	A= 0.4	B= 0.1	A= 2	B= 1
		A= 0.3	B= 0.1	A= 0.1	B= 0.02	A= 0.1	B= 0.02	A= 0.15	B= 0.02	A= 0.3	B= 0.05	A= 2	B= 0.5
	1Ω	A= 0.7	B= 0.4	A= 0.4	B= 0.3	A= 0.4	B= 0.3	A= 0.4	B= 0.3	A= 1	B= 1		
		A= 1	B= 0.2	A= 0.25	B= 0.2	A= 0.25	B= 0.2	A= 0.25	B= 0.2	A= 0.7	B= 0.5		
	100mΩ	A= 4	B= 4	A= 3	B= 2	A= 3	B= 2	A= 3	B= 2				
		A= 2.5	B= 2	A= 2	B= 1	A= 2	B= 1	A= 2	B= 1				
*1	Range	42Hz to 99.9Hz		100Hz to 1kHz		1.001kHz to 10kHz		10.01kHz to 100kHz		100.1kHz to 1MHz		1.001MHz to 5MHz	
1 year	100MΩ	A= 6	B= 6	A= 3	B= 3	A= 3	B= 3						
		A= 3.75	B= 3	A= 1.5	B= 2.25	A= 1.5	B= 2.25						
	10MΩ	A= 1.2	B= 0.6	A= 0.6	B= 0.3	A= 0.6	B= 0.3	A= 1.5	B= 0.75				
		A= 1.5	B= 0.3	A= 0.375	B= 0.15	A= 0.375	B= 0.15	A= 1.5	B= 0.75				
	1MΩ	A= 0.6	B= 0.075	A= 0.225	B= 0.075	A= 0.225	B= 0.075	A= 0.45	B= 0.12	A= 4.5	B= 1.5		
		A= 0.45	B= 0.15	A= 0.225	B= 0.03	A= 0.225	B= 0.03	A= 0.45	B= 0.12	A= 4.5	B= 0.75		
	100kΩ	A= 0.525	B= 0.015	A= 0.12	B= 0.015	A= 0.225	B= 0.015	A= 0.375	B= 0.06	A= 0.6	B= 0.45	A= 3	B= 0.75
		A= 0.375	B= 0.015	A= 0.075	B= 0.015	A= 0.12	B= 0.015	A= 0.225	B= 0.03	A= 0.45	B= 0.45	A= 3	B= 0.45
	10kΩ	A= 0.525	B= 0.015	A= 0.12	B= 0.015	A= 0.12	B= 0.015	A= 0.3	B= 0.03	A= 0.45	B= 0.045	A= 2.25	B= 0.3
		A= 0.375	B= 0.0075	A= 0.075	B= 0.0075	A= 0.075	B= 0.0075	A= 0.12	B= 0.03	A= 0.225	B= 0.03	A= 1.5	B= 0.3
	1kΩ	A= 0.525	B= 0.015	A= 0.12	B= 0.015	A= 0.12	B= 0.015	A= 0.3	B= 0.03	A= 0.45	B= 0.045	A= 2.25	B= 0.3
		A= 0.375	B= 0.0075	A= 0.075	B= 0.0075	A= 0.075	B= 0.0075	A= 0.12	B= 0.03	A= 0.225	B= 0.03	A= 1.5	B= 0.3
	100Ω	A= 0.525	B= 0.03	A= 0.12	B= 0.03	A= 0.12	B= 0.03	A= 0.3	B= 0.03	A= 0.45	B= 0.045	A= 2.25	B= 0.3
		A= 0.375	B= 0.015	A= 0.075	B= 0.015	A= 0.075	B= 0.015	A= 0.12	B= 0.03	A= 0.225	B= 0.03	A= 1.5	B= 0.3
	10Ω	A= 0.6	B= 0.06	A= 0.3	B= 0.045	A= 0.3	B= 0.045	A= 0.3	B= 0.045	A= 0.6	B= 0.15	A= 3	B= 1.5
		A= 0.45	B= 0.15	A= 0.15	B= 0.03	A= 0.15	B= 0.03	A= 0.225	B= 0.03	A= 0.45	B= 0.075	A= 3	B= 0.75
	1Ω	A= 1.05	B= 0.6	A= 0.6	B= 0.45	A= 0.6	B= 0.45	A= 0.6	B= 0.45	A= 1.5	B= 1.5		
		A= 1.5	B= 0.3	A= 0.375	B= 0.3	A= 0.375	B= 0.3	A= 0.375	B= 0.3	A= 1.05	B= 0.75		
	100mΩ	A= 6	B= 6	A= 4.5	B= 3	A= 4.5	B= 3	A= 4.5	B= 3				
		A= 3.75	B= 3	A= 3	B= 1.5	A= 3	B= 1.5	A= 3	B= 1.5				

Basic Accuracy Table 5 (1.001 V to 5.000 V)

1 kΩ range or more

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |10 \times Zx[\Omega] - \text{Range}[\Omega]|}{\text{Range}[\Omega]}\right)$$

100 Ω range or less

$$\text{Basic accuracy} = \pm\left(A + \frac{B \times |\text{Range}[\Omega] - Zx[\Omega]| \times 10}{\text{Range}[\Omega]}\right)$$

Zx: sample of impedance
A, B: basic accuracy coefficient
Accuracy coefficient for Z (%): upper values in the following table
Accuracy coefficient for θ (°): lower values in the following table

When the frequency is 1.001 MHz or more, (f [MHz] +3)/4 must be multiplied to the basic accuracy.

*1: Guaranteed accuracy period

*1	Range	42Hz to 99.9Hz	100Hz to 1kHz	1.001kHz to 10kHz	10.01kHz to 100kHz	100.1kHz to 1MHz	1.001MHz to 5MHz
6 months	100MΩ	A= 4.5 B= 4 A= 4 B= 2	A= 2.5 B= 2 A= 2 B= 1.5	A= 2.5 B= 2 A= 2 B= 1.5			
	10MΩ	A= 1 B= 0.4 A= 2 B= 0.3	A= 0.5 B= 0.2 A= 0.3 B= 0.1	A= 0.5 B= 0.2 A= 0.3 B= 0.1	A= 1.2 B= 0.5 A= 1.2 B= 0.5		
	1MΩ	A= 0.5 B= 0.1 A= 0.4 B= 0.2	A= 0.2 B= 0.05 A= 0.2 B= 0.02	A= 0.2 B= 0.05 A= 0.2 B= 0.02	A= 0.5 B= 0.08 A= 0.5 B= 0.08	A= 3.2 B= 1 A= 3.2 B= 0.5	
	100kΩ	A= 0.4 B= 0.01 A= 0.3 B= 0.02	A= 0.15 B= 0.01 A= 0.08 B= 0.01	A= 0.2 B= 0.01 A= 0.1 B= 0.01	A= 0.3 B= 0.04 A= 0.2 B= 0.03	A= 1 B= 0.3 A= 0.5 B= 0.3	
	10kΩ	A= 0.4 B= 0.01 A= 0.3 B= 0.01	A= 0.15 B= 0.01 A= 0.08 B= 0.01	A= 0.15 B= 0.01 A= 0.08 B= 0.01	A= 0.25 B= 0.02 A= 0.1 B= 0.02	A= 0.7 B= 0.05 A= 0.2 B= 0.02	
	1kΩ	A= 0.4 B= 0.01 A= 0.3 B= 0.01	A= 0.15 B= 0.01 A= 0.08 B= 0.01	A= 0.15 B= 0.01 A= 0.08 B= 0.01	A= 0.25 B= 0.02 A= 0.1 B= 0.02	A= 0.5 B= 0.05 A= 0.2 B= 0.02	
	100Ω	A= 0.4 B= 0.02 A= 0.3 B= 0.01	A= 0.15 B= 0.02 A= 0.08 B= 0.01	A= 0.15 B= 0.02 A= 0.08 B= 0.01	A= 0.25 B= 0.02 A= 0.1 B= 0.02	A= 0.5 B= 0.05 A= 0.2 B= 0.02	
	10Ω	A= 0.5 B= 0.04 A= 0.35 B= 0.2	A= 0.25 B= 0.04 A= 0.15 B= 0.02	A= 0.25 B= 0.04 A= 0.15 B= 0.02	A= 0.25 B= 0.04 A= 0.2 B= 0.02	A= 0.7 B= 0.1 A= 0.4 B= 0.05	
	1Ω	A= 0.8 B= 0.5 A= 2 B= 0.2	A= 0.5 B= 0.4 A= 0.3 B= 0.2	A= 0.5 B= 0.4 A= 0.3 B= 0.2	A= 0.5 B= 0.4 A= 0.3 B= 0.2	A= 1.4 B= 1 A= 0.8 B= 1	
	100mΩ	A= 5 B= 4 A= 3.5 B= 2	A= 4 B= 2 A= 2.5 B= 1	A= 4 B= 2 A= 2.5 B= 1	A= 4 B= 2 A= 2.5 B= 1		
*1	Range	42Hz to 99.9Hz	100Hz to 1kHz	1.001kHz to 10kHz	10.01kHz to 100kHz	100.1kHz to 1MHz	1.001MHz to 5MHz
1 year	100MΩ	A= 6.75 B= 6 A= 6 B= 3	A= 3.75 B= 3 A= 3 B= 2.25	A= 3.75 B= 3 A= 3 B= 2.25			
	10MΩ	A= 1.5 B= 0.6 A= 3 B= 0.45	A= 0.75 B= 0.3 A= 0.45 B= 0.15	A= 0.75 B= 0.3 A= 0.45 B= 0.15	A= 1.8 B= 0.75 A= 1.8 B= 0.75		
	1MΩ	A= 0.75 B= 0.15 A= 0.6 B= 0.3	A= 0.3 B= 0.075 A= 0.3 B= 0.03	A= 0.3 B= 0.075 A= 0.3 B= 0.03	A= 0.75 B= 0.12 A= 0.75 B= 0.12	A= 4.8 B= 1.5 A= 4.8 B= 0.75	
	100kΩ	A= 0.6 B= 0.015 A= 0.45 B= 0.03	A= 0.225 B= 0.015 A= 0.12 B= 0.015	A= 0.3 B= 0.015 A= 0.15 B= 0.015	A= 0.45 B= 0.06 A= 0.3 B= 0.045	A= 1.5 B= 0.45 A= 0.75 B= 0.45	
	10kΩ	A= 0.6 B= 0.015 A= 0.45 B= 0.015	A= 0.225 B= 0.015 A= 0.12 B= 0.015	A= 0.225 B= 0.015 A= 0.12 B= 0.015	A= 0.375 B= 0.03 A= 0.15 B= 0.03	A= 1.05 B= 0.075 A= 0.3 B= 0.03	
	1kΩ	A= 0.6 B= 0.015 A= 0.45 B= 0.015	A= 0.225 B= 0.015 A= 0.12 B= 0.015	A= 0.225 B= 0.015 A= 0.12 B= 0.015	A= 0.375 B= 0.03 A= 0.15 B= 0.03	A= 0.75 B= 0.075 A= 0.3 B= 0.03	
	100Ω	A= 0.6 B= 0.03 A= 0.45 B= 0.015	A= 0.225 B= 0.03 A= 0.12 B= 0.015	A= 0.225 B= 0.03 A= 0.12 B= 0.015	A= 0.375 B= 0.03 A= 0.15 B= 0.03	A= 0.75 B= 0.075 A= 0.3 B= 0.03	
	10Ω	A= 0.75 B= 0.06 A= 0.525 B= 0.3	A= 0.375 B= 0.06 A= 0.225 B= 0.03	A= 0.375 B= 0.06 A= 0.225 B= 0.03	A= 0.375 B= 0.06 A= 0.3 B= 0.03	A= 1.05 B= 0.15 A= 0.6 B= 0.075	
	1Ω	A= 1.2 B= 0.75 A= 3 B= 0.3	A= 0.75 B= 0.6 A= 0.45 B= 0.3	A= 0.75 B= 0.6 A= 0.45 B= 0.3	A= 0.75 B= 0.6 A= 0.45 B= 0.3	A= 2.1 B= 1.5 A= 1.2 B= 1.5	
	100mΩ	A= 7.5 B= 6 A= 5.25 B= 3	A= 6 B= 3 A= 3.75 B= 1.5	A= 6 B= 3 A= 3.75 B= 1.5	A= 6 B= 3 A= 3.75 B= 1.5		

Index

- A -

Absolute value setting (ABS) 84,88
Admittance 33,164
Averaging 77
Averaging setting screen 78

- B -

Beep sound 109
Beep sound setting screen 110

- C -

Cable length 82
Comparator screen 86
Condition setting screen 81
Conductance 33,164
Constant current (CC) 39,44
Constant voltage (CV) 39,43
Continuous test 116,138
Contrast adjustment knob 3
Current limit 45

- D -

DC Bias 140
Delay time 74
Deviation percentage (Δ%) 84,95
Display parameters 32

- E-

EXT I/O connector 4,132
Equations (for calculation) 164
External trigger 72

- F -

Factory settings 114
Frequency setting screen 35

- G -

GP-IB interface 169
Guard terminal 3,127
Guarding 127

- H -

Handle 6

- I -

Impedance 33,164
Impedance phase angle 33,164
Inductance 33
Interference 129-131
Internal trigger 72

- K -

Key lock 4,124
Key lock switch 4

- L -

LCD screen 11
Limit setting screen 46
Loss coefficient 33

- M -

Measurement ranges 48
Menu keys 12
Menu screen 12,31
Monitor display 12,30

- N -

Noise 129-131

- O -

Open circuit compensation 52,69
Open circuit compensation screen 53
Open circuit residual components 69
Open circuit voltage (V) 39,42

- P -

Panel load function 106
Panel load screen 107
Panel numbers 102,106,116
Panel save function 102
Panel save screen 103
Parallel equivalent circuit mode 34
Parameter keys 16,30
Parameter setting screen 32
Percentage setting 84,92
Power supply fuse 153,154
Power switch 3,10

- Q -

Q factor 33

- R -

RS-232C interface 169
Range setting screen 49
Reactance 33,164
Residual charge protection 143
Residual conductance 69
Residual inductance 69
Residual resistance 69

- S-

Saved test conditions 102
Series equivalent circuit mode 34
Short circuit compensation 60
Short circuit compensation screen 62
Short circuit residual component 69
Shorting bar 61
Specification 159
Stand 5
Static capacitance 33,159
Susceptance 33,164
System reset 113

- T -

Test cables 8,82,131
Test fixture 69
Test frequency 35
Test level setting screen 40
Test parameters 32
Test ranges 48,161
Test signal levels 39
Test speed 80
Test speed setting screen 81
Test terminals 3,8
Trigger delay function 74
Trigger delay setting screen 75
Trigger setting screen 72

- V -

Voltage limit 45
Voltage selector (power inlet) 4,154

HIOKI

DECLARATION OF CONFORMITY

Manufacturer's Name:	HIOKI E.E. CORPORATION
Manufacturer's Address:	81 Koizumi, Ueda, Nagano 386-1192, Japan
Product Name:	LCR HiTESTER
Model Number:	3532-50
Options:	9518-01 GP-IB INTERFACE 9593-01 RS-232C INTERFACE 9261 TEST FIXTURE 9262 TEST FIXTURE 9263 SMD TEST FIXTURE 9268 DC BIAS VOLTAGE UNIT 9269 DC BIAS CURRENT UNIT 9140 4-TERMINAL PROBE 9143 PINCHER PROBE 9165 CONNECTION CORD 9166 CONNECTION CORD 9151-02 GP-IB CONNECTOR CABLE 9151-04 GP-IB CONNECTOR CABLE

The above mentioned products conform to the following product specifications:

Safety:	EN61010-1:2001
EMC:	EN61326:1997+A1:1998+A2:2001+A3:2003 ClassB equipment Minimum immunity test requirement EN61000-3-2:2000 EN61000-3-3:1995+A1:2001

Supplementary Information:

The products herewith comply with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC.

HIOKI E.E. CORPORATION

15 September 2006

T. Yoshiike

Tatsuyoshi Yoshiike
President

3532C999-03

HIOKI 3532-50 LCR HiTESTER

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• All reasonable care has been taken in the production of this manual, but if you find any points which are unclear or in error, please contact your supplier or the International Sales and Marketing Department at HIOKI headquarters.
• In the interests of product development, the contents of this manual are subject to revision without prior notice.
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Instruction Manual

3532-50
3522-50
LCR HiTESTER

9593-01

RS-232C INTERFACE

HIOKI E. E. CORPORATION

December 2012 Revised edition 7 9593A983-07 12-12H

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Contents

Introduction ..... **i**

Chapter 1 Before Use **1**

1.1 Check of External Appearance and Accessories 1
1.2 Shipping Precautions 2
1.3 Points for Attention During Use 3
1.4 Installing the RS-232C Interface 4

Chapter 2 Overview **5**

2.1 Introduction to the 9593-01 RS-232C INTERFACE 5
2.2 Specifications 6

Chapter 3 Names of Parts **9**

3.1 Controls and Connections 9

Chapter 4 Operation **11**

4.1 Setting the RS-232C Communication Conditions 11
4.2 Communication Methods by the RS-232C 12
4.3 Message Format 13
4.3.1 Program Message 13
4.3.2 Response Messages 13
4.4 Headers 14
4.5 Data Formats 15
4.6 Delimiters 16
4.7 Separators 16
4.8 Abbreviation of Compound Commands 17
4.9 Output Queue 18
4.10 Input Buffer 18
4.11 Event Registers 19

Chapter 5 Command Reference **21**

5.1 Command Summary 21
5.2 Format of Command Explanations 25
5.3 Particular Commands 26
5.5 Response Format for Queries as Numerical Value 82
5.6 Initialization Items 84

Chapter 6 Sample Programs 85
Chapter 7 Troubleshooting 93
Index ..... INDEX 1

Introduction

Thank you for purchasing the HIOKI 9593-01 RS-232C INTERFACE for the 3532-50 and 3522-50 LCR HiTESTERs.
To obtain maximum performance from the product, please read this manual first, and keep it handy for future reference.

This manual contains information and warnings essential for safe operation of the product and for maintaining it in safe operating condition. Before using the product, be sure to carefully read the following safety notes.

The following symbols in this manual indicate the relative importance of cautions and warnings.

⚠ WARNING	Indicates that incorrect operation presents a significant hazard that could result in serious injury or death to the user.
⚠ CAUTION	Indicates that incorrect operation presents a possibility of injury to the user or damage to the product.
NOTE	Advisory items related to performance or correct operation of the product.

Chapter 1
Before Use

1.1 Check of External Appearance and Accessories

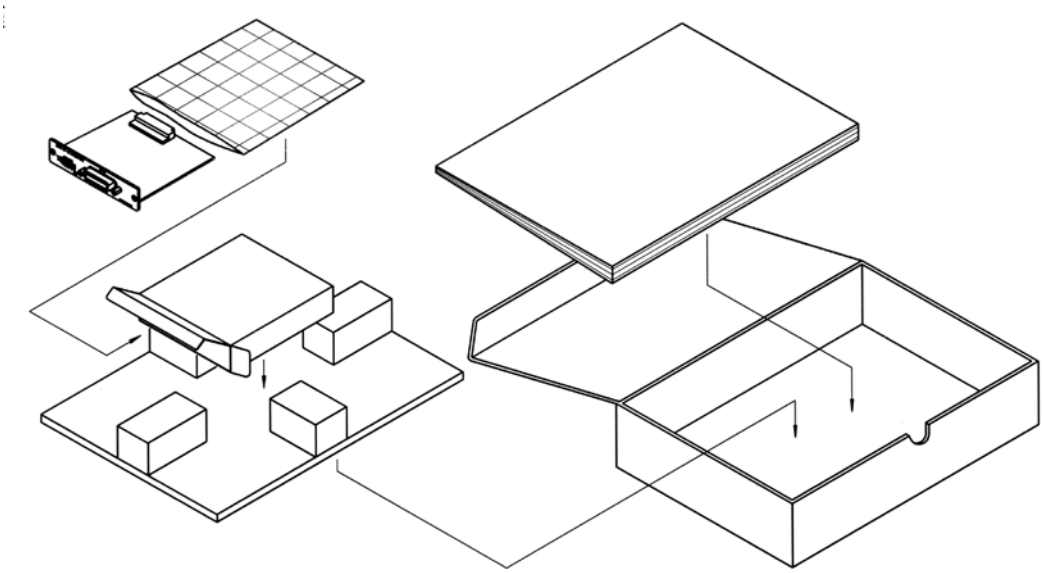
When you receive the product, inspect it carefully to ensure that no damage occurred during shipping.
In particular, check the accessories, panel switches, and connectors. If damage is evident, or if it fails to operate according to the specifications, contact your dealer or Hioki representative.

(1) 9593-01 RS-232C INTERFACE

(2) This instruction manual

1.2 Shipping Precautions

If reshipping the unit, preferably use the original packing.



If this is not available, use the following procedure.

1. Wrap the unit in plastic sheeting.

2. After wrapping cushioning material around the unit, pack it into a cardboard box, and then seal up the box with adhesive tape.

1.3 Points for Attention During Use

(1) If you change the communication condition of the 3532-50/3522-50 while using it, you should immediately turn the power off and on again. If you do not do so, the communication conditions will not be changed to the new one.

(2) Always be sure to secu
re the RS-232C cable to the 9593-01 unit by tightening up the fixing screws provided.

(3) Program messages sent just after the power has been turned on are executed after the self test has terminated.

(4) It is vital that the proper data format is used when inputting commands with data values to the 3532-50/3522-50 units.

(5) For details of the various functions, refer to the instruction manuals for the 3532-50/3522-50 units.

1.4 Installing the RS-232C Interface

⚠ WARNING

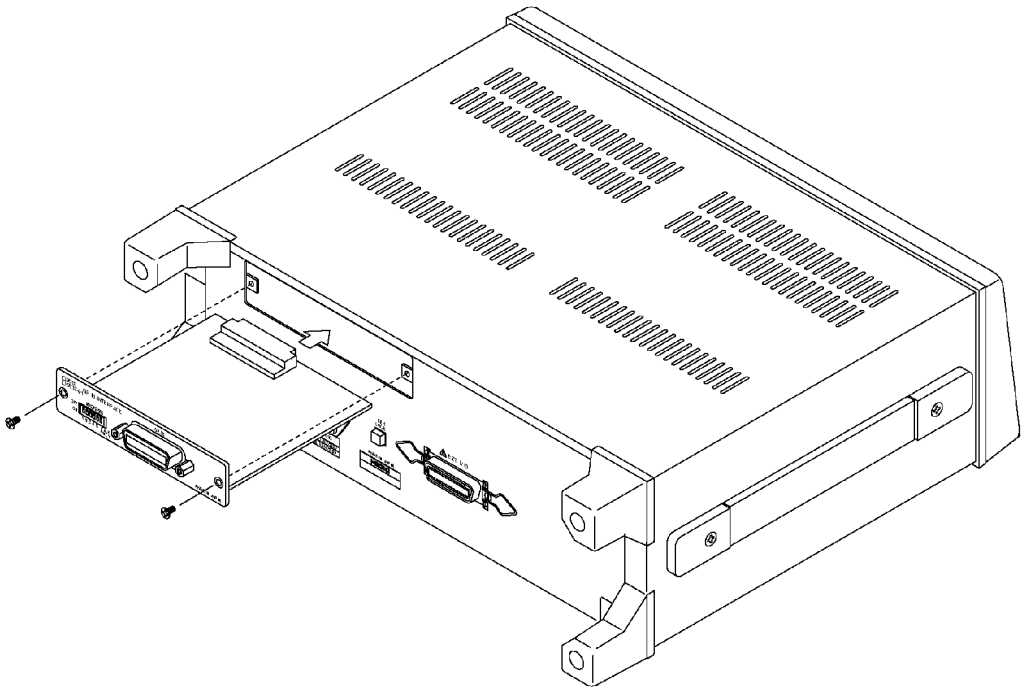
- To avoid electric shock accident, before removing or replacing an input module, confirm that the instrument is turned off and that the power cord and connection cables are disconnected.
- The mounting screws must be firmly tightened or the input unit may not perform to specifications, or may even fail.
- To avoid the danger of electric shock, never operate the product with an input module removed. To use the product after removing an input module, install a blank panel over the opening of the removed module.

⚠ CAUTION

When inserting in the interface, hold the metal plate. Directly touching the board may cause static electricity and lead to damage of the instrument. (Using the wrist strap for preventing static electricity when inserting is recommended.)

The space for fitting the 9593-01 RS-232C INTERFACE in the rear panel of the 3532-50/3522-50 are covered with a blanking plate. Follow these three steps to install the 9593-01 interface:

1. Remove the fixing screws, and take off the blanking plate.
2. Insert the 9593-01 RS-232C INTERFACE into the exposed slot in the rear of the unit in the figure below.
3. Push the 9593-01 firmly into place, and fix with the screws removed in step 1.



Chapter 2
Overview

2.1 Introduction to the 9593-01 RS-232C INTERFACE

By connecting the 9593-01 RS-232C INTERFACE to the 3532-50 or the 3522-50 LCR HiTESTER, it is possible to control the main unit via the RS-232C bus.

2.2 Specifications

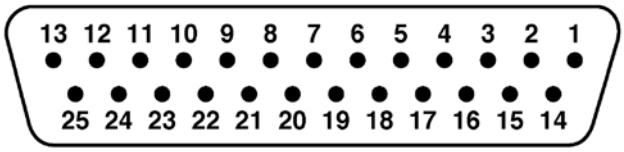
Transfer system	Start-stop synchronization
Baud rate	2400, 4800, 9600, 19200 bps
Data length	7 or 8 bits
Parity	Even, odd, or none
Stop bits	1 or 2 bits
Delimiter	CR+LF, CR
Handshake	hardware

Selected by DIP switch.

Electrical characteristic

Input voltage levels	+5 V to +15 V -15 V to -5 V	ON OFF
Output voltage levels (load impedance 3 kΩ to 7 kΩ)	+5 V to +9 V -9 V to -5 V	ON OFF

Connector



RS-232C Interface Connector Pin Assignments
(D-subminiature 25-pin female)

NOTE The connector on the 9593-01 is for terminal (DTE).

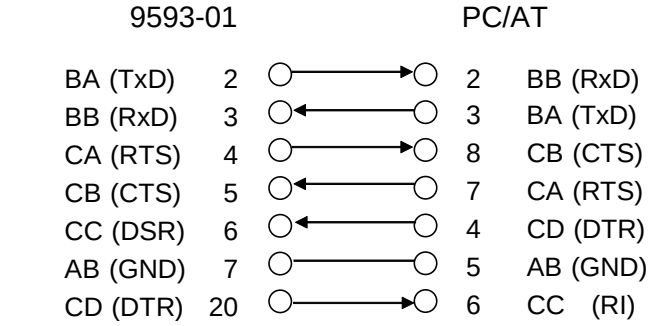
Signal Assignments and Explanation

Connector (Dsub) Pin number	Circuit		Description
	RS-232C	CCITT	
2	BA(TxD)	103	Transmitted Data
3	BB(RxD)	104	Received Data
4	CA(RTS)	105	Request to Send
5	CB(CTS)	106	Clear to Send
7	AB(GND)	102	Signal Ground
20	CD(DTR)	108/2	Data Terminal Ready
Other pins			Unused

Connecting method

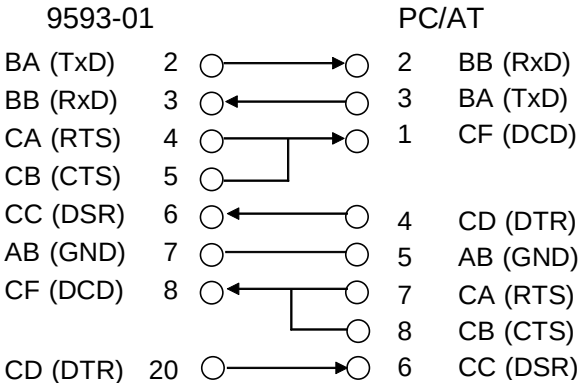
When connecting to the controller (DTE), use a cross cable which meets the connector specifications of both sides of the 9593-01 and the controller.

When connecting to the PC/AT:



D-subminiature 25-pin male

D-subminiature 9-pin female



D-subminiature 25-pin male

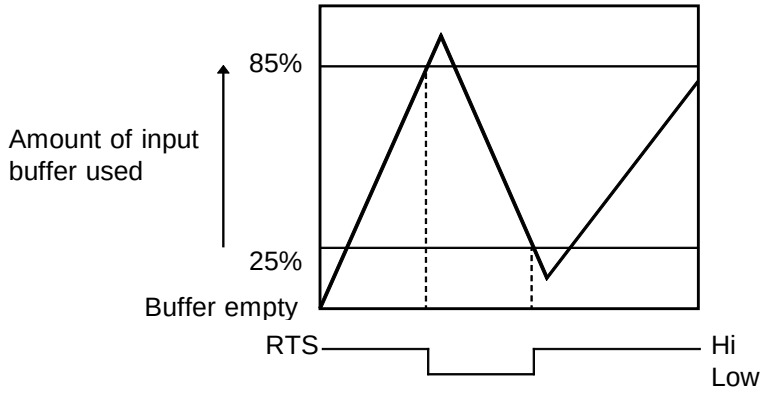
D-subminiature 9-pin female

Handshake

(1) Controls when receiving

When the receiving buffer is more than 85% full, to indicate to the controller that the empty buffer capacity is low (RTS is set to Low).

Processing of data in the buffer continues, and when the receiving buffer is less than 25 % full, to indicate to the controller that there is ample buffer capacity (RTS is set to Hi)



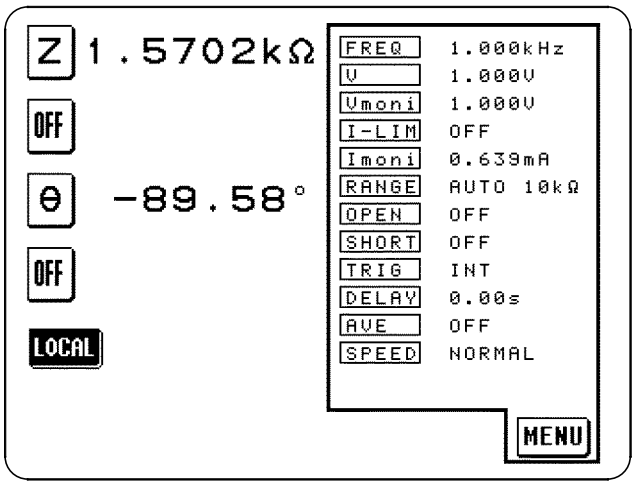
(2) Controls when transmitting

When CTS is Low, transmission is suspended; it is Hi transmission resumes.

Chapter 3
Names of Parts

3.1 Controls and Connections

(1) Initial Screens



During communications (in the remote state), the **LOCAL** key to release the remote state is displayed on the screen.
Press this key to resume the normal state (local state).

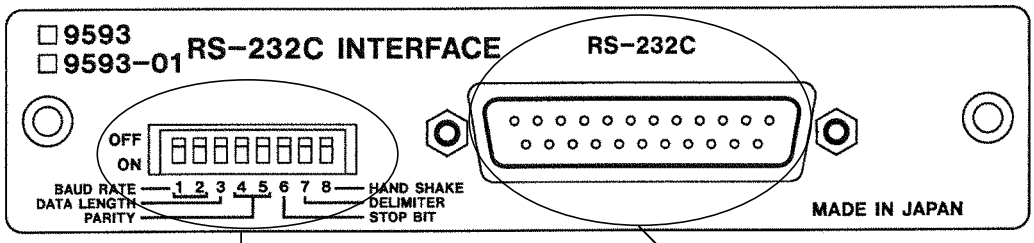
During communications, the initial screen is forcibly displayed excluding the following conditions.

- When executing OPEN/SHORT correction or sending the execution command (correction execution screen appears).
- When the magnification display screen appears.

(2) 9593-01 RS-232C INTERFACE

⚠ WARNING To avoid electrocution, turn off the power to all devices before pluggingor unplugging any of the RS-232C INTERFACE connectors.

⚠ CAUTION To avoid damage to the product, do not short-circuit the output terminal and do not input voltage to the output terminal.



Communication condition setting switches

RS-232C connector

Communication condition setting switches

These are used to set the communication condition of the 3532-50/3522-50 units on the RS-232C bus. For how to set these switches, refer to Section 4.1, "Setting the RS-232C Communication Conditions."

RS-232C connector

Connect the RS-232C cable to this connector.

Chapter 4
Operation

4.1 Setting the RS-232C Communication Conditions

- Use the communication condition setting switches on the RS-232C panel to set the communication condition.
- On dispatch from the factory, this address is initially set to 00000000.

NOTE

If you change the communication condition while the 3532-50 or 3522-50 is being used, then you should immediately turn the power off and on again.
If this is not done, the communication condition will not be changed to the new one.

Bits	Description
1	Baud rate
2	
3	Data length
4	Parity
5	
6	Stop bits
7	Delimiter
8	Handshake

0: OFF 1: ON

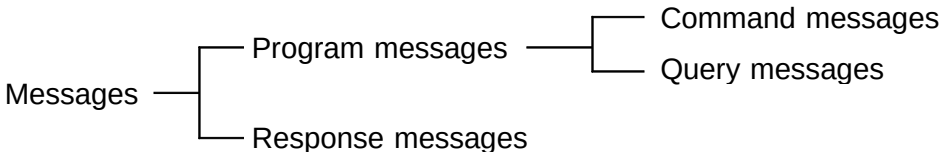
Bits		Description
1	2	Baud rate
0	0	9600
0	1	4800
1	0	2400
1	1	19200
3		Data length
0		8 bits
1		7 bits
4	5	Parity
0	0	None
0	1	None
1	0	Even
1	1	Odd

6	Stop bits
0	1 bit
1	2 bits
7	Delimiter
0	CR+LF
1	CR

When using with the personal computer, set bit 8 to 0.
When using with the optional 9442 printer, set all bits to 1.

4.2 Communication Methods by the RS-232C

- In order to control the 3532-50/3522-50 by the RS-232C, there are several kinds of messages.
- Of these, program messages are those received by the 3532-50/3522-50 from the computer, while response messages are those sent from the 3532-50/3522-50 to the computer.



(1) Program messages

Program messages are command messages or query messages.

- Command messages are orders for controls of the 3532-50/3522-50, such as for making measurement condition settings or for reset or the like.

  Example FREQUENCY <data>
  (Command message which sets the frequency)

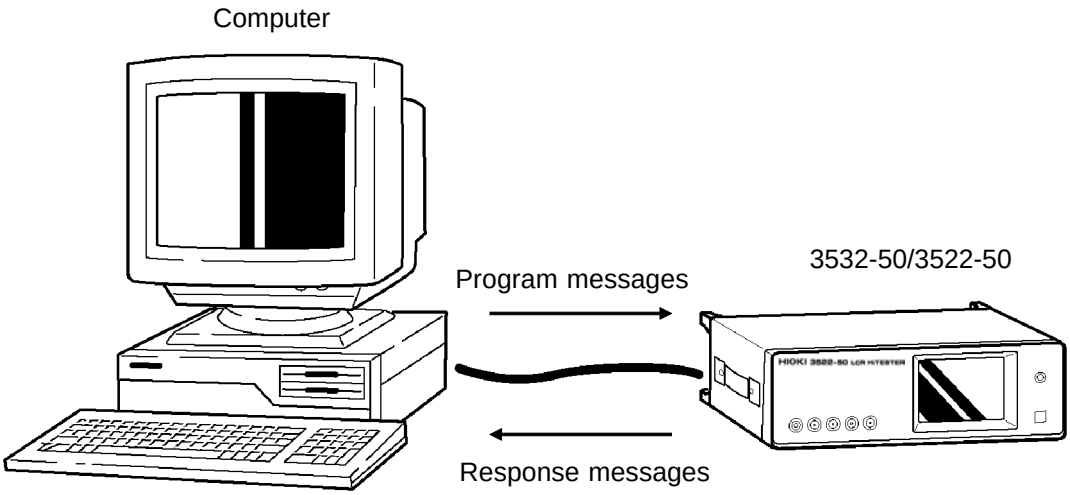
- Query messages are orders for responses relating to results of operation, results of measurement, or the state of 3532-50/3522-50 settings. (A question mark "?" is suffixed at the end of the command.)

  Example FREQUENCY?
  (Queries the current frequency)

(2) Response messages

It represents the response data for query messages from the 3532-50/3522-50.

Example FREQUENCY 1.000E+03
(Current frequency is 1 kHz.)



4.3 Message Format

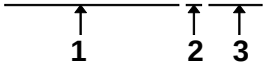
The commands for the 3532-50/3522-50 are as far as possible mnemonic. Furthermore, all commands have a long form, and an abbreviated short form.

4.3.1 Program Message

The program message is made up from header and data portions

Example Command message to set frequency to 1 kHz

:FREQUENCY 1000



1 Header portion

2 Space separating header portion and data portion.

3 Data portion (ASCII-format text or numeric values.
Some messages have no data portions...query messages, etc.)

A command header can be abbreviated. The whole command form is referred to as the "long form" and the abbreviated form as the "short form." In this manual, the short form is written in upper case letters, and then this is continued in lower case letters so as to constitute the long form. Either of these forms will be accepted during operation, but intermediate forms will not be accepted. Further, during operation both lower case letters and upper case letters will be accepted without distinction.
For "FREQUENCY", either "FREQuency" (the long form) or "FREQ" (the short form) will be accepted. However, any one of "FREQU", or "FRE" is wrong and will generate an error.

4.3.2 Response Messages

It represents the response message for query messages from the 3532-50/3522-50.
Response messages generated by the 3532-50/3522-50 are in long form and in upper case letters.

Example FREQUENCY 1.000E+03
(Current frequency is 1 kHz.)

NOTE If an error occurs when the query message is received, the query does not produce response message.

4.4 Headers

(1) Program message headers

There are three types of header: simple headers, compound headers, and particular headers.

- Simple header

  A header consisting of a single word beginning with a letter.

  Examples :HEADer, etc.

- Compound header

  A header consisting of a sequence of words separated by colons.

  Examples :BEEPer:KEY, RANGe:AUTO, etc.

- Particular header

  A header beginning with an asterisk (*) to indicate that it is a particular command.

  Examples *RST, etc.

(2) Response message

Headers in response messages can be enabled or disabled by using the "HEADer" command.

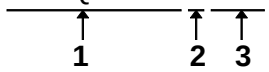
Example When frequency is set to 1 kHz:

:FREQUENCY?

(Query message asking for the current setting of the frequency.)

Response message when headers are on.

:FREQUENCY 1000



1 Header portion

2 Space separating header portion and data portion.

3 Data portion

Response message when headers are off.

1000

(Data portion only)

NOTE The headers are set to off when powering on.

4.5 Data Formats

The 3532-50/3522-50 use character string data and decimal numeric data, and the type used varies according to the command in question.

(1) Character data

Character string data must always begin with an alphabetic character, and the characters following can be either alphabetic characters or numerals. Although in character data either upper case letters or lower case letters are accepted, response messages output by the 3532-50/3522-50 are always in upper case letters.

Example :TRIGger INT

(2) Decimal data

The numeric data values are all represented in decimal, in three formats identified as NR1, NR2 and NR3, and each of these can appear as either a signed number or an unsigned number. Unsigned numbers are taken as positive.

Further, if the accuracy of a numerical value exceeds the limit which the 3532-50/3522-50 can deal, it is rounded off. (5 and above is rounded up; 4 and below is rounded down).

NR1 format - integer data.

Examples +12, -23, 34

NR2 format - fixed point numbers.

Examples +1.23, -23.45, 3.456

NR3 format - floating point numbers.

Examples +1E-2, -2.3E+4

The term "NRf format" includes all these three formats.

When the 3532-50 or 3522-50 is receiving it accepts NRf format, but when it is sending response messages it utilizes whichever one of the formats NR1 to NR3 is indicated in the specified command.

Examples :RANGe 6
:RANGe +6.012
:RANGe 0.0006E4

4.6 Delimiters

The term "delimiter" is used to refer to the following possibilities for separating data sequences.
The 3532-50 and 3522-50 recognizes either a carriage return (CR) or a carriage return plus linefeed (CR+LF) as delimiters.

(1) CR (carriage return only)

(2) CR+LF (carriage return plus linefeed)

4.7 Separators

(1) Message unit separator

A semicolon (;) is used as a message unit separator when it is desired to set out several messages on a single line.

Example :RANGe:AUTO ON;:BEEP:KEY ON;*IDN?

NOTE When messages are combined in this way, if a syntax error occurs, all subsequent messages up to the next delimiter will be ignored.

(2) Header separator

In a message which has a header and data, a space (represented by " " in the examples) is used as the header separator to separate the header from the data.

Example :LEVel V

(3) Data separator

If a message has several data items, commas (,) are required as data separators for separating these data items from one another.

Example :COMParator:FLIMit:ABSolute <lower limit>,<upper limit>

4.8 Abbreviation of Compound Commands

When several compound headers have a common head portion (for example, :BEEPer:KEY and :BEEPer:COMParator, etc.), then, when and only when writing them directly following on from one another, this common portion (:BEEPer: in this example) can be omitted.
This common portion is called "the current path", by analogy with the general concept of the current directory in the directory structure of UNIX or MSDOS, and until it is cleared the analysis of following commands is performed by deeming them to be preceded by the current path which has been curtailed in the interests of brevity. This manner of using the current path is shown in the following example:

Normal expression

:BEEPer:KEY ON;:BEEPer:COMParator NG

Abbreviated expression

:BEEPer: KEY ON;COMParator NG

This becomes the current path, and can be curtailed from the following commands.

The current path is cleared when the power is turned on, when a colon (:) appears at the start of a command, and when delimiter is detected.

Messages with particular headers can be executed without relation to the current path. Further, they have no effect upon the current path.
With the 3532-50/3522-50, there are 12 possible current paths:

:APPLication:DISPlay
:BEEPer:
:COMParator:FLIMit:
:COMParator:SLIMit:
:CORRection:
:LEVel:
:LIMiter:
:MEASure:
:RANGe:
:TRIGger:
:USER:
:SCALe:

4.9 Output Queue

Response messages accumulate in the output queue and all data are received and cleared.

The output queue is also cleared when the power is turned off and turned on again.

The 3532-50/3522-50 have an output queue of 300 bytes capacity. If the response messages overflow this limit of 300 bytes, a query error is generated, and the output buffer is cleared

4.10 Input Buffer

The 3532-50/3522-50 have an input buffer of 300 bytes capacity.
When more than 300 bytes of data are transmitted, when the buffer is full any subsequent bytes received will be ignored.
(When the controller handshake setting is not the same as the 9593-01.)

4.11 Event Registers

The 3532-50/3522-50 include three 8-bit event registers. It is possible to determine the
status of the unit by reading these registers.

The event register is cleared in the following situations:

- When a "*CLS" command is executed.
- When an event register query is executed. (*ESR?, :ESR0?, :ESR1?)
- When the unit is powered on.

(1) Standard event status register (SESR)

Standard Event Status Register (SESR) Bit Assignments

Bit 7 PON	Power on flag. When the power is turned on, or on recovery from a power cut, this bit is set to 1.
Bit 6	Unused.
Bit 5 CME	Command error. When a command which has been received contains a syntactic or semantic error, this bit is set to 1. ・ The command is not supported by the 3532-50/3522-50. ・ There is a mistake in a program header. ・ The number of data parameters is wrong. ・ The format of the parameters is wrong.
Bit 4 EXE	Execution error. When for some reason a command which has been received cannot be executed, this bit is set to 1. ・ The designated data value is outside the set range. ・ The designated data value is not acceptable. ・ Execution is impossible because some other function is being performed.
Bit 3 DDE	Device dependent error. When a command cannot be executed due to some cause other than a command error, a query error, or an execution error, this bit is set to 1. ・ Execution is impossible due to an abnormality inside the 3532-50/3522-50. ・ During open or short circuit compensation, valid data cannot be obtained.
Bit 2 QYE	Query error. This bit is set to 1 when a query error is detected by the output queue control. ・ When the data overflows the output queue. ・ When data in the output queue has been lost.
Bit 1	Unused.
Bit 0	Unused.

(2) Event status registers 0 and 1 (ESR0 and ESR1)

Event Status Register 0 (ESR0) Bit Assignments

Bit 7	Unused
Bit 6 COF	Constant current or constant voltage
Bit 5 LOF	Limit overflow
Bit 4 IOF	Impedance range overflow
Bit 3 IUF	Impedance range underflow
Bit 2 IDX	Data sampling completed
Bit 1 EOM	Measurement completed
Bit 0 CEM	Compensation data measurement completed

Event Status Register 1 (ESR1) Bit Assignments

Bit 7	Unused
Bit 6 AND	Logical product (AND) of comparison results (bit1, bit4)
Bit 5 SLO	Second parameter below lower limit
Bit 4 SIN	Second parameter within limits
Bit 3 SHI	Second parameter above upper limit
Bit 2 FLO	First parameter below lower limit
Bit 1 FIN	First parameter within limits
Bit 0 FHI	First parameter above upper limit

Chapter 5
Command Reference

5.1 Command Summary

Particular Commands

Command	Function	Ref page
*CLS	Clears event register.	26
*ESR?	Queries standard event status register (SESR).	26
*IDN?	Queries device ID.	27
*RST	Device initialization.	28
*TRG	Performs sampling once.	29
*TST?	Queries the result of the self-test.	29
*WAI	Waits until all execution is fully completed.	30

Commands Specific to the 3532-50･3522-50

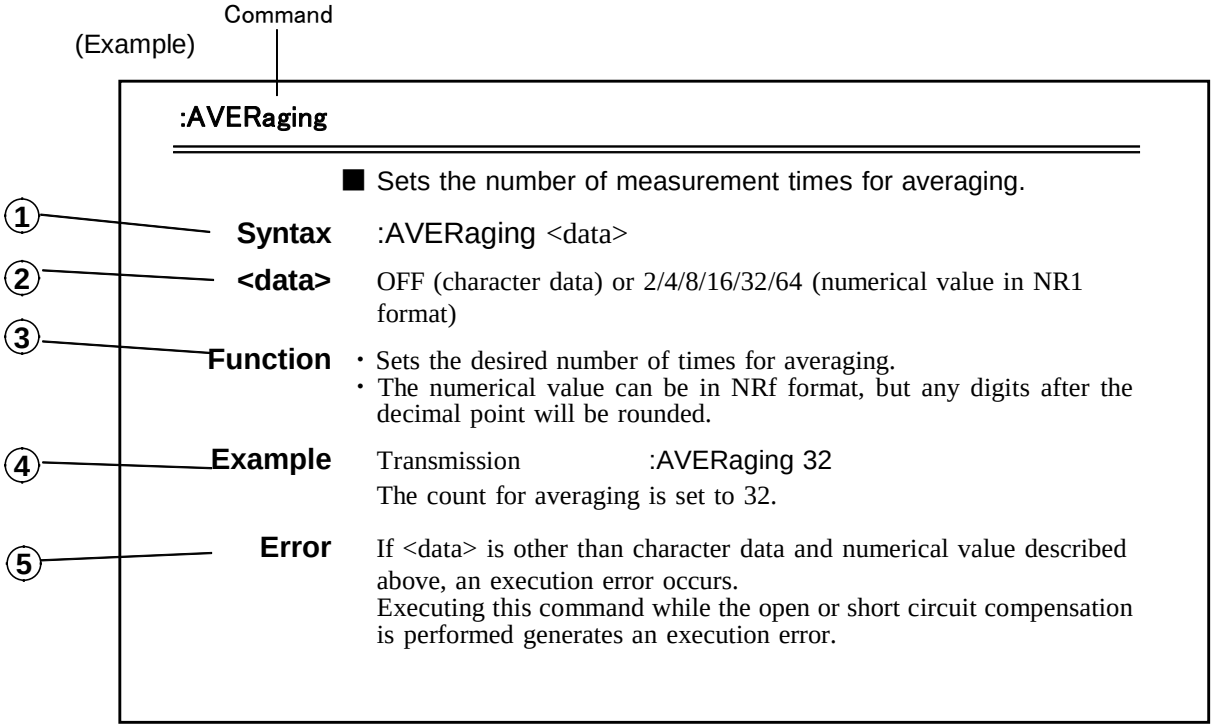
Command	Function	Ref page
■ Display function		
:APPLication:DISPlay:LIGHt	Setting for LCD display.	31
:APPLication:DISPlay:LIGHt?	Queries the setting for LCD display.	31
:APPLication:DISPlay:MONItor	Setting for voltage and current monitors.	32
:APPLication:DISPlay:MONItor?	Queries the setting for voltage and current monitors.	32
■ Averaging function		
:AVERaging	Sets the number of measurement times for averaging.	33
:AVERaging?	Queries the number of measurement times for averaging.	33
■ Beep sound function		
:BEEPer:COMParator	Sets the beep sound for the comparator.	34
:BEEPer:COMParator?	Queries the beep sound for the comparator.	34
:BEEPer:KEY	Sets the beep sound for key input.	35
:BEEPer:KEY?	Queries the beep sound for key input.	35

Command	Function	Ref page
■ External DC bias function		
:BIAS	Enables and disables the external DC bias function.	36
:BIAS?	Queries the external DC bias function enablement	36
■ Cable length setting function		
:CABLe	Sets the cable length.	36
:CABLe?	Queries the cable length.	37
■ Comparator function		
:COMParator	Enables and disables the comparator function.	37
:COMParator?	Queries the comparator function enablement.	37
:COMParator:FLIMit	(first parameter)	
:ABSolute	Sets the upper and lower limit values (absolute values).	38
:ABSolute?	Queries the upper and lower limit values (absolute values).	38
:DEViation	Sets the reference value and the upper and lower limit values (deviation percentage values).	39
:DEViation?	Queries the reference value and the upper and lower limit values (deviation percentage values).	39
:MODE	Sets the first parameter setting mode.	40
:MODE?	Queries the first parameter setting mode.	40
:PERcent	Sets the reference value and the upper and lower limit values (percentage values).	41
:PERcent?	Queries the reference value and the upper and lower limit values (percentage values).	41
:COMParator:SLIMit	(second parameter)	
:ABSolute	Sets the upper and lower limit values (absolute values).	42
:ABSolute?	Queries the upper and lower limit values (absolute values).	42
:DEViation	Sets the reference value and the upper and lower limit values (deviation percentage values).	43
:DEViation?	Queries the reference value and the upper and lower limit values (deviation percentage values).	43
:MODE	Sets the second parameter setting mode.	44
:MODE?	Queries the second parameter setting mode.	44
:PERcent	Sets the reference value and the upper and lower limit values (percentage values).	45
:PERcent?	Queries the reference value and the upper and lower limit values (percentage values).	45
■ Open and short circuit compensation function		
:CORRection:DATA?	Queries the open and short circuit compensation values.	46
:CORRection:OPEN	Enables and disables the open circuit compensation function.	47
:CORRection:OPEN?	Queries the open circuit compensation function enablement.	48
:CORRection:SHORt	Enables and disables the short circuit compensation	49
:CORRection:SHORt?	Queries the short circuit compensation function enablement.	50

Command	Function	Ref page
■ Monitor function		
:DISPlay:MONItor?	Queries the monitored voltage and current.	50
■ Communication error confirmation		
:ERRor?	Queries the RS-232C error.	51
■ Event register		
:ESR0?	Queries event status register 0.	51
:ESR1?	Queries event status register 1.	52
■ Test frequency function		
:FREQuency	Sets the test frequency.	53
:FREQuency?	Queries the test frequency.	53
■ Headers		
:HEADer	Enables and disables headers for the response message.	54
:HEADer?	Queries headers enablement.	54
■ EXT I/O Output		
:IO:OUTPut:DELay	Sets the delay time for judgement result output ↔ $\overline{\text{EOM}}$ output period in EXT I/O.	55
:IO:OUTPut:DELay?	Queries the delay time for judgement result output ↔ $\overline{\text{EOM}}$ output period in EXT I/O.	55
:IO:RESult:RESet	Sets output of judgment result signal line in EXT I/O.	56
:IO:RESult:RESet?	Queries output of judgment result signal line in EXT I/O.	56
■ Test signal level function		
:LEVel	Sets the test signal level.	55
:LEVel?	Queries the test signal level.	55
:LEVel:CCURRent	Sets the constant current level value.	56
:LEVel:CCURRent?	Queries the constant current level value.	56
:LEVel:CVOLTage	Sets the constant voltage level value.	57
:LEVel:CVOLTage?	Queries the constant voltage level value.	57
:LEVel:VOLTage	Sets the open circuit voltage level value.	58
:LEVel:VOLTage?	Queries the open circuit voltage level value.	58
■ Limit function		
:LIMiter	Enables and disables the limit setting function.	59
:LIMiter?	Queries the limit setting function enablement.	59
:LIMiter:CURRent	Sets the current limit value.	60
:LIMiter:CURRent?	Queries the current limit value.	60
:LIMiter:VOLTage	Sets the voltage limit value.	61
:LIMiter:VOLTage?	Queries the voltage limit value.	61
■ Panel load function		
:LOAD	Transfers the specified panel number.	62

Command	Function	Ref page
■ Normal testings		
:MEASure?	Queries the data item.	63
:MEASure:ITEM	Sets test parameter.	65
:MEASure:ITEM?	Queries test parameter.	66
■ Parameter settings (*:1 to 4)		
:PARAmeter1 (2, 3, or 4)	Sets displayed parameters.	67
:PARAmeter1 (2, 3, or 4)?	Queries displayed parameters.	67
:PARAmeter*:DIGit	Sets the number of displayed digits.	68
:PARAmeter*:DIGit?	Queries the number of displayed digits.	68
■ Test range function		
:RANGe	Sets test range.	69
:RANGe?	Queries test range setting.	70
:RANGe:AUTO	Sets the automatic test ranging.	71
:RANGe:AUTO?	Queries the automatic test range setting.	71
■ Panel saving function		
:SAVE	Saves the test conditions in specified panel number.	72
:SAVE?	Queries the panel number in which data is saved.	72
■ Scaling function		
:SCALe	Enables and disables the scaling function.	73
:SCALe?	Queries the scaling function.	73
:SCALe:FVALue	Sets the first parameters (a and b) in the scaling function.	74
:SCALe:FVALue?	Queries the first parameters (a and b) in the scaling function.	74
:SCALe:SVALue	Sets the second parameters (a and b) in the scaling function.	75
:SCALe:SVALue?	Queries the second parameters (a and b) in the scaling function.	75
■ Test speed function		
:SPEEd	Sets the testing speed.	76
:SPEEd?	Queries the testing speed.	76
■ Trigger function		
:TRIGger	Sets the type of trigger.	77
:TRIGger?	Queries the trigger setting.	77
:TRIGger:DELAy	Sets the trigger delay time.	78
:TRIGger:DELAy?	Queries the trigger delay time.	78
■ ID function		
:USER:IDENtity	Sets the user ID.	79
:USER:IDENtity?	Queries the user ID.	79

5.2 Format of Command Explanations



① Specifies the syntax for the command (a space is represented by " " in this syntax).

② For a command that has parameters, specifies their format.
- Numeric data values in the following formats
  NR1: integer data
  NR2: fixed point numbers
  NR3: floating point numbers
- Character data

③ Specifies the function of the command.

④ These are simple examples of the use of the command.

⑤ Specifies what types of error may occur.
For query commands, this time is the time taken when headers are on.

5.3 Particular Commands

*CLS

■ Clears the event registers.

Syntax *CLS

Function
- Clears all the event registers (SESR, ESR0, ESR1).
- This has no effect upon the output queue.

Error If the data parameters are set after this command, a command error occurs.

*ESR?

■ Reads out the contents of the standard event status register (SESR).

Syntax *ESR?

Function
- Returns the contents of the standard event status register (SESR) as a numerical value in NR1 format from 0 to 255, and then clears standard event status register.
- No header is affixed to the response message.

Example Response 32

Bit 5 of SESR has been set to 1.

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
PON	Unused	CME	EXE	DDE	QYE	Unused	Unused

Standard Event Status Register (SESR)

Error If the response message is longer than 300 bytes, a query error is generated.

*IDN?

■ Queries manufacturer's name, model name, and software version.

Syntax *IDN?

Function
- The response consists of the name of the manufacturer of the unit, the model name, and the software version.
- No header is affixed to the response message.

First field	Manufacturer's name
Second field	Model name
Third field	Fixed for fifty
Fourth field	Software version

Example Response HIOKI,3532,50,V01.01

Error If the response message is longer than 300 bytes, a query error is generated.

*RST

■ Performs device initial setting.

Syntax *RST

Function Resets the 3532-50. The items which are reset are listed below.

Test parameters	Impedance (Z), phase angle (θ)
Test frequency	1 kHz
Test signal level	Open circuit voltage mode (V mode)
V mode set value	1.00 V
CV (constant voltage) set value	1.00 V
CC (constant current) set value	10.00 mA
Limit function	OFF
Voltage limit set value	5.00 V
Current limit set value	50.00 mA
Test range	AUTO
Open circuit compensation	OFF
Short circuit compensation	OFF
Trigger setting	Internal trigger
Trigger delay time	0 s
Averaging	OFF
Test speed setting	NORMAL
Beep sound setting	ON for key input, OFF for comparator
DC bias function (3522-50 only)	OFF
Cable length (3532-50 only)	0 m
Comparator	
Comparator setting mode	Both first and second parameters set to absolute value
Absolute value set values	
First parameter	Upper and lower limit values: OFF
Second parameter	Upper and lower limit values: OFF
Percent set values	
First parameter	Reference value: 1000 Upper and lower limit values: OFF
Second parameter	Reference value: 10 Upper and lower limit values: OFF
Panel save	All contents clear
Scaling	Correction coefficient a: 1.0000, b: 0
Number of displayed digits	5 digits
EXT I/O output (3522-50, 3532-50 only)	Delay time for Judgement Result and $\overline{\text{EOM}}$ Output Period: 0.0 s Judgment Results Reset: OFF

Error If the data parameters are set after this command, a command error occurs.

*TRG

■ Issues external trigger.

Syntax *TRG

Function In external trigger mode, performs measurement once.

Example Transmission :TRIGger EXTernal;*TRG;:MEASure?

Error Executing this command in internal trigger mode generates an execution error.
If the data parameters are set after this command, a command error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

*TST?

■ Requests execution of, and queries the result of, the self test.

Syntax *TST?

Function
- Performs the self test of the 3532-50, and returns the result thereof as a numerical value in NR1 format from 0 to 15.
- No header is affixed to the response message.

bit 0	a ROM error occurred
bit 1	a RAM error occurred
bit 2	an I/O error occurred
bit 3	an interrupt error occurred
bit 4	unused
bit 5	unused
bit 6	unused
bit 7	unused

Example Response 6

A RAM error (bit 1) and an I/O error (bit 2) have occurred.

Error If the response message is longer than 300 bytes, a query error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

*WAI

■ Waits until all execution is fully completed.

Syntax *WAI

Function The unit goes into waiting state until the previous operation has been completed.

Note All of the specific commands are in any case sequential commands except the :MEASure? query. Therefore, using this *WAI command has an effect upon only :MEASure? query.

Example Transmission (If the frequency is set to 1 kHz)
When not using the *WAI command

```
:FREQuency 50;:MEASure?
```

The response for :MEASure? is the test value at frequency of 1 kHz.

When using the *WAI command

```
:FREQuency 50;*WAI;:MEASure?
```

The response for :MEASure? is the test value of frequency at 50 Hz.

Error If the data parameters are set after this command, a command error occurs.

5.4 Commands Specific to the 3532-50・3522-50

:APPLication:DISPlay:LIGHt

■ Setting for LCD display.

Syntax :APPLication:DISPlay:LIGHt <data>

<data> ON/OFF (character data)

Function ・Sets for LCD display.

ON The LCD display and backlight remain on permanently.

OFF The LCD display and backlight remain off permanently.

When OFF is selected, the LCD display and backlight go out approximately 10 seconds after the touch panel is last touched.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:APPLication:DISPlay:LIGHt?

■ Queries the setting for LCD display.

Syntax :APPLication:DISPlay:LIGHt?

Function Returns the setting for LCD display as character data.

ON The LCD display and backlight remain on permanently.

OFF The LCD display and backlight remain off permanently.

Error If the response message is longer than 300 bytes, a query error is generated.

:APPLication:DISPlay:MONItor

■ Setting for voltage and current monitors (Vmoni, Imoni).

Syntax :APPLication:DISPlay:MONItor <data>

<data> ON/OFF (character data)

Function ・Sets for voltage and current monitors (Vmoni, Imoni).

ON	The voltage and current monitors display indications.
OFF	The voltage and current monitors do not display indications.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:APPLication:DISPlay:MONItor?

■ Queries the setting for voltage and current monitors (Vmoni, Imoni).

Syntax :APPLication:DISPlay:MONItor?

Function Returns the setting for voltage and current monitors (Vmoni, Imoni) as character data.

ON	The voltage and current monitors display indications.
OFF	The voltage and current monitors do not display indications.

Error If the response message is longer than 300 bytes, a query error is generated.

:AVERaging

■ Sets the number of measurement times for averaging.

Syntax :AVERaging <data>

<data> OFF (character data) or 2/4/8/16/32/64 (numerical value in NR1 format)

Function
- Sets the desired number of times for averaging.
- The numerical value can be in NRf format, but any digits after the decimal point will be rounded.

Example Transmission :AVERaging 32

The count for averaging is set to 32.

Error If <data> is other than character data and numerical value described above, a command error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:AVERaging?

■ Queries the number of times for averaging.

Syntax :AVERaging?

Function Returns the current setting of the number of times for averaging as character data or numerical value in NR1 format.

OFF, 2, 4, 8 ,16, 32, 64

Examples Response

If headers are on :AVERAGING 32
If headers are off 32

Error If the response message is longer than 300 bytes, a query error is generated.

:BEEPer:COMParator

■ Sets the beep sound for the comparator.

Syntax :BEEPer:COMParator <data>

<data> IN/NG/OFF (character data)

Function Sets the beep sound produced when the comparator makes decisions.

IN	When the comparator result is within limits, a beep sound is emitted.
NG	When the comparator result is out of limits, a beep sound is emitted.
OFF	No beep sound is emitted.

Example Transmission :BEEPer:COMParator NG
When the value is out of limits, a beep sound is emitted.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:BEEPer:COMParator?

■ Queries the beep sound for the comparator.

Syntax :BEEPer:COMParator?

Function Returns the beep sound setting for when the comparator makes decision as character data.

IN	When the comparator result is within limits, a beep sound is emitted.
NG	When the comparator result is out of limits, a beep sound is emitted.
OFF	No beep sound is emitted.

Example Response

If headers are on	:BEEPER:COMPARATOR NG
If headers are off	NG

Error If the response message is longer than 300 bytes, a query error is generated.

:BEEPer:KEY

■ Enables and disables the beep sound for key input.

Syntax :BEEPer:KEY <data>

<data> ON/OFF (character data)

Function Sets the beep sound produced each time a key is pressed.

ON	A beep sound is emitted.
OFF	No beep sound is emitted.

Example Transmission :BEEPer:KEY ON
When a key is pressed, a beep sound is emitted.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:BEEPer:KEY?

■ Queries the beep sound for key input.

Syntax :BEEPer:KEY?

Function Returns the beep sound setting for when a key is pressed as character data.

ON	A beep sound is emitted.
OFF	No beep sound is emitted.

Example Response

If headers are on	:BEEPER:KEY ON
If headers are off	ON

Error If the response message is longer than 300 bytes, a query error is generated.

:BIAS (3522-50 only)

■ Enables and disables the external DC bias function.

Syntax :BIAS <data>

<data> ON/OFF (character data)

Function Turns the external DC bias function on and off.

Example Transmission :BIAS ON
The external DC bias function is turned on.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:BIAS? (3522-50 only)

■ Queries the external DC bias function enablement.

Syntax :BIAS?

Function Returns the current enablement state of the external DC bias function as character data.

ON, OFF

Example Response
If headers are on :BIAS ON
If headers are off ON

Error If the response message is longer than 300 bytes, a query error is generated.

:CABLe (3532-50 only)

■ Sets the cable length.

Syntax :CABLe <data>

<data> 0/1 (NR1 numerical data)
0: sets to 0 m
1: sets to 1m

Function Sets the cable length.

Example Transmission :CABLe 0
The cable length is set to 0 m.

Error If <data> is other than numerical data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:CABLe? (3532-50 only)

■ Queries the cable length.

Syntax :CABLe?

Function Returns the current cable length setting as NR1 numerical data.

0, 1

Example Response
If headers are on :CABLE 0
If headers are off 0

Error If the response message is longer than 300 bytes, a query error is generated.

:COMParator

■ Enables and disables the comparator function.

Syntax :COMParator <data>

<data> ON/OFF (character data)

Function Turns the comparator function on and off.

Example Transmission :COMParator ON
The comparator function is turned on.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator?

■ Queries the comparator function enablement.

Syntax :COMParator?

Function Returns the current enablement state of the comparator function as character data.

ON, OFF

Example Response
If headers are on :COMPARATOR ON
If headers are off ON

Error If the response message is longer than 300 bytes, a query error is generated.

:COMParator:FLIMit:ABSolute

■ Sets the lower and upper limit values for the first comparator parameter as absolute values.

Syntax :COMParator:FLIMit:ABSolute <low>,<high>

<data>

<low>	lower limit value	OFF (character data) or numerical value in NR3 format
<high>	upper limit value	OFF (character data) or numerical value in NR3 format

Function
- Sets the lower and upper limit values for the first comparator parameter (i.e. the principal measured value) as absolute numerical values.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

Note The upper and lower limit values which are set as absolute values, and which are set as percentage values are stored individually.

Example Transmission :COMParator:FLIMit:ABSolute 1.1234E-06,1.2345E-06
The lower limit value is set to 1.1234E-06 and the upper limit value is set to 1.2345E-06.

Error If <data> is other than character data or numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator:FLIMit:ABSolute?

■ Queries the lower and upper limit values which are set as absolute values for the first comparator parameter.

Syntax :COMParator:FLIMit:ABSolute?

Function Returns the lower and upper limit values which are set as absolute values for the first comparator parameter as character data or numerical value in order.
OFF (character data) or numerical value in NR3 format

Example Response
If headers are on :COMPARATOR:FLIMIT:ABSOLUTE 1.1234E-06,1.2345E-06
If headers are off 1.1234E-06,1.2345E-06

Error If the response message is longer than 300 bytes, a query error is generated.

:COMParator:FLIMit:DEViation

■ Sets the reference value and lower and upper limit values for the first comparator parameter as deviation percentage (Δ%).

Syntax :COMParator:FLIMit:DEViation <ref>,<low>,<high>

<data>

<ref>	reference value	Numerical value in NR3 format
<low>	lower limit value	OFF (character data) or numerical value in NR3 format
<high>	upper limit value	OFF (character data) or numerical value in NR3 format

Function ・Sets the reference value and the lower and upper limit values for the first comparator parameter as deviation percentage.

Note The reference value and the lower and upper limit values of the % mode and Δ% mode are common. Therefore this command and the ":COMParator:FLIMit:PERcent" command do the same action.

Example Transmission :COMParator:FLIMit:DEViation 1.2345E-6,-10.0,10.0
The reference value is set to 1.2345E-06, the lower limit value is set to -10%, and the upper limit value is set to 10%.

Error If <data> is other than character data or numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator:FLIMit:DEViation?

■ Queries the reference value and the lower and upper limit values which are set as deviation percentage (Δ%) for the first comparator parameter.

Syntax :COMParator:FLIMit:DEViation?

Function Returns the reference value and the lower and upper limit values witch are set as deviation percentage (Δ%) for the first comparator parameter as <ref>, <low>, <hi> in order.

Note The reference value and the lower and upper limit values of the % mode and Δ% mode are common. Therefore this command and the ":COMParator:FLIMit:PERcent" command do the same action.

Example Response
If headers are on :COMPARATOR:FLIMIT:DEVIATION 1.2345E-6,-10.0,10.0
If headers are off 1.2345E-6,-10.0,10.0

Error If the response message is longer than 300 bytes, a query error is generated.

:COMParator:FLIMit:MODE

■ Set the reference value and the first parameter setting mode for the comparator.

Syntax :COMParator:FLIMit:MODE <data>

<data> ABSolute/PERcent/DEViation (character data)

Function • Sets the first parameter setting mode for the comparator function.

ABSolute	Absolute value setting mode (ABS)
PERcent	Percentage setting mode (%)
DEViation	Deviation percentage setting mode (Δ%)

Example Transmission :COMParator:FLIMit:MODE PERcent
The percentage setting mode is selected.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator:FLIMit:MODE?

■ Queries the reference value and the setting mode of the first parameter for the comparator.

Syntax :COMParator:FLIMit:MODE?

Function Returns the current setting mode for the first parameter for the comparator function as character data.

ABSOLUTE	Absolute value setting mode (ABS) is selected.
PERCENT	Percentage setting mode (%) is selected.
DEVIATION	Deviation percentage setting mode (Δ%) is selected.

Example Response

If headers are on	:COMPARATOR:FLIMIT:MODE PERCENT
If headers are off	PERCENT

Error If the response message is longer than 300 bytes, a query error is generated.

:COMParator:FLIMit:PERcent

■ Sets the reference value and the lower and upper limit values for the first comparator parameter as percentage.

Syntax :COMParator:FLIMit:PERcent <ref>,<low>,<high>

<data>

<ref>	reference value	numerical value in NR3 format
<low>	lower limit value	OFF (character data) or numerical value in NR1 format
<high>	upper limit value	OFF (character data) or numerical value in NR1 format

Function
- Sets the lower and upper limit values for the first comparator parameter (i.e. the principal measured value) as percentage relative to a reference value.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.
- The reference value <ref> cannot be set to OFF.

Note The upper and lower limit values which are set as absolute values, and which are set as percentage values are stored individually.

Example Transmission :COMParator:FLIMit:PERcent 1.2345E-06,-20,20
The reference value is set to 1.2345E-06, the lower limit value is set to -20%, and the upper limit value is set to 20%.

Error If <data> is other than character data or numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator:FLIMit:PERcent?

■ Queries the reference value and the lower and upper limit values which are set as percentage for the first comparator parameter.

Syntax :COMParator:FLIMit:PERcent?

Function Returns the reference value and the lower and upper limit values which are set as percentage for the first comparator parameter as <ref>,<low>,<high> in order.

<ref>	Numerical value in NR3 format
<low>, <high>	Both are OFF (character data) or numerical value in NR1 format

Example Response
If headers are on :COMPARATOR:FLIMIT:PERCENT 1.2345E-06,-20,20:COMParator:FLIMit:PERcent?
If headers are off 1.2345E-06,-20,20

Error If the response message is longer than 300 bytes, a query error is generated.

:COMParator:SLIMit:ABSolute

■ Sets the lower and upper limit values for the second comparator parameter as absolute values.

Syntax :COMParator: SLIMit:ABSolute <low>,<high>

<data>

<low>	lower limit value	OFF (character data) or numerical value in NR3 format
<high>	upper limit value	OFF (character data) or numerical value in NR3 format

Function
- Sets the lower and upper limit values for the second comparator parameter as absolute numerical value.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

Note The upper and lower limit values which are set as absolute values, and which are set as percentage values are stored individually.

Example Transmission :COMParator:SLIMit:ABSolute 1.1234E-06,1.2345E-06
The lower limit value is set to 1.1234E-06, and the upper limit value is set to 1.2345E-06.

Error If <data> is other than character data or numerical value described above, a command error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator:SLIMit:ABSolute?

■ Queries the lower and upper limit values which are set as absolute values for the second comparator parameter.

Syntax :COMParator:SLIMit:ABSolute?

Function Returns the lower and upper limit values which are set as absolute numerical values for the second comparator parameter as character data or numerical value in order.
OFF (character data) or numerical value in NR3 format

Example Response
If headers are on :COMPARATOR:SLIMIT:ABSOLUTE 1.1234E-06,1.2345E-06
If headers are off 1.1234E-06,1.2345E-06

Error If the response message is longer than 300 bytes, a query error occurs.

:COMParator:SLIMit:DEViation

■ Sets the reference value and the lower and upper limit values for the second comparator parameter as deviation percentage (Δ%).

Syntax :COMParator:SLIMit:DEViation <ref>,<low>,<high>

<data>

<ref>	reference value	Numerical value in NR3 format
<low>	lower limit value	OFF (character data) or numerical value in NR3 format
<high>	upper limit value	OFF (character data) or numerical value in NR3 format

Function • Sets the reference value and the lower and upper limit values for the second comparator parameter as deviation percentage.

Note The reference value and the lower and upper limit values of the % mode and Δ% mode are common. Therefore this command and the ":COMParator:SLIMit:PERcent" command do the same action.

Example Transmission :COMParator:SLIMit:DEViation 1.0000E-3,OFF,5
The reference value is set to 1.0000E-3, the lower limit value is set to OFF, and the upper limit value is set to 5%.

Error If <data> is other than character data or numerical value described above, a command error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator:SLIMit:DEViation?

■ Queries the reference value and the lower and upper limit values for the second comparator parameter as deviation percentage (△%).

Syntax :COMParator:SLIMit:DEViation?

Function Returns the reference value and the lower and upper limit values witch are set as deviation percentage (△%) for the second comparator parameter as <ref>,<low>,<hi> in order.

Note The reference value and the lower and upper limit values of the % mode and △% mode are common. Therefore this command and the ":COMParator:SLIMit:PERcent" command do the same action.

Example Response
If headers are on :COMPARATOR:SLIMIT:DEVIATION 1.0000E-3,OFF,5
If headers are off 1.0000E-3,OFF,5

Error If the response message is longer than 300 bytes, a query error occurs.

:COMParator:SLIMit:MODE

■ Sets the second parameter setting mode for the comparator.

Syntax :COMParator:SLIMit:MODE <data>

<data> ABSolute/PERcent/DEViation (character data)

Function ・Sets the second parameter setting mode for the comparator function.

ABSolute Absolute value setting mode (ABS)
PERcent Percentage value setting mode (%)
DEViation Deviation percentage setting mode (Δ%)

Example Transmission :COMParator:SLIMit:MODE PERcent
The percentage setting mode is selected.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator:SLIMit:MODE?

■ Queries the setting mode of the second parameter for the comparator.

Syntax :COMParator:SLIMit:MODE?

Function Returns the current setting mode for the second parameter for the comparator function as character data.

ABSOLUTE Absolute value setting mode (ABS) is selected.

PERCENT Percentage setting mode (%) is selected.

DEVIATION Deviation percentage setting mode (Δ%) is selected.

Example Response
If headers are on :COMPARATOR:SLIMIT:MODE PERCENT
If headers are off PERCENT

Error If the response message is longer than 300 bytes, a query error is generated.

:COMParator:SLIMit:PERcent

■ Sets the reference value and the lower and upper limit values for the second comparator parameter as percentage.

Syntax :COMParator:SLIMit:PERcent <ref>,<low>,<high>

<data>

<ref>	reference value	Numerical data in NR3 format
<low>	lower limit value	OFF (character data) or numerical value in NR1 format
<high>	upper limit value	OFF (character data) or numerical value in NR1 format

Function
- Sets the lower and upper limit values for the second comparator parameter as percentage relative to a reference value.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.
- The reference value <ref> cannot be set to OFF.

Note The upper and lower limit values which are set as absolute values, and which are set as percentage values are stored individually.

Example Transmission :COMParator:SLIMit:PERcent 1.2345E-06,-20,20
The reference value is set to 1.2345E-06, the lower limit value is set to -20%, and the upper limit value is set to 20%.

Error If <data> is other than character data or numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:COMParator:SLIMit:PERcent?

■ Queries the reference value and the lower and upper percent values which are set as percentage for the second comparator parameter.

Syntax :COMParator:SLIMit:PERcent?

Function Returns the lower and upper limit values which are set as percentage for the second comparator parameter as <ref>, <low>, <high> in order.

<ref>	Numerical value in NR3 format
<low>, <high>	Both are OFF (character data) or numerical value in NR1 format

Example Response
If headers are on :COMPARATOR:SLIMIT:PERCENT 1.2345E-06,-20,20
If headers are off 1.2345E-06,-20,20

Error If the response message is longer than 300 bytes, a query error is generated.

:CORRection:DATA?

■ Queries the open circuit and short circuit compensation values.

Syntax :CORRection:DATA?

Function Returns the open and short circuits compensation values at the currently test frequency as <residual impedance of short circuit compensation>, <phase angle of short circuit compensation>, <residual impedance of open circuit compensation>, <phase angle of open circuit compensation> in order.

Residual impedance	Numerical value in NR3 format or OFF (character data)
Phase angle	Numerical value in NR2 format or OFF (character data)

When the compensation setting is OFF, or when the set test frequency of the compensation differs from the current test frequency, returns the character data "OFF."

Example Response

If headers are on	:CORRECTION:DATA OFF,OFF,247.45E+06,-21.58
If headers are off	OFF,OFF,247.45E+06,-21.58

The short circuit compensation for the current test frequency is set to OFF, and open circuit compensation is 247.45 MΩ, -21.58 .

Error If the response message is longer than 300 bytes, a query error is generated.

:CORRection:OPEN

■ Enables and disables the open circuit compensation function.

Syntax :CORRection:OPEN <data>

<data> OFF/ALL (character data) or numerical data in NR3 format
3532-50: 42.0E+00 to 5.000E+06
3522-50: 1E-03 to 100.0E+03

Function
- Enables and disables the open circuit compensation function.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

OFF	The open circuit compensation is not performed.
ALL	The open circuit compensation is performed at all the test frequencies.
Numerical data	The open circuit compensation is performed at the set test frequency only (spot compensation). For DC compensation, set to 0.

Note When the compensation is performed at all the test frequencies, about 3 minutes compensation (using the 3532-50) or about 2 minutes compensation (using the 3522-50) is required. Executing the command which changes test settings during compensation is performed at all the test frequencies generates an execution error. Be sure not to execute commands other than commands for checking each status registers such as *ESR? and :ESR0?.
When the SPOT compensation is performed, it takes about maximum 15 minutes (1 mHz compensation) for the 3522-50 to read the compensation data.

Example Transmission :CORRection:OPEN 1E+3
The open circuit compensation function at 1 kHz is set to ON.

Error If <data> is other than character data or numerical value described above, an execution error occurs.
Executing this command while the comparator function is performed generates an execution error.

:CORRection:OPEN?

■ Queries the open circuit compensation function enablement.

Syntax :CORRection:OPEN?

Function Returns the current setting of open circuit compensation function enablement as character data or a numerical value in NR3 format.

OFF	The open circuit compensation function has been set to off.
ALL	The open circuit compensation function at all the test frequencies has been set to on.
Numerical data	The open circuit compensation function at the set test frequency has been set to on (spot compensation).

Example Response

If headers are on :CORRECTION:OPEN 1.000E+03

If headers are off 1.000E+03

The open circuit compensation at 1 kHz has been enabled.

Error If the response message is longer than 300 bytes, a query error is generated.

:CORRection:SHORt

■ Enables and disables the short circuit compensation function.

Syntax :CORRection:SHORt <data>

<data> OFF/ALL (character data) or numerical data in NR3 format
3532-50: 42.0E+00 to 5.000E+06
3522-50: 0.000E+00 to 100.0E+03

Function
- Enables and disables the short circuit compensation function.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

OFF	The short circuit compensation is not performed.
ALL	The short circuit compensation is performed at all the test frequencies.
Numerical data	The short circuit compensation is performed at the set test frequency (spot compensation). 0: compensation for DC

Note When the compensation is performed at all the test frequencies, about 3 minutes compensation (using the 3532-50) or about 2 minutes compensation (using the 3522-50) is required. Executing the commands which changes test settings during compensation for all frequency generate an execution error. Be sure not to execute commands other than that of checking each status registers such as *ESR? and :ESR0?.
When the SPOT compensation is performed, it takes about maximum 15 minutes (1 mHz compensation) for the 3522-50 to read the compensation data.

Example Transmission :CORRection:SHORt 1E+3
The short circuit compensation function at 1 kHz is enabled.

Error If <data> is other than character data or numerical value described above, an execution error occurs.
Executing this command while the comparator function is performed generates an execution error.

:CORRection:SHORt?

■ Queries the short circuit compensation function enablement.

Syntax :CORRection:SHORt?

Function Returns the current setting of the short circuit compensation enablement as character data or a numerical value in NR3 format.

OFF	The short circuit compensation function has been set to off.
ALL	The short circuit compensation function at all the test frequencies has been set to on.
Numerical data	The short circuit compensation function at the set test frequency has been set to on (spot compensation).

Example Response

If headers are on :CORRECTION:SHORT 1.000E+03
If headers are off 1.000E+03

The open circuit compensation function at 1 kHz has been enabled.

Error If the response message is longer than 300 bytes, a query error is generated.

:DISPlay:MONItor?

■ Queries the voltage and current monitored parameters.

Syntax :DISPlay:MONItor?

Function Returns the monitored parameters as <voltage monitored value> and <current monitored value> in order.

Voltage monitored value Numerical value in NR2 format
Current monitored value Numerical value in NR3 format

Example Response

If headers are on :DISPLAY:MONITOR 1.23,0.12E-03
If headers are off 1.23,0.12E-03

Error If the response message is longer than 300 bytes, a query error occurs.

:ERRor?

■ Reads out RS-232C communication condition errors.

Syntax :ERRor?

Function
- Returns the value of RS-232C communication condition errors as a numerical value in NR1 format from 0 to 7, and then clears RS-232C communication condition errors.
- No header is prefixed to the response message.

					4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Unused	Unused	Unused	Unused	Unused	Overrun error	Framing error	Parity error

Example Response 4
An overrun error has occurred.

Error If the response message is longer than 300 bytes, a query error is generated.

:ESR0?

■ Reads out event status register 0.

Syntax :ESR0?

Function
- Returns the value of event status register 0 (ESR0) as a numerical value in NR1 format from 0 to 255, and then clears event status register 0.
- No header is prefixed to the response message.

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Unused	COF	LOF	IOF	IUF	IDX	EOM	CEM

Event Status Register 0 (ESR0)

Example Response 4
Bit 2 of ESR0 has been set to 1.

Error If the response message is longer than 300 bytes, a query error is generated.

:ESR1?

■ Reads out event status register 1.

Syntax ESR1?

Function
- Returns the value of event status register 1 (ESR1) as a numerical value in NR1 format from 0 to 255, and then clears event status register 1.
- No header is prefixed to the response message.

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Unused	AND	SLO	SIN	SHI	FLO	FIN	FHI

Event Status Register 1 (ESR1)

Example Response 64
Bit 6 of ESR1 has been set to 1.

Error If the response message is longer than 300 bytes, a query error is generated.

:FREQuency

■ Sets the test frequency.

Syntax FREQuency <data>

<data> Numerical data in NR3 format
3532-50: 42.0E+00 to 5.000E+06
3522-50: 0 to 100.0E+03

Function
- Sets the testing frequency.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.
- Specify <data> to 0 at DC measurement.

Note (for 3532-50) If the test frequency is greater than 100 kHz, the test range which can be set is limit. If it is greater than 1 MHz, the range of test signal level is limit. When the test range and the test signal level are greater than each range after changing frequencies, they are automatically change over the highest range compatible with this test frequency setting. For details, refer to the 3532-50 instruction manual.

Example Transmission :FREQuency 1.000E+03
The test frequency is set to 1 kHz.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:FREQuency?

■ Queries the test frequency.

Syntax :FREQuency?

Function Returns the currently test frequency as a numerical value in NR3 format.

Example Response
If headers are on :FREQUENCY 1.000E+03
If headers are off 1.000E+03
The test frequency has been set to 1 kHz.

Error If the response message is longer than 300 bytes, a query error is generated.

:HEADer

■ Enables and disables headers for the response message

Syntax :HEADer <data>

<data> ON/OFF (character data)

Function
- Sets whether or not the 3532-50 will prefix headers to its response messages.
- When powering on, <data> is initially set to OFF.

Example Transmission :HEADer ON
Headers are prefixed to response messages.

Error If <data> is other than character data described above, an execution error occurs.

:HEADer?

■ Queries headers for the response messages enablement.

Syntax :HEADer?

Function Returns the setting of headers for the response messages as character data.
ON,OFF

Example Response
If headers are on :HEADER ON
If headers are off OFF

Error If the response message is longer than 300 bytes, a query error is generated.

:IO:OUTPut:DELay

■ Sets the delay time for Judgement Result Output and $\overline{\text{EOM}}$ Output Period in EXT I/O.

Syntax :IO:OUTPut:DELay <data>

<data> 0 to 0.0999 (NR1)

Function ・Sets the delay time for comparator judgement result output and $\overline{\text{EOM}}$ output period in EXT I/O.
A numeric value in NRf format is accepted but non significant digits are rounded off so the numeric.

Example Transmission :IO:OUTPut:DELay 0.0005
Sets the delay time for comparator judgement result output and $\overline{\text{EOM}}$ output period in EXT I/O to 500 µs.

Note There is an approximate error of 40 µs in the delay time entered for comparator ↔ $\overline{\text{EOM}}$ period for the setting value. In addition, during measurement, a trigger input from EXT/IO or communicating by interface may lead to the delay time varying widely. As far as possible, try not to control from external sources when carrying out measurement.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:IO:OUTPut:DELay?

■ Queries the delay time for Judgement Result Output and $\overline{\text{EOM}}$ Output Period in EXT I/O.

Syntax :IO:OUTPut:DELay?

Function Returns settings the delay time for comparator judgement result output and $\overline{\text{EOM}}$ output period in EXT I/O.

Example Response
If headers are on :IO:OUTPUT:DELAY 0.0005
If headers are off 0.0005
The delay time for comparator judgement result output and $\overline{\text{EOM}}$ output period in EXT I/O set at 500 µs.

Error If the response message is longer than 300 bytes, a query error is generated.

:IO:RESult:RESet

■ Sets the Output of Judgment Result Signal Line in EXT I/O.

Syntax :IO:RESult:RESet <data>

<data> ON/OFF (character data)

Function
- Resets the judgment results when the start-of-measurement signal (trigger signal) is input.
- Updates the measurement results when measurement ends.

Example Transmission :IO:RESult:RESet OFF
Sets the judgment results to be updated when measurement ends.

Note The judgment result signal line indicates judgment results for M or S-HI, M or S-IN, M or S-LO and AND for comparator measurement.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:IO:RESult:RESet?

■ Queries the Output of Judgment Result Signal Line in EXT I/O.

Syntax :IO:RESult:RESet?

Function Returns the setting of whether to reset the judgment result signal line in EXT I/O.

Example Response
If headers are on :IO:RESULT:RESET OFF
If headers are off OFF
The judgment results are set to be updated when judgment ends.

Error If the response message is longer than 300 bytes, a query error is generated.

:LEVel

■ Sets the test signal level.

Syntax :LEVel <data>

<data> V/CV/CC (character data)

Function Sets the test signal level to one of the followings.

V	Open circuit voltage level
CV	Constant voltage level
CC	Constant current level

Example Transmission :LEVel CV
The test signal level is set to constant voltage.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:LEVel?

■ Queries the test signal level.

Syntax :LEVel?

Function Returns the test signal level as character data.

V	Open circuit voltage level
CV	Constant voltage level
CC	Constant current level

Example Response
If headers are on :LEVEL CV
If headers are off CV
The test signal level has been set to constant voltage.

Error If the response message is longer than 300 bytes, a query error occurs.

:LEVel:CCURRent

■ Sets the constant current value.

Syntax :LEVel:CCURRent <data>

<data> Numerical data in NR3 format
3532-50: 0.01E-03 and 99.99E-03 (frequency 42 Hz to 1 MHz)
0.01E-03 and 20.00E-03 (frequency 1.001 MHz to 5 MHz)
3522-50: 0.01E-03 and 99.99E-03

Function
- Sets the value of the constant current.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.
- When the test signal frequency is set to a value greater than 1MHz, the range which can be set is from 10 μA to 20 mA.

Example Transmission :LEVel:CCURRent 10.00E-03
The constant current value is set to 10 mA.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:LEVel:CCURRent?

■ Queries the constant current value.

Syntax :LEVel:CCURRent?

Function Returns the value of the constant current as a numerical value in NR3 format.

Example Response
If headers are on :LEVEL:CCURRENT 10.00E-03
If headers are off 10.00E-03
The constant current value has been set to 10 mA.

Error If the response message is longer than 300 bytes, a query error is generated.

:LEVel:CVOLTage

■ Sets the constant voltage value.

Syntax :LEVel:CVOLTage <data>

<data> Numerical data in NR3 format
3532-50: 0.010 to 5.000 (frequency 42 Hz to 1 MHz)
0.010 to 1.000 (frequency 1.001 MHz to 5 MHz)
3522-50: 0.010 to 5.000

Function
- Sets the value of the constant voltage.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

Example Transmission :LEVel:CVOLTage 1.234
The constant voltage value is set to 1.234 V.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:LEVel:CVOLTage?

■ Queries the constant voltage values.

Syntax :LEVel:CVOLTage?

Function Returns the constant voltage value as a numerical value in NR2 format.

Example Response
If headers are on :LEVEL:CVOLTAGE 1.234
If headers are off 1.234
The constant voltage level has been set to 1.234 V.

Error If the response message is longer than 300 bytes, a query error is generated.

:LEVel:VOLTage

■ Sets the open circuit voltage value.

Syntax :LEVel:VOLTage <data>

<data> Numerical data in NR3 format
3532-50: 0.010 to 5.000 (frequency 42 Hz to 1 MHz)
0.010 to 1.000 (frequency 1.001 MHz to 5 MHz)
3522-50: 0.010 to 5.000

Function
- Sets the open circuit voltage value.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

Example Transmission :LEVel:VOLTage 1.234
The open circuit voltage value is set to 1.234 V.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:LEVel:VOLTage?

■ Queries the open circuit voltage values.

Syntax :LEVel:VOLTage?

Function Returns the open circuit voltage value as a numerical value in NR2 format.

Example Response
If headers are on :LEVEL:VOLTAGE 1.234
If headers are off 1.234
The open circuit voltage level has been set to 1.234 V.

Error If the response message is longer than 300 bytes, a query error is generated.

:LIMiter

■ Enables and disables the limit value setting function.

Syntax :LIMiter <data>

<data> ON/OFF (character data)

Function Sets the limit value setting function to ON or OFF.

Example Transmission :LIMiter ON
The limit value setting function is enabled.

Error If <data> is other than character data described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:LIMiter?

■ Queries the limit value setting function enablement.

Syntax :LIMiter?

Function Returns the current setting of the limit value setting function enablement as character data.
ON,OFF

Example Response
If headers are on :LIMITER ON
If headers are off ON

Error If the response message is longer than 300 bytes, a query error is generated.

:LIMiter:CURRent

■ Sets the current limit value.

Syntax :LIMiter:CURRent <data>

<data> Numerical data in NR3 format from 0.01E-03 to 99.99E-03

Function
- Sets the current limit value.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

Example Transmission :LIMiter:CURRent 10.00E-03
The current limit value is set to 10 mA.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:LIMiter:CURRent?

■ Queries the current limit value.

Syntax :LIMiter:CURRent?

Function Returns the current limit value as a numerical value in NR3 format.

Example Response
If headers are on :LIMITER:CURRENT 10.00E-03
If headers are off 10.00E-03
The current limit value has been set to 10 mA.

Error If the response message is longer than 300 bytes, a query error is generated.

:LIMiter:VOLTage

■ Sets the voltage limit value.

Syntax :LIMiter:VOLTage <data>

<data> Numerical data in NR2 format
0.010 to 5.000

Function
- Sets the voltage limit value.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

Example Transmission :LIMiter:VOLTage 1.234
The voltage limit value is set to 1.234 V.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:LIMiter:VOLTage?

■ Queries the voltage limit value.

Syntax :LIMiter:VOLTage?

Function Returns the voltage limit value as a numerical value in NR2 format.

Example Response
If headers are on :LIMITER:VOLTAGE 1.234
If headers are off 1.234
The voltage limit value has been set to 1.234 V.

Error If the response message is longer than 300 bytes, a query error is generated.

:LOAD

■ Loads the test conditions of the specified panel number.

Syntax :LOAD <data>

<data> Numerical data in NR1 format
1 to 30

Function
- Sets the panel number which you wish to load.
- The numerical value can be in NRf format, but any digits after the decimal point will be rounded.

Example Transmission :LOAD 2
The test conditions which are saved in panel number 2 is loaded.

Error If <data> is other than numerical value described above, an execution error occurs.
If the panel number in which the settings have not been saved is selected, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:MEASure?

■ Queries measured data items.

Syntax :MEASure?

Function Returns the measured values of test data items as numerical values in NR2 and NR3 format.

1. During normal testing

Returns the measured value of the parameter that bits of MR0 (measurement register 0) and MR1 (measurement register 1) have been set to 1 in the following order; impedance (Z), admittance (Y), phase angle (PHASE), series capacitance (CS), parallel capacitance (CP), loss coefficient (D), series inductance (LS), parallel inductance (LP), Q factor (Q), series resistance (RS), conductance (G), parallel resistance (RP), reactance (X), and susceptance (B).

When powering on, the test parameters are initially set to impedance (Z) and phase angle (θ).

The contents of MR0 and MR1 are set with the :MEASure:ITEM command.

2. During comparator testing

Returns the measured values of the first and second parameters which have been set and the comparator result.

The result of the comparison is as follows.

Within limits or logical product limits	0
Above the upper limit or out of logical product limits	1
Below the lower limit	-1

The data is returned as shown below.

<logical product of comparison result>, <test value of the first parameter>, <comparison result of first parameter>, <test value of second parameter>, <comparison result of second parameter>

Sets the first parameter with the ":PARameter1" command, and sets the second parameter with the ":PARameter3" command. When the parameter is set to OFF, the data is not returned.

3. During scaling testing

The data is returned as shown below.
<test value of the first parameter>, <test value of second parameter>

Sets the first parameter with the ":PARameter1" command, and sets the second parameter with the ":PARameter3" command. When the parameter is set to OFF, the data is not returned.

Note The results of output when using the *WAI command differs from when not using, since the :MEASure? query is not sequential command.

If the test frequency is set to 1 kHz:

When the *WAI command is not used
Transmission :FREQuency 50;:MEASure?

The response message of this :MEASure? query is the measured value of frequency at 1 kHz.

When using the *WAI command
Transmission :FREQuency 50;*WAI;:MEASure?

The response message of this :MEASure? query is the measured value of frequency at 50 Hz.

Example 1. During normal testing

When querying the measured values for impedance (Z), phase angle (θ), parallel capacitance (Cp), loss coefficient (D):

Transmission :MEASure:ITEM 53,0;:MEASure?

Response

If headers are on Z 31.981E+03,PHASE -88.05,CP 4.9736E-09,D 0.03405
If headers are off 31.981E+03,-88.05,4.9736E-9,0.03405

2. During comparator testing

When comparator testing for impedance (Z) and phase angle (θ).

Transmission :PARameter1 Z;:PARameter3 PHASe
:COMParator ON
:MEASure?

Response

If headers are on 1,Z 31.981E+03,0,PHASE -88.05,-1
If headers are off 1,31.981E+03,0,-88.05,-1

The decision result of the first parameter is within limits, and that of the second parameter is below the lower limit.

3. During scaling testing

When comparator testing for impedance (Z) and phase angle (θ).

Transmission :PARameter1 Z;:PARameter3 PHASe
:SCALe ON
:MEASure?

Response

If headers are on Z 31.981E+03,0,PHASE -88.05
If headers are off 31.981E+03,0,-88.05

Error If the response message is longer than 300 bytes, a query error is generated. During comparator testing and scaling testing, if parameters both first and second are set to OFF, an execution error occurs.

Executing this command while the open or short circuit compensation is performed generates an execution error.

:MEASure:ITEM

■ Sets the test parameter for response of the :MEASure? query during normal testing.

Syntax :MEASure:ITEM <MR0>,<MR1>

<data> Numerical data in NR1 format from 0 to 255

Function
- Specifies the test parameters for response of the :MEASure? query during normal testing with bits.
- The items of two registers (MR0 and MR1) are as follows.

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Lp	Ls	D	Cp	Cs	θ	Y	Z

Measurement Register 0 (MR0)

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Unused	Unused	B	X	Rp	G	Rs	Q

Measurement Register 1 (MR1)

- When the power is turned on, the test parameter is set to impedance (Z) and phase angle (θ) that is; <MR0> is 5 and <MR1> is 0.
- The numerical value can be in NRf format, but any digits after the decimal point will be rounded.

Example Transmission :MEASure:ITEM 53,18
The test parameters for response are set to impedance (Z), phase angle (θ), equivalent parallel circuit capacitance (Cp), loss coefficient (D), series resistance (Rs), reactance (X).

Error If <data> is other than numerical value described above, an execution error occurs.

:MEASure:ITEM?

■ Queries the test parameter for response of the :MEASure? query during normal testing.

Syntax :MEASure:ITEM?

Function Returns the test parameter to response the :MEASure? query during normal testing as bits <MR0> and <MR1>.
The items of two registers (MR0 and MR1) are as follows.

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Lp	Ls	D	Cp	Cs	θ	Y	Z

Measurement Register 0 (MR0)

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Unused	Unused	B	X	Rp	G	Rs	Q

Measurement Register 1 (MR1)

Example Response
If headers are on :MEASURE:ITEM 53,18
If headers are off 53,18
The test parameters to response have been set to impedance (Z), phase angle (θ), parallel capacitance (Cp), loss coefficient (D), series resistance(Rs), reactance (X).

Error If the response message is longer than 300 bytes, a query error is generated.

:PARameter1 (2, 3, or 4)

■ Sets the displayed parameters.

Syntax :PARameter1 (2, 3, or 4) <data>

<data>

Z	Impedance
Y	Admittance
PHASe	Phase angle
CS	Series equivalent static capacitance
CP	Parallel equivalent static capacitance
D	Loss coefficient
LS	Series equivalent inductance
LP	Parallel equivalent inductance
Q	Q factor
RS	Series equivalent resistance
G	Conductance
RP	Parallel equivalent resistance
X	Reactance
B	Susceptance
OFF	

Function Sets the displayed parameters.

Example Transmission :PARameter1 Z;:PARameter3 PHASe
The first parameter is set to impedance, and the third parameter is set to phase angle.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:PARameter1 (2, 3, or 4)?

■ Queries the displayed parameters.

Syntax :PARameter1 (2, 3, or 4)?

Function Returns the displayed parameters as character data.

Z, Y, PHASE, CS, CP, D, LS, LP, Q, RS, G, RP, X, B, OFF

Example Response
If headers are on :PARAMETER2 PHASE
If headers are off PHASE
The second parameter has been set to phase angle.

Error If the response message is longer than 300 bytes, a query error occurs.

:PARameter1 (2, 3, or 4):DIGit

■ Sets the number of displayed digits for the test parameters.

Syntax :PARameter 1 (2, 3, or 4):DIGit <data>

<data> Numerical data in NR1 format
3 to 5

Function Sets the number of displayed digits for the first to fourth parameters.

Example Transmission :PARameter1:DIGit 4
The number of displayed digits for the first parameter is set to 4.

Note The response message for the ":MEASure?" query is always returned in 5 digits.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:PARameter1 (2, 3, or 4):DIGit?

■ Queries the number of displayed digits for the test parameters.

Syntax :PARameter1 (2, 3, or 4):DIGit?

Function Returns the number of displayed digits for the first to fourth parameters as numerical data in NR1 format

Example Response
If headers are on :PARAMETER1:DIGIT 4
If headers are off 4
The number of displayed digits for the first parameter has been set to 4.

Error If the response message is longer than 300 bytes, a query error occurs.

:RANGe

■ Sets the test range.

Syntax :RANGe <data>

<data> Numerical data in NR1 format
1 to 10

Function
- Sets the test range.
- The numerical value can be in NRf format, but any digits after the decimal point will be rounded.
- If this command is executed, the setting of the :RANGe:AUTO command is automatically changed to OFF.
- The numerical value corresponding to the test range and frequency which can be set is as follows.

●: settable / ---: cannot be set

Range number	Range (Ω)	to 100.0 kHz	100.1 kHz to 1.000 MHz	1.001 MHz to 5.000 MHz
1	0.1	●	●	●
2	1	●	●	●
3	10	●	●	●
4	100	●	●	●
5	1 k	●	●	●
6	10 k	●	●	●
7	100 k	●	●	●
8	1 M	●	●	---
9	10 M	●	---	---
10	100 M	●	---	---

For 3532-50 If the test frequency is greater than 100 kHz, the range number 9 (10 MΩ range) cannot be set. If the test frequency is greater than 1 MHz, the range number 8 (1 MΩ range) cannot be set.

Example Transmission :RANGe 5
The test range is set to 1 kΩ.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:RANGe?

■ Queries the test range.

Syntax :RANGe?

Function Returns the test range setting as numerical value in NR1 format.
The numerical value corresponding to the test range and frequency which can be set is as follows.

Range number	Range (Ω)
1	0.1
2	1
3	10
4	100
5	1 k
6	10 k
7	100 k
8	1 M
9	10 M
10	100 M

Example Response
If headers are on :RANGE 5
If headers are off 5
The test range has been set to range 5 (1 kΩ).

Error If the response message is longer than 300 bytes, a query error is generated.

:RANGe:AUTO

■ Enables and disables the auto-range function.

Syntax :RANGe:AUTO <data>

<data> ON/OFF (character data)

Function Switches between automatic and manual setting of test range.

ON	Switches the automatic setting.
OFF	Switches the manual setting.

Example Transmission :RANGe:AUTO ON

The test range is switched to automatic selection (auto-ranging).

Error If <data> is other than character data described above, an execution error occurs.

Executing this command while the open or short circuit compensation is performed generates an execution error.

:RANGe:AUTO?

■ Queries the autorange function enablement.

Syntax :RANGe:AUTO?

Function Returns whether the test range is automatically set as character data.

ON, OFF

Examples Response

If headers are on :RANGE:AUTO ON

If headers are off ON

Error If the response message is longer than 300 bytes, a query error is generated.

:SAVE

■ Saves the test conditions in specified panel number.

Syntax :SAVE <number>, <name>

<data> <number> Numerical data in NR1 format between 1 and 30
<name> Character data, up to 20 characters

Function
- Saves the test conditions in specified panel number with name to be saved.
- The numerical value can be in NRf format, but any digits after the decimal point will be rounded.
- The capital letters, numbers, and hyphen can be used.
- If 21 or more characters are entered, the first 20 characters are used.

Example Transmission :SAVE 3,TEST1
The test condition is saved as a name "TEST1" in panel number 3.

Error If <data> is other than numerical value and character data described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:SAVE?

■ Queries the panel number saved.

Syntax :SAVE? <data>

<data> Numerical data in NR1 format between 0 and 30

Function
- Returns 1 when the test conditions are saved in specified panel number, and returns 0 when not saved.
- The numerical value can be in NRf format, but any digits after the decimal point will be rounded.
- The response message has no headers.

Example Transmission :SAVE? 3
Response 1
The test condition is saved in panel number 3.

Error If <data> is other than numerical value and character data described above, an execution error occurs.

:SCALe

■ Enables and disables the scaling function.

Syntax :SCALe <data>

<data> ON/OFF

Function Enables and disables the scaling function.

Example Transmission :SCALe ON
Enables the scaling function.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:SCALe?

■ Queries the scaling function.

Syntax :SCALe?

Function Returns the setting of scaling function enablement as character data.
ON, OFF

Example Response
If headers are on :SCALE ON
If headers are off ON

Error If the response message is longer than 300 bytes, a query error occurs.

:SCALe:FVALue

■ Sets the first parameters (a and b) in the scaling function.

Syntax :SCALe:FVALue <a>, <b>

<data> Numerical data in NR3 format

Function
- Sets the first parameters (a and b values) in the scaling function.
- For calculation equation of the scaling function, see the Instruction Manual of main unit.

Example Transmission :SCALe:FVALue 2.0000E+00,1.0000E+00
Sets a value to 2.0000, and b value to 1.0000.

Error If <data> is other than numerical data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:SCALe:FVALue?

■ Queries the first parameters (a and b) in the scaling function.

Syntax :SCALe:FVALue?

Function Returns the setting of the first parameters (a and b values) in the scaling function as a numerical value in NR3 format.

Example Response
If headers are on :SCALE:FVALUE 2.0000E+00,1.0000E+00
If headers are off 2.0000E+00,1.0000E+00

Error If the response message is longer than 300 bytes, a query error occurs.

:SCALe:SVALue

■ Sets the second parameters (a and b) in the scaling function.

Syntax :SCALe:SVALue <a>, <b>

<data> Numerical data in NR3 format

Function
- Sets the second parameters (a and b values) in the scaling function.
- For calculation equation of the scaling function, see the Instruction Manual of main unit.

Example Transmission :SCALe:SVALue 2.0000E+00,1.0000E+00
Sets a value to 2.0000, and b value to 1.0000.

Error If <data> is other than numerical data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:SCALe:SVALue?

■ Queries the second parameters (a and b) in the scaling function.

Syntax :SCALe:SVALue?

Function Returns the setting of the second parameters (a and b values) in the scaling function as a numerical value in NR3 format.

Example Response
If headers are on :SCALE:SVALUE 2.0000E+00,1.0000E+00
If headers are off 2.0000E+00,1.0000E+00

Error If the response message is longer than 300 bytes, a query error occurs.

:SPEEd

■ Sets the testing speed.

Syntax :SPEEd <data>

<data> FAST/NORMal/SLOW/SLOW2 (character data)

Function Sets the testing speed.

Example Transmission :SPEEd NORMal

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:SPEEd?

■ Queries the testing speed.

Syntax :SPEEd?

Function Returns the setting of testing speed as character data.
FAST, NORMAL, SLOW, SLOW2

Example Response
If headers are on :SPEED NORMAL
If headers are off NORMAL

Error If the response message is longer than 300 bytes, a query error is generated.

:TRIGger

■ Sets the type of trigger.

Syntax :TRIGger <data>

<data> INTernal/EXTernal (character data)

Function Sets the type of trigger.
INTernal Internal trigger mode
EXTernal External trigger mode

Example Transmission :TRIGger INTernal
The trigger mode is set to internal trigger.

Error If <data> is other than character data described above, an execution error occurs. Executing this command while the open or short circuit compensation is performed generates an execution error.

:TRIGger?

■ Queries the trigger setting.

Syntax :TRIGger?

Function Returns the trigger setting as character data.
INTERNAL/EXTERNAL

Example Response
If headers are on :TRIGGER INTERNAL
If headers are off INTERNAL
The trigger mode has been set to internal triggering.

Error If the response message is longer than 300 bytes, a query error is generated.

:TRIGger:DELAy

■ Sets the trigger delay time.

Syntax :TRIGger:DELAy <data>

<data> Numerical data in NR2 format from 0.00 to 9.99.

Function
- Sets the trigger delay time.
- The numerical value can be in NRf format, but rounding is performed for figures beyond the last valid decimal place.

Example Transmission :TRIGger:DELAy 0.05
The trigger delay time is set to 50 ms.

Error If <data> is other than numerical value described above, an execution error occurs.
Executing this command while the open or short circuit compensation is performed generates an execution error.

:TRIGger:DELAy?

■ Queries the trigger delay time.

Syntax :TRIGger:DELAy?

Function Returns the current setting of trigger delay time as a numerical value in NR2 format from 0.00 to 9.99.

Example Response
If headers are on :TRIGGER:DELAY 0.05
If headers are off 0.05
The trigger delay time has been set to 50 ms.

Error If the response message is longer than 300 bytes, a query error is generated.

:User:IDENtity

■ Set the user ID.

Syntax :USER:IDENtity <data>

<data> For example: AB-9593

Function
- The user can set an identity code.
- The ID is backed up in the same way as the main unit settings.
- The capital and lowercase letters, digits 0 to 9, and hyphen can be used.
- If an ID of eight or more characters is entered, the first seven characters are used.
- The user ID is cleared by the system reset of the main unit.

Example Transmission :USER:IDEN AB-9593
This sets the user ID to "AB-9593"

Error If <data> is other than character data described above, a command error occurs.

:User:IDENtity?

■ Queries the user ID.

Syntax USER:IDENtity?

Function Returns a user ID as seven characters data <data>.

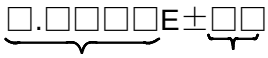
Example Response
If headers are on :USER:IDENTITY AB-9593
If headers are off AB-9593

Error
- If the response message is longer than 300 bytes, a query error is generated.

5.5 Response Format for Queries as Numerical Value

(1) Test value

1. The response formats for |Z| (impedance),|Y| (admittance), Cs (static capacitance in series equivalent circuit mode), Cp (static capacitance in parallel equivalent circuit mode), Ls (inductance in series equivalent circuit mode), Lp (inductance in parallel equivalent circuit mode), Rs (effective resistance in series equivalent circuit mode), G (conductance), Rp (effective resistance in parallel equivalent circuit mode), X (reactance), B (susceptance) are as follows. (in NR3 format)

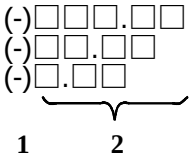


1 Mantissa	Five digits and decimal point
2 Exponent	Two digits

When the value is overflow or underflow, the following value is displayed.

Overflow	99999E+99
Underflow	-99999E+99

2. The response formats (in NR2 format) for θ (phase angle).



1 Sign	Only when the value is negative, minus (-) is prefixed.
2 Numerical	Up to the second decimal point

When the value is overflow or underflow, the following value is displayed.

Overflow	999.9
Underflow	-999.9

3. The response formats (in NR2 format) for D (loss coefficient)

□.□□□□□ Up to the fifth decimal point

When the value is overflow or underflow, the following value is displayed.

Overflow	999999
Underflow	-999999

4. The response formats (in NR2 format) for Q (Q factor)

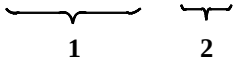
□.□□ Up to the second decimal point
□□.□□
□□□.□□

When the value is overflow or underflow, the following value is displayed.

Overflow	9999
Underflow	-9999

(2) Frequency response format (in NR3 format)

□.□□□E±□□
□□.□□E±□□
□□□.□E±□□



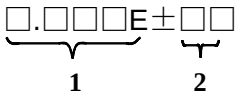
1 Mantissa Three or four digits and decimal point
2 Exponent Two digits

(3) Voltage response format (in NR2 format)

□.□□□

Four digits and decimal point

(4) Current response format (in NR3 format)



1 Mantissa Four digits and decimal point
2 Exponent Two digits

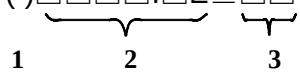
(5) Trigger delay response format (in NR2 format)

□.□□

Mantissa Three digits and decimal point

(6) Reference value (percentage value), upper and lower limit values (absolute value), scaling correction coefficient for comparator (in NR3 format)

(-)□.□□□□E±□□
(-)□□.□□□E±□□
(-)□□□.□□E±□□
(-)□□□□.□E±□□



1 Sign When the value is negative, minus (-) is prefixed.
2 Mantissa Five digits and decimal point
3 Exponent two digits

5.6 Initialization Items

The following table shows which items are initialized and which not, under various conditions.

Item \ Initialization method	Power on	*RST command	*CLS command
RS-232C Communication conditions *1	---	---	---
Device specific functions (ranges etc.)	---	●	---
Output queue	●	---	---
Input buffer	●	---	---
Event registers	● *2	---	●
Current path	●	---	---
Headers on/off	●	●	---
Measurement resister	●	●	---

*1 When the power is turned on, item is discriminated.
*2 Except the PON bit (bit 7).

Chapter 6
Sample Programs

The following sample programs are all written for the Microsoft Quick BASIC.
For more details on the Quick BASIC, refer to the Quick BASIC documentation.
All commands in the sample programs are used in the short form, and the communication condition setting switches of the 3532-50 or 3522-50 is taken as 00000010 (baud rate: 9600bps, data length: 8 bits, parity: non, stop bit: 1 bit, delimiter: CR).

(1) Open- and short-circuit compensation

Summary This program carries out open- and short-circuit compensation on the 3532-50or 3522-50.

Program List

```
10 OPEN "COM1:9600,N,8,1" FOR RANDOM AS #1
20 PRINT #1, ":HEAD OFF"
30 PRINT #1, "*CLS"
40 CORR.OPEN:
50 INPUT "Prepare unit for open circuit compensation, then press Enter", A$
60 PRINT "Collecting open circuit compensation data"
70 PRINT #1, ":CORR:OPEN ALL"
80 OPEN.LOOP:
90 PRINT #1, ":ESR0?"
100 INPUT #1, A
110 IF (A AND 1) = 0 THEN GOTO OPEN.LOOP
120 PRINT #1, "*ESR?"
130 INPUT #1, A
140 IF (A AND 8) = 0 THEN GOTO CORR.SHORT
150 PRINT "Open circuit compensation failed"
160 GOTO CORR.OPEN
170 CORR.SHORT:
180 INPUT "Prepare unit for short circuit compensation, then press Enter", A$
190 PRINT "Collecting short circuit compensation data"
200 PRINT #1, ":CORR:SHOR ALL"
210 SHORT.LOOP:
220 PRINT #1, ":ESR0?"
230 INPUT #1, A
240 IF (A AND 1) = 0 THEN GOTO SHORT.LOOP
250 PRINT #1, "*ESR?"
260 INPUT #1, A
270 IF (A AND 8) = 0 THEN GOTO CORR.END
```

```
280 PRINT "Short circuit compensation failed"
290 GOTO CORR.SHORT
300 CORR.END:
310 PRINT "Compensation operations completed"
320 CLOSE
330 END
```

Program comments

Line	Comments
10	Open the RS-232C circuit file.
20	Switch off headers for the response message.
30	Clear bits of each event registers.
70	Execute open circuit compensation (at all the test frequencies).
90-110	Wait until the bit for the compensation completed is 1.
120-140	When the valid data cannot be obtained, the bit 3 of SESR is 1.
320	Close the RS-232C circuit file.

(2) Basic settings and testing

Summary

This program selects the test conditions for measurement on the 3532-50or 3522-50.

・It carries out a single test measurement, and displays the result on the screen.

・It also displays the monitored voltage and current values on the screen.

Program List

```
10 OPEN "COM1:9600,N,8,1" FOR RANDOM AS #1
20 PRINT #1,":TRIG EXT"
30 PRINT #1,":AVER 8"
40 PRINT #1,":FREQ 1.234E3"
50 PRINT #1,":RANG:AUTO ON"
60 PRINT #1,":LEV V"
70 PRINT #1,":LEV:VOLT 1.00"
80 PRINT #1,":TRIG:DELA 0.02"
90 PRINT #1,":SPEE SLOW"
100 PRINT #1,":MEAS:ITEM 5,18"
110 PRINT #1,"*TRG;:MEAS?"
120 LINE INPUT #1,A$
130 PRINT #1,":DISP:MONI?"
140 LINE INPUT #1,B$
150 PRINT A$
160 PRINT B$
170 CLOSE
180 END
```

Program comments

Line	Comments
10	Open the RS-232C circuit file.
20	Select external trigger mode.
30	Set the count for averaging to 8.
40	Set the test frequency to 1.234 kHz.
50	Enable auto-ranging.
60	Select voltage measurement.
70	Set the test voltage to 1 V.
80	Set the trigger delay time to 20 ms.
90	Set the testing speed to SLOW.
100	Make a setting for Z (impedance), θ (phase angle), Rs (series equivalent resistance), X (reactance) to return.
110	Query the sampling data and measurement value.
130	Query the monitored value for the test signal.
150-160	Display the test results.
170	Close the RS-232C circuit file.

(3) Saving the 3532-50 settings using the panel save function

Summary This program makes the settings for the 3532-50 and saves the settings to the panel number 1 as "TEST1".

Program List

```
10 OPEN "COM1:9600,N,8,1" FOR RANDOM AS #1
20 PRINT #1,":FREQ 100E3"
30 PRINT #1,":LEV V"
40 PRINT #1,":LEV:VOLT 1.00;CVOLT 0.50;CCURR 5.00E-3"
50 PRINT #1,":LIM OFF"
60 PRINT #1,":LIM:CURR 15.00E-3;VOLT 3.00"
70 PRINT #1,":RANG:AUTO ON"
80 PRINT #1,":TRIG INT"
90 PRINT #1,":TRIG:DELA 0.02"
100 PRINT #1,":AVER 2"
110 PRINT #1,":SPEE SLOW"
120 PRINT #1,":BEEP:KEY ON;COMP NG"
130 PRINT #1,":PAR1 Z;:PAR2 PHAS"
140 PRINT #1,":PAR3 CP;:PAR4 D"
150 PRINT #1,":SAVE 1,TEST1"
160 CLOSE
170 END
```

Program comments

Line	Comments
10	Open the RS-232C circuit file.
20	Set the test frequency to 100 kHz.
30	Select the voltage test signal level.
40	Make the following settings using the current path. V(open circuit voltage): 1 V CV(constant voltage): 0.5 V (value setting only) CC(constant current): 5 mA (value setting only)
50	Set the limit value setting function to OFF
60	Set the current limit value to 15 mA (value setting only). Set the voltage limit value to 3 V (value setting only).
70	Enable auto-ranging.
80	Select internal trigger mode.
90	Set the trigger delay time to 20 ms.
100	Set the count for averaging to 2.
110	Set the testing speed to SLOW.
120	Set the beep sound.
130-140	Set displayed parameters.
150	Save the settings to the panel number 1.
160	Close the RS-232C circuit file.

(4) Carrying out comparator testing

Summary This program first makes the comparator settings.

At the end of testing, it displays the numbers of the samples which were outside the comparator limit.

Sample nos. decided HI for CP:2 5
Sample nos. decided LOW for CP:

All measured results

Sample number: 1	3.8686E-04	.34823
Sample number: 2	3.8704E-04	.34823
Sample number: 3	3.8681E-04	.34843
Sample number: 4	3.8694E-04	.34804
Sample number: 5	3.8698E-04	.34823

Program List

```
10 OPEN "COM1:9600,N,8,1" FOR RANDOM AS #1
20 PRINT #1, ":PAR1 CP;:PAR3 D"
30 PRINT #1, ":TRIG EXT"
40 PRINT #1, ":HEAD OFF"
50 PRINT #1, ":FREQ 1.234E3"
60 PRINT #1, ":RANG:AUTO ON"
70 PRINT #1, ":LEV CV;:LEV:CVOLT 1.00"
80 PRINT #1, ":COMP:FLIM:MODE ABS;ABS 386.80E-6,386.95E-6"
90 PRINT #1, ":COMP:SLIM:MODE PER;PER 1.0000,OFF,OFF"
100 NUM.SET:
110 INPUT "Number of samples to measure:"; X
120 IF X <= 0 THEN GOTO NUM.SET
130 OPTION BASE 1
140 DIM F.ALL(X), CP(X), F.CP(X), D(X), F.D(X)
150 PRINT #1, ":COMP ON"
160 INPUT "Prepare sample, then press Enter", A$
170 CLS
180 I = 1
190 MEAS.LOOP:
200 PRINT #1, "*TRG;:MEAS?"
210 INPUT #1, F.ALL(I), CP(I), F.CP(I), D(I), F.D(I)
220 I = I + 1
230 IF I > X THEN GOTO MEAS.END
240 CLS
250 PRINT "Prepare sample number ";I;
260 INPUT ", then press Enter", A$
270 GOTO MEAS.LOOP
280 MEAS.END:
290 PRINT #1, ":COMP OFF"
300 CLS
310 PRINT "Sample nos. decided HI for CP:";
320 FOR I = 1 TO X
330     IF F.CP(I) = 1 THEN PRINT I;
340 NEXT I
350 PRINT
360 PRINT "Sample nos. decided LOW for CP:";
370 FOR I = 1 TO X
380     IF F.CP(I) = -1 THEN PRINT I;
390 NEXT I
400 PRINT
```

```
410 PRINT
420 PRINT "All measured results"
430 FOR I = 1 TO X
440     PRINT "Sample number"; I, CP(I), D(I)
450 NEXT I
460 CLOSE
470 END
```

Program comments

Line	Comments
10	Open the RS-232C circuit file.
20	Set the first parameter to Cp,and the second parameter to D.
30	Select external trigger mode.
40	Switch off headers for the response message.
50	Set the test frequency to 1.234 kHz.
60	Enable auto-ranging.
70	Set the constant voltage to 1 V.
80	Set the first parameter for the comparator function as absolute value (the current path is used in this settings).
90	Set the second parameter for the comparator function as percentage value.Since both settings of lower and upper limits are OFF,the comparator result is always IN (within limits). Input appropriate reference value (the current path is also used in this settings).
130-140	Initialize variables.
150	Switch on the comparator function.
190-280	Measurement loop Returns data as total result, measurement value of CP, CP decision, measurement value of D, D decision in order.
290	Switch off the comparator function.
310-340	Check HI decision for CP.
360-390	Check LOW decision for CP.
460	Close the RS-232C circuit file.

(5) Frequency characteristics measurement for impedance

Summary

This program measures the impedance frequency characteristics at various frequencies.

It outputs the test result to a file.

The number of test point: 34
50/ 60/ 80 Hz
100/ 120/ 150/ 200/ 250/ 300/ 400/ 500/ 600/ 800 Hz
1/ 1.2/ 1.5/ 2/ 2.5/ 3/ 4/ 5/ 6/ 8 kHz
10/ 12/ 15/ 20/ 25/ 30/ 40/ 50/ 60/ 80/ 100 kHz

Program List

```
10 OPEN "COM1:9600,N,8,1" FOR RANDOM AS #1
20 PRINT #1, ":COMP OFF;:TRIG EXT"
30 PRINT #1, ":LEV V;:LEV:VOLT 1.00"
40 PRINT #1, ":MEAS:ITEM 1,0"
50 PRINT #1, ":HEAD OFF"
60 OPTION BASE 1
70 PNT = 34
80 DIM TABLE(10), F(PNT), Z(PNT)
90 RESTORE F.DATA
100 F.DATA:
110 DATA 1,1.2,1.5,2,2.5,3,4,5,6,8
120 FOR I = 1 TO 10
130     READ TABLE(I)
140 NEXT I
150 EX = 10: T = 8
160 FOR I = 1 TO PNT
170     F(I) = EX * TABLE(T)
180     PRINT #1, ":FREQ " + STR$(F(I))
190     PRINT #1, "*TRG;:MEAS?"
200     INPUT #1, Z(I)
210     PRINT F(I), Z(I)
220     IF T = 10 THEN T = 1: EX = EX * 10 ELSE T = T + 1
230 NEXT I
240 GOSUB SAVE.DATA:
250 CLS
260 CLOSE
270 END
280 SAVE.DATA:
290 INPUT "Input the file name to be saved.", F.NAME$
300 OPEN F.NAME$ FOR OUTPUT AS #2
310 FOR I = 1 TO PNT
320     PRINT #2, F(I); ","; Z(I)
330 NEXT I
340 CLOSE #2
350 RETURN
```

Program comments

Line	Comments
10	Open the RS-232C circuit file.
20	Switch off the comparator function, and select external trigger mode.
30	Set the measured voltage to 1V.
40	Make a settings to response the parameter for Z by using the :MEAS? query.
90-140	Set frequency mantissa table.
150	Measure from EX*TABLE(T=8) = 50 (Hz)
160-230	Measurement loop
170-180	Transmit character data by transforming the numerical values.
190	Query the sampling data and measurement value.
220	Change the frequency value to the new one.
240	Save the test frequency and test results to the file.
280-350	Routines to save the measurement value to the file.

Chapter 7
Troubleshooting

If the RS-232C appears to be malfunctioning, refer to the information below before calling for servicing.

Symptom	Cause / Treatment
The RS-232C has stopped working completely.	Are the cables properly connected?
	Are all the devices powered on?
	Has the communication condition been correctly set?
Transmission on the RS-232C is not taking place properly.	Is the controller delimiter set correctly? (Refer to Section 4.5, "Delimiter".)
When attempting to read data using a BASIC INPUT statement, the RS-232C bus hangs.	Be sure to transmit one query before each INPUT statement.
	Have any of these transmitted queries resulted in as error?
Although a command has been transmitted, nothing has happened.	Using the "*ESR?" query, inspect the standard event status register, and check what type of error has occurred.
	Using the "ERRor?" query, and check whether transmission error occurred on the RS-232C.
The amount of data read in is insufficient.	If the data includes one or more commas, then try using a LINE INPUT statement.
Sending several queries, produces only one response.	Has an error occurred?
	Send the queries one at a time, and read the responses individually. When you want to read them in all at once, try doing so by putting them all on one line separated by the message separator character.

Symptom	Cause / Treatment
Although a response has been read in, the data does not appear.	Have the response messages from 3532-50･3522-50 exceeded the buffer capacity of the computer?
	Try dividing up their reading in, by increasing the number of variables of the INPUT statement.
The response message to a query differs from the display on the front panel of the 3532-50･3522-50.	Due to the response message being produced at the instant that the 3532-50･3522-50 receives the query, there is a possibility that it may not agree with the display at the instant that the controller reads it in.
Beeper sounds when *TRG command is transferred.	Is the trigger is set to internal trigger?
	*TRG command can be used for the external trigger setting. For the internal trigger setting, an execution error occurs.

Service

If damage is suspected, check the "Troubleshooting" section before contacting your dealer or Hioki representative.

Index

- A -

Abbreviating messages with compound headers 17
Attention during use 3

- B -

Baud rate 11

- C -

Character data 15
Command errors 19
Command messages 12
Command reference 21
Communication conditions set switch 11
Comparator result logical product 20
Compound headers 14
Connector cable 6

- D -

Data length 11
Data portion 13
Data separators 16
Decimal data 15
Delimiters 16
Device dependent error 19

- E -

Event register 19
Event status register 19, 26
Event status register 0 ..... 20, 51
Event status register 1 ..... 20, 52

- H -

Hand shake 6, 8
Header portion 14
Header separators 16

- I -

Initialization items 84
Input buffer 18

- L -

Long form 13

- M -

Message 12
Message format 13
Message unit separators 16

- N -

NR1 format 15
NR2 format 15
NR3 format 15
NRf format 15
Names of the parts 9

- O -

Output queue 18

- P -

Parity 6, 11
Particular command 21
Power turn-on flag 19
Program message headers 14
Program messages 12

- Q -

Query error 19

- R -

RS-232C connector 6
Response message 12

- S -

Sample programs 85
Separators 16
Shipping 2
Short form 13
Simple type headers 14
Specification 6
Standard event status registers 19, 26
Stop bits 6, 11

- T -

Troubleshooting 91

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KEITHLEY

Model 6514 System Electrometer
Instruction Manual

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Instruction Manual

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting

cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The symbol indicates a connection terminal to the equipment frame.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Table of Contents

1 Getting Started

General information 1-2
- Warranty information 1-2
- Contact information 1-2
- Safety symbols and terms 1-2
- Inspection 1-2
- Options and accessories 1-3

System electrometer features 1-4
Front and rear panel familiarization 1-5
- Front panel summary 1-5
- Rear panel summary 1-8

Power-up 1-10
- Line power connection 1-10
- Line frequency selection 1-10
- Power-up sequence 1-11

Display 1-12
- Status and error messages 1-12

Default settings 1-12
SCPI programming 1-15

2 Measurement Concepts

Measurement overview 2-2
Performance considerations 2-2
- Warm-up period 2-2
- Autozero 2-2

Connection fundamentals 2-3
- Input connector 2-3
- Low noise input cables 2-5
- Basic connections to DUT 2-6
- Test fixture 2-9
- Input protection 2-11
- Floating measurements 2-11

Zero check and zero correct 2-13
- Zero check 2-13
- Zero correct 2-14
- SCPI programming — zero check and zero correct 2-15

Input bias current and offset voltage calibration 2-17
- Front panel 2-17
- SCPI programming 2-18

Measurement considerations 2-19

3 Volts and Ohms Measurements

Measurement overview 3-2
Guarding 3-2
Test circuit leakage 3-2
Input cable leakage and capacitance 3-3
Volts and ohms measurement procedure 3-4
V-Drop and I-Source for ohms 3-6
SCPI programming 3-7
Programming example 3-8
Volts and ohms measurement considerations 3-9
Loading effects 3-9
Cable leakage resistance 3-9
Input capacitance (settling time) 3-10
Guarding input cable 3-12
Application 3-14
Capacitor dielectric absorption 3-14

4 Amps Measurements

Measurement overview 4-2
Amps measurement procedure 4-2
Damping 4-4
High impedance measurement techniques 4-5
SCPI programming 4-8
Programming example 4-9
Amps measurement considerations 4-9
Input bias current 4-9
Voltage burden 4-9
Noise 4-10
Applications 4-13
Diode leakage current 4-13
Capacitor leakage current 4-14
Cable insulation resistance 4-14
Surface insulation resistance (SIR) 4-15

5 Coulombs Measurements

Measurement overview 5-2
Auto discharge 5-2
Coulombs measurement procedure 5-3
SCPI programming 5-5
Programming example 5-6
Coulombs measurement considerations 5-6
Input bias current 5-6
External voltage source 5-6
Zero check hop and auto discharge hop 5-7
Application 5-7
Capacitance measurements 5-7

6 Range, Units, Digits, Rate, and Filters

Range, units, and digits 6-2
Range 6-2
Units 6-4
Digits 6-4
SCPI programming - range and digits 6-4
Rate 6-6
SCPI programming — rate 6-7
Filters 6-8
Median filter 6-8
Digital filter 6-9
SCPI programming — filters 6-10

7 Relative, mX+b and Percent (%)

Relative 7-2
Setting and controlling relative 7-2
SCPI programming — relative 7-3
mX+b and percent (%) 7-4
mX+b 7-4
Percent (%) 7-5
SCPI programming — mX+b and percent 7-6

8 Buffer

Buffer operations 8-2
Store 8-2
Recall 8-2
Buffer statistics 8-3
SCPI programming 8-4
Programming example 8-6

9 Triggering

Trigger models 9-2
Idle and initiate 9-4
Trigger model operation 9-4
Trigger model configuration — front panel 9-7
SCPI programming 9-9
Programming example 9-10
External triggering 9-11
Input trigger requirements 9-11
Output trigger specifications 9-12
External trigger example 9-12

10 Limit Tests

Limit testing 10-2
Binning 10-4
- Component handler interface 10-6
- Component handler types 10-7
- Digital output clear pattern 10-8

Front panel operation 10-10
- Limit test configuration 10-10
- Perform limit tests 10-11

SCPI programming 10-12
- Programming example 10-15

11 Digital I/O, Analog Outputs, and External Feedback

Digital I/O port 11-2
- Sink mode — controlling external devices 11-3
- Source mode — logic control 11-5
- Setting digital output lines 11-5
- SCPI programming — digital output pattern 11-6

Analog outputs 11-7
- 2V analog output 11-7

External feedback 11-11
- Electrometer input circuitry 11-11
- Shielded fixture construction 11-12
- Non-standard coulombs ranges 11-13
- External feedback procedure 11-13
- Logarithmic currents 11-15
- Non-decade current gains 11-16
- SCPI programming — external feedback 11-17

12 Remote Operation

Selecting and configuring an interface 12-2
- Interfaces 12-2
- Languages 12-2
- Interface selection and configuration procedures 12-2

GPIB operation and reference 12-5
- GPIB bus standards 12-5
- GPIB bus connections 12-5
- Primary address selection 12-7
- General bus commands 12-8
- Front panel GPIB operation 12-10
- Programming syntax 12-11

RS-232 interface reference 12-17
- Sending and receiving data 12-17
- RS-232 settings 12-17
- RS-232 connections 12-18
- Error messages 12-19

13 Status Structure

Overview 13-2
Clearing registers and queues 13-4
Programming and reading registers 13-5
- Programming enable registers 13-5
- Reading registers 13-6

Status byte and service request (SRQ) 13-7
- Status byte register 13-7
- Service request enable register 13-8
- Serial polling and SRQ 13-9
- Status byte and service request commands 13-9

Status register sets 13-11
- Register bit descriptions 13-11
- Condition registers 13-15
- Event registers 13-16
- Event enable registers 13-17

Queues 13-18
- Output queue 13-18
- Error queue 13-19

14 Common Commands

15 SCPI Signal Oriented Measurement Commands

16 DISPlay, FORMat, and SYSTem

DISPlay subsystem 16-2
FORMat subsystem 16-4
SYSTem subsystem 16-8

17 SCPI Reference Tables

General notes 17-2

18 Performance Verification

Introduction 18-2
Verification test requirements 18-3
- Environmental conditions 18-3
- Warm-up period 18-3
- Line power 18-3

Recommended test equipment 18-4
Verification limits 18-6
- Example reading limits calculation 18-6
- Recalculating resistance reading limits 18-6

Calibrator voltage calculations 18-7
- Current calculations 18-7
- Charge calculations 18-7

Performing the verification test procedures 18-8
Test summary 18-8
Test considerations 18-8
Restoring factory defaults 18-9
Input bias current and offset voltage calibration 18-9
Offset voltage calibration 18-9
Input bias current calibration 18-9
Volts measurement accuracy 18-10
Amps measurement accuracy 18-12
20µA-20mA range accuracy 18-12
20pA-2µA range accuracy 18-13
Ohms measurement accuracy 18-15
2kΩ-20MΩ range accuracy 18-15
200MΩ-200GΩ range accuracy 18-17
Coulombs measurement accuracy 18-18

19 Calibration

Introduction 19-2
Environmental conditions 19-2
Temperature and relative humidity..... 19-2
Warm-up period 19-2
Line power 19-2
Calibration considerations 19-3
Calibration cycle 19-3
Recommended calibration equipment 19-3
Calibration errors 19-5
Calibration menu 19-5
Aborting calibration 19-5
Current and charge calculations 19-6
Manual calculations..... 19-6
Automatic calculations 19-6
Calibration procedure 19-7
Preparing for calibration 19-7
Input bias current and offset voltage calibration 19-7
Volts calibration 19-8
Amps calibration 19-10
Coulombs calibration 19-14
Ohms calibration 19-16
Entering calibration dates and saving calibration 19-18
Locking out calibration 19-18
Changing the calibration code 19-18
Resetting the calibration code 19-19
Displaying calibration dates 19-19
Displaying the calibration count 19-20

20 Routine Maintenance

Introduction 20-2
Setting line voltage and replacing line fuse 20-2
- Front panel tests 20-4
- DISP test 20-4
- KEY test 20-4

A Specifications

B Status and Error Messages

C General Measurement Considerations

Measurement considerations C-2
- Ground loops C-2
- Triboelectric effects C-3
- Piezoelectric and stored charge effects C-3
- Electrochemical effects C-4
- Humidity C-4
- Light C-4
- Electrostatic interference C-4
- Magnetic fields C-5
- Electromagnetic Interference (EMI) C-5

D DDC Emulation Commands

DDC language D-2

E Example Programs

Programming examples E-2
- Changing function and range E-2
- One-shot triggering E-3
- Generating SRQ on buffer full E-4
- Storing readings in buffer E-5
- Taking readings using the :READ? command E-6
- Controlling the Model 6514 via the RS-232 COM2 port ... E-7

F IEEE-488 Bus Overview

Introduction F-2
Bus description F-3
Bus lines F-5
- Data lines F-5
- Bus management lines F-5
- Handshake lines F-6

Bus commands F-7
- Uniline commands F-8
- Universal multiline commands F-8
- Addressed multiline commands F-9
- Address commands F-9
- Unaddress commands F-9
- Common commands F-10
- SCPI commands F-10
- Command codes F-10
- Typical command sequences F-11
- IEEE command groups F-12

Interface function codes F-13

G IEEE-488 and SCPI Conformance Information

Introduction G-2

H Calibration Options

Introduction H-2
Reading calibration standard values H-2
- Data transfer connections H-2
- Reading values H-2
- Example program H-3

Remote calibration H-4
- Calibration commands H-4
- Remote calibration overview H-4

List of Illustrations

1 Getting Started

Figure 1-1 Model 6514 front panel 1-5
Figure 1-2 Model 6514 rear panel 1-8

2 Measurement Concepts

Figure 2-1 Input connector configurations 2-4
Figure 2-2 Maximum input levels 2-5
Figure 2-3 Basic connections for unguarded measurements 2-6
Figure 2-4 Shielding for unguarded measurements 2-7
Figure 2-5 Basic connections for guarded measurements 2-8
Figure 2-6 General purpose test fixture 2-9
Figure 2-7 Capacitor test circuit without protection 2-11
Figure 2-8 Capacitor test circuit with protection 2-11
Figure 2-9 Floating measurements 2-12
Figure 2-10 Equivalent input impedance with zero check enabled 2-14

3 Volts and Ohms Measurements

Figure 3-1 High-impedance voltage measurements 3-3
Figure 3-2 Connections for unguarded volts and ohms 3-5
Figure 3-3 Connections for guarded volts and ohms 3-6
Figure 3-4 Meter loading 3-9
Figure 3-5 Effects of input capacitance 3-11
Figure 3-6 Settling time 3-12
Figure 3-7 Unguarded input cable 3-12
Figure 3-8 Guarded input cable 3-13
Figure 3-9 Measuring dielectric absorption 3-15

4 Amps Measurements

Figure 4-1 Connections for amps 4-4
Figure 4-2 High impedance current measurements 4-5
Figure 4-3 Floating current measurements 4-7
Figure 4-4 Voltage burden considerations 4-10
Figure 4-5 Source resistance and capacitance 4-11
Figure 4-6 Connections; diode leakage current test 4-13
Figure 4-7 Connections; capacitor leakage current test 4-14
Figure 4-8 Connections; cable insulation resistance test 4-14
Figure 4-9 Connections; surface insulation resistance test 4-15

5 Coulombs Measurements

Figure 5-1 Typical connections for coulombs 5-4
Figure 5-2 Measuring capacitors 5-7

6 Range, Units, Digits, Rate, and Filters

Figure 6-1 Speed vs. noise characteristics 6-6
Figure 6-2 Digital filter types; moving and repeating 6-9

8 Buffer

Figure 8-1 Buffer locations 8-3

9 Triggering

Figure 9-1 Trigger model — front panel operation 9-2
Figure 9-2 Trigger model — remote operation 9-3
Figure 9-3 Measure action block of trigger model 9-6
Figure 9-4 Trigger link connection operation 9-11
Figure 9-5 Trigger link input pulse specifications 9-11
Figure 9-6 Trigger link output pulse specifications 9-12
Figure 9-7 DUT test system 9-12
Figure 9-8 Trigger link connections 9-13
Figure 9-9 Operation model for triggering example 9-14

10 Limit Tests

Figure 10-1 Limit tests 10-2
Figure 10-2 Limit tests example 10-2
Figure 10-3 Operation model for limit test 10-3
Figure 10-4 Binning system 10-4
Figure 10-5 Operation model for limit testing with binning 10-5
Figure 10-6 Handler interface connections 10-6
Figure 10-7 Digital output auto-clear timing example 10-9

11 Digital I/O, Analog Outputs, and External Feedback

Figure 11-1 Digital I/O port 11-2
Figure 11-2 Digital I/O port simplified schematic 11-3
Figure 11-3 Controlling externally powered relays 11-4
Figure 11-4 NAND gate control 11-5
Figure 11-5 Typical 2V analog output connections 11-8
Figure 11-6 Typical preamp out connections 11-9
Figure 11-7 Electrometer input circuitry (external feedback mode) 11-12
Figure 11-8 Shielded fixture construction 11-14
Figure 11-9 “Transdiode” logarithmic current configuration 11-15
Figure 11-10 Non-decade current gains 11-16

12 Remote Operation

Figure 12-1 IEEE-488 connector 12-5
Figure 12-2 IEEE-488 connections 12-6
Figure 12-3 IEEE-488 connector location 12-7
Figure 12-4 RS-232 interface connector 12-18

13 Status Structure

Figure 13-1 6514 status mode structure 13-3
Figure 13-2 16-bit status register 13-6
Figure 13-3 Status byte and service request 13-7
Figure 13-4 Standard event status 13-12
Figure 13-5 Operation event status 13-13
Figure 13-6 Measurement event status 13-14
Figure 13-7 Questionable event status 13-15

16 DISPlay, FORMat, and SYSTem

Figure 16-1 ASCII data format 16-5
Figure 16-2 IEEE-754 single precision data format (32 data bits) 16-5
Figure 16-3 Key-press codes 16-10

18 Performance Verification

Figure 18-1 Connections for volts verification 18-10
Figure 18-2 Connections for 20µA-20mA range verification 18-12
Figure 18-3 Connections for 20pA-20µA range verification 18-13
Figure 18-4 Connections for ohms verification (2kΩ-20MΩ ranges) ... 18-15
Figure 18-5 Connections for ohms verification (200MΩ-200GΩ ranges) 18-17
Figure 18-6 Connections for coulombs verification 18-18

19 Calibration

Figure 19-1 Connections for volts calibration 19-8
Figure 19-2 Connections for 20µA-20mA range calibration 19-10
Figure 19-3 Connections for 20pA-2mA range calibration 19-11
Figure 19-4 Connections for coulombs calibration 19-14
Figure 19-5 Connections for ohms calibration (2kΩ and 2MΩ ranges) 19-16
Figure 19-6 Connections for ohms calibration (2GΩ range) 19-17

20 Routine Maintenance

Figure 20-1 Power module 20-3

C General Measurement Considerations

Figure C-1 Power line ground loops C-2
Figure C-2 Eliminating ground loops C-3

F IEEE-488 Bus Overview

Figure F-1 IEEE-488 bus configuration F-4
Figure F-2 IEEE-488 handshake sequence F-6
Figure F-3 Command codes F-8

H Calibration Options

Figure H-1 Data transfer connections H-2

List of Tables

1 Getting Started

Table 1-1 SCPI commands - line frequency 1-10
Table 1-2 Default settings 1-13

2 Measurement Concepts

Table 2-1 Basic measurement capabilities 2-2
Table 2-2 SCPI commands — autozero 2-3
Table 2-3 Display messages for zero check and zero correct 2-13
Table 2-4 SCPI commands — zero check and zero correct 2-15
Table 2-5 SCPI commands — input bias current and offset voltage calibration 2-18
Table 2-6 Summary of measurement considerations 2-19

3 Volts and Ohms Measurements

Table 3-1 SCPI commands — volts and ohms function 3-7

4 Amps Measurements

Table 4-1 SCPI commands — amps function 4-8
Table 4-2 Minimum recommended source resistance values 4-11

5 Coulombs Measurements

Table 5-1 SCPI commands — coulombs function 5-5

6 Range, Units, Digits, Rate, and Filters

Table 6-1 Measurement ranges 6-2
Table 6-2 SCPI commands — range and digits 6-4
Table 6-3 SCPI commands — rate 6-7
Table 6-4 SCPI commands — filters 6-10

7 Relative, mX+b and Percent (%)

Table 7-1 Range symbols for rel values 7-3
Table 7-2 SCPI commands — relative (null) 7-3
Table 7-3 SCPI commands — mX+b and percent 7-6

8 Buffer

Table 8-1 SCPI commands — buffer 8-4

9 Triggering

Table 9-1 Auto delay settings 9-6
Table 9-2 SCPI commands — triggering 9-9

10 Limit Tests

Table 10-1 Test limit display messages 10-3
Table 10-2 SCPI commands — limit tests 10-12

11 Digital I/O, Analog Outputs, and External Feedback

Table 11-1 SCPI commands — digital outputs 11-6
Table 11-2 Example 2V analog output values 11-7
Table 11-3 Full-range preamp out values 11-10
Table 11-4 SCPI commands — external feedback 11-17

12 Remote Operation

Table 12-1 General bus commands 12-8
Table 12-2 PC serial port pinout 12-19
Table 12-3 RS-232 connector pinout 12-19

13 Status Structure

Table 13-1 Common and SCPI commands — reset registers and clear queues 13-4
Table 13-2 SCPI command — data formats for reading status registers 13-6
Table 13-3 Common commands — status byte and service request enable registers 13-9
Table 13-4 Common and SCPI commands — condition registers 13-16
Table 13-5 Common and SCPI commands — event registers 13-16
Table 13-6 Common and SCPI commands — event enable registers 13-17
Table 13-7 SCPI commands — error queue 13-20

14 Common Commands

Table 14-1 IEEE-488.2 common commands and queries 14-2

15 SCPI Signal Oriented Measurement Commands

Table 15-1 Signal oriented measurement command summary 15-2

16 DISPlay, FORMat, and SYSTem

Table 16-1 SCPI commands — display 16-2
Table 16-2 SCPI commands — data format 16-4
Table 16-3 SCPI commands — system 16-8

17 SCPI Reference Tables

Table 17-1 CALCulate command summary 17-2
Table 17-2 FORMat command summary 17-5
Table 17-3 DISPlay command summary 17-5
Table 17-4 SENSe command summary 17-6
Table 17-5 STATus command summary 17-9
Table 17-6 SOURce command summary 17-9
Table 17-7 SYSTem command summary 17-11
Table 17-8 TRACe command summary 17-12
Table 17-9 TRIGger command summary 17-13

18 Performance Verification

Table 18-1 Recommended verification equipment 18-4
Table 18-2 Voltage measurement accuracy reading limits 18-11
Table 18-3 20mA-20mA range current measurement accuracy reading limits 18-13
Table 18-4 20pA-2µA range current measurement accuracy reading limits 18-14
Table 18-5 2kΩ-20MΩ range resistance measurement accuracy limits 18-16
Table 18-6 200MΩ-200GΩ resistance measurement accuracy limits 18-17
Table 18-7 Coulombs measurement accuracy reading limits 18-19

19 Calibration

Table 19-1 Recommended calibration equipment 19-4
Table 19-2 Calibration menu 19-5
Table 19-3 Volts calibration summary 19-9
Table 19-4 20mA-20mA range amps calibration summary 19-11
Table 19-5 20pA-2µA range amps calibration summary 19-13
Table 19-6 Coulombs calibration summary 19-15
Table 19-7 Ohms calibration summary 19-17

20 Routine Maintenance

Table 20-1 Power line fuse 20-3
Table 20-2 Front panel tests 20-4

B Status and Error Messages

Table B-1 Status and error messages B-2

D DDC Emulation Commands

Table D-1 Device dependent command summary D-2

F IEEE-488 Bus Overview

Table F-1 IEEE-488 bus command summary F-7
Table F-2 Hexadecimal and decimal command codes F-10
Table F-3 Typical bus sequence F-11
Table F-4 Typical addressed command sequence F-11
Table F-5 IEEE command groups F-12
Table F-6 Model 6514 interface function codes F-13

G IEEE-488 and SCPI Conformance Information

Table G-1 IEEE-488 documentation requirements G-2
Table G-2 Coupled commands G-4

H Calibration Options

Table H-1 Calibration commands H-4

1 Getting Started

- **General information** — Covers general information that includes warranty information, contact information, safety symbols and terms, inspection, and available options and accessories.
- **System electrometer features** — Summarizes the features of Model 6514.
- **Front and rear panel familiarization** — Summarizes the controls and connectors of the instrument.
- **Power-up** — Covers line power connection, line voltage setting, fuse replacement, power line frequency, and the power-up sequence.
- **Display** — Provides information about the display of Model 6514.
- **Default settings** — Covers the five instrument setup configurations available to the user; three user defined, GPIB defaults, or factory defaults.
- **SCPI programming** — Explains how SCPI commands are presented in this manual.

General information

Warranty information

Warranty information is located at the front of this manual. Should your Model 6514 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

Contact information

Worldwide phone numbers are listed at the front of this manual. If you have any questions, please contact your local Keithley representative or call one of our Application Engineers at 1-800-348-3735 (U.S. and Canada only).

Safety symbols and terms

The following symbols and terms may be found on the instrument or used in this manual:

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on the instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Inspection

Model 6514 was carefully inspected electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. (There may be a protective film over the display lens, which can be removed). Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment. The following items are included with every Model 6514 order:

- Model 6514 System Electrometer with line cord.
- Model 237-ALG-2 triax cable.
- Accessories as ordered.
- Certificate of calibration.
- Model 6514 Instruction Manual (P/N 6514-901-01).
- Manual Addenda (pertains to any improvements or changes concerning the instrument or manual).

If an additional manual is required, order the appropriate manual package. The manual packages include a manual and any pertinent addenda.

Options and accessories

Input cables, connectors and adapters

Model 237-ALG-2 — This is a 6.6 ft (2-meter) low-noise triax cable terminated with a 3-slot male triax connector on one end and 3 alligator clips on the other. (One Model 237-ALG-2 is included).

Model 237-BNC-TRX adapter — This is a male BNC to 3-lug female triax connector (guard disconnected). It is used to terminate a triax cable with a BNC plug.

Model 237-TRX-T adapter — This is a 3-slot male to dual 3-lug female triax tee adapter for use with 7078-TRX triax cables.

Model 237-TRX-TBC connector — This is a 3-lug female triax bulkhead (internal mount) connector with cap for assembly of custom test fixtures and interface connections.

Model 7078-TRX-TBC connector — This is a 3-lug female triax bulkhead (external mount) connector with cap for assembly of custom test fixtures and interface connections.

Model 7078-TRX-3, 7078-TRX-10 and Models 7078-TRX-20 triax cables — These are low noise triax cables terminated at both ends with 3-slot male triax connectors. The -3 model is 3 ft (0.9m) in length, the -10 model is 10 ft (3m) in length, and the -20 model is 20 ft (6m) in length.

CS-751 barrel adapter — This is a barrel adapter that allows you to connect two triax cables together. Both ends of the adapter are terminated with 3-lug female triax connectors.

GPIB and trigger link cables and adapters

Models 7007-1 and 7007-2 shielded GPIB cables — Connect Model 6514 to the GPIB bus using shielded cables and connectors to reduce electromagnetic interference (EMI). Model 7007-1 is lm long; Model 7007-2 is 2m long.

Models 8501-1 and 8501-2 trigger link cables — Connect Model 6514 to other instruments with Trigger Link connectors (e.g., Model 7001 Switch System). Model 8501-1 is lm long; Model 8501-2 is 2m long.

Model 8502 trigger link adapter — Lets you connect any of the six trigger link lines of Model 6514 to instruments that use the standard BNC trigger connectors.

Model 8503 DIN to BNC trigger cable — Lets you connect trigger link lines one (Voltmeter Complete) and two (External Trigger) of Model 6514 to instruments that use BNC trigger connectors. Model 8503 is lm long.

Rack mount kits

Model 4288-1 single fixed rack mount kit — Mounts a single Model 6514 in a standard 19-inch rack.

Model 4288-2 side-by-side rack mount kit — Mounts two instruments (Models 182, 428, 486, 487, 2000, 2001, 2002, 2010, 2400, 2410, 2420, 2430, 6430, 6514, 6517 A, 7001) side-by-side in a standard 19-inch rack.

Model 4288-4 side-by-side rack mount kit — Mounts Model 6514 and a 5.25-inch instrument (Models 195A, 196, 220, 224, 230, 263, 595, 614, 617, 705, 740, 775A, 6512) side-by-side in a standard 19-inch rack.

Carrying case

Model 1050 padded carrying case — A carrying case for Model 6514. Includes handles and shoulder strap.

System electrometer features

Model 6514 is a 6½-digit high-performance system electrometer. It can measure voltage, current, resistance and charge. Details on its measurement capabilities are explained in Section 2 of this manual (see “Measurement Overview”).

Features of Model 6514 System Electrometer include:

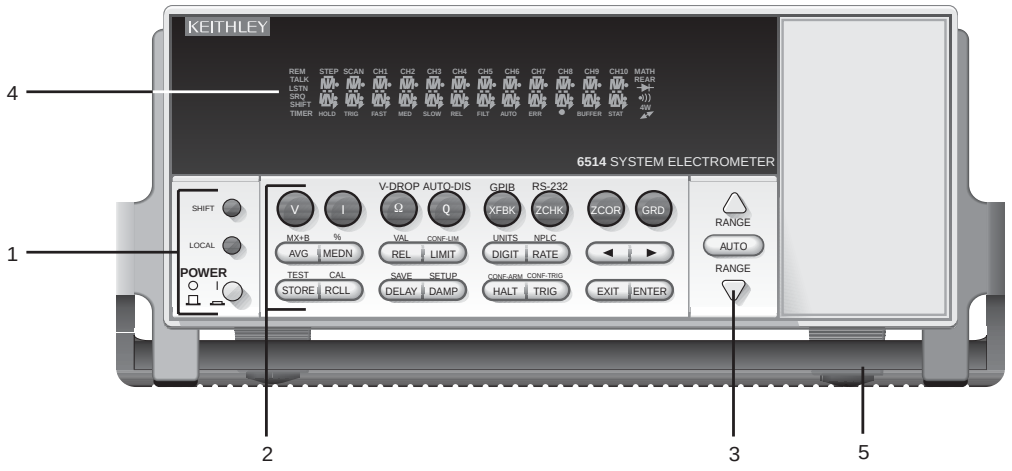
- **Setup storage** — Five instrument setups (three user, GPIB defaults and factory defaults) can be saved and recalled.
- **mX+b and percent** — These calculations provide mathematical manipulation of readings.
- **Relative** — Null offsets or establish baseline values.
- **Buffer** — Store up to 2500 readings in the internal buffer.
- **Limits** — Set up to two stages of high and low reading limits to test devices.
- **Digital I/O port** — Four output lines and one input line to control external circuitry. Use as an interface between limit tests and component handler.
- **Analog outputs** — Provides a 2V analog output for a full range input. Preamp out provides a driven guard for Volts, or can be used for external feedback measurements.
- **External feedback** — Extends the measurement capabilities of the electrometer; logarithmic currents, non-decade current ranges and non-standard charge ranges.
- **Remote interface** — Model 6514 can be controlled using the IEEE-488 interface (GPIB) or the RS-232 interface.
- **GPIB programming language** — When using the GPIB, the instrument can be programmed using the SCPI or DDC programming language.

Front and rear panel familiarization

Front panel summary

The front panel of Model 6514 is shown in Figure 1-1.

Figure 1-1 Model 6514 front panel



NOTE *Most keys provide a dual function or operation. The nomenclature on a key indicates its unshifted function/operation, which is selected by pressing the key. Nomenclature (in blue) above a key indicates its shifted function. A shifted function is selected by pressing the SHIFT key and then the function/operation key.*

1 Special keys and power switch

SHIFT	Use to select a shifted function or operation.
LOCAL	Cancels GPIB remote mode.
POWER	Power switch. In position turns 6514 on (I), out position turns it off (O).

2 Function and operation keys

Top Row

Unshifted

V	Selects voltage measurement function.
I	Selects current measurement function.
Ω	Selects resistance measurement function.
Q	Selects charge measurement function.
XFBK	Enables/disables External Feedback.
ZCHK	Enables/disables Zero Check.
ZCOR	Enables/disables Zero Correct.
GRD	Enables/disables Guard.

Shifted

V-DROP	Enables/disables V-drop measurements for Ω function.
AUTO-DIS	Sets and enables/disables Auto Discharge for charge measurements.
GPIB	Configures and enables/disables GPIB interface.
RS-232	Configures and enables/disables RS-232 interface.

Middle Row

Unshifted

AVG	Configures and enables/disables digital filter.
MEDN	Configures and enables/disables median filter.
REL	Enables/disables Relative (Rel).
LIMIT	Performs configured limit tests.
DIGIT	Sets display resolution.
RATE	Selects measurement rate.
◀ and ▶	Controls cursor position for making selections or editing values.

Shifted

MX+B	Configures and enables/disables mX+b math function.
%	Configures and enables/disables Percent math function.
VAL	Sets Rel value and enables Rel.
CONF-LIM	Configures limit tests.
UNITS	Selects engineering units for scientific notation for display readings.
NPLC	Set rate by setting PLC value.

Bottom Row

Unshifted

STORE	Sets the number of readings to store and enables the buffer.
RCLL	Displays stored readings (including maximum, minimum, peak-to-peak, average, and standard deviation). The ▲ and ▼ range keys scroll through the buffer, and the ◀ or ▶ key toggles between reading number and reading.
DELAY	Sets user delay between trigger and measurement.
DAMP	Enables/disables damping for current measurements.
HALT	Stops measurement process. Puts 6514 in idle state.
TRIG	Trigger measurement(s). Takes 6514 out of idle state.
EXIT	Cancels selection, moves back to measurement display.
ENTER	Accepts selection, moves to next choice or back to measurement display.

Shifted

TEST	Performs key-press test or display test.
CAL	Accesses calibration.
SAVE	Saves present setup to a memory location.
SETUP	Restores setup stored in a memory location, or to GPIB or factory defaults.
CONF-ARM	Configures Arm Layer of trigger model.
CONF-TRIG	Configures Trigger Layer of trigger model.

3 Range keys

▲	Selects the next higher voltage measurement range.
▼	Selects the next lower voltage measurement range.
AUTO	Enables/disables autorange.

4 Display annunciators

* (asterisk)	Readings being stored in buffer.
↔ (more)	Indicates additional selections are available.
AUTO	Autorange enabled.
BUFFER	Recalling readings stored in buffer.
ERR	Questionable reading, or invalid cal step.
FAST	Fast (0.1 PLC) reading rate selected.
FILT	Filter enabled.
LSTN	Instrument addressed to listen over GPIB.
MATH	mX+b or Percent (%) calculation enabled.
MED	Medium (1 PLC) reading rate selected.
REL	Relative enabled for present measurement function.
REM	Instrument in GPIB remote mode.
SHIFT	Accessing a shifted key.
SLOW	Slow reading rate selected; 6 PLC for 60Hz or 5 PLC for 50Hz.
SRQ	Service request over GPIB.
STAT	Displaying buffer statistics.
TALK	Instrument addressed to talk over GPIB bus.
TIMER	Timer controlled triggering in use.
TRIG	External triggering (GPIB or trigger link) selected.

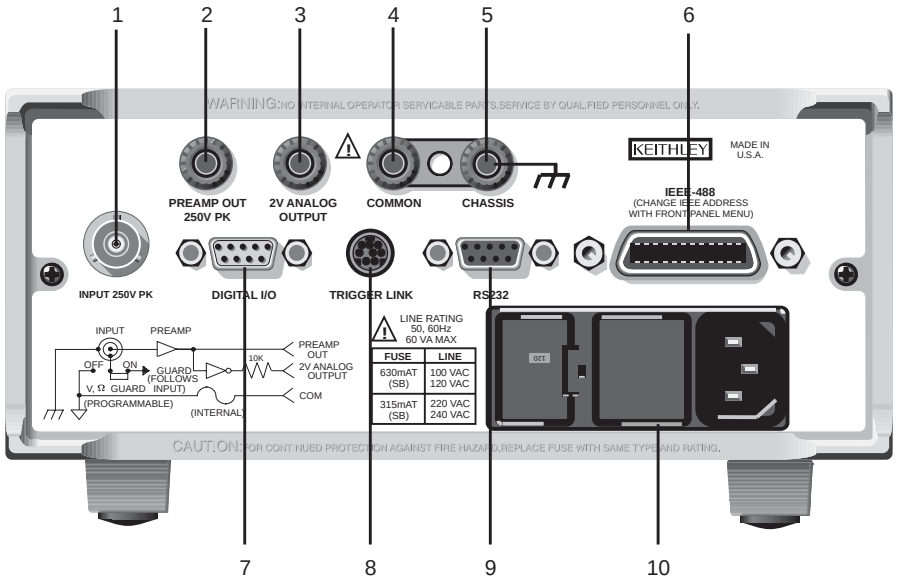
5 Handle

Pull out and rotate to desired position.

Rear panel summary

The rear panel of Model 6514 is shown in Figure 1-2.

Figure 1-2
Model 6514
rear panel



1 INPUT

This standard 3-lug female triax connector is used to connect the signal to be measured to the input of Model 6514. Mates to a triax cable terminated with a 3-lug male triax connector.

2 PREAMP OUT

Provides a guard output for Volts measurements. Can be used as an inverting output or with external feedback for the Amps and Coulombs modes.

3 2V ANALOG OUTPUT

Provides a scaled DC output voltage. A full range input will result in a 2V analog output. For the volts function, the output is non-inverting.

4 COMMON

Use as input low, or the common for the 2V Analog Output and Preamp Out.

5 CHASSIS

This terminal is connected to the chassis of Model 6514 and to power line earth ground via the power line cord. For floating measurements (up to 500V peak), remove the ground link between COMMON and CHASSIS.

6 IEEE-488

Connector for IEEE-488 (GPIB) operation. Use a shielded cable, such as Models 7007-1 and 7007-2.

7 DIGITAL I/O

Male DB-9 connector for digital output lines and component handler signals.

8 TRIGGER LINK

Eight-pin micro-DIN connector for sending and receiving trigger pulses among connected instruments. Use a trigger link cable or adapter, such as Models 8501-1, 8501-2, 8502 and 8503.

9 RS-232

Female DB-9 connector for RS-232 operation. Use a straight-through (not null modem) DB-9 shielded cable.

10 Power module

Contains the AC line receptacle, power line fuse, and line voltage setting. The instrument can be configured for line voltages of 100V/120V/220V/240VAC at line frequencies of 50 or 60Hz.

Power-up

Line power connection

Perform the following procedure to connect Model 6514 to line power and turn on the instrument.

1. Check to be sure the line voltage setting on the power module is correct for the operating voltage in your area. The line voltage setting is indicated in the window on the power module (see Figure 1-2). The upside-down 120 setting is for line voltages of 100/120VAC, and the upside-down 240 setting is for line voltages of 220/240VAC. The procedure to change the line voltage setting is provided in Section 20.

CAUTION **Operating the instrument on an incorrect line voltage may cause damage to the instrument, possibly voiding the warranty.**

2. Before plugging in the power cord, make sure the front panel power switch is in the off (O) position.
3. Connect the female end of the supplied power cord to the AC receptacle on the rear panel. Connect the other end of the power cord to a grounded AC outlet.

WARNING **The power cord supplied with Model 6514 contains a separate ground wire for use with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.**

4. Turn on the instrument by pressing the front panel power switch to the on (1) position.

Line frequency selection

During the power-up sequence, the selected line frequency setting is displayed. The line frequency setting can be changed from the front panel by holding in the TRIG key during the power-up sequence. This action toggles between 50 and 60Hz. The command to remotely set line frequency is listed in Table 1-1.

SCPI programming

Table 1-1
SCPI commands - line frequency

Command	Description
SYSTem :LFRequency <freq> :LFRequency?	SYSTem Subsystem: Select power line frequency (in Hz); 50 or 60. Read present line frequency setting.

Power-up sequence

The following power-up sequence occurs when the Model 6514 is turned on:

1. The Model 6514 performs self-tests on its EPROM and RAM with all digits and annunciators turned on. If a failure is detected, the instrument momentarily displays an error message and the ERR annunciator turns on. Error messages are listed in Appendix B.

NOTE *If a problem develops while the instrument is under warranty, return it to Keithley Instruments Inc., for repair.*

2. If the instrument passes the self-tests, the firmware revision levels are displayed. For example:
   6514 REV: A01
3. The detected line frequency is then displayed. For example:
   FREQ: 60Hz
4. Lastly, information on the selected remote interface is displayed:
   a. GPIB — If the GPIB is the selected interface, the instrument will display the selected language (SCPI or DDC) and primary address. Examples:
      SCPI ADDR: 14
      DDC ADDR: 14
   b. RS-232 — If RS-232 is the selected interface, the instrument will display the baud rate setting. For example:
      RS-232: 9600b

Display

Readings can be displayed in engineering units or scientific notation (see "Units" in Section 6 for details). Annunciators indicate various states of operation. See "Front Panel Summary" (presented earlier in this section) for a complete listing of display annunciators.

NOTE The Display and Keys Test allows you to test display digit segments and annunciators, and check the functionality of front panel keys. These tests are accessed by pressing SHIFT and then TEST. Refer to Section 20 for details.

Status and error messages

Status and error messages are displayed momentarily. During operation and programming, you will encounter a number of front panel messages. Typical messages are either of status or error variety, as listed in Appendix B.

Default settings

Model 6514 can be restored to one of five default setup configurations; factory (FACT), GPIB and three user-saved (USR0, USR1 and USR2). As shipped from the factory, Model 6514 powers up to the factory default settings. Factory default settings provide a general purpose setup for front panel operation, while the GPIB default settings do the same for remote operation. Factory and GPIB default settings are listed in Table 1-2.

For front panel operation, the instrument will power up to whichever default setup was last saved or restored. For example, if you save the present instrument setup as USR0, the instrument will subsequently power up to the USR0 setup.

NOTE At the factory, the factory default setup is saved as the USR0, USR1 and USR2 setups.

Saving a user setup — Perform the following steps to save a user setup:

1. Configure Model 6514 for the desired measurement application.
2. Press SHIFT and then SAVE to access the save setup menu.
3. Use the ▲ or ▼ key to display the desired memory location (0 = USR0, 1 = USR1, 2 = USR2).
4. Press ENTER.

Restoring a setup — Perform the following steps to restore a setup:

1. Press SHIFT and then SETUP to display the restore menu:
2. Use the ▲ or ▼ key to display the desired setup (FACT, GPIB, USR0, USR1 or USR2).
3. Press ENTER.

Remote operation

Saving and restoring user setups — The *SAV and *RCL commands are used to save and recall user setups. These commands are documented in Section 14.

Restoring factory or GPIB default setups — The SYSTem:PRESet command returns Model 6514 to the factory defaults and the *RST command returns it to the GPIB defaults. The *RST command is documented in Section 14 and SYSTem:PRESet is covered in Section 16 (SYSTem Subsystem).

Selecting power-on setup — The SYSTem:POSetup command is used to select which setup to return to on power-up. The SYSTem:POSetup command is documented in Section 16 (SYSTem Subsystem).

Table 1-2
Default settings

Setting	**Factory**	**GPIB**
Arm Layer (CONF-ARM):		
Arm-In Source Event	IMM	IMM
Arm Count	INF	1
Input Trigger Link Line	1	1
Source Bypass	NEVER	NEVER
Output Trigger Link Line	2	2
Output Trigger	Off	Off
Auto Discharge	Off	Off
Level	2e-6	2e-6
Buffer (STORE):	Disabled	Disabled
Count	No effect	No effect
Digital Filter (AVG):	Off	Off
Count	10	10
Type	Moving	Moving
Display Resolution (DIGIT)	5½-digits	5½-digits
Function	Volts	Volts
Guard	Off	Off
GPIB:	No effect (On at factory)	No effect (On at factory)
Address	No effect (14 at factory)	No effect (14 at factory)
Language	No effect (SCPI at factory)	No effect (SCPI at factory)

Table 1-2 (cont.)
Default settings

Setting	**Factory**	**GPIB**
Limit Tests:		
Limit 1 and Limit 2:	Disabled	Disabled
HI and LO Values	1, -1	1, -1
Digital Fail Output Patterns	15	15
Digital Output Pass Pattern	15	15
Auto-Clear	Off	Off
Delay	0.00010 sec	0.00010 sec
Output Clear Pattern	15	15
Line 4 Mode	End of Test	End of Test
Median Filter:	Off	Off
Rank	1	1
MX+B:	Disabled	Disabled
“M” Value	1.0	1.0
“B” Value	0.0	0.0
Units	MXB	MXB
Percent:	Disabled	Disabled
Reference	1.0	1.0
Range	20V	Auto
Rate:	Slow	Slow
NPLC	6.0 (60Hz) or 5.0 (50Hz)	6.0 (60Hz) or 5.0 (50Hz)
Rel:	Off	Off
Rel Value (VAL)	0.0	0.0
RS-232:	No effect (Off at factory)	No effect (Off at factory)
All Settings	No effect	No effect
Trigger Layer (CONF-TRIG):		
Trig-In Source Event	IMM	IMM
Trigger Count	1	1
Trigger Delay	0	0
Input Trigger Link Line	1	1
Source Bypass	NEVER	NEVER
Output Trigger Link Line	2	2
Units	No effect	No effect
V-Drop	Disabled	Disabled
Zero Check	Enabled	Enabled
Zero Correct	Disabled	Disabled

SCPI programming

SCPI programming information is integrated with front panel operation throughout this manual. SCPI commands are listed in tables, and additional information that pertains exclusively to remote operation is provided after each table. The SCPI tables may reference you to other sections of this manual.

NOTE *Except for Section 17, most SCPI tables in this manual are abridged. That is, they exclude most optional command words and query commands. Optional command words and query commands are summarized as follows.*

Optional command words — In order to be in conformance with the IEEE-488.2 standard, Model 6514 accepts optional command words. Any command word that is enclosed in brackets ([]) is optional and does not have to be included in the program message.

Query commands — Most command words have a query form. A query command is identified by the question mark (?) that follows the command word. A query command requests (queries) the programmed status of that command. When a query command is sent and Model 6514 is addressed to talk, the response message is sent to the computer.

NOTE *For complete details, see "Programming Syntax" in Section 12.*

2
Measurement Concepts

- **Measurement overview** — Explains the basic measurement capabilities of Model 6514.
- **Performance considerations** — Covers a couple of considerations that affect overall performance; warm-up and autozero.
- **Connection fundamentals** — Covers fundamental information about connecting test circuits to the electrometer.
- **Zero check and zero correct** — Provides operation information on these two important aspects of the basic measurement process.
- **Measurement considerations** — Summarizes the various factors that affect low level measurements.

Measurement overview

The basic measurement capabilities of Model 6514 are summarized in Table 2-1. Accuracy for each measurement function and range is listed in specifications (Appendix A).

Table 2-1
Basic measurement capabilities

Function	Reading Range	Available Ranges
Volts	±10uV to ±210V	2V, 20V and 200V
Amps	±100aA to ±21mA	20pA, 200pA, 2nA, 20nA, 200nA, 2uA, 20uA, 200uA, 2mA and 20mA
Ohms	10mΩ to 210GΩ	2kΩ, 20kΩ, 200kΩ, 2MΩ, 20MΩ, 200MΩ, 2GΩ, 20GΩ and 200GΩ
Coulombs	10fC to 21µC	20nC, 200nC, 2µC, and 20µC

Performance considerations

Warm-up period

Model 6514 can be used within one minute after it is turned on. However, the instrument should be turned on and allowed to warm up for at least one hour before use to achieve rated accuracy. If the instrument has been exposed to extreme temperatures, allow extra time for the internal temperature to stabilize.

Autozero

To help maintain stability and accuracy over time and changes in temperature, the Model 6514 periodically measures internal voltages corresponding to offsets (zero) and amplifier gains. These measurements are used in the algorithm to calculate the reading of the input signal. This process is known as autozeroing.

When autozero is disabled, the offset and gain measurements are not performed. This increases measurement speed. However, the zero and gain reference points will eventually drift resulting in inaccurate readings of the input signal. It is recommended that autozero only be disabled for short periods of time.

Autozero cannot be disabled from the front panel, however, it can be enabled from the front panel by restoring factory or GPIB default conditions.

SCPI programming

Table 2-2
SCPI commands — autozero

Command	Description	Default
SYSTem	SYSTem Subsystem:	
:AZERo		
[:STATe] <b>	Enable or disable autozero.	ON

Programming example

The following command sequence will perform one zero corrected amps measurement:

```
SYST:AZER OFF              ' Disable autozero.
SYST:AZER ON               ' Enable autozero.
```

Connection fundamentals

The following provides important fundamental information on input connections to Model 6514. Typical connection drawings are included with the various measurement procedures provided in subsequent sections of this manual.

Input connector

The rear panel INPUT connector is a 3-lug female triax connector that will mate to a cable terminated with a male triax connector.

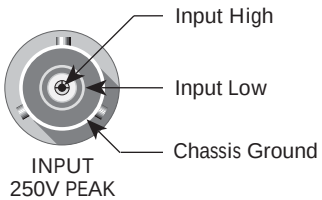
Input configurations

As shown in Figure 2-1, the input connector can be configured in two ways. With guard off (Figure 2-1A), input low is connected to the inner shell of the connector. This configuration is used for Amps, Coulombs, unguarded Volts and unguarded Ohms measurements.

With guard on (Figure 2-1B), the driven guard is connected to the inner shell of the triax connector. Input low is accessed via the COMMON terminal through an internal 0.1Ω fuse. This configuration is used for guarded Volts and guarded Ohms measurements only. The GRD key toggles guard on and off.

NOTE *The state of guard (on or off) has no affect on the Amps and Coulombs functions. The unguarded configuration is always selected for the Amps and Coulombs functions.*

Figure 2-1
Input connector configurations



A. Unguarded (GRD off)

B. Guarded (GRD on)

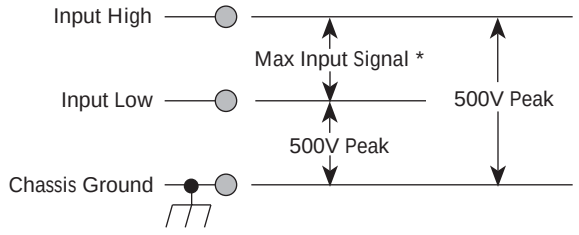
Maximum input levels

The maximum input levels to Model 6514 are summarized in Figure 2-2.

WARNING **The maximum common-mode input voltage, which is the voltage between the input (HI or LO) and chassis ground, is 500V peak. Exceeding this value may create a shock hazard.**

CAUTION **Connecting PREAMP OUT, COMMON, or 2V ANALOG OUTPUT to earth while floating the input may damage the instrument.**

Figure 2-2
Maximum input levels



* Max Input Signal - 250V Peak, DC to 60Hz sine wave (10 seconds maximum in mA ranges).

Low noise input cables

When making precision measurements, you should always use low noise cables. The following low noise cables are recommended for use with Model 6514:

- Model 237-ALG-2 — This 2-meter low noise triax cable mates directly to the input connector of Model 6514. The other end is terminated with three alligator clips. The clip with the red boot is input high, black boot is input low or guard, and the green boot is chassis ground.
- Model 7078-TRX-3 — This 3-foot low noise triax cable is terminated with a 3-slot triax connector on either end.
- Models 7078-TRX-10 and 7078-TRX-20 — Same as Model 7078-TRX-3 except that they are 10 feet and 20 feet in length.

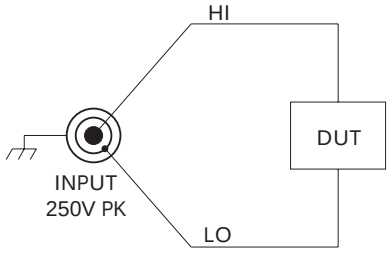
NOTE *As a general rule, always use the shortest possible cable for volts, amps and ohms measurements.*

Basic connections to DUT

Unguarded connections

Basic unguarded connections are shown in Figure 2-3, the DUT is the voltage, current, resistance or charge to be measured. Circuit high is connected to the center conductor of the input connector and circuit low is connected to the inner shell of the connector. For unguarded volts and ohms measurements, the driven guard (GRD) must be off.

Figure 2-3
Basic connections for unguarded measurements



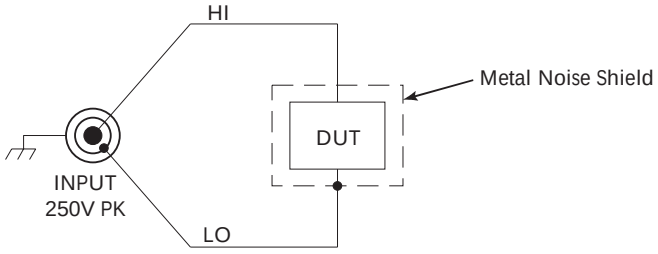
NOTE: For Volts and Ohms, GRD must be off.

Noise and safety shields — Figure 2-4 shows typical shielding for unguarded measurements. A noise shield is used to prevent unwanted signals from being induced on the electrometer input. Measurements that may benefit from effective shielding include unguarded volts and ohms, amps below 1uA, and low level coulombs.

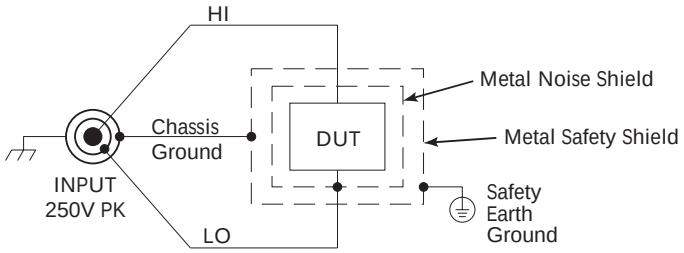
Typically, the noise shield is connected to electrometer input LO. However, better noise performance may be achieved by connecting the noise shield to both input LO and chassis ground. Electrometer LO can be connected to chassis ground by installing the ground link between the COMMON and CHASSIS binding posts.

A safety shield is required whenever a hazardous voltage (>30V) is present on the noise shield or when the test circuit (DUT) is floated above earth ground at a hazardous voltage level (see "Floating Measurements"). Connections for the safety shield is shown in Figure 2-4B. The metal safety shield must completely surround the noise shield or floating test circuit, and it must be connected to safety earth ground using #18 AWG or larger wire.

Figure 2-4 Shielding for unguarded measurements



A. Noise Shield



B. Safety Shield

Guarded connections

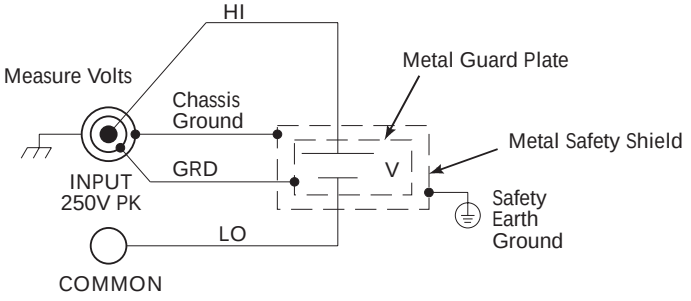
The basic guarded connections for volts and ohms are shown in Figure 2-5. For these measurements, circuit high is connected to the center conductor of the input connector while circuit low is connected to the COMMON banana jack terminal. With guard (GRD) on, the driven guard is available at the inner shell of the triax connector which is connected to the metal guard plate.

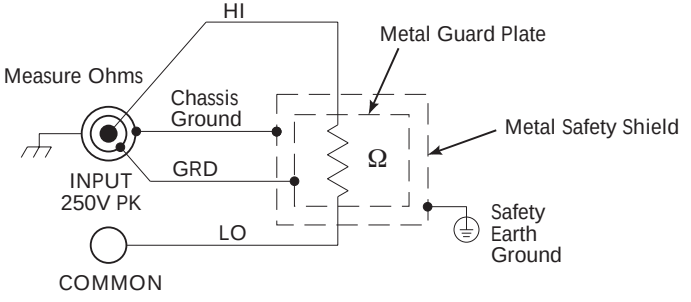
WARNING **The guard voltage is at the same potential as the input. Therefore, hazardous voltage on the input will also be present on the guard plate. To prevent electric shock, always use a metal safety shield (as shown in Figure 2-5) for guarded voltage measurements above 30Vrms (42V peak). The metal safety shield must be connected to safety earth ground using #18 AWG or larger wire.**

WARNING **With an open input, up to 250V peak may be present on the guard terminals while in Volts or Ohms. To prevent this, enable zero check whenever the input is open.**

The driven guard is used to eliminate leakage current and capacitance in high impedance circuits which could corrupt the volts or ohms measurement. The concept of guarding techniques are covered in Section 3.

Figure 2-5
Basic connections for guarded measurements



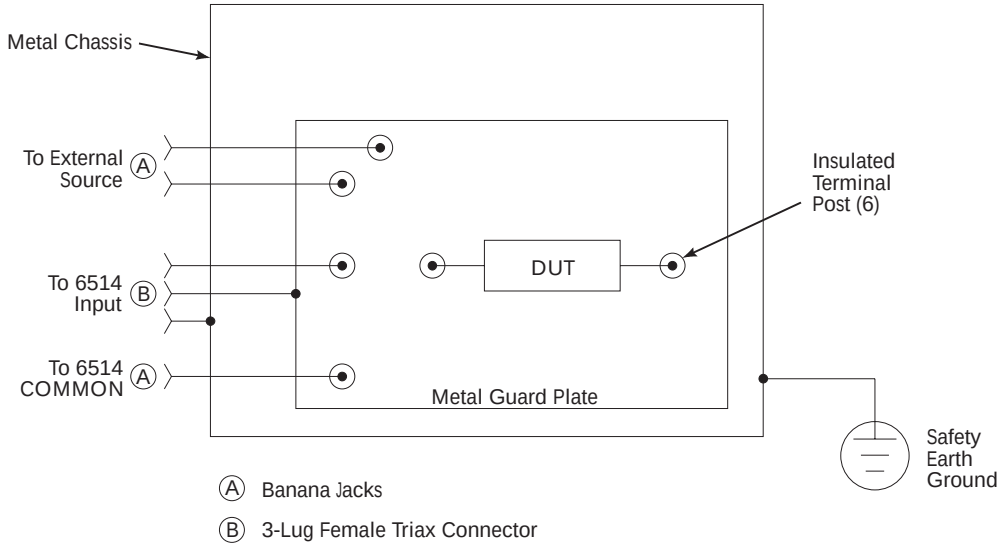


NOTE: GRD must be on.

Test fixture

Whenever possible, use a shielded low leakage test fixture to make precision measurements. A general purpose test fixture is shown in Figure 2-6. This test fixture will accommodate a variety of connection requirements.

Figure 2-6 General purpose test fixture



Test fixture chassis

- The chassis of the test fixture should be metal so that it can function as a shield for the DUT or test circuit. The metal chassis should be connected to chassis ground of Model 6514 via the triax cable.
- The test box must have a lid that closes to prevent contact with live circuitry.
- The test fixture must have a screw terminal that is used exclusively for connection to safety earth ground.

WARNING **To provide protection from shock hazards, the test fixture chassis must be properly connected to safety earth ground. A grounding wire (#18 AWG or larger) must be attached securely to the test fixture at a screw terminal designed for safety grounding. The other end of the ground wire must be attached to a known safety earth ground.**

Guard plate

A metal guard plate will provide guarding or noise shielding for the DUT or test circuit. It will also serve as a mounting panel for DUT or test circuits. The guard plate must be insulated with 1000V spacing from the chassis of the test fixture.

Connectors, terminals and internal wiring

Basic connector requirements include a 3-lug female triax connector, and three banana jacks. One banana jack is used to make the COMMON connection to the electrometer for guarded measurements. The other two banana jacks will accommodate connection to an external power supply. The banana jacks must be insulated from the chassis of the test fixture. The outer shell of the triax connector must be referenced to chassis ground. Therefore, DO NOT insulate the outer shell of the triax connector from the metal chassis of the test fixture.

DUT and test circuits are to be mounted on the guard plate using insulated terminals. To minimize leakage, select terminals that use virgin Teflon insulators.

Inside the test fixture, use an insulated wire to connect the inner shell of the triax connector to the guard plate. For unguarded measurements, the guard plate will serve as a noise shield. For the volts and ohms functions, turning GRD on will connect guard to the guard plate.

Handling and cleaning test fixtures

Dust, body oil, solder flux, and other contaminants on connector and terminal insulators can significantly decrease the leakage resistance resulting in excessive leakage currents. Contaminants on DUT and test circuit components can create a leakage path. The leakage currents may be large enough to corrupt low-level measurements.

Handling tips:

- Do not touch the bodies of DUT or test circuit components. If you cannot handle them by their leads, use clean cotton gloves to install them in the test fixture.
- Do not touch any connector or terminal insulator.
- If installing a test circuit that is on a PC board, handle the board by the edges. Do not touch any board traces or components.

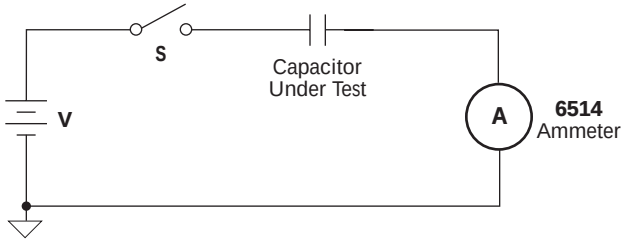
Cleaning tips:

- Use dry nitrogen gas to clean dust off connector and terminal insulators, DUT, and other test circuit components.
- If you have just built the test fixture, remove any solder flux using methanol along with clean foam-tipped swabs or a clean soft brush. Clean the areas as explained in the next tip.
- To clean contaminated areas, use methanol and clean foam-tipped swabs. After cleaning a large area, you may want to flush the area with methanol. Blow dry with dry nitrogen gas.
- After cleaning, the test fixture (and any other cleaned devices or test circuits) should be allowed to dry in a 50°C low-humidity environment for several hours.

Input protection

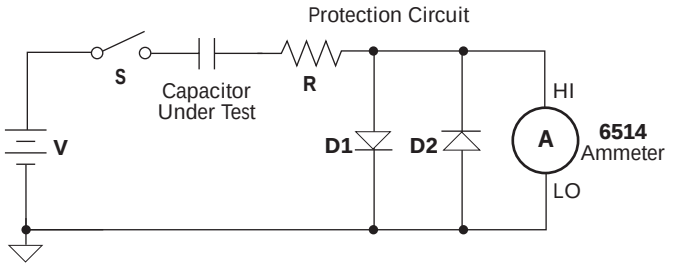
Model 6514 incorporates protection circuitry against nominal overload conditions. However, a high voltage (>250V) and resultant current surge could damage the input circuitry. A typical test circuit to measure the leakage current of a capacitor is shown in Figure 2-7. When Switch S is closed, an initial charging current will flow and the high voltage will be seen across the input of Model 6514.

Figure 2-7
Capacitor test circuit without protection



Adding a resistor and two diodes (1N3595) as shown in Figure 2-8 will provide considerable extra protection. The resistor must be large enough to limit the current through the diodes to 10mA or less, and be large enough to withstand the supply voltage. The protection circuit should be enclosed in a light-tight conductive shield.

Figure 2-8
Capacitor test circuit with protection



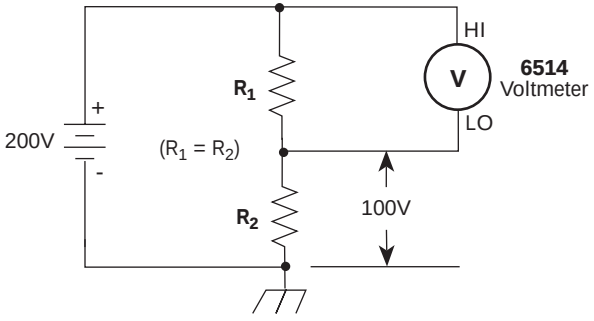
Floating measurements

With the ground link between the COMMON and CHASSIS banana jack terminals removed, Model 6514 can perform floating measurements up to 500V above chassis ground. These measurements can result in safety concerns.

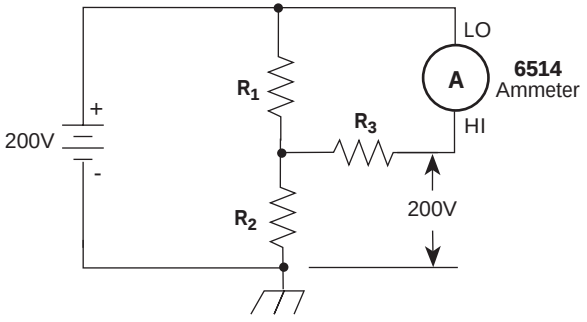
Figure 2-9 shows two examples where Model 6514 floats at a hazardous voltage level. In Figure 2-9A, a shock hazard (100V) exists between meter input LO and chassis ground. If meter input LO is connected to a noise shield, then the shock hazard will also be present on that shield.

In Figure 2-9B, a shock hazard (200V) exists between the meter input (HI and LO) and chassis ground. If meter LO is connected to a shield, then the shock hazard will also be present on that shield.

Figure 2-9
Floating measurements



A. Voltage measurement



B. Current measurement

WARNING **The maximum voltage (common-mode) between electrometer LO and chassis ground is 500V. Exceeding this value may create a shock hazard.**

WARNING **When floating input LO above 30V from earth (chassis) ground, hazardous voltage will be present at the analog outputs (PREAMP OUT and 2V ANALOG OUTPUT). Hazardous voltage may also be present when the input voltage exceeds 30V in the Volts function.**

CAUTION **Connecting PREAMP OUT, COMMON or 2V ANALOG OUTPUT to earth (chassis) ground while floating the input may damage the instrument.**

Zero check and zero correct

Table 2-3 lists the display messages associated with zero check and zero correct. The two-character message is displayed along with the reading.

Table 2-3
Display messages for zero check and zero correct

Display Message	Zero Check	Zero Correct
ZC	On	Off
ZZ	On	On
CZ	Off	On

Zero check

When zero check is enabled (on), the input amplifier is reconfigured to shunt the input signal to low as shown in Figure 2-10. With zero check enabled, it will remain enabled when a different function is selected. With zero check disabled, it will remain disabled when the volts, amps or coulombs function is selected.

NOTE Zero check will always enable whenever the ohms function is selected.

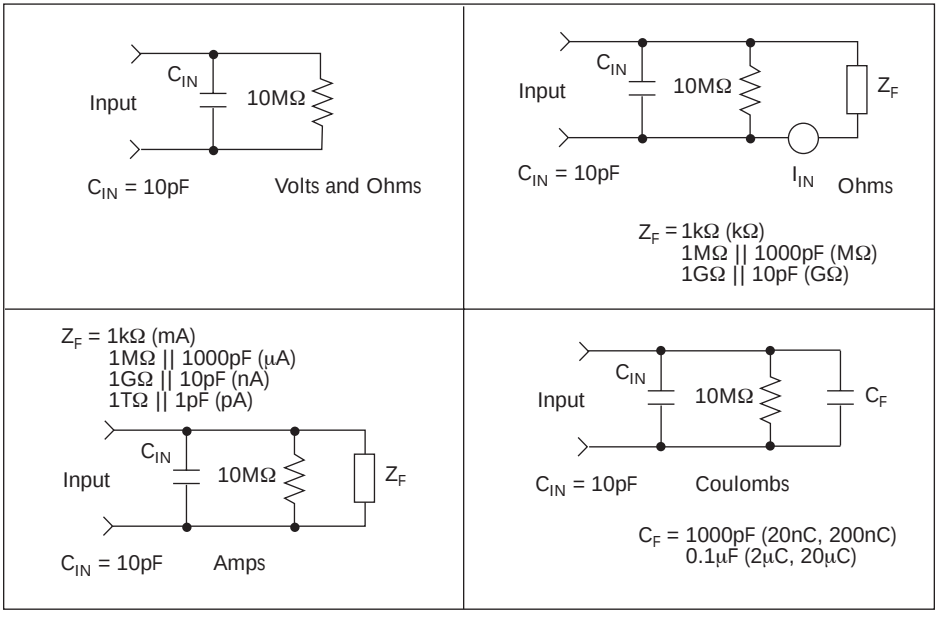
Zero check is enabled by pressing the ZCHK key. Pressing ZCHK a second time disables zero check.

NOTE To ensure proper operation, always enable zero check before changing functions.

For coulombs, enabling zero check dissipates the charge. That is, the charge reading is reset to zero. When zero check is disabled, a sudden change in the charge reading (zero check hop) occurs. This effect can be cancelled by enabling Relative (REL) immediately after zero check is disabled. Relative is explained in Section 7.

For volts, amps and ohms, leave zero check enabled when connecting or disconnecting input signals. For coulombs, disable zero check before connecting the input signal. If zero check is left enabled when you connect the input signal, the charge will dissipate through the 10MΩ resistor (see Figure 2-10).

Figure 2-10 Equivalent input impedance with zero check enabled



Zero correct

Model 6514 has a zero correct feature to algebraically subtract the voltage offset term from the measurement. Perform the following steps to zero correct the volts or amps function:

NOTE The ZCOR key toggles zero correct on and off. If zero correct is enabled ("ZZ" or "CZ" message displayed), press ZCOR to disable it.

1. Select the volts (V) or amps (I) function.
2. Enable zero check ("ZC" message displayed).
3. Select the range that will be used for the measurement, or select the lowest range.
4. Press ZCOR to enable zero correct ("ZZ" message displayed).
5. Press ZCHK to disable zero check.
6. Readings can now be taken from the display. The "CZ" message indicates that the displayed reading is zero corrected.

NOTES *Zero check will enable whenever the ohms function is selected.*

Model 6514 will remain zeroed even if it is upranged. If downranged, re-zero the instrument.

Model 6514 does not have to be re-zeroed as long as the ambient temperature remains stable.

Zero correction cancels the voltage offset term of the amplifier. With both zero check and zero correct enabled, the instrument may not display a perfectly zeroed reading.

If Model 6514 is operating at, or near T_{CAL}, zero correction will have very little affect. T_{CAL} is the internal temperature of Model 6514 when it was last calibrated.

SCPI programming — zero check and zero correct

Table 2-4
SCPI commands — zero check and zero correct

Commands	Description	Default	Ref
SYSTem	SYSTem Subsystem:		
:ZCHeck <b>	Enable or disable zero check.	ON	
:ZCORrect	Zero correct:		
[:STATe] <b>	Enable or disable zero correct.	OFF	A
:ACQuire	Acquire a new zero correct value.		B
INITiate	Trigger a reading.		B

A) SYSTem:ZCORrect[:STATe] <b>

This method to perform zero correction is consistent with the way it is performed from the front panel. That is, zero correction is performed while zero check is enabled:

```
SYST:ZCH  ON                    ' Enable zero check.
SYST:ZCOR  ON                   ' Perform zero correction.
```

A second method to perform zero correction is to first acquire the zero correct value (see Ref. B).

B) SYSTem:ZCORrect:ACQuire

The zero correct value can only be acquired while zero check is enabled. The internal offset will become the correction value. Zero correction can then be performed with zero check disabled. This acquire method makes it convenient if you need to re-zero the selected function often.

The following command sequence uses the acquire method to zero correct the 2V range:

```
SYST:ZCH ON                    ' Enable zero check.
FUNC 'VOLT'                    ' Select Volts function.
VOLT:RANG 2                    ' Select 2V range.
INIT                           ' Trigger one reading.
SYST:ZCOR:ACQ                  ' Acquire zero correct value.
SYST:ZCH OFF                   ' Disable zero check.
SYST:ZCOR ON                   ' Perform zero correction.
```

The INITiate command in the above sequence is used to trigger a reading. This reading is the offset that is acquired as the zero correct value. See Section 9 for more information on INITiate.

NOTE *Sending the :ACQuire command while zero check is disabled will result in an error. The command will not be executed.*

Input bias current and offset voltage calibration

The input bias current and offset voltage calibration procedures that follow should be performed periodically to actively cancel input bias current and offset voltage, optimizing measurement accuracy, particularly at low levels.

Front panel

Front panel input bias current calibration

1. Access the front panel calibration menu by pressing SHIFT then CAL.

NOTE See Section 19 for details on other calibration menu selections.

2. From the calibration menu, use the down RANGE key to display the following:
   CAL: IOFFSET
3. Press ENTER. The instrument will prompt for the triax shielding cap as follows:
   INPUT CAP
4. Connect a triax shielding cap to the rear panel INPUT jack. (Use a Keithley CAP-31 or equivalent.)
5. Press ENTER to complete input bias current calibration.
6. If you wish to perform front panel offset voltage calibration, proceed to Step 2 of the procedure below. Otherwise, press EXIT to return to normal display.

Front panel offset voltage calibration

1. Access the front panel calibration menu by pressing SHIFT then CAL.
2. From the calibration menu, use the up or down RANGE key to display the following:
   CAL: VOFFSET
3. Press ENTER. The instrument will prompt for a short:
   INPUT SHORT
4. Connect a triax short to the rear panel INPUT jack. (Use the supplied Model 237-ALG-2 triax cable or equivalent with red and black alligator clips connected together.)
5. Press ENTER to complete offset voltage calibration.
6. Press EXIT to return to normal display.

SCPI programming

Table 2-5 lists SCPI commands used for input bias current and offset voltage calibration.

Table 2-5
SCPI commands — input bias current and offset voltage calibration

Commands	Description
:CALibration:UNPRotected:IOFFset	Input bias current calibration.
:CALibration:UNPRotected:VOFFset	Offset voltage calibration.

SCPI command input bias current calibration

1. Connect a triax shielding cap to the rear panel INPUT jack. (Use a Keithley CAP-31 or equivalent.)
2. Send the following command to perform input bias current calibration:
   :CAL:UNPR:IOFF
3. Allow the Model 6514 to complete the calibration process.

SCPI command offset voltage calibration

1. Connect a triax short to the rear panel INPUT jack. (Use the supplied Model 237-ALG-2 triax cable or equivalent with red and black alligator clips connected together.)
2. Send the following command to perform offset voltage calibration:
   :CAL:UNPR:VOFF
3. Allow the Model 6514 to complete the calibration process.

Measurement considerations

There are a variety of factors to consider when making low level measurements. These considerations are listed and summarized in Table 2-6. For comprehensive information on all measurement considerations, refer to the Low Level Measurements handbook, which is available from Keithley Instruments.

Table 2-6
Summary of measurement considerations

Considerations	**Description**
For V and Ω measurements:	*See Section 3 for details*
Loading effects	Circuit loading caused by a high impedance voltage source.
Cable leakage resistance	For unguarded measurements, leakage resistance in the triax cable (between HI and LO) shunts the voltage to be measured.
Input capacitance (settling time)	At very high resistance levels, effects of cable capacitance can slow down measurement response time.
Guarding input cable	Eliminates the effects of leakage resistance for high impedance measurements and input capacitance when using a long input cable.
For I measurements:	*See Section 4 for details*
Input bias current	Offset current of Model 6514 could affect low current measurements.
Voltage burden	Offset voltage of Model 6514 could cause errors if it is high in relation to the voltage of the measured circuit.
Noise	Noise generated by source resistance and source capacitance.
For Q measurements:	*See Section 5 for details*
Input bias current	Offset current of Model 6514 is integrated along with the input signal, affecting the final reading.
External voltage source	Input current to Model 6514 should be limited to <1mA.
Zero check hop	Sudden change in the charge reading when zero check is turned off.
Auto-discharge hop	Sudden change in the charge reading when auto-discharge resets the charge reading to zero.

Table 2-6 (cont.)
Summary of measurement considerations

Considerations	**Description**
For all measurements:	*See Appendix C for details*
Ground loops	Multiple ground points can create error signals.
Triboelectric effects	Charge currents generated in a cable by friction between a conductor and the surrounding insulator (i.e. bending a triax cable).
Piezoelectric and stored charge effects	Currents generated by mechanical stress on certain insulating materials.
Electrochemical effects	Currents generated by the formation of chemical batteries on a circuit board caused by ionic contamination.
Humidity	Reduces insulation resistance on PC boards and test connection insulators.
Light	Light sensitive components must be tested in a light-free environment.
Electrostatic interference	Charge induced by bringing a charged object near your test circuit.
Magnetic fields	The presence of magnetic fields can generate EMF (voltage).
Electromagnetic interference (EMI)	EMI from external sources (i.e. radio and TV transmitters) can affect sensitive measurements.

3
Volts and Ohms Measurements

- **Measurement overview** — Summarizes the volts and ohms measurement capabilities of Model 6514.
- **Guarding** — Explains guarding and the benefits derived from it for high-impedance volts and ohms measurements.
- **Volts and ohms measurement procedure** — Provides the procedure to measure volts and ohms.
- **SCPI programming** — Covers the basic SCPI command used for the volts and ohms functions.
- **Volts and ohms measurement considerations** — Covers measurement considerations that apply to volts and ohms measurements.
- **Application** — Shows how to measure dielectric absorption of a capacitor.

Measurement overview

Volts measurements — Model 6514 can make volts measurements from 10µV to 210V using three measurement ranges; 2V, 20V, and 200V.

Ohms measurements — Model 6514 makes ohms measurements by sourcing a test current and measuring the voltage drop across the DUT. The resistance reading is then calculated (R = V/1) and displayed. The electrometer can make ohms measurements from 10mΩ to 210GΩ using nine measurement ranges; 2kΩ, 20kΩ, 200kΩ, 2MΩ, 20MΩ, 200MΩ, 2GΩ, 20GΩ,and 200GΩ.

NOTE Accuracy specifications for all measurement functions are provided in Appendix A.

Guarding

The purpose of guarding is to eliminate the effects of leakage resistance and capacitance, that can exist between input HI and input LO. This leakage resistance and capacitance could adversely affect high-impedance measurements.

Test circuit leakage

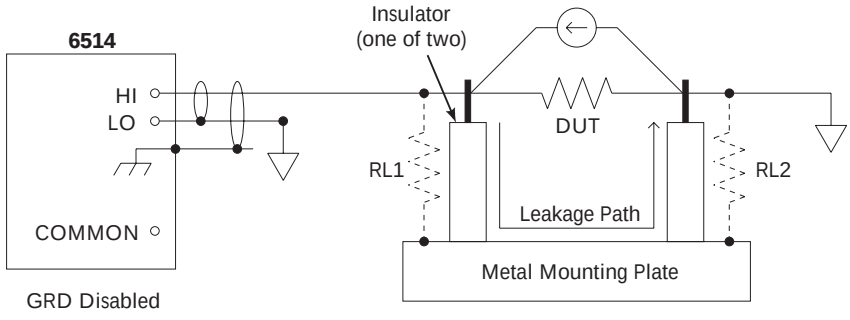
In a test circuit, leakage current can occur through the insulators of the terminals for the DUT (device under test). In Figure 3-1, the test circuit consists of a current source in series with the DUT. The objective is to make an accurate voltage measurement of the DUT.

In Figure 3-1A, a resistance leakage path through the insulators (RL1 and RL2) shunts current around the DUT. If this leakage current is high in comparison to the DUT current, significant measurement error will occur. To keep error <0.1%, the leakage resistance must be 1000 times greater than the resistance of the DUT. For example, if the nominal resistance of the DUT is 100MΩ, leakage resistance must be >100GΩ.

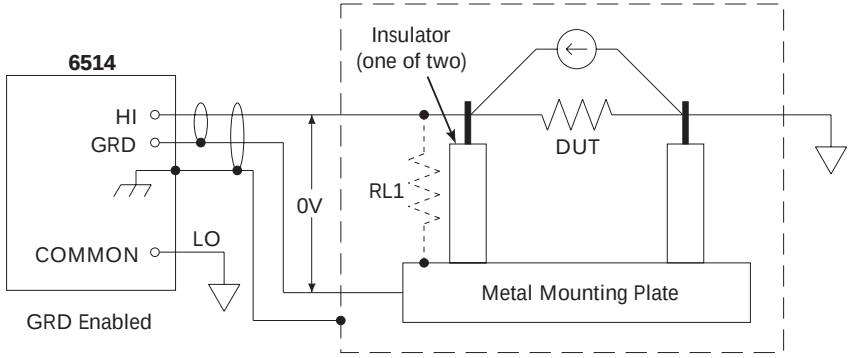
Figure 3-1B shows how to use guarding to eliminate the effects of leakage resistance. With GRD enabled, the driven guard, which is at the same potential as input HI, is connected to the metal mounting plate (now known as the guard plate). With both ends of RL1 at the same potential, current will not flow through the insulator. With no current leakage path, all current flows through the DUT allowing an accurate voltage measurement.

The above explanation also pertains to ohms measurements. The only difference is that the test current is provided by Model 6514.

Figure 3-1
High-impedance voltage measurements



A. Unguarded



B. Guarded

Input cable leakage and capacitance

In a similar manner to leakage in the test circuit, leakage in the input cable could also corrupt high-impedance measurements. In the unguarded mode, leakage in a triax cable occurs between the center conductor (HI) and the inner shield (LO).

Inherently, an input cable has capacitance that is formed by the center conductor (HI), inner shield (LO) and the insulator between them. For high-impedance measurements, the RC time constant can significantly slow down measurement response.

To minimize the effects of cable leakage, and input capacitance, keep the input cable as short as possible and use guard. With guard enabled, the same potential is applied to both the center conductor and inner shield of the cable. This eliminates leakage current and capacitor charging/discharging.

NOTE *Detailed information on "Cable Leakage Resistance", "Input Capacitance (Settling Time)" and "Guarding Input Cables" is provided in "Volts and Ohms Measurement Considerations" (located in this section).*

Volts and ohms measurement procedure

CAUTION **The maximum input voltage to Model 6514 is 250V peak. Exceeding this value may cause damage to the instrument that is not covered by the warranty.**

WARNING **The maximum common-mode input voltage, which is the voltage between the input (HI or LO) and chassis ground, is 500V peak. Exceeding this value may create a shock hazard.**

Step 1 Enable zero check and select the volts (V) or ohms (Ω) function

Zero check should always be enabled before making function or connection changes. The ZCHK key toggles zero check on and off. When on, the "ZC" or "ZZ" message is displayed. See Section 2 for details on zero check.

The volts function is selected by pressing the V key, and the ohms function is selected by pressing the Ω key.

NOTE *Zero check will enable whenever the ohms function is selected.*

Step 2 Enable or disable guard

The GRD key toggles the driven guard on and off. If performing unguarded measurements, press GRD until the "GUARD OFF" message is displayed. If performing guarded measurements, press GRD until the "GUARD ON" message is displayed.

WARNING **Hazardous voltage may be present on the inner shield of the triax cable when GRD is on. A metal safety shield connected to safety earth ground (as shown in Figure 3-5) must be used for voltage measurements at or above 30V.**

Step 3 Perform zero correction (volts only)

To achieve optimum accuracy for low voltage measurements, it is recommended that you zero correct the electrometer. To do so, select the 2V range (which is the lowest range) and press the ZCOR key until the "ZZ" message is displayed. See Section 2 for details on zero correction.

Step 4 Select a manual measurement range or enable auto range

Use the RANGE ▲ and ▼ keys to select a manual measurement range, or press AUTO to enable auto range. With auto range enabled, the instrument will automatically go to the most sensitive range to make the measurement. See Section 6 for details on range.

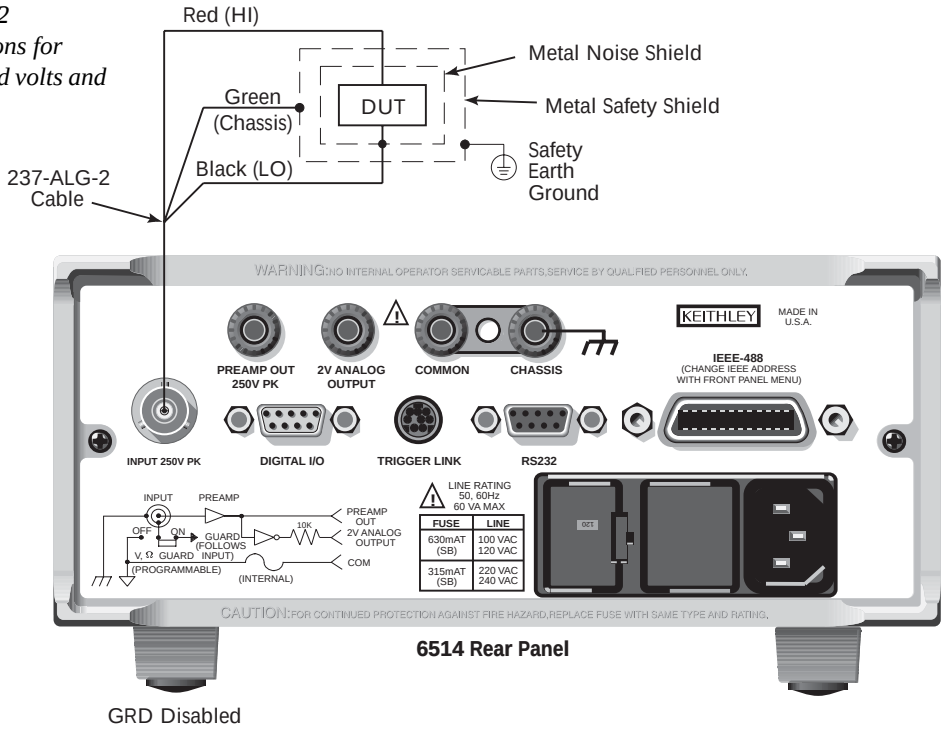
Step 5 Connect the DUT to the electrometer

NOTE *Fundamental information on making connections to the electrometer input is provided in Section 2 ("Connection Fundamentals").*

WARNING **A metal safety shield is required whenever a hazardous voltage (>30V) is present on a noise shield or guard shield. As shown in Figures 3-2 and 3-3, the safety shield must be connected to safety earth ground using #18 AWG wire or larger.**

Unguarded connections — Connections for unguarded volts and ohms measurements are shown in Figure 3-2, where the DUT is the voltage or resistance to be measured. If a hazardous voltage (>30V) is present on the noise shield, or the test circuit is floating above earth ground at a hazardous voltage level, a safety shield must be used as shown.

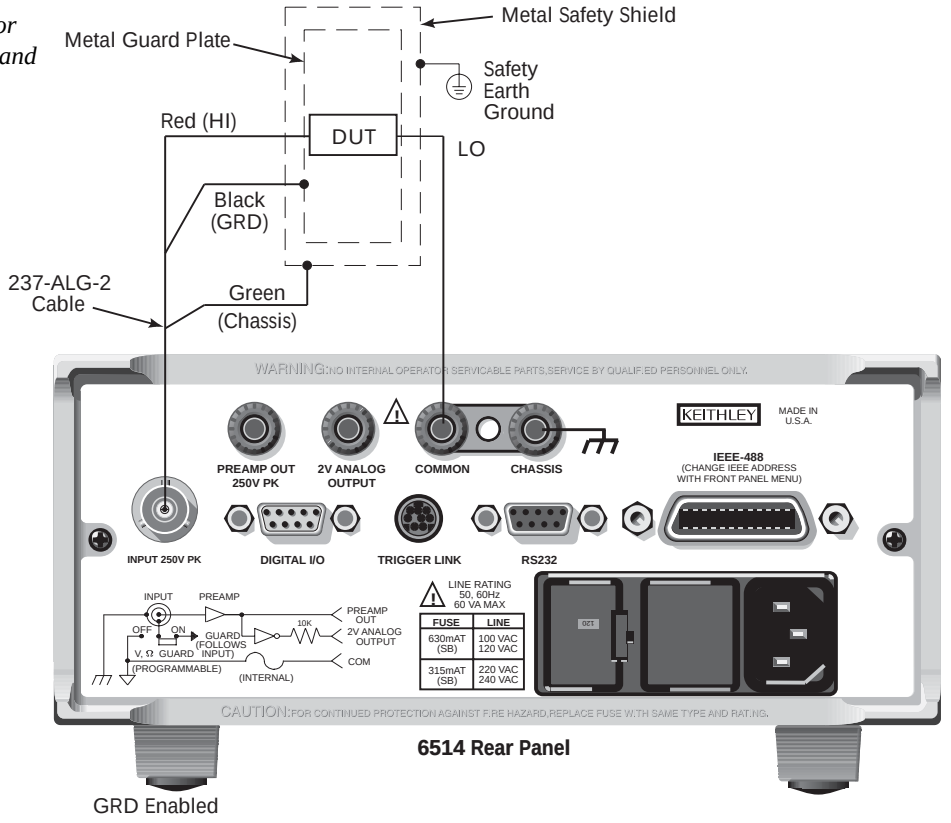
Figure 3-2
Connections for unguarded volts and ohms



Guarded connections — Connections for guarded volts and ohms measurements are shown in Figure 3-3. The driven guard (GRD) must be enabled for these measurements.

WARNING **With an open input, up to 250V peak may be present on the guard terminals while in Volts or Ohms. To prevent this, make sure zero check is enabled whenever the input is open.**

Figure 3-3
Connections for guarded volts and ohms



Step 6 Disable zero check and take a reading from the display

V-Drop and I-Source for ohms

Model 6514 performs ohms measurement by sourcing a known test current through the DUT and then measuring the voltage drop across it. The resistance reading is then calculated (R = V/I) and displayed.

While the electrometer is measuring ohms, the test current through the DUT and the voltage drop across it can be displayed as follows:

V-Drop — While displaying an ohms reading, press SHIFT and then Ω to display the voltage drop across the DUT. The "VΩ" message will indicate that a V-Drop reading is being displayed. To return to the normal ohms reading, again press SHIFT and then Ω.

Test current — While displaying an ohms or V-Drop reading, press the Ω key. The test current (ISRC) will be displayed for as long as you hold the key down.

WARNING **The ohms function has a 250V compliance. To prevent electric shock, always enable zero check to disable the test signal before making or breaking connections to DUT.**

SCPI programming

Table 3-1
SCPI commands — volts and ohms function

Commands	Description	Default	Ref
[SENSe]	SENSe Subystem:		
:FUNCtion <name>	Select function; 'VOLTage' or 'RESistance'.	VOLT	A
:DATA?	Return latest "raw" reading.		B
:VOLTage			
:GUARd <b>	Enable or disable guard.	OFF	C
:RESistance			
:GUARd <b>	Enable or disable guard.	OFF	C
INITiate	Trigger one or more readings.		B
READ?	Trigger and return reading(s).		B

A) SENSe:FUNCtion <name>

Parameters

'VOLTage'	Volts function
'RESistance'	Ohms function
'CURRent'	Amps function
'CHARge'	Coulombs function

Note that the parameter names are enclosed in single quotes ('). However, double quotes (") can instead be used. Each measurement function "remembers" its own unique range setting.

B) SENSe:DATA?

This command does not trigger a reading. It simply returns the last "raw" reading string. It will not return the result of any instrument calculation. The reading reflects what is applied to the input.

To return a fresh (new) reading, you can send the INITiate command to trigger one or more readings before sending :DATA?. Details on INITiate are provided in Section 9.

While Model 6514 is busy performing measurements, the :DATA? command will not return the reading string until the instrument finishes and goes into the idle state.

NOTES *The format that the reading string is returned in is set by commands in the FORMat Subsystem (see Section 16).*

If there is no reading available when :DATA? is sent, an error (-230) will occur.

The READ? command can be used to return "fresh" readings. This command triggers and returns the readings. See Section 15 for details.

C) :GUARd Commands

Either of the two guard commands (VOLTage:GUARd or RESistance:GUARd) can be used to control the state of guard.

Programming example

The following command sequence will perform one zero corrected voltage measurement on the 2V range:

```
*RST                  ' Return to RST defaults.
SYST:ZCH ON           ' Enable zero check.
VOLT:GUAR ON          ' Enable guard.
FUNC 'VOLT'           ' Select Volts function.
VOLT:RANG 2           ' Select 2V range.
SYST:ZCOR ON          ' Perform zero correction.
SYST:ZCH OFF          ' Disable zero check.
READ?                 ' Trigger and return one reading.
```

Volts and ohms measurement considerations

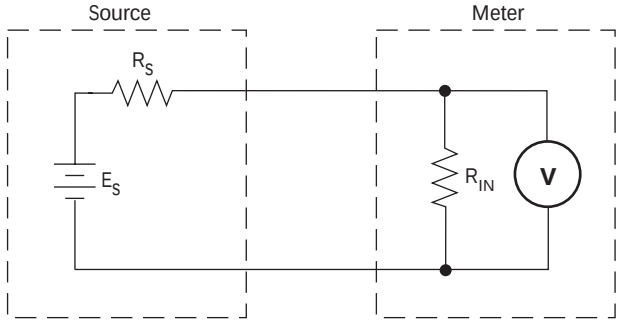
NOTE *Since Model 6514 uses the source I measure V (calculate R) technique to measure resistance, measurement considerations that apply to the volts function also apply to the ohms function.*

Some considerations for making accurate volts and ohms measurements are summarized as follows. Additional measurement considerations are covered in Appendix C. For comprehensive information on precision measurements, refer to the Low Level Measurements handbook, which is available from Keithley Instruments.

Loading effects

Circuit loading can be detrimental to high-impedance voltage measurements. To see how meter loading can affect accuracy, refer to Figure 3-4. R_S represents the resistance component of the source, while R_{IN} represents the input resistance of the meter. The percent error due to loading can be calculated using the formula in the illustration. To keep the error under 0.1%, the input resistance (R_{IN}) must be about 1000 times the value of the source resistance (R_S). The input resistance of Model 6514 is >200TΩ. Therefore, to keep the error under 0.1%, the source resistance of the measured voltage must be <200GΩ.

Figure 3-4
Meter loading



Cable leakage resistance

In an unguarded voltage measurement, leakage current occurs in the input triax cable between the center conductor (HI) and the inner shield (LO). This leakage resistance shunts the voltage source to be measured. If the resistance of the source is not significantly less than the leakage resistance of the cable, measurement errors will occur.

The effects of leakage resistance can be eliminated by using guard to make high impedance voltage measurements. See “Guarding Input Cable” for more information. In general, guarding should be used when DUT resistance is $10^9\Omega$ or greater.

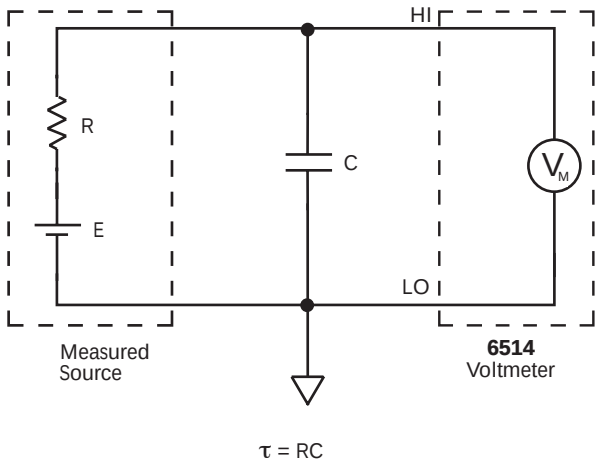
Input capacitance (settling time)

The settling time of the circuit is particularly important when making volts measurements of a source that has high internal resistance (Figure 3-5A), or when making high-resistance ohms measurements (Figure 3-5B).

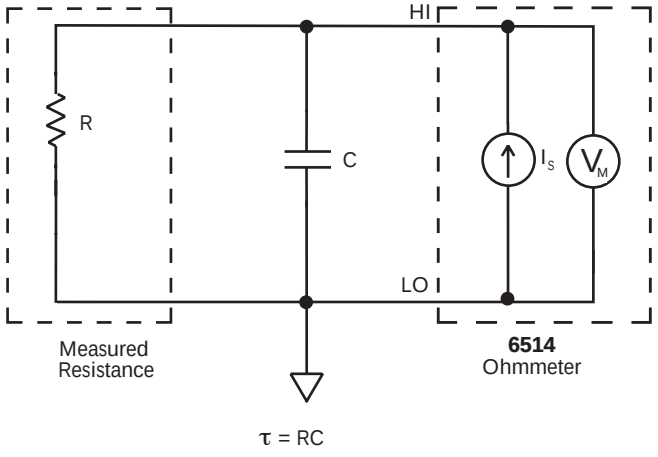
In both cases, the shunt capacitance (C) has to fully charge before an accurate voltage measurement can be made by V_M of Model 6514. The time period for charging the capacitor is determined by the RC time constant (one time constant, τ = RC), and the familiar exponential curve of Figure 3-6 results. Therefore, it becomes necessary to wait four or five time constants to achieve an accurate reading. For example, if R = 100G(and the input cable has a nominal capacitance of 10pF, the RC time constant would be 1 second. If 1% accuracy is required, a single measurement would require at least five seconds.

There are two basic ways to minimize this problem: (1) keep capacitance in the system to an absolute minimum by keeping connecting cables as short as possible, and (2) use guarding. There is, however, a limit to how short the cable can be. Using guard can reduce these effects by up to a factor of 1000 (see “Guarding Input Cable”).

Figure 3-5
Effects of input capacitance

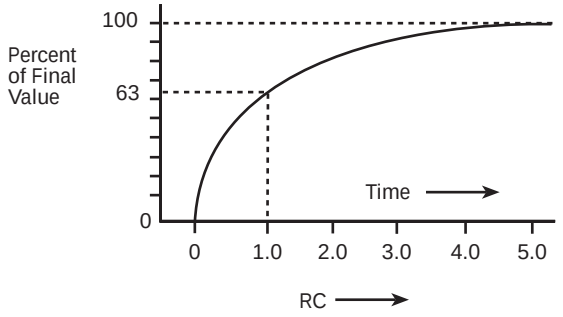


A. High-Impedance Volts Measurement (Unguarded)



B. High-Impedance Ohms Measurement (Unguarded)

Figure 3-6
Settling time

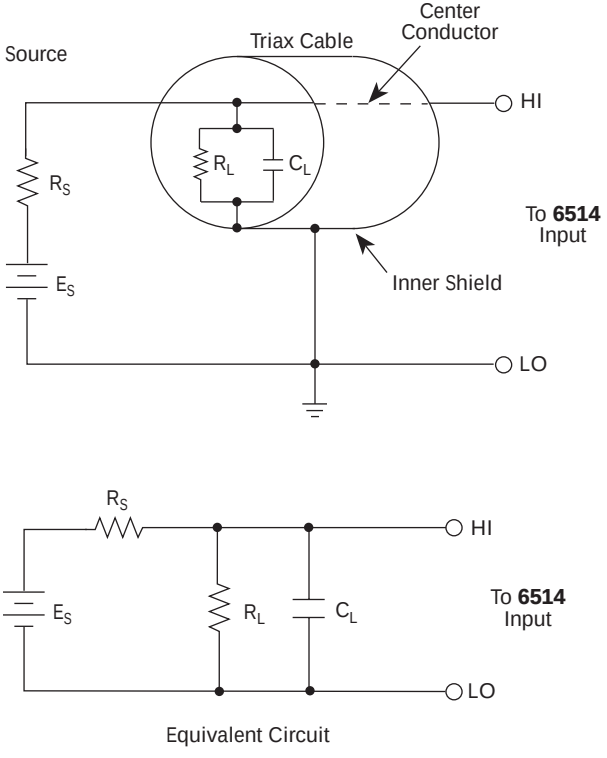


Guarding input cable

Guarding should be used for high-impedance measurements and for low voltage measurements that use long input cables.

To better understand the concept of guarding, review the unguarded circuit shown in Figure 3-7. E_S and R_S represents the resistance and voltage components of the source, and R_L and C_L represents the leakage resistance and cable capacitance of the triax input cable. The equivalent circuit shows the divider that is formed. If R_S is large enough, the divider will significantly attenuate the voltage seen at the input of Model 6514 (see "Cable Leakage Resistance"). Also, R_S and the cable capacitance (C_L) could create a long RC time constant resulting in a slow measurement response (see "Input Capacitance").

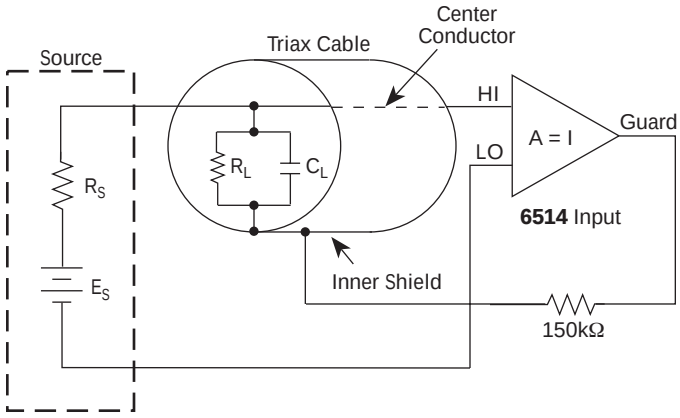
Figure 3-7
Unguarded input cable



Guarding the circuit minimizes these effects by driving the inner shield of the triax cable at signal potential, as shown in Figure 3-8. Here, a unity gain amplifier with a high input impedance and low output impedance is used. Since the center conductor (HI) and the inner shield (Guard) of the cable are at virtually the same potential, the potential across R_L is zero, so no current flows. Also, with a zero potential across C_L, there is no capacitor charging process to slow down the measurement response.

For the volts and ohms functions, the input of Model 6514 places the driven guard on the inner shield of the triax cable when GRD is enabled.

Figure 3-8
Guarded input cable



Application

Capacitor dielectric absorption

Dielectric absorption occurs when randomly oriented permanent dipoles of molecules with a capacitor dielectric are aligned by an applied electric field. After a capacitor has been disconnected from a discharge circuit, a residual charge remains on the capacitor, and a voltage will be re-established across the capacitor terminals.

For timing and integrating applications, dielectric absorption (or a residual capacitor voltage) can seriously degrade the accuracy of the circuit. Thus, a capacitor's dielectric absorption must be known and compensated for in circuits where capacitance tolerance is a significant factor in circuit accuracy.

Dielectric absorption is not normally specified by a manufacturer since its importance is application dependent. The parameter can be defined as the capacitor's discharge current at a designated time following the initiation of a discharge cycle. The capacitor is typically charged up to the maximum voltage that will be applied. The measurement of the discharge current is usually made at a discharge time interval that will be used in the application of the device, or no longer than one minute. Acceptable capacitors have current levels below a required maximum limit.

Dielectric absorption can also be expressed as a percentage of residual voltage with respect to a charging voltage. This ratio is determined by charging the capacitor to the rated voltage. The capacitor is then discharged for a second time interval. Finally, the capacitor is open-circuited, and the residual voltage across the capacitor is measured after a third time constant.

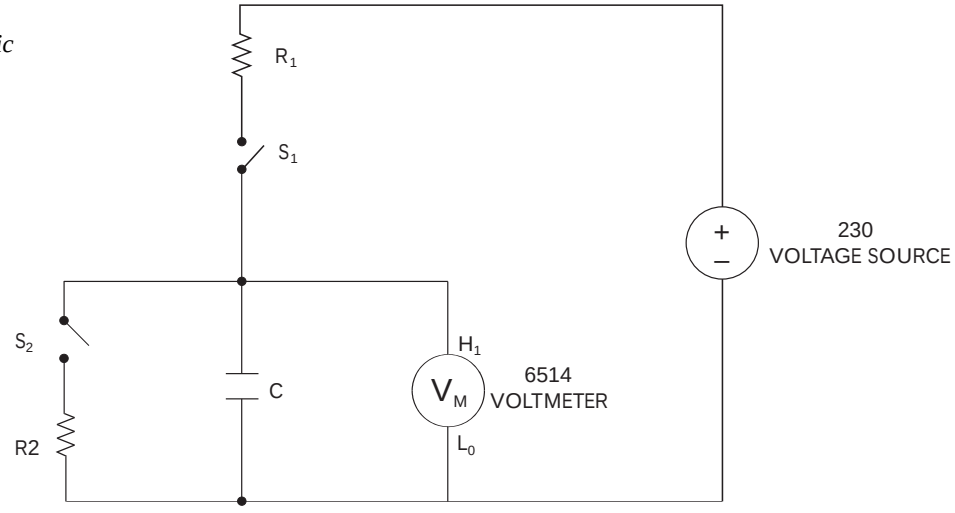
The Model 6514 is particularly useful in measuring dielectric absorption because it draws virtually no charge from the capacitor during the measurement, nor does it induce charge on the capacitor being measured.

The test circuit in Figure 3-9A uses Keithley Model 230 as a voltage source and Model 6514 to perform the voltage measurements. Figure 3-9B shows the voltage waveform across the capacitor during the three phases of the test.

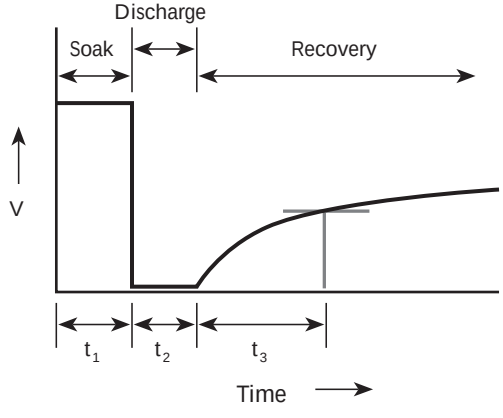
Initially, capacitor C is charged through R_1 for the required soak time (t_1 in Figure 3-9B). Soak time is typically one or two minutes, depending on the capacitor value. Next, the voltage source is turned off, and the capacitor is discharged through R_2 (t_2). The capacitor is allowed to sit for a few minutes with S_2 and S_1 open (t_3), and the residual voltage is then measured by Model 6514. Dielectric absorption is then calculated as follows:

% Dielectric Absorption = (Residual Voltage / Soak Voltage) × 100%

Figure 3-9
Measuring dielectric absorption



A. Connections



B. Voltage Waveform

4
Amps Measurements

- **Measurement overview** — Summarizes the current measurement capabilities of Model 6514.
- **Amps measurement procedure** — Provides the procedure to measure amps.
- **High-Impedance measurement techniques** — Explains non-driven guarding techniques to eliminate leakage currents in high-impedance test circuits.
- **SCPI programming** — Covers the basic SCPI commands used for the amps function.
- **Amps measurement considerations** — Covers measurement considerations that apply to amps measurements.
- **Applications** — Covers applications to measure diode leakage current, capacitor leakage current, cable insulation resistance, and surface insulation resistance.

Measurement overview

Amps measurements — Model 6514 can make amps measurements from 100aA to 21mA using 10 measurement ranges; 20pA, 200pA, 2nA, 20nA, 200nA, 2µA, 20µA, 200µA, 2mA, and 20mA.

External feedback — The external feedback mode of Model 6514 can be used to measure logarithmic currents, and re-configure the input to use non-decade current ranges. Measurements using the external feedback mode are covered in Section 11.

NOTE *Accuracy specifications for all measurement functions are provided in Appendix A.*

Amps measurement procedure

CAUTION **The maximum input voltage and current to Model 6514 is 250V peak and 21mA. Exceeding either of these values may cause damage to the instrument that is not covered by the warranty.**

WARNING **The maximum common-mode input voltage, which is the voltage between the input (HI or LO) and chassis ground, is 500V peak. Exceeding this value may create a shock hazard.**

To achieve optimum precision for low-level current measurements, input bias current and voltage burden can be minimized by performing the offset correction procedures in Section 19. Information about these offsets are provided in "Current Measurement Considerations" (located in this section).

NOTE *After measuring high voltage or high ohms, it may take several minutes for the input current to drop to within specified limits. Input current can be verified by placing the protection cap on the input triax connector, and then installing the ground link between COMMON and CHASSIS ground. With the instrument on the 20pA range and zero check disabled, allow the reading to settle until the input bias current is within specifications. The specifications for input bias current are listed in Appendix A.*

Perform the following steps to measure current:

Step 1 Enable zero check and select the amps (I) function

Zero check should always be enabled before making function or connection changes. The ZCHK key toggles zero check on and off. When on, the "ZC" or "ZZ" message is displayed. See Section 2 for details on zero check.

The amps function is selected by pressing the I key.

Step 2 Perform zero correction

To achieve optimum accuracy for low current measurements, it is recommended that you zero correct the electrometer. To do so, select the 20pA range (which is the lowest range) and press the ZCOR key until the "ZZ" message is displayed. See Section 2 for details on zero correction.

Step 3 Select a manual measurement range or enable auto range

Use the RANGE ▲ and ▼ keys to select a manual measurement range, or press AUTO to enable auto range. With auto range enabled, the instrument will automatically go to the most sensitive range to make the measurement. See Section 6 for details on range.

Step 4 Connect the current to be measured to the electrometer

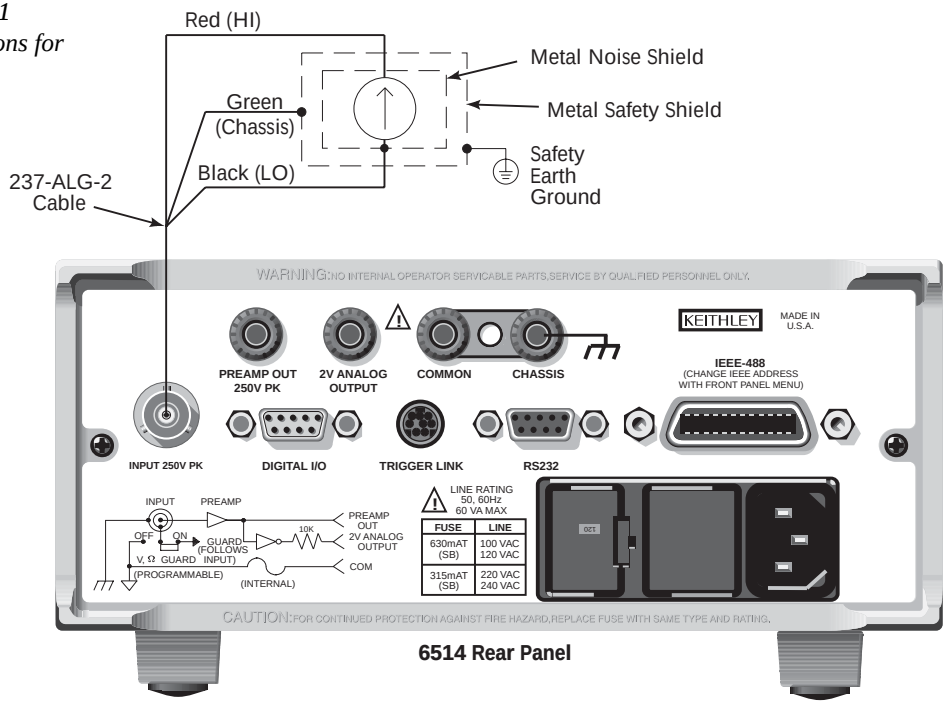
Basic connections for amps measurements are shown in Figure 4-1.

NOTE *Fundamental information on making connections to the electrometer input is provided in Section 2 ("Connection Fundamentals").*

WARNING **A safety shield is required whenever a hazardous voltage (>30V) is present on the noise shield. This can occur when the test circuit is floated above earth ground at a hazardous voltage level (see "Floating Measurements" in Section 2). Connections for the safety shield are shown in Figure 4-1. The metal safety shield must completely surround the noise shield or foating test circuit, and it must be connected to safety earth ground using #18 AWG or larger wire.**

NOTE *High-impedance current measurements require special measurement techniques. These connection techniques are covered in "High-Impedance Measurement Techniques" (located in this section).*

Figure 4-1
Connections for amps



6514 Rear Panel

Step 5 Disable zero check and take a reading from the display

If the readings are noisy, you may want to use damping and/or filtering to reduce noise. Use filtering if the noise is caused by a noisy input signal and use damping if noise is caused by input capacitance. Filtering is covered in Section 6, and damping is discussed next.

Damping

High capacitance seen at the input will increase reading noise. This capacitance can be attributed to a long input cable or to the capacitance of the source, or a combination of both. Enabling damping will reduce this type of noise for current measurements. However, damping will also slow down the response of the measurement.

Perform the following steps to enable or disable damping:

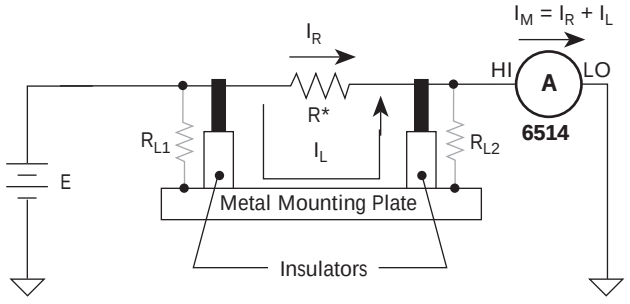
1. Press DAMP to display the present state of damping.
2. Use the ▲ or ▼ key to display ON or OFF.
3. Press ENTER.

High impedance measurement techniques

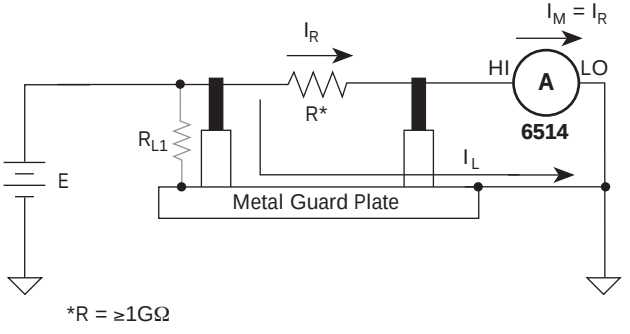
Significant leakage could occur across a high impedance (≥1GΩ) DUT through the insulators as shown in Figure 4-3A where R_{L1} and R_{L2} represent the leakage resistance. Instead of measuring just the current (I_R) through R, you are also measuring the leakage current (I_L). The current measured by the ammeter is $I_R + I_L$.

By connecting ammeter input LO to the metal mounting (guard) plate as shown in Figure 4-2B, the leakage current (I_L) is shunted to ammeter input LO and is not measured by the ammeter. Therefore, the ammeter only measures I_R.

Figure 4-2
High impedance current measurements



A. Unguarded



B. Guarded

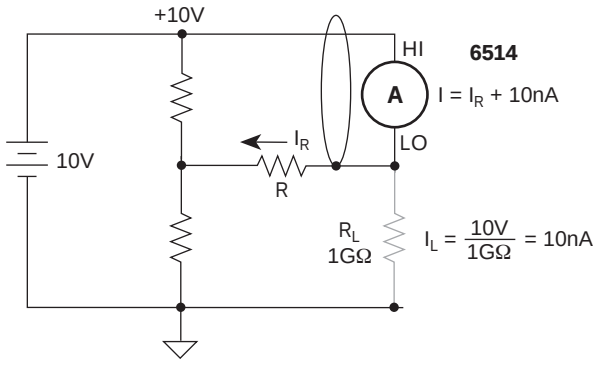
Floating current measurements — As discussed in Section 3 for volts measurements, guarding uses a conductor at essentially the same potential as input HI to drastically reduce leakage currents in high-impedance test circuits. No current can flow when there is a 0V drop across a leakage resistance.

For floating current measurements, ammeter input LO can be used as the guard since it totally surrounds input HI (via the input triax cable), and is at nearly the same potential as input HI. The actual voltage drop, known as voltage burden, depends on which measurement range is being used. The voltage burden values are listed in the specifications (Appendix A).

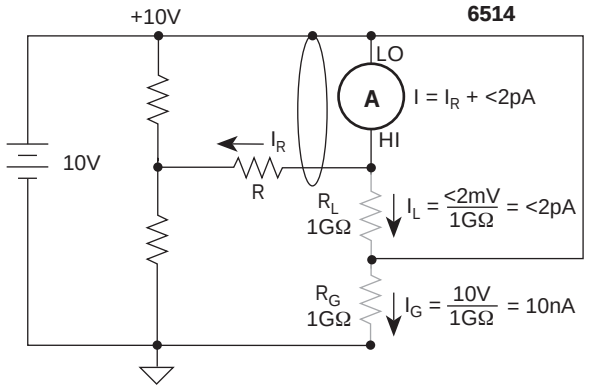
Figure 4-3A shows an unguarded floating current measurement in a high impedance circuit. The goal is to measure the current (I_R) through resistor R. However, a leakage path (R_L) exists from ammeter input LO to test circuit common. Since the ammeter drops essentially 0V, approximately 10V is dropped by R_L. The current through R_L will be approximately 10nA (10V/1GΩ = 10nA). Therefore, the current that is measured by Model 6514 is the sum of the two currents ($I = I_R$ +10nA). Obviously, if I_R is a low level current, then the 10nA leakage will corrupt the measurement.

Figure 4-3B shows the guarded version of the same circuit. Notice that the only difference is that the connections to the electrometer are reversed. Resistor R_L now represents the leakage from ammeter input HI to ammeter input LO, and resistor R_G represents the leakage from ammeter input LO (guard) to test circuit common. As previously mentioned, the ammeter drops almost 0V. If the actual voltage drop across the ammeter is <2mV, it then follows that there is a <2mV drop across R_L. Therefore, the current through R_L is <2pA (<2mV/1GΩ = <2pA). The current that is being measured by Model 6514 is the sum of the two currents ($I = I_R +$ <2pA). The use of guarding reduced the leakage current from 10nA to <2pA. Note that the 10nA leakage current (I_G) from ammeter input LO to test circuit common still exists, but it is of no consequence since it is not measured by Model 6514.

Figure 4-3
Floating current measurements



A. Unguarded



B. Guarded

SCPI programming

Table 4-1
SCPI commands — amps function

Commands	Description	Default	Ref
[SENSe]	SENSe Subystem:		
:FUNCtion 'CURrent'	Select Amps function.	VOLT	A
:DATA?	Return latest "raw" reading.		B
:CURRent			
:DAMPing <b>	Enable or disable damping.	OFF	
INITiate	Trigger one or more readings.		B
READ?	Trigger and return reading(s).		B

A) SENSe:FUNCtion <name>

Parameters

'CURRent'	Amps function
'VOLTage'	Volts function
'RESistance'	Ohms function
'CHARge'	Coulombs function

Note that the parameter names are enclosed in single quotes ('). However, double quotes (") can instead be used. Each measurement function "remembers" its own unique range setting.

B) SENSe:DATA?

This command does not trigger a reading. It simply returns the last "raw" reading string. It will not return the result of any instrument calculation. The reading reflects what is applied to the input.

To return a fresh (new) reading, you can send the INITiate command to trigger one or more readings before sending :DATA?. Details on INITiate are provided in Section 9.

While Model 6514 is busy performing measurements, the :DATA? command will not return the reading string until the instrument finishes and goes into the idle state.

NOTES *The format that the reading string is returned in is set by commands in the FORMat Subsystem (see Section 16).*

If there is no reading available when :DATA? is sent, an error (-230) will occur.

The READ? command can be used to return "fresh" readings. This command triggers and returns the readings. See Section 15 for details.

Programming example

The following command sequence will perform one zero corrected amps measurement:

```
*RST                    ' Return 6514 to RST defaults.
SYST:ZCH ON             ' Enable zero check.
FUNC 'CURR'             ' Select the Amps function.
CURR:RANG 20e-12        ' Select the 20pA range.
SYST:ZCOR ON            ' Perform zero correction.
CURR:RANG:AUTO ON       ' Enable auto range.
SYST:ZCH OFF            ' Disable zero check.
READ?                   ' Trigger and return one reading.
```

Amps measurement considerations

Some considerations for making accurate amps measurements are summarized as follows. Additional measurement considerations are covered in Appendix C. For comprehensive information on precision measurements, refer to the Low Level Measurements handbook, which is available from Keithley Instruments.

Input bias current

An ideal ammeter would read 0A with an open input. In practice, however, ammeters do have some current that flows when the input is open. This current is known as the input bias (offset) current and may be large enough to corrupt low current measurements.

The input bias current for Model 6514 is listed in the specifications. Input bias current may be reduced by performing the current offset correction procedure explained in Section 19.

Voltage burden

The input resistance of the ammeter causes a small voltage drop across the input terminals. This voltage is known as the voltage burden. If the voltage burden is large in relation to the voltage of the measured circuit, then significant measurement errors will occur.

Refer to Figure 4-4 to see how voltage burden affects current measurements. Assume V_S is 5mV and R_S is 5kΩ to configure a 1uA current source (5mV/5kΩ = 1μA). An ideal ammeter with zero voltage burden would measure the current source as follows:

$$I_M = \frac{E_S}{R_S} = \frac{5mV}{5k\Omega} = 1\mu A$$

In practice however, every ammeter has a voltage burden. If the voltage burden (V_B) is 1mV, the current will be measured as follows:

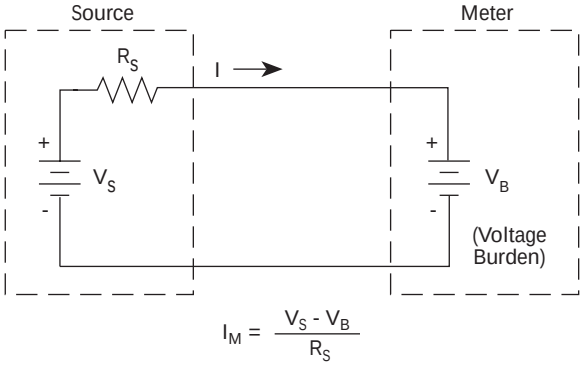
$$I_M = \frac{V_S - V_B}{R_S} = \frac{5mV - 1mV}{5k\Omega} = 0.8\mu A$$

The 1mV voltage burden caused a 20% measurement error. Percent error in a measured reading (I_M) due to voltage burden can be calculated as follows:

$$I_M\%error = \frac{100\%}{(V_S/V_B)}$$

The voltage burden of Model 6514 depends on the selected range (see specifications). Voltage burden may be reduced by performing the offset correction procedure in Section 19.

Figure 4-4
Voltage burden considerations



Noise

Noise can seriously affect sensitive current measurements. The following paragraphs discuss how source resistance and input capacitance affect noise performance.

Source resistance

The source resistance of the DUT will affect the noise performance of current measurements. As the source resistance is reduced, the noise gain of the ammeter will increase, as we will now discuss.

Figure 4-5 shows a simplified model of the feedback ammeter. R_S and C_S represents the source resistance and source capacitance, V_S is the source voltage, and V_{NOISE} is the noise voltage. Finally, R_F and C_F are the feedback resistance and capacitance respectively.

The source noise gain of the circuit can be given by the following equation:

$$\text{Output } V_{NOISE} = \text{Input } V_{NOISE}(1 + R_F/R_S)$$

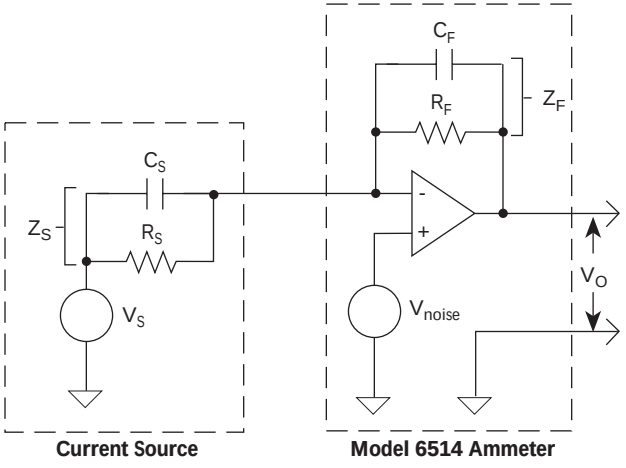
Note that as R_S decreases in value, the output noise increases. For example, when $R_F = R_S$, the input noise is multiplied by a factor of two. Since decreasing the source resistance can have a detrimental effect on noise performance, there are usually minimum recommended source resistance values based on measurement range. Table 4-2 summarizes minimum recommended

source resistance values for various measurement ranges. Note that the recommended source resistance varies by measurement range because the R_F value also depends on the measurement range.

Table 4-2
Minimum recommended source resistance values

Range	Minimum Recommended Source Resistance
pA	1GΩ to 100GΩ
nA	1MΩ to 100MΩ
µA	1kΩ to 100kΩ
mA	1Ω to 100Ω

Figure 4-5
Source resistance and capacitance



Source capacitance

DUT source capacitance will also affect the noise performance of the Model 6514 ammeter. In general, as source capacitance increases, the noise also increases. To see how changes in source capacitance can affect noise gain, again refer to the simplified ammeter model in Figure 4-5. The elements of interest for this discussion are the capacitance, C_S and the feedback capacitance C_F. Taking into account the capacitive reactance of these two elements, the previous noise gain formula must be modified as follows:

$$\text{Output } V_{NOISE} = \text{Input } V_{NOISE}(1 + Z_F/Z_S)$$

Here, Z_F represents the feedback impedance made up of C_F and R_F, while Z_S is the source impedance formed by R_S and C_S. Furthermore,

$$Z_F = \frac{R_F}{\sqrt{[(2\pi f R_F C_F)^2 + 1]}}$$

and,

$$Z_S = \frac{R_S}{\sqrt{[(2\pi f R_S C_S)^2 + 1]}}$$

Note that as C_S increases in value, Z_S decreases in value, thereby increasing the noise gain. Again, at the point where $Z_S = Z_F$, the input noise is amplified by a factor of two.

The maximum value of source capacitance (C_S) for Model 6514 ammeter is 10,000pF. You can, however, usually measure at higher source capacitance values by inserting a resistor in series with the ammeter input, but remember that any series resistance will increase the voltage burden by a factor of I_{IN} R_{SERIES}. For example, the range of resistance listed in Table 4-2 will result in voltage burden values in range of 1mV to 1V. A useful alternative to a series resistor is a series diode, or two diodes in parallel back-to-back. The diodes can be small-signal types and should be in a light-tight enclosure.

Applications

The following applications require an external voltage source. The Keithley Model 230 voltage source is fully programmable and can source up to 100V at 100mA.

With the proper use of external triggering between Models 6514 and 230, the tests can be automated. All of the applications require a bias time or delay, which can be provided by the delay feature of Model 6514. When Model 6514 is triggered, a measurement will not be performed until the delay period expires.

NOTE External triggering and delay are covered in Section 9.

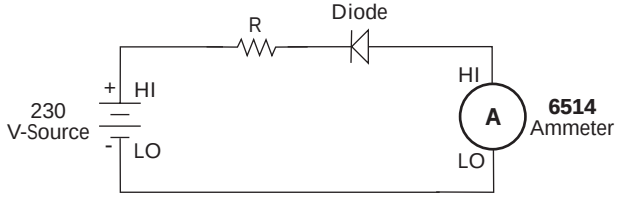
Diode leakage current

Figure 4-6 shows how to measure the leakage current for a diode. By sourcing a positive voltage, the leakage current through the diode will be measured. Note that if you source a negative voltage, you will forward bias the diode. Resistor R is used to limit current in the event that the diode shorts out or it becomes forward biased. Select a value of R that will limit current to 20mA or less.

A profile for leakage current can be developed by measuring current at various voltage levels. For example, you can program Model 230 to source from 1 to 10V in 1V steps. With the proper use of external triggering, Model 6514 will perform a current measurement on each voltage step. To ensure that the voltage is settled before each current measurement, you can program Model 6514 for a delay. For example, if you program Model 6514 for a one second delay, each measurement will be performed after the voltage step is allowed to settle for one second. The current measurements can be stored in the buffer.

NOTE Buffer operation is covered in Section 8.

Figure 4-6
Connections; diode leakage current test



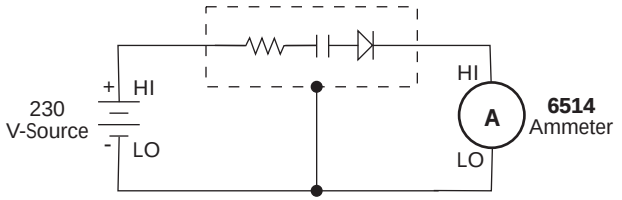
Equivalent Circuit

Capacitor leakage current

Figure 4-7 shows how to measure the leakage current for a capacitor. The magnitude of the leakage is dependent on the type of dielectric and the applied voltage. A resistor and a diode are used to limit noise for the measurement.

For this test, a fixed bias voltage is to be applied to the capacitor for a specified time to allow the capacitor to fully charge (current decays exponentially with time). The leakage current is then measured. After the measurement, the voltage source is set to output 0V for a specified time to allow the capacitor to discharge.

Figure 4-7
Connections; capacitor leakage current test



Equivalent Circuit

Cable insulation resistance

NOTE *For this test, Model 6514 uses the source voltage, measure current method to determine resistance. Once a current measurement is performed, resistance can be calculated.*

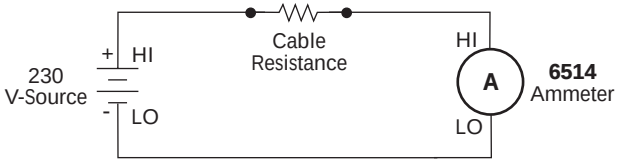
Figure 4-8 shows how to measure the insulation resistance of a cable. The resistance of the insulator between the shield and the inner conductor is being measured. The cable sample should be kept as short as possible to minimize input capacitance to the ammeter.

For this test a fixed bias voltage is applied across the insulator for a specified time to allow the charging effects of cable capacitance to stabilize. The current is then measured. Cable resistance (R) can then be calculated as follows:

$R = V/I$

where; V is the sourced bias voltage
I is the measured current

Figure 4-8
Connections; cable insulation resistance test



Equivalent Circuit

Surface insulation resistance (SIR)

NOTE *For this test, Model 6514 uses the source voltage, measure current method to determine resistance. Once a current measurement is performed, resistance can be calculated.*

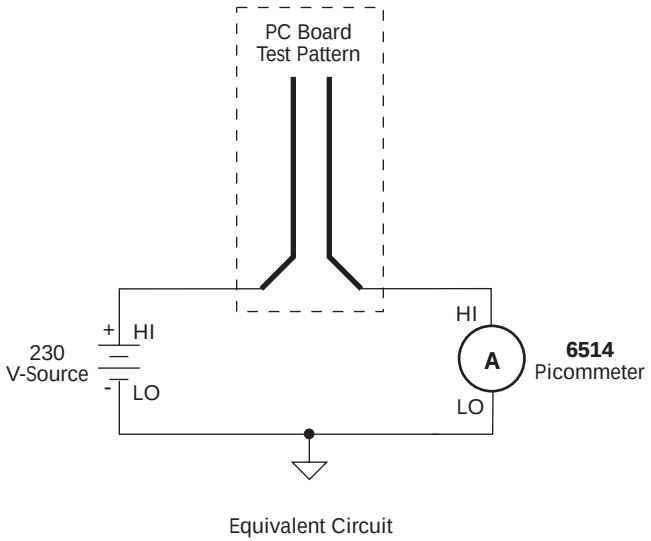
Figure 4-9 shows how to measure the insulation resistance between PC board traces. Note that the drawing shows a "Y" test pattern for the measurement. This is a typical test pattern for SIR tests.

A bias voltage (typically 50V) is applied to the test pattern for a specified time (typically one second) to polarize the test pattern. The test voltage (typically 100V) is then applied and, after a specified time (typically one second), Model 6514 measures the current. Surface insulation resistance can now be calculated as follows:

SIR = V/I

where; V is the sourced test voltage
I is the measured current

Figure 4-9
Connections; surface insulation resistance test



5
Coulombs Measurements

- **Measurement overview** — Summarizes the charge measurement capabilities of the Model 6514.
- **Auto discharge** — Explains how to use the auto discharge feature of Model 6514.
- **Coulombs measurement procedure** — Provides the procedure to measure coulombs.
- **SCPI programming** — Covers the basic SCPI commands used for the coulombs function.
- **Amps measurement considerations** — Covers measurement considerations that apply to coulombs measurements.
- **Application** — Summarizes an application to measure capacitance.

Measurement overview

Coulombs measurements — Model 6514 can make coulombs measurements from 10fC to 2.1µC using four measurement ranges; 20nC, 200nC, 2µC, and 20µC.

In the coulombs function, an accurately known capacitor is placed in the feedback loop of the amplifier so that the voltage developed is proportional to the integral of the input current in accordance with the following formula:

$$V = \frac{1}{C}\int i\,dt = \frac{Q}{C}$$

Where; V is the voltage
C is the known capacitance
Q is the charge

The voltage is scaled and displayed as charge.

External feedback — The external feedback mode of Model 6514 can be used to measure non-standard charge ranges. Measurements using the external feedback mode are covered in Section 11.

NOTE Accuracy specifications for all measurement functions are provided in Appendix A.

Auto discharge

Model 6514 has an auto discharge feature for the coulombs function. When enabled, auto discharge resets the charge reading to zero when the specified charge level is reached. After the integrator resets, the charge measurement process simply restarts at zero. The charge reading resets every time the specified charge level is reached.

When auto discharge is disabled, you can use zero check to reset the integrator.

Perform the following steps to set an auto discharge level and enable it:

1. Press SHIFT and then AUTO-DIS to display the present auto discharge level.
2. Use the cursor keys (◀ and ▶) and (▲ and ▼) to enter a discharge level. To change polarity, place the cursor on the "+" or "-" sign and press ▲ or ▼. To change range, place the cursor on the range indicator and use the ▲ and ▼ keys.
3. With the desired auto discharge level displayed, press ENTER.

NOTE Pressing SHIFT and then AUTO-DIS a second time disables auto discharge ("DISCHRG OFF" displayed briefly).

Coulombs measurement procedure

CAUTION **The maximum input voltage and current to Model 6514 is 250V peak and 21mA. Exceeding either of these values may cause damage to the instrument that is not covered by the warranty.**

WARNING **The maximum common-mode input voltage, which is the voltage between the input (HI or LO) and chassis ground, is 500V peak. Exceeding this value may create a shock hazard.**

NOTE *After measuring high voltage in the volts function, it may take several minutes for input current to drop to within specified limits. Input current can be verified by placing the protection cap on the input triax connector, and then installing the ground link between COMMON and CHASSIS ground. With the instrument on the 20pA range and zero check disabled, allow the reading to settle until the input bias current is within specifications. The specifications for input bias current are listed in Appendix A.*

Perform the following steps to measure charge:

Step 1 Enable zero check and select the coulombs (Q) function

Zero check should always be enabled before making function or connection changes. The ZCHK key toggles zero check on and off. When on, the "ZC" or "ZZ" message is displayed. See Section 2 for details on zero check.

The coulombs function is selected by pressing the Q key.

Step 2 Select a manual measurement range or enable auto range.

Use the RANGE ▲ and ▼ keys to select a manual measurement range, or press AUTO to enable auto range. With auto range enabled, the instrument will auto range between the HIGH range group (2µC and 20µC) or the LOW range group (20nC and 200nC). To select the HIGH range group, press SHIFT and then the RANGE ▲ key. To select the LOW range group, press SHIFT and then the RANGE ▼ key. See Section 6 for details on range.

Step 3 If desired, set and enable auto discharge

See "Auto Discharge" to set an auto discharge level and enable it.

Step 4 Connect the input cable to Model 6514 (open input)

Make sure that the test circuit is not connected to the input.

Step 5 Disable zero check and press the REL key

When zero check is turned off, a charge may be induced on the input. Pressing the REL key zeroes the display. See "Zero Check Hop" in "Coulombs Measurement Considerations" (in this section). Details on Relative are provided in Section 7.

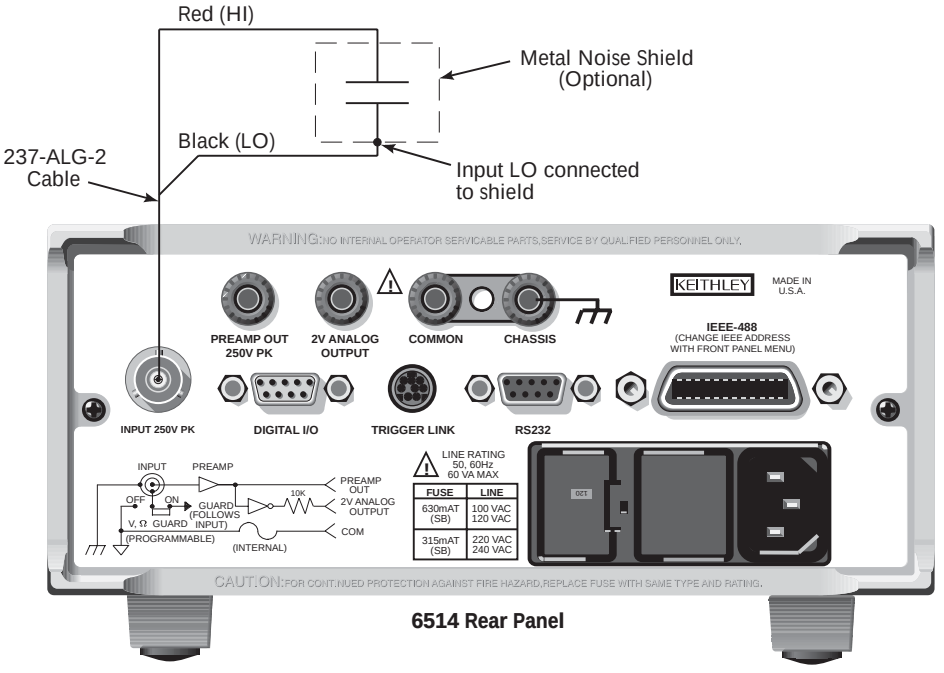
NOTE *If the zeroed reading drifts significantly after REL is enabled, disable REL and toggle zero check on and off until drift is minimized. Enable zero check and repeat Step 5.*

Step 6 Connect the charge to be measured to the electrometer

Basic connections for amps measurements are shown in Figure 5-1.

NOTE *See "Connection Basics" in Section 2 for fundamental information on making connections to the electrometer input.*

Figure 5-1
Typical connections for coulombs



Step 7 Take the charge reading from the display

If using auto discharge, use the REL key to zero the display when the integrator resets. Remember that Rel was enabled in Step 5. Therefore, you will have to press REL twice. The first press disables Rel, and the second press re-enables it to zero the display. See "Auto Discharge Hop" in "Coulombs Measurement Considerations" (in this section).

SCPI programming

Table 5-1
SCPI commands — coulombs function

Commands	Description	Default	Ref
[SENSe]	SENSe Subystem:		
:FUNCtion 'CHARge'	Select coulombs function.	VOLT	A
:DATA?	Return latest "raw" reading.		B
:CHARge			
:ADIScharge	Auto discharge:		
[:STATe] <b>	Enable or disable auto discharge.	OFF	
:LEVel <NRf>	Set auto discharge level; -2.1e-5 to 2.1e-5.	2e-6	
INITiate	Trigger one or more readings.		B
READ?	Trigger and return reading(s).		B

A) SENSe:FUNCtion <name>

Parameters

'CHARge'	Coulombs function
'CURRent'	Amps function
'VOLTage'	Volts function
'RESistance'	Ohms function

Note that the parameter names are enclosed in single quotes ('). However, double quotes (") can instead be used. Each measurement function "remembers" its own unique range setting.

B) SENSe:DATA?

This command does not trigger a reading. It simply returns the last "raw" reading string. It will not return the result of any instrument calculation. The reading reflects what is applied to the input.

To return a fresh (new) reading, you can send the INITiate command to trigger one or more readings before sending :DATA?. Details on INITiate are provided in Section 9.

While Model 6514 is busy performing measurements, the :DATA? command will not return the reading string until the instrument finishes and goes into the idle state.

NOTES *The format that the reading string is returned in is set by commands in the FORMat Subsystem (see Section 16).*

If there is no reading available when :DATA? is sent, an error (-230) will occur.

The READ? command can be used to return "fresh" readings. This command triggers and returns the readings. See Section 15 for details.

Programming example

The following command sequence will perform one coulombs measurement:

```
*RST                        ' Return 6514 to RST defaults.
SYST:ZCH ON                 ' Enable zero check.
FUNC 'CHAR'                 ' Select the Coulombs function.
CHAR:RANG:AUTO ON           ' Enable auto range.
                            ' Connect input cable.
SYST:ZCH OFF                ' Disable zero check.
CALC2:NULL:STAT ON          ' Enable Rel to zero the display.
                            ' Connect charge circuit to DUT.
READ?                       ' Trigger and return one reading.
```

Coulombs measurement considerations

Some considerations for making accurate Coulombs measurements are summarized as follows. Additional measurement considerations are covered in Appendix C. For comprehensive information on precision measurements, refer to the Low Level Measurements handbook, which is available from Keithley Instruments.

Input bias current

A primary consideration when making charge measurements is the input bias (offset) current of the integrating amplifier. Any such current is integrated along with the input signal and reflected in the final reading. Model 6514 has a maximum input bias of 4fA for charge at T_{CAL} (temperature at time of calibration). This input offset translates into a charge of 4fC per second at the T_{CAL} temperature. This value must be subtracted from the final reading to obtain the correct value.

Input bias current may be reduced by performing the offset correction procedure explained in Section 19.

External voltage source

When using an external voltage source, the input current should be limited to less than 1mA by placing a resistor in series with the high input lead. The value of this resistor should be at least:

$R = 1000 \times V$ (ohms)

where; V is the voltage across the resistor, or the compliance of the current being integrated.

Zero check hop and auto discharge hop

Using the zero check feature (going from the enabled state to the disabled state) causes a sudden change in the charge reading and is known as zero check hop. This sudden change in charge also occurs when the auto discharge feature resets the charge reading to zero. This hop in charge can be eliminated by taking a reading the instant zero check is disabled or when an auto discharge occurs, and subtracting it from all subsequent readings. A better way to deal with this hop in charge is to enable Rel immediately after zero check is disabled or when auto discharge resets the charge reading. This action nulls out the charge reading caused by the hop.

Application

Capacitance measurements

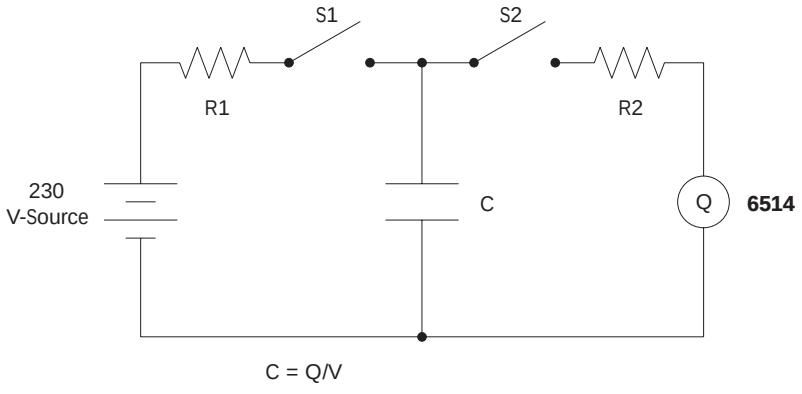
Figure 5-2 shows a general test circuit to measure a capacitor (C). Resistors R1 and R2 are used to limit current. Select a value for R1 that will limit current to ≤100mA, and select a value for R2 that will limit current to ≤20mA.

When switch S1 is closed, the Keithley Model 230 voltage source charges the capacitor. After waiting sufficient time for the capacitor to fully charge, open switch S1 and close switch S2 to measure the charge. The capacitance can now be calculated as follows:

$C = Q/V$

where; C is the capacitance (in farads)
Q is the measured charge (in coulombs)
V is the voltage used to charge the capacitor

Figure 5-2 Measuring capacitors



6
Range, Units, Digits, Rate, and Filters

- **Range, units, and digits** — Provides details on measurement range, reading units, and display resolution selection. Includes the SCPI commands for remote operation.
- **Rate** — Provides details on reading rate selection. Includes the SCPI commands for remote operation.
- **Filters** — Explains how to configure and control the digital and median filters. Includes the SCPI commands for remote operation.

Range, units, and digits

Range

The ranges for each measurement function are listed in Table 6-1. The range setting (fixed or AUTO) is remembered by each function.

Table 6-1
Measurement ranges

V	I	Ω	Q
2V	20pA	2kΩ	20nC
20V	200pA	20kΩ	200nC
200V	2nA	200kΩ	2µC
	20nA	2MΩ	20µC
	200nA	20MΩ	
	2uA	200MΩ	
	20uA	2GΩ	
	200uA	20GΩ	
	2mA	200GΩ	
	20mA		

The full scale readings for every measurement range are 5% over range. For example, on the 20V range, the maximum input voltage is ± 21V. Input values that exceed the maximum readings cause the overflow message (“OVERFL0W”) to be displayed.

Manual ranging

To select a range, press the RANGE ▲ or ▼ key. The instrument changes one range per key-press. The selected range is displayed momentarily. If the instrument displays the “OVER-FLOW” message on a particular range, select a higher range until an on-range reading is dis-played. Use the lowest range possible without causing an overflow to ensure best accuracy and resolution.

Autoranging

When using autorange, the instrument automatically goes to the most sensitive available range to measure the applied signal. Up-ranging occurs at 105% of range, while down-ranging occurs at the range value. For example, if on the 20V range, the instrument will go up to the 200V range when the input signal exceeds 21V. While on the 200V range, the instrument will go down to the 20V range when the input level goes to 20V.

The AUTO key toggles the instrument between manual ranging and autoranging. The AUTO annunciator turns on when autoranging is selected. To disable autoranging, press AUTO or the RANGE ▲ or ▼ key. Pressing AUTO to disable autoranging leaves the instrument on the present range.

Every time an autorange occurs, a search for every available range of the selected function is performed. The time it takes to perform the search could slow down range change speed significantly. For V, I and (measurements, upper and/or lower autorange limits can be set to reduce search time. For Q measurements, the instrument will only autorange between the two higher charge ranges (high range group), or between the two lower charge ranges (low range group).

NOTE *Range limits and groups are not in effect for manual ranging. Every range is accessible with manual range selection.*

Autorange limits for V, I and Ω

Search time for V, I and Ω can be reduced by setting upper and/or lower autorange limits. For example, if you know the maximum input will be around 1µA, you can set the upper current range limit to 2µA. This eliminates the 20µA, 200µA, 2mA and 20mA ranges from the search, therefore, increasing the range change speed. Should the input exceed 2.1µA, the "OVERFLOW" message will be displayed.

Perform the following steps to set upper and/or lower autorange limits.

1. Select the V, I or Ω function.
2. Press SHIFT and then one of the following RANGE keys:
   a. Press the RANGE ▲ key to display the present UPPER range limit.
   b. Press the RANGE ▼ key to display the present LOWER range limit.
3. Use the RANGE ▲ and ▼ keys to display the desired limit.
4. Press ENTER.

NOTE *If you attempt to select an incompatible range limit, it will be ignored and "TOO LARGE" or "TOO SMALL" will be displayed briefly. For example, if the lower range limit is 20V, trying to set the upper limit to 2V will result in the "TOO SMALL" error.*

Autorange groups for Q

To optimize range change speed for charge measurements, the instrument will only autorange between two ranges. With the high range group selected, the instrument can only autorange between the 2µC and 20µC ranges. With the low range group selected, the instrument can only autorange between the 20nC and 200nC ranges.

If the HIGH range group is presently selected and the instrument is on the 20nC or 200nC range (autorange disabled), pressing the AUTO range key will initially select the 2µA range and then enable autorange. If the range group is then changed to LOW, the instrument will initially go to the 200nC range with autorange enabled. Therefore, the instrument will always stay within the selected range group with autorange enabled.

NOTE *With the low range group selected, the "OVERFLOW" message will be displayed when the input signal exceeds 210nC.*

Perform the following steps to select autorange group for Q:

1. Select the Q function.
2. Press Shift and then one of the follow RANGE keys:
   a. Press the RANGE ▲ key to select the HIGH range group (2µC and 20µC).
   b. Press the RANGE ▼ key to select the LOW range group (20nC and 200nC).

Units

Readings can be displayed using engineering (ENG) units (i.e. 1.236 MΩ) or scientific (SCI) notation (i.e. 1.236E+06Ω). Perform the following steps to change the units setting:

1. Press SHIFT and then DIGIT to display the present units setting (ENG or SCI).
2. Press the RANGE ▲ or ▼ key to display the desired units setting.
3. Press ENTER.

NOTE *1. The units setting can only be changed from the front panel (no remote operation).*
2. Scientific notation provides more resolution on small values than engineering units.

Digits

The DIGIT key sets display resolution for Model 6514. Display resolution can be set from 3½ to 6½ digits. This single global setting affects display resolution for all measurement functions.

To set display resolution, press (and release) the DIGIT key until the desired number of digits is displayed.

NOTE *Changing the integration rate changes display resolution, but changing display resolution does not change the rate setting (see RATE for details).*

SCPI programming - range and digits

Table 6-2
SCPI commands — range and digits

Commands	Description	Default
For Range:		
[:SENSe]	SENSe Subsystem:	
:VOLTage	Measure voltage:	
:RANGe	Range selection:	
[:UPPer] <n>	Specify expected reading; -210 to 210 (V).	20V
: AUTO <b>	Enable or disable autorange.	(see Note)
:ULIMit <n>	Specify upper range limit for autorange; -210 to 210 (V).	200V
:LLIMit <n>	Specify lower range limit for autorange; -210 to 210 (V).	2V

Table 6-2 (cont.)
SCPI commands — range and digits

Commands	Description	Default
:CURRent	Measure current:	
:RANGe	Range selection:	
[:UPPer] <n>	Specify expected reading; -0.021 to 0.021 (A).	200µA
: AUTO <b>	Enable or disable autorange.	(see Note)
:ULIMit <n>	Specify upper range limit for autorange; -0.021 to 0.021 (A).	20mA
:LLIMit <n>	Specify lower range limit for autorange; -0.021 to 0.021 (A).	20pA
:RESistance	Measure resistance:	
:RANGe	Range selection:	
[:UPPer] <n>	Specify expected reading; 0 to 2.1e11 (Ω).	200kΩ
: AUTO <b>	Enable or disable autorange.	(see Note)
:ULIMit <n>	Specify upper range limit for autorange; 0 to 2.1e11 (Ω).	200GΩ
:LLIMit <n>	Specify lower range limit for autorange; 0 to 2.1e11 (Ω).	2kΩ
:CHARge	Measure charge:	
:RANGe	Range selection:	
[:UPPer] <n>	Specify expected reading; -21e-6 to 21e-6 (C).	200nC
: AUTO <b>	Enable or disable autorange.	(see Note)
:LGRoup <name>	Select autorange group; HIGH or LOW	HIGH
For Digits:		
DISPlay	DISPlay Subsystem:	
:DIGITs <n>	Set display resolution; 4 to 7, where: 4 = 3½-digit resolution 5 = 4½-digit resolution 6 = 5½-digit resolution 7 = 6½-digit resolution Note: Rational numbers can be used. For example, to set 4 resolution, send a value of 4.5 (the 6514 rounds it to 5).	6

Note: *RST default is ON and SYSTem:PRESet default is OFF.

Programming example — range and digits

The following command sequence selects the 200V range and sets display resolution to 3:

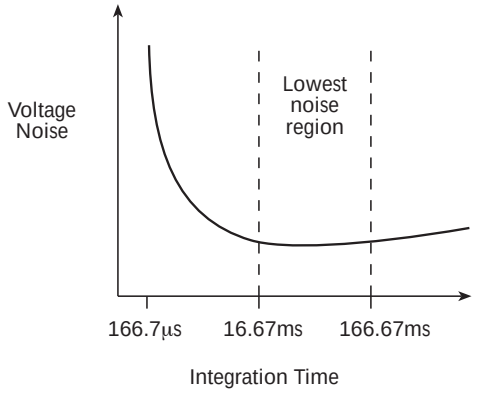
```
*RST                    ' Restore RST defaults.
VOLT:RANG 200           ' Set V function to 200V range.
DISP:DIG 3.5            ' Set display resolution to 3½ digits.
```

Rate

The RATE key selects the integration time of the A/D converter. This is the period of time the input signal is measured. The integration time affects the amount of reading noise, as well as the ultimate reading rate of the instrument. The integration time is specified in parameters based on a number of power line cycles (NPLC), where 1 PLC for 60Hz is 16.67msec (1/60) and 1 PLC for 50Hz (and 400Hz) is 20msec (1/50).

In general, Model 6514 has a parabola-like shape for its speed vs. noise characteristics and is shown in Figure 6-1. Model 6514 is optimized for the 1 PLC to 10 PLC reading rate. At these speeds (lowest noise region in the graph), Model 6514 will make corrections for its own internal drift and still be fast enough to settle a step response <100ms.

Figure 6-1
Speed vs. noise characteristics



The rate setting is global for all measurement functions. Therefore, it does not matter what function is presently selected when you set rate.

There are two ways to set rate. You can select slow, medium, or fast by using the RATE key, or you can set the number of power cycles from the NPLC menu that is accessed by pressing SHIFT and then NPLC.

Rate Key — The RATE key selections are explained as follows:

- SLOW — Selects the slowest front panel integration time (6 PLC for 60 Hz or 5 PLC for 50 Hz) and sets display resolution to 5½-digit resolution. The SLOW rate provides better noise performance at the expense of speed.
- MED — Selects the medium integration time (1 PLC) and sets display resolution to 5½-digit resolution. Select the MED rate when a compromise between noise performance and speed is acceptable.
- FAST — Selects the fastest front panel integration time (0.1 PLC) and sets display resolution to 4½-digit resolution. Select the FAST rate if speed is of primary importance (at the expense of increased reading noise).

To change the rate setting, press (and release) the RATE key until the desired rate annunciator (SLOW, MED or FAST) is displayed.

NPLC Menu — From this menu you can set rate by setting the PLC value. Perform the following steps to set NPLC:

1. Press SHIFT and then NPLC to display the present PLC value.
2. Use the ◄, ►, ▲, and ▼ keys to display the desired PLC value (0.01 to 10).
3. Press ENTER.

NOTE *The SLOW, MED or FAST annunciator will only turn on if the set PLC value corresponds exactly to the slow (5 or 6 PLC), medium (1 PLC) or fast (0.1 PLC) integration rate. For example, with the integration rate set to 2 PLC, none of the rate annunciators will turn on.*

SCPI programming — rate

As shown in Table 6-3, there are four commands to set rate. However, since the rate setting is global and affects all measurement functions, it doesn't matter which command you use to set it.

Table 6-3
SCPI commands — rate

Command	Description	Default
[:SENSe]	SENSe Subsystem:	
:VOLTage		
:NPLCycles <n>	Specify integration rate; 0.01 to 10 (PLCs)	6.0 (60Hz) 5.0 (50Hz)
:CURRent		
:NPLCycles <n>	Specify integration rate; 0.01 to 10 (PLCs)	6.0 (60Hz) 5.0 (50Hz)
:RESistance		
:NPLCycles <n>	Specify integration rate; 0.01 to 10 (PLCs)	6.0 (60Hz) 5.0 (50Hz)
:CHARge		
:NPLCycles <n>	Specify integration rate; 0.01 to 10 (PLCs)	6.0 (60Hz) 5.0 (50Hz)

Programming example — rate

The following command sets the integration rate for all measurement functions to 2 PLC:

```
VOLT:NPLC 2              ' Set integration rate to 2 PLC.
```

Filters

Filtering stabilizes noisy measurements caused by noisy input signals. The Model 6514 uses two types of filters: median and digital. The displayed, stored or transmitted reading is simply the result of the filtering processes. Note that both the median and digital filters can be in effect at the same time.

With both filters enabled, the median filter operation is performed first. After the median filter yields a reading, it is sent to the stack of the digital filter. Therefore, a filtered reading will not be displayed until both filter operations are completed.

The settings for the filter are global. Therefore, the filter configuration applies to all four measurement functions. The MEDN key is used to configure and control the median filter, and the AVG key is used to configure and control the digital filter. When either the median or digital filter is enabled, the FILT annunciator is on.

Median filter

The median filter is used to determine the "middle-most" reading from a group of readings that are arranged according to size. For example, assume the following readings:

20V, 1V, 3V

The readings are re-arranged in an ascending order as follows:

1V, 3V, 20V

From the above readings, it is apparent that 3V is the median (middle-most) reading. The number of sample readings used for the median calculation is determined by the selected rank (1 to 5) as follows:

Sample readings = $(2 \times R) + 1$

where; R is the selected rank (1 to 5)

For example, a rank of 5 will use the last 11 readings to determine the median; $(2 \times 5) + 1 = 11$. Each new reading replaces the oldest reading, and the median is then determined from the updated sample of readings.

Median filter operation — The median filter operates as a moving type filter. For example, if the median filter is configured to sample 11 readings (Rank 5), the first filtered reading will be calculated (and displayed) after 11 readings are acquired and placed in its filter stack. Each subsequent reading will then be added to the stack (oldest reading discarded) and another median filter reading will be calculated and displayed. The median filter operation will reset (start over) whenever the Zero Check operation is performed or the function is changed.

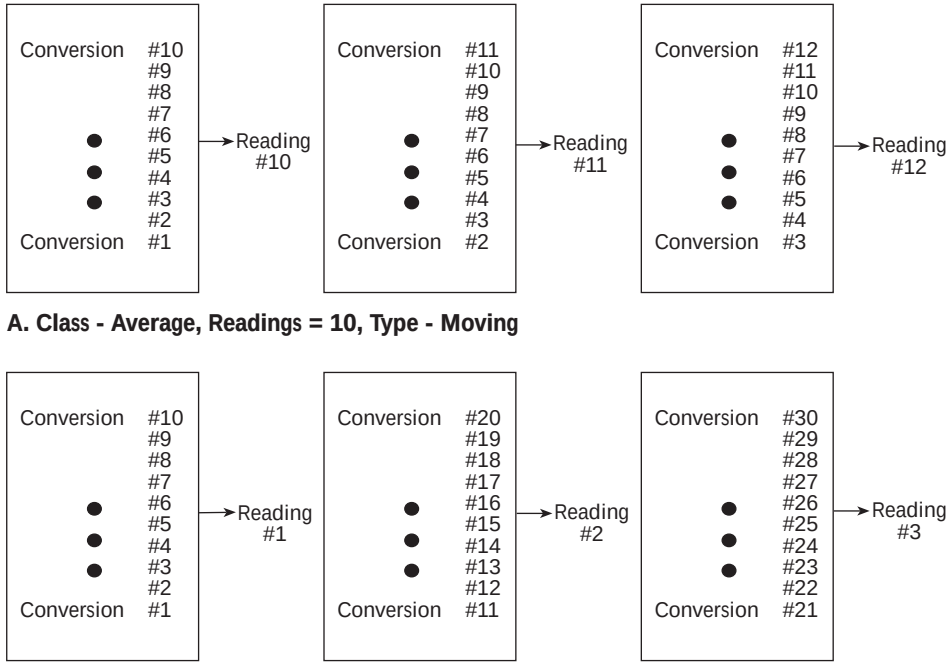
Median filter configuration control

The MEDN key is a toggle-action key. It will either disable the median filter (displays “MEDIAN OFF”), or access the configuration menu to enable the median filter.

1. Press the MEDN key to display the present filter rank.
2. Use the RANGE ▲ or ▼ key to display the desired rank (1 to 5) and press ENTER.

Digital filter

Figure 6-2 Digital filter types; moving and repeating



Digital filter types

The digital filter can be either a moving or repeating type. Filter types are compared in Figure 6-2.

Moving Filter - Every time a reading conversion occurs, the readings in the stack are averaged to yield a single filtered reading. The stack type is first-in, first-out. After the stack fills, the newest reading conversion replaces the oldest. Note that the instrument does not wait for the stack to fill before releasing readings.

Repeating Filter - Takes a selected number of reading conversions, averages them, and yields a reading. It then flushes its stack and starts over.

Response time

The various filter parameters have the following effects on the time needed to display, store, or output a filtered reading:

- Filter type: The time to the first reading is the same for both types, but thereafter, the moving mode yields a faster reading than repeating mode.
- Number of reading conversions: Speed and accuracy are tradeoffs.

Operation consideration

- The digital filter operation will reset (start over) whenever the zero check operation is performed or the function is changed.

Digital filter configuration and control

The AVG key is a toggle-action key. It will either disable the digital filter (display "AVERAGE OFF"), or access the configuration menu to enable the digital filter.

NOTE *For the following procedure, use the ◀ and ▶ keys and the RANGE ▲ and ▼ keys to set values. The ◀ and ▶ keys provide cursor control, while the ▲ and ▼ keys increment and decrement the value.*

1. Press the AVG key to display the present number of reading conversions to average (filter count).
2. Key in desired filter count value (1 to 100) and press ENTER. The present filter type (repeating or moving) is displayed.
3. Use the ▲ or ▼ key to display the desired filter type (REPEAT or MOVNG AV) and press ENTER.

SCPI programming — filters

Table 6-4
SCPI commands — filters

Commands	Description	Default
For median filter:		
[:SENSe[1]]	SENSe Subsystem:	
:MEDian	Median Filter:	
:RANK <n>	Specify filter rank; 1 to 5.	1
[:STATe] <b>	Enable or disable median filter.	OFF
For digital filter:		
[:SENSe[1]]	SENSe Subsystem:	
:AVERage	Digital Filter:	
:TCONtrol <name>	Select filter control; MOVing or REPeat.	REP
:COUNt <n>	Specify filter count; 1 to 100.	10
[:STATe] <b>	Enable or disable digital filter.	OFF

Programming example

The following command sequence configures and enables both filters:

```
' Median Filter:
MED:RANK 5                ' Set rank to 5.
MED ON                    ' Enable median filter.

' Digital Filter:
AVER:COUN 20              ' Set filter count to 20.
AVER:TCON MOV             ' Select moving filter.
AVER ON                   ' Enable digital filter.
```

7 Relative, mX+b and Percent (%)

- **Relative** — Explains how to null an offset or establish a baseline value. Includes the SCPI commands for remote operation.
- **mX+b and percent (%)** — Covers these two basic math operations, and includes the SCPI commands for remote operation.

Relative

Relative (Rel) nulls an offset or subtracts a baseline reading from present and future readings. When a Rel value is established, subsequent readings will be the difference between the actual input and the Rel value.

Displayed (Rel'ed) Reading = Actual Input - Rel Value

A Rel value is the same for all measurement ranges. For example, a Rel value of 1 is 1V on the 2V range, 1V on the 20V range, and 1V on the 200V range. Note that function changes disables Rel.

When a Rel value is larger than the selected range, the display is formatted to accommodate the Rel'ed reading. However, this does not increase the maximum allowable input for that range. An over-range input signal will still cause the display to overflow. For example, on the 20V range, Model 6514 still overflows for a 20.1V input.

NOTE Rel can be used on the result of the percent (%) or mX+b calculations. However, Rel will disable whenever a math function is enabled or disabled.

Setting and controlling relative

From the front panel, there are two ways to set the Rel value. You can use the input reading as the Rel value or you can manually key in the Rel value.

REL key

When the REL key is used to enable Rel, the present display reading is used as the Rel value. Perform the following steps to set a Rel value:

1. Display the reading you want as the Rel value. This could be a zero offset reading that you want to null out, or it could be an applied level that you want to use as a baseline.
2. Press REL. The REL annunciator turns on and subsequent readings will be the difference between the actual input and the Rel value.
3. To disable REL, press the REL key a second time or select a different measurement function. The REL annunciator turns off.

NOTE When Rel is disabled, the Rel value is remembered and can be reinstated from the VAL key.

VAL key

The SHIFT-VAL key sequence displays the present Rel value. From this display you can enable Rel using that Rel value or you can key in a different Rel value.

1. Press SHIFT and then VAL to display the present Rel value.
2. To change the Rel value, use the ◀, ▶, ▲ and ▼ keys to change the value. To change polarity, place the cursor on the polarity sign and press ▲ or ▼. To change range, place the cursor on the range symbol (at the end of the reading) and use the ▲ and ▼ keys (see Table 7-1).
3. With the desired Rel value displayed, press ENTER to enable Rel.

Table 7-1
Range symbols for rel values

Symbol	Prefix	Exponent
P	pico-	10^{-12}
N	nano-	10^{-9}
µ	micro-	10^{-6}
m	milli-	10^{-3}
^	(none)	10^{0}
K	kilo-	10^{3}
M	mega-	10^{6}
G	giga-	10^{9}
T	tera-	10^{12}

SCPI programming — relative

Table 7-2
SCPI commands — relative (null)

Commands	Description	Default	Ref
CALCulate2	CALCulate2 Subsystem:		
:FEED <name>	Specify reading to Rel; SENSe[1] or CALCulate[1].	SENS	A
:NULL	Configure and control Relative.		
:ACQuire	Use input signal as Rel value.		
:OFFSet <NRf>	Specify Rel value; -9.999999e20 to 9.999999e20.	0.0	
:STATe <b>	Enable or disable Rel.	OFF	
:DATA?	Return Rel'ed readings triggered by INITiate.		B
:LATest?	Return only the latest Rel'ed reading.		B
INITiate	Trigger one or more readings.		

A) :FEED <name> Specify reading to Rel

With SENSe[1] selected, the Rel operation will be performed on the input signal. With CALCulate[1] selected, the Rel operation will be performed on the result of the Percent (%) or mX+b calculation.

B) :DATA? and :DATA:LATest?

With Rel enabled, these commands will return one or more Rel'ed readings. They will not trigger fresh (new) readings. Use the INITiate command to trigger new readings (see Section 9 for details on INITiate).

If the instrument is programmed to perform a finite number of measurements, the :DATA? command will return all the Rel'ed readings after the last reading is taken. The :DATA:LATest? command will only return the last (latest) Rel'ed reading.

If the instrument is programmed to perform an infinite number of measurements (arm count or trigger count set to infinite), you cannot use the :DATA? command to return Rel'ed readings. However, you can use the :DATA:LATest? command to return the last Rel'ed reading after aborting the measurement process. After sending the INITiate command to start the measurement process, use the ABORt command to abort the measurement process, then use :DATA:LATest? to return to the last Rel'ed reading.

Programming example — relative

This program fragment establishes a 1V baseline for voltage measurements:

```
FUNC 'VOLT'              ' Select V function.
CALC2:NULL:OFFS 1        ' Set Rel value of 1V.
CALC2:NULL:STAT ON       ' Enable Rel.
CALC2:FEED SENS          ' Rel input signal.
INIT                     ' Trigger reading(s).
CALC2:DATA?              ' Request Rel'ed reading.
```

mX+b and percent (%)

mX+b

This math operation manipulates normal display readings (X) mathematically according to the following calculation:

Y = mX+b

where: X is the normal display reading
m and b are user-entered constants for scale factor and offset
Y is the displayed result

To configure and control the mX+b calculation, perform the following steps:

1. Press SHIFT and then MX+B to display the present scale factor:
   M: +1.0000000 ^ (factory default)
2. Key in a scale factor value. The ◄ and ► keys control cursor position and the ▲ and ▼ range keys increment and decrement the digit value. To change range, place the cursor

on the range symbol and use the ▲ and ▼ keys. With the cursor on the polarity sign, the ▲ and ▼ keys toggle polarity.

NOTE Range symbols are defined in Table 7-1

3. Press ENTER to enter the M value and display the offset (B) value:
   B: +00.000000 P (factory default)
4. Key in the offset value.
5. Press ENTER to enter the B value and display the three-character UNITS designator:
   UNITS: MXB (factory default)
6. Use the ◄ and ► cursor keys, and the ▲ and ▼ keys if you wish to change the units designator. Each character can be any letter in the alphabet (A through Z).
7. Press ENTER. The MATH annunciator will turn on, and the result of the calculation will be displayed. Note that the calculation will be applied to all measurement functions.
8. To disable mX+b, again press SHIFT and then MX+B. The MATH annunciator will turn off.

Percent (%)

This math function determines percent deviation from a specified reference value. The percent calculation is performed as follows:

$$\text{Percent} = \frac{\text{Input}}{\text{Reference}} \times 100\%$$

where: Input is the normal display reading
Reference is the user entered constant
Percent is the displayed result

To configure and control the percent calculation, perform the following steps:

1. Press SHIFT and then % to display the present reference value:
   REF: +1.000000 ^ (factory default)
2. Key in a reference value. The ◄ and ► keys control cursor position and the ▲ and ▼ range keys increment and decrement the digit value. To change range, place the cursor on the range symbol and use the ▲ and ▼ keys. With the cursor on the polarity sign, the ▲ and ▼ keys toggle polarity.
3. Press ENTER. The MATH annunciator will turn on, and the result of the calculation will be displayed. Note that the calculation will be applied to all measurement functions.
4. To disable percent, again press SHIFT and then %. The MATH annunciator will turn off.

NOTES The result of the percent calculation is positive when the input exceeds the reference, and negative when the input is less than the reference.

The result of the percent calculation may be displayed in exponential notation. For example a displayed reading of + 2.500E+03% is equivalent to 2500% (2.5K %).

Rel can be used on the result of the mX+b or percent math operation. Note however that Rel will disable whenever a math function is enabled or disabled. See "Relative" for details on using Rel.

SCPI programming — mX+b and percent

Table 7-3
SCPI commands — mX+b and percent

Commands	Description	Default	Ref
CALCulate[1]	CALCulate1 Subsystem:		
:FORMat <name>	Select calculation; MXB or PERCent.	MXB	
:KMATh	Path to configure mX+b and percent:		
:MMFactor <n>	Specify scale factor (M) for mX+b; -9.99999e20 to 9.99999e20.	1.0	
:MBFactor <n>	Specify offset (B) for mX+b; -9.99999e20 to 9.99999e20.	0.0	
:MUNits <name>	Specify units for mX+b; 3 characters “A” through “Z”.	MXB	
:PERCent	Percent:	1.0	
:REFerence <n>	Specify reference value; -9.99999e20 to 9.99999e20.		
:ACQuire	Use input signal as reference value.		
:STATe <b>	Enable or disable the selected calculation.	OFF	
:DATA?	Returns all CALC1 results triggered by the INITiate.		A
:DATA:LATest?	Returns only the latest CALC1 reading.		A

A) :DATA? and :DATA:LATest?

The INITiate command must be sent to trigger the measurements and calculations. The number of calculations depend on how many measurements the instrument is programmed to perform.

If the instrument is programmed to perform a finite number of measurements, the :DATA? command will return all the CALC1 readings after the last reading is taken. The :DATA:LATest? command will only return the last (latest) CALC1 reading.

If the instrument is programmed to perform an infinite number of measurements (arm count or trigger count set to infinite), you cannot use the :DATA? command to return CALC1 readings. However, you can use the :DATA:LATest? command to return the last CALC1 reading after aborting the measurement process. After sending the INITiate command to start the measurement process, use the ABORt command to abort the measurement process, then use :DATA:LATest? to return the last CALC1 reading.

Programming example — mX+b

This command sequence performs a single mX+b calculation and displays the result on the computer CRT:

```
*RST                    ‘ Restores RST defaults.
CALC:FORM MXB           ‘ Selects mX+b calculation.
CALC:KMAT:MMF 2         ‘ Sets scale factor (M) to 2.
CALC:KMAT:MBF 0.5       ‘ Sets offset (B) to 0.5.
CALC:STAT ON            ‘ Enables calculation.
INIT                    ‘ Perform one measurement and
                          calculate mX+b.
CALC:DATA?              ‘ Request mX+b result.
```

8 Buffer

- **Buffer operations** — Explains how to store and recall readings including buffer statistics.
- **SCPI programming** — Covers the SCPI commands used to control buffer operations.

Buffer operations

Model 6514 has a buffer to store from one to 2500 readings. It also stores overflow readings. Each reading has a timestamp. The timestamp for each reading is referenced to the time the measure/store process is started. In addition, recalled data includes statistical information (maximum, minimum, peak-to-peak, average and standard deviation).

The buffer fills with the specified number of readings and stops. Readings are placed in the buffer after any math operations are performed. Math operations include relative, mX+b, percent, or limits.

Buffered data is overwritten each time the storage operation is selected. The data is volatile; it is not saved through a power cycle.

Measurement function changes are permissible during the storage process. Note however, that the statistics will be based on the readings of the different measurement functions.

Store

Perform the following steps to store readings:

1. Set up the instrument for the desired configuration.
2. Press the STORE key.
3. Use the cursor keys ◄ and ►, and the RANGE keys ▲ and ▼ to set the number of readings to store (1 to 2500).
4. Press ENTER to enable the buffer. If in the immediate trigger mode, the storage process will start immediately. If in the external input trigger mode, each input trigger (or press of TRIG key) will store a reading. See Section 9 for information on triggering.

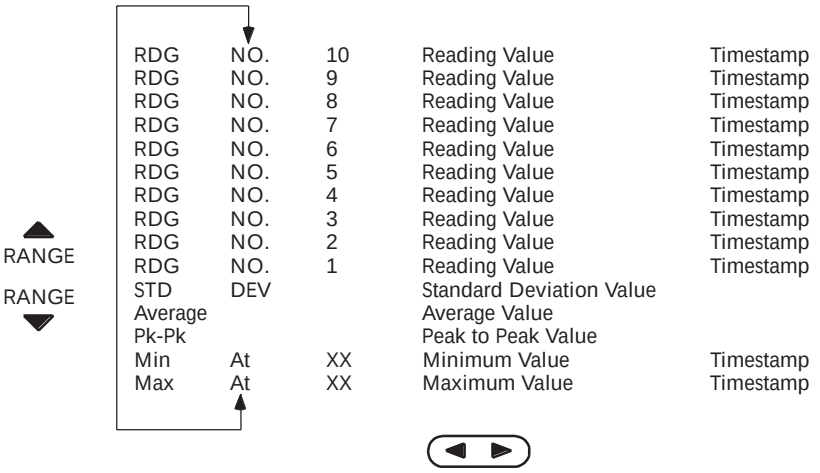
NOTE *The asterisk (*) annunciator turns on to indicate that the data storage operation is enabled. It will turn off when the storage process is finished (buffer full).*

Recall

Perform the following steps to view stored readings and buffer statistics:

1. Press RCLL. The message “RDG NO. 1” is displayed. Note that the arrow annunciator (↔) also turns on to indicate that additional data is available for viewing.
2. As shown in Figure 8-1, use the RANGE keys ▲ and ▼ and the cursor keys ◄, ► to navigate through the reading numbers, reading values, timestamps, and buffer statistics.
3. To return to the normal display, press EXIT.

Figure 8-1
Buffer locations



Buffer statistics

- **MIN** and **MAX** provides the minimum and maximum readings stored in the buffer. It also indicates the buffer location of these readings.
- The **PK-PK (peak-to-peak)** value is the difference between the maximum and minimum readings stored in the buffer:
  PK-PK = MAX - MIN
- **Average** is the mean of the buffer readings. Mean is calculated as follows:

$$y = \frac{\sum_{i=1}^{n} X_i}{n}$$

Where: X_i is a stored reading
n is the number of stored readings

- The **STD DEV** value is the standard deviation of the buffered readings. Standard deviation is calculated as follows:

$$y = \sqrt{\frac{\sum_{i=1}^{n} X_i^2 - \left(\frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)^2\right)}{n-1}}$$

Where: X_i is a stored reading
n is the number of stored readings

SCPI programming

Commands associated with buffer operation are listed in Table 8-1. The TRACe commands are used to store and recall readings in the buffer. The FORMat:ELEMents command is used to specify which data elements to include in the response message for TRACe:DATA? (which is the command to read the buffer). The CALCulate3 commands are used to obtain statistics from the buffer data.

NOTE The Model 6514 uses IEEE-754 floating point format for statistics calculations.

Table 8-1
SCPI commands — buffer

Commands	Description	Default	Ref
:TRACe	TRACe Subsystem:	See Note	
:CLEar	Clear readings from buffer.		
:FREE?	Query bytes available and bytes in use.		A
:POINts <n>	Specify number of readings to store; 1 to 2500.	100	
:ACTual?	Returns number of readings actually stored in buffer.		
:FEED <name>	Select source of readings; SENSe[1], CALCulate[1] or CALCulate2.	SENS1	B
:CONTrol <name>	Select buffer control mode; NEVer or NEXT.	NEV	C
:TSTamp	Timestamp:		
:FORMat <name>	Select timestamp format; ABSolute or DELTa.	ABS	D
:DATA?	Read all readings in buffer.		E
:FORMat	FORMat Subsystem:		Sec 16
:ELEMents <list>	Specify data elements for :TRACe:DATA? response message; READing, TIME and STATus.	All 3	F
:CALCulate3	CALCulate3 Subsystem:		
:FORMat <name>	Select buffer statistic; MINimum, MAXimum, MEAN, SDEViation or PKPK.	MEAN	G
:DATA?	Read the selected buffer statistic.		H

Note: SYSTem:PRESet and *RST have no effect on :TRACe commands. The listed defaults are power-on defaults.

A) TRACe:FREE?

Two values, separated by commas, are returned. The first value indicates how many bytes of memory are available, and the second value indicates how many bytes are reserved to store readings.

B) TRACe:FEED <name>

Name parameters:

- SENSe — Raw input readings are stored in the buffer.
- CALCulate1 — The results of the mX+b or percent (%) calculation are stored in the buffer. See Section 7 for information on mX+b and percent.
- CALCulate2 — Test limit or Rel readings are stored in the buffer. See Section 10 for information on limit tests.

C) TRACe:FEED:CONTrol <name>

Name parameters:

- NEXT — Enables the buffer and turns on the asterisk (*) annunciator. After the buffer stores the specified number of readings, the asterisk annunciator turns off.
- NEVer — Disables the buffer.

D) TRACe:TSTamp:FORMat <name>

Name parameters:

- ABSolute — Each timestamp is referenced to the first reading stored in the buffer.
- DELTa — Timestamps provide the time between each buffer reading.
- The timestamp data element can be included with each buffer reading (see Ref F).

E) TRACe:DATA?

1. The response message will include one to three data elements for each stored reading. Use the FORMat:ELEMents command (see Ref F) to specify the elements.
2. Reading an empty buffer will result in the “ERROR: -230” display message.
3. Buffer data can be sent in the binary format. See the FORMat Subsystem in Section 16 for details.

F) FORMat:ELEMents <list>

1. List parameters:
   - READing —Includes the buffer reading in each data string.
   - TIME — Includes the timestamp for each reading. Timestamp can be in the absolute or delta format (see Ref D).
   - STATus — Includes a status word for each reading. It provides status information on instrument operation. See “FORMat Subsystem” in Section 16 for details.
2. At least one data element must be in the list. Listed elements must be separated by a comma (i.e. FORMat:ELEMents READing, TIME). Elements not listed will not accompany the response message for TRACe:DATA?.

G) CALCulate3:FORMat <name>

This command selects the statistic to be returned by CALCulate3:DATA? (see Ref H). Name parameters:

- MINimum — Select the lowest reading stored in the buffer.
- MAXimum — Select the largest reading stored in the buffer.
- MEAN — Select the mean average statistic for the readings stored in the buffer.
- SDEViation — Select the standard deviation statistic for the readings stored in the buffer.
- PKPK — Select the peak-to-peak statistic for readings stored in the buffer. Peak-to-Peak is calculated as follows: PKPK = MAXimum - MINimum.

H) CALCulate3:DATA?

1. If the number of data points in the buffer is one or none, CALCulate3:DATA? will result in an error (-230).
2. If there is a lot of data in the buffer, some statistic operations may take too long and cause a bus time-out error. To avoid this, send calc3:data? and then wait for the MAV (message available) bit in the Status Byte Register to set before addressing the Model 6514 talk (see Section 13).

Programming example

The following program fragment stores 20 readings into the buffer and then calculates the mean average on the buffer readings:

```
' Select data elements:
*RST                      ' Return 6514 to RST defaults.
FORM:ELEM READ,TIME       ' Select reading and timestamp.

' Store and Recall Readings:
TRAC:POIN 20              ' Set buffer size to 20.
TRAC:FEED SENS            ' Store raw input readings.
TRAC:FEED:CONT NEXT       ' Start storing readings.
TRAC:DATA?                ' Request all stored readings.

' Acquire Mean Statistic for Buffer Readings:
CALC3:FORM MEAN           ' Select mean statistic.
CALC3:DATA?               ' Request mean statistic.
```

9 Triggering

- **Trigger models** — Explains the various components of the trigger models, which control the triggering operations of the instrument. Also explains how to configure the trigger model from the front panel.
- **SCPI programming** — Includes the commands used to configure the trigger model, and the commands to control the measurement process.
- **External triggering** — Explains external triggering which allows Model 6514 to trigger other instruments, and be triggered by other instruments.

Trigger models

The flowcharts in Figures 9-1 and 9-2 summarize triggering for Model 6514. They are called trigger models because they are modeled after the SCPI commands to control triggering (operation).

Figure 9-1 Trigger model — front panel operation

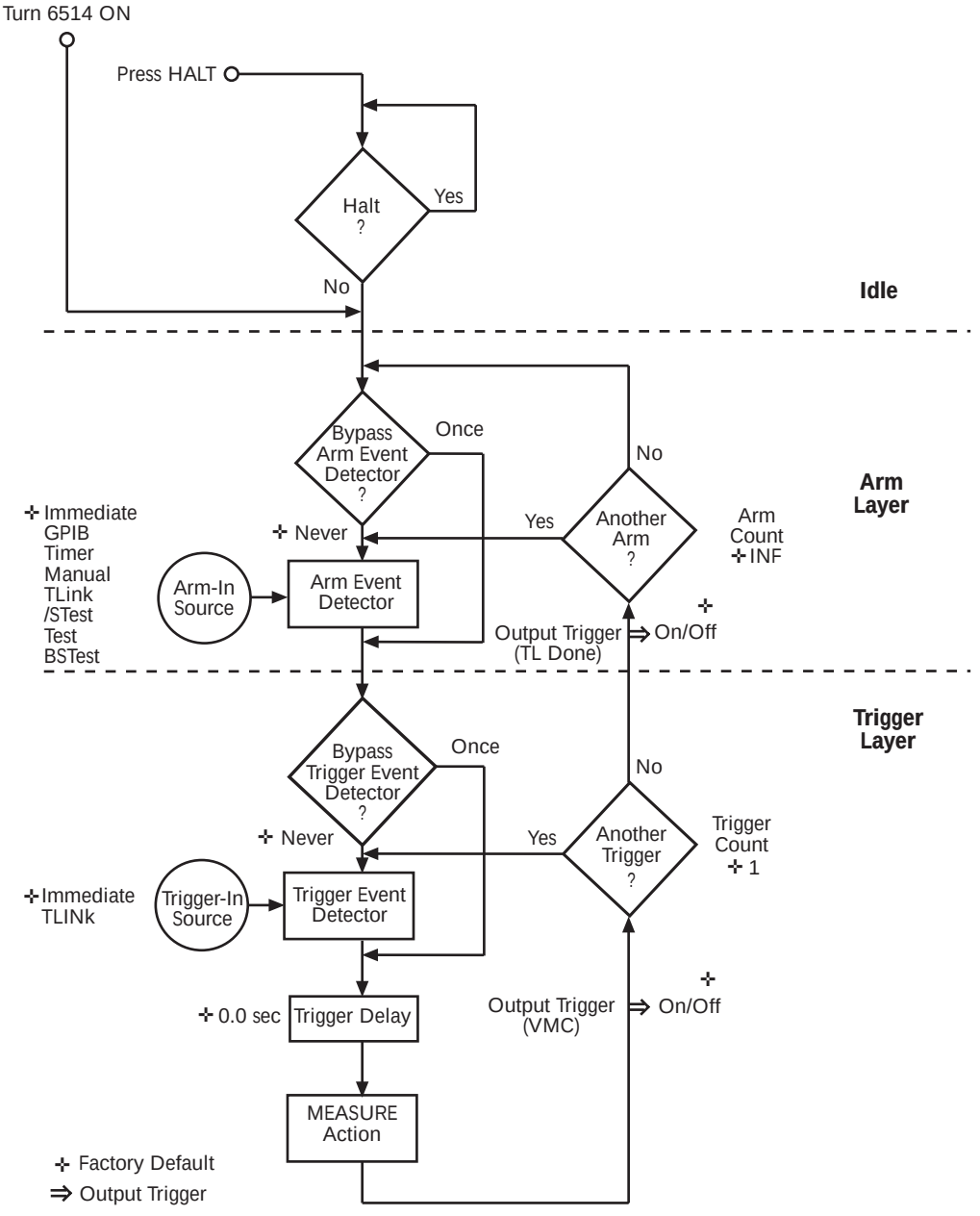
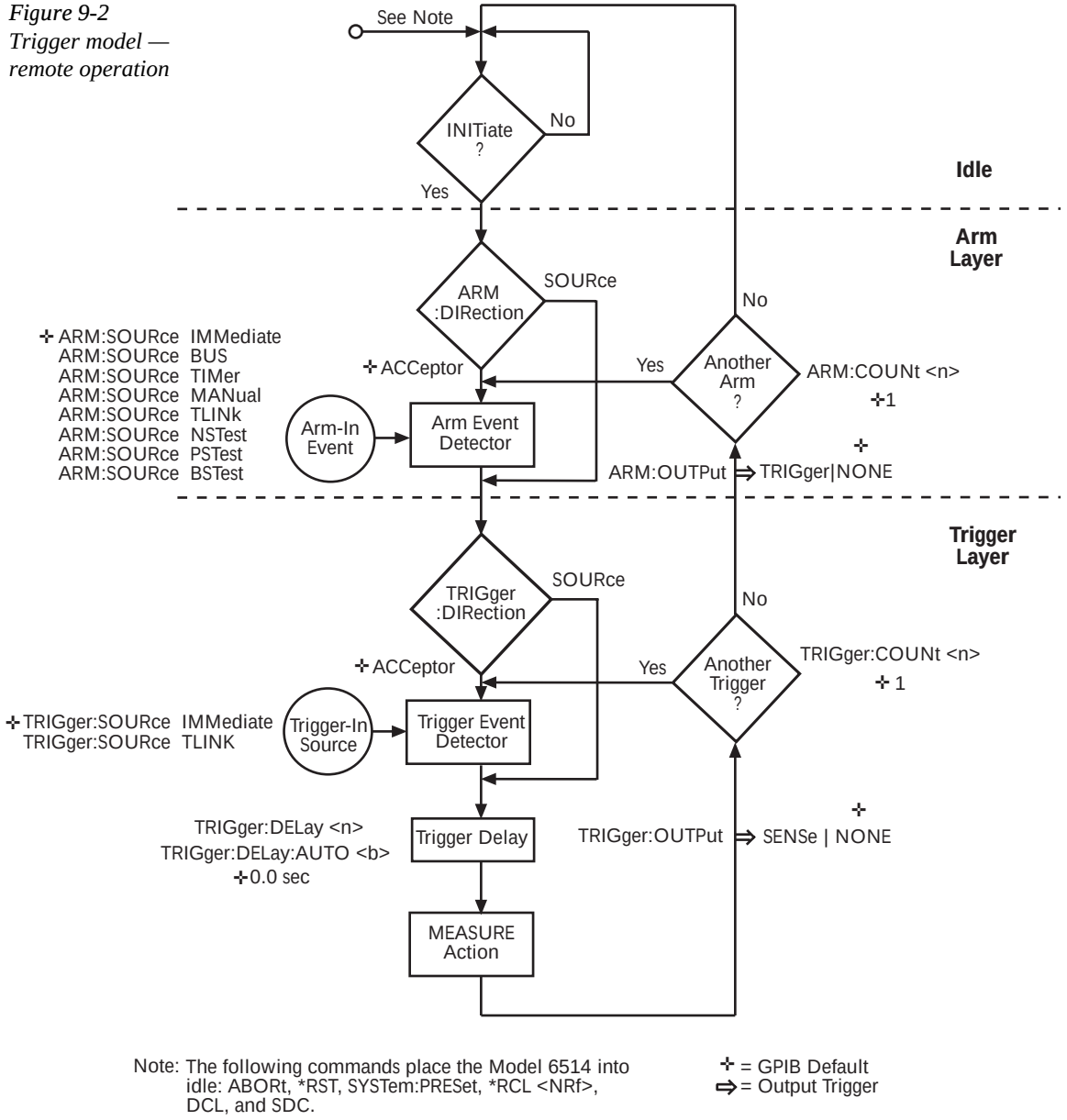


Figure 9-2
Trigger model — remote operation



Note: The following commands place the Model 6514 into idle: ABORt, *RST, SYSTem:PRESet, *RCL <NRf>, DCL, and SDC.

✣ = GPIB Default
⇨ = Output Trigger

The only difference between front panel operation (Figure 9-1) and remote operation (Figure 9-2) is within the idle state of the instrument. Nomenclature in Figure 9-1 relates to the various names used for configuration menu items, while Figure 9-2 provides the SCPI commands to control operation.

Idle and initiate

While in the idle state, the instrument cannot perform measurements. While in idle, the reading remains frozen or dashes replace the reading (i.e. -.------ V). Once Model 6514 is taken out of idle, operation proceeds through the trigger model.

Front panel operation — As shown in Figure 9-1, Model 6514 immediately leaves the idle state when it is turned on. Typically, operation remains in the arm and trigger layers of the trigger model. However, Model 6514 can be put into the idle state at any time by pressing the HALT key. To take the instrument out of idle, press the TRIG key. Other front panel keys can instead be pressed, but they may change the setup.

Remote operation — As shown in Figure 9-2, an initiate command is required to take the instrument out of idle. The following commands perform an initiate operation:

- INITiate
- READ?
- MEASure?

While operating within the trigger model (not in idle), most commands will not be executed until the instrument completes all of its programmed operations and returns to the idle state. The IFC, SDC and DCL commands can be executed under any circumstance while operating within the trigger model. They will abort any other command or query.

The following commands can be executed while operating within the trigger model except when a READ? or MEASure? is being processed.

- ABORt
- SYSTem:PRESet
- *TRG or GET
- *RST
- *RCL <NRf>

NOTE *For fastest response, use SDC or DCL to return to idle (see Section 12 for details on general bus commands).*

Trigger model operation

Once the instrument is taken out of idle, operation proceeds through the trigger model to perform a measurement (measure action).

NOTE *The following discussion focuses on the front panel trigger model (Figure 9-1). However, equivalent SCPI commands are included where appropriate.*

Event detectors and control sources

A control source holds up operation until the programmed event occurs and is detected. Note that there are two detector bypasses. A bypass around a detector is only enabled if the appropri-

ate TLink control source is selected. See TLink control source (Arm-In and Trigger-In) as follows for details.

Arm-In source — The Arm-In control sources are explained as follows:

- **Immediate** (ARM:SOURce IMMediate) — Event detection for the arm layer is satisfied immediately allowing operation to continue on into the trigger layer.
- **GPIB** (ARM:SOURce BUS) — Event detection for the arm layer is satisfied when a bus trigger (GET or *TRG) is received by Model 6514.
- **Timer** (ARM:SOURce TIMer) — Event detection for the arm layer is immediately satisfied after the instrument leaves the idle state. Detection for each subsequent pass is satisfied when the programmed timer interval elapses. The timer resets to its initial state when the instrument goes back into idle.
- **Manual** (ARM:SOURce MANual) — Event detection for the arm layer is satisfied by pressing the TRIG key. Model 6514 must be in the local mode for it to respond to the TRIG key. Press LOCAL or send LOCAL 14 over the bus to place Model 6514 in local.
- **TLink** (ARM:SOURce TLINk) — Event detection for the arm layer is satisfied when an input trigger via the TRIGGER LINK connector is received by Model 6514. Note that if the source bypass is set to ONCE (ARM:DIRection SOURce), operation will initially loop around the source detector after the instrument leaves the idle state. Detection for each subsequent pass is satisfied by an input trigger. The bypass resets when the instrument goes into idle.
- **/STest** (ARM:SOURce NSTest) — Event detection for the arm layer is satisfied when a negative going pulse (via the SOT line of the Digital I/O) is received from a component handle (see “Limit Testing” in Section 10).
- **Test** (ARM:SOURce PSTest) — Event detection for the arm layer is satisfied when a positive going pulse (via the SOT line of the Digital I/O) is received from a component handle (see “Limit Testing” in Section 10).
- **BSTest** (ARM:SOURce BSTest) — Event detection for the arm layer is satisfied when either a positive-going or a negative-going pulse (via the SOT line of the Digital I/O) is received from a component handler (see “Limit Testing” in Section 10).

Trigger-In source — The Trigger-In control sources are explained as follow:

- **Immediate** (TRIGger:SOURce IMMediate) — Event detection for the trigger layer is satisfied immediately allowing operation to continue on to perform a measurement.
- **TLink** (TRIGger:SOURce TLINk) — Event detection for the trigger layer is satisfied when an input trigger via the TRIGGER LINK connector is received by Model 6514. Note that if the source bypass is set to ONCE (TRIGger:DIRection SOURce), operation will loop around the source detector on the initial pass through the arm layer. Detection for each subsequent pass is satisfied by an input trigger. The bypass resets when Model 6514 leaves the trigger layer.

Trigger delay

A programmable delay is available after event detection. It can be set manually (0 to 999.9998 seconds) or an auto delay can be used. With auto delay selected, the Model 6514 automatically sets delay according to function and range. The auto delay settings are listed in Table 9-1.

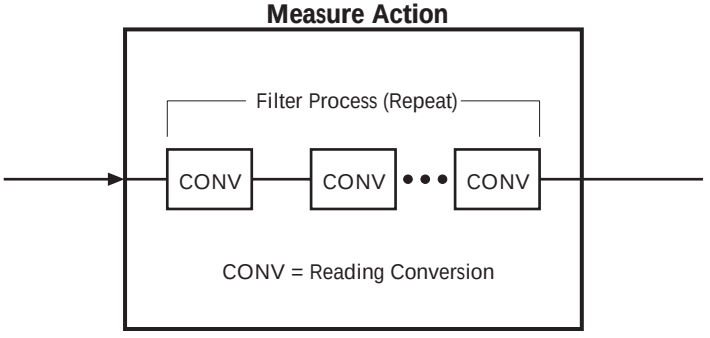
Table 9-1
Auto delay settings

Volts		Amps		Ohms		Coulombs	
Range	**Delay**	**Range**	**Delay**	**Range**	**Delay**	**Range**	**Delay**
2V	5ms	20pA	2500ms	2kΩ	5ms	20nC	3ms
20V	3ms	200pA	2500ms	20kΩ	1ms	200nC	3ms
200V	2ms	2nA	10ms	200kΩ	1ms	2μC	3ms
		20nA	10ms	2MΩ	10ms	20μC	3ms
		200nA	10ms	20MΩ	10ms		
		2μA	10ms	200MΩ	10ms		
		20μA	5ms	2GΩ	50ms		
		200μA	5ms	20GΩ	50ms		
		2mA	1ms	200GΩ	50ms		
		20mA	0.5ms				

Measure action

The measure action block of the trigger model is where a measurement is performed. However, if the repeating filter is enabled (see Figure 9-3), the instrument samples the specified number of reading conversions to yield single filtered reading. Only one reading conversion is performed if the digital filter is disabled, or after the specified number of reading conversions for a moving average filter is reached.

Figure 9-3
Measure action block of trigger model



Output triggers

Model 6514 can send out an output trigger (via the rear panel TRIGGER LINK connector) right after the measure action and/or when operation leaves the trigger layer. An output trigger can be used to trigger another instrument to perform an operation (e.g., select the next output step for a source).

Counters

Programmable counters are used to repeat operations within the trigger model layers. For example, if the trigger count is set for 10, operation will keep looping around in the trigger layer until 10 measurements are performed. If the arm count is set to 2, operation will then loop back through the arm layer and go back into the trigger layer to perform 10 more measurements.

Trigger model configuration — front panel

NOTE *See "SCPI Programming" (Table 9-2) for the SCPI commands to configure the trigger model.*

There are two separate configuration menus to configure the trigger model; one for the arm layer and one for the trigger layer. Note that trigger delay can be set from either the trigger layer configuration menu or from the DELAY key.

Once in a menu structure, use the ▲ and ▼ keys to display menu items. Use the cursor (◀ and ▶) and the ▲ and ▼ keys to key in values. A menu item or value is selected by pressing ENTER. Use the EXIT key to exit from the menu.

Arm layer configuration menu — The configuration menu for the arm layer is structured as follows. Bullets denote the main items of the menu. To access the menu, press SHIFT and then CONF-ARM.

- **ARM-IN** — Select the Arm-in control source:
  IMM (Immediate), **GPIB**, **TIMER**(1), **MAN** (Manual), **TLINK**(2), **/STEST**, **TEST**, or **BSTEST**.
  1. TIMER — You will be prompted to enter the timer interval (in hour, minute, second format). The TIMER annunciator will turn on. The minimum timer setting is 0.001 seconds.
  2. TLINK — Select the input trigger link line (1 to 6). You will then be prompted to enable (ONCE) or disable (NEVER) the source bypass.
- **ARM-OUT** — Configure the output trigger:
  LINE — Select the output trigger link line (1 to 6).
  EVENT — Enable (ON) or disable (OFF) the trigger layer done output trigger.
- **COUNT** — Set a finite (FIN) arm count (1 to 2500), or select infinite (INF) arm count.

NOTE *Input trigger and output trigger cannot share the same Trigger Link line. Defaults set line 1 as the input and line 2 as the output.*

Trigger layer configuration menu — The configuration menu for the trigger layer is structured as follows. Bullets denote the main items of the menu. To access the menu, press SHIFT and then CONF-TRIG.

- **TRIG-IN** — Select the Trig-In control source:
  IMM (Immediate), or **TLINK**. After selecting TLINK, select the input trigger link line (1 to 6). You will then be prompted to enable (ONCE) or disable (NEVER) the source bypass.

- **TRIG-OUT** — Configure output triggers:
  LINE — Select the output trigger link line (1 to 6).
  VMC — Enable (ON) or disable (OFF) the VMC (voltmeter complete) output trigger.
- **DELAY** — Configure the trigger delay of the trigger layer:
  MAN — Manually set the delay (0 to 999.9998 seconds).
  AUTO — Selects auto delay. The delay is set according to function/range (see Table 9-1).
- **COUNT** — Set a finite (FIN) trigger count (1 to 2500), or select infinite (INF) trigger count.

NOTE *Input trigger and output trigger cannot share the same trigger link line. Defaults set line 1 as the input and line 2 as the output.*

DELAY Menu — To access the menu for trigger delay, press the DELAY key.

- **DELAY** — Configure the trigger delay of the trigger layer:
  MAN — Manually set the delay (0 to 999.9998 seconds).
  AUTO — Selects auto delay. The delay is set according to function/range (see Table 9-1).

SCPI programming

Table 9-2
SCPI commands — triggering

Command	Description	Default	Ref
ABORt	Reset trigger system (goes to idle state).		A
INITiate	Initiate one trigger cycle.		B
FETch?	Request latest reading.		B
READ?	Trigger and request a “fresh” reading.		B
ARM[:SEQuence[1]]	Arm Layer:		
[:LAYer[1]]			
:SOURce <name>	Select control source; IMMediate, TIMer, BUS, TLINk, STESt, PSTest, NSTest, BSTest, or MANual.	IMM	C
:COUNt <n>	Set measure count; 1 to 2500, or INF (infinite).	1	
:TIMer <n>	Set timer interval; 0.001 to 99999.999 (sec).	0.1	
[:TCONfigure]			
:DIRection <name>	Enable (SOURce) or disable (ACCeptor) bypass.	ACC	D
[:ASYNchronous]	Configure input/output triggers:		
:ILINe <NRf>	Select input trigger line; 1, 2, 3, 4, 5 or 6.	1	E
:OLINe <NRf>	Select output trigger line; 1, 2, 3, 4, 5 or 6.	2	E
:OUTPut <name>	Output trigger (TRIGger) or not at all (NONE).	NONE	
TRIGger[:SEQuence[1]]	Trigger Layer:		
:SOURce <name>	Select control source; IMMediate or TLINk.	IMM	
:COUNt <n>	Set measure count; 1 to 2500, or INF (infinite).	1	
:DELay <n>	Set trigger delay; 0 to 999.9998 (sec).	0.0	
:AUTO <b>	Enable or disable auto delay.	OFF	
[:TCONfigure]			
:DIRection <name>	Enable (SOURce) or disable (ACCeptor) bypass.	ACC	D
[:ASYNchronous]	Configure input/output triggers:		
:ILINe <NRf>	Select input trigger line; 1, 2, 3, 4, 5 or 6.	1	E
:OLINe <NRf>	Select output trigger line; 1, 2, 3, 4, 5 or 6.	2	E
:OUTPut <name>	Output trigger after measurement (SENSe) or not at all (NONE).	NONE	
:TRIGger:CLEar	Clear pending input trigger.	NONE	F

A) ABORt

If operation has been started by the INITiate command, ABORt will cancel all operations and immediately return to the instrument to the idle state. If operation has been started by READ? (or MEASure?), ABORt has no affect.

B) INITiate

1. After sending this command to take the instrument out of idle, the instrument will perform one or more measurements and then return to idle. The FETch? command can then be used to read the last reading that was measured.
2. If INITiate is sent while the instrument is operating within the trigger model, it will not execute until the operation returns to the idle state.
3. One alternative to using INITiate, is to use the READ? command. When READ? is sent, the instrument is taken out of idle and all readings that are taken are returned (see Section 15 for details on READ?).

C) ARM:SOURce <name>

With the TIMer control source selected, use the ARM:TIMer command to set the timer interval.

D) DIRection <name>

The source bypass can only be used if the TLINk control source is selected.

E) ILINe <name> and OLINe <name>

Input trigger and output trigger cannot share the same trigger link line. Defaults set line 1 as the input and line 2 as the output.

F) :TRIGger:CLEar

When this action command is sent, any pending (latched) input triggers are cleared immediately. When the Model 6514 is being latched by another instrument, it may inadvertently receive and latch input triggers that do not get executed. These pending triggers could adversely affect subsequent operation.

When using external triggering, it is recommended that TRIGger:CLEar be sent after sending the ABORt command and at the beginning of a program before sending an initiate command (See “INITiate” command).

Programming example

The following command sequence will trigger and return 10 readings.

```
*RST                          ‘ Return 6514 to RST defaults.
ARM:SOURce IMMediate          ‘ Set arm control source Immediate.
ARM:COUNt 1                   ‘ Set arm count to 1.
TRIGger:SOURce IMMediate      ‘ Set trigger control source
                                Immediate.
TRIGger:COUNt 10              ‘ Set trigger count to 10.
READ?                         ‘ Trigger and return 10 readings.
```

External triggering

Input and output triggers are received and sent via the rear panel TRIGGER LINK connector. The trigger link has six lines. At the factory, line #2 is selected for output triggers and line #1 is selected for input triggers. These input/output assignments can be changed as previously explained in this section. The connector pinout is shown in Figure 9-4.

Figure 9-4
Trigger link connection operation

Rear Panel Pinout

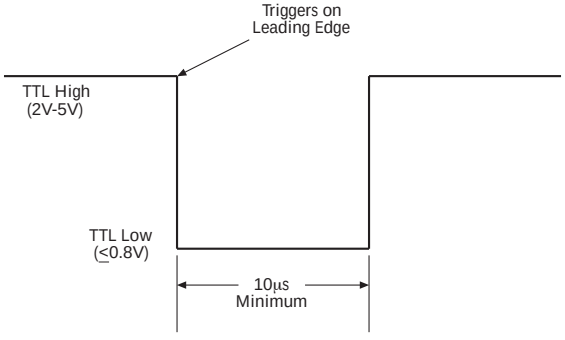
Trigger Link

Pin Number	Description
1	Trigger Link 1
2	Trigger Link 2
3	Trigger Link 3
4	Trigger Link 4
5	Trigger Link 5
6	Trigger Link 6
7	Ground
8	Ground

Input trigger requirements

An input trigger is used to satisfy event detection for a trigger model layer that is using the TLINK control source. The input requires a falling-edge, TTL compatible pulse with the specifications shown in Figure 9-5.

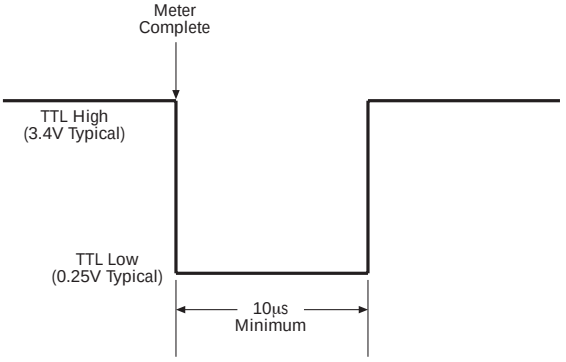
Figure 9-5
Trigger link input pulse specifications



Output trigger specifications

Model 6514 can be programmed to output a trigger immediately after a measurement and/or when operation leaves the trigger layer of the trigger model. The output trigger provides a TTL-compatible output pulse that can be used to trigger other instruments. The specifications for this trigger pulse are shown in Figure 9-6. A trigger link line can source 1mA and sink up to 50mA.

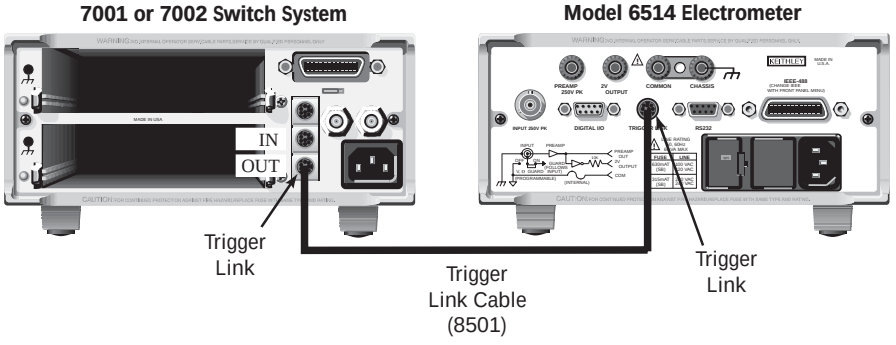
Figure 9-6
Trigger link output pulse specifications



External trigger example

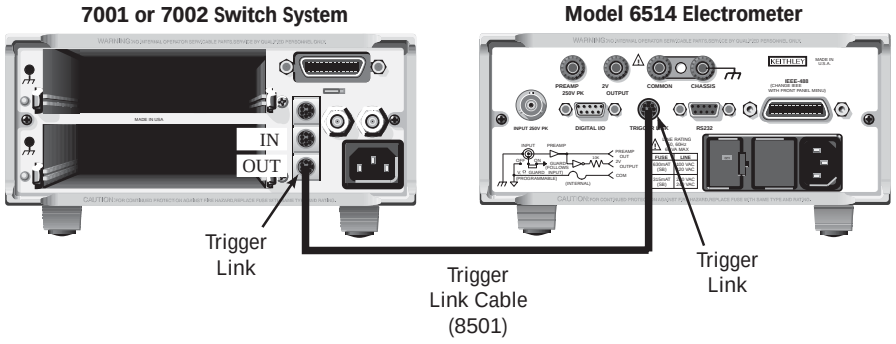
In a simple test system, you may want to close a switching channel and measure the resistance of a DUT connected to that channel. Such a test system is shown in Figure 9-7, which uses a Model 6514 to measure 10 DUTs switched by a Model 7011 multiplexer card in a Model 7001 or 7002 switch system.

Figure 9-7
DUT test system



The trigger link connections for this test system are shown in Figure 9-8. The trigger link of Model 6514 is connected to the trigger link (IN or OUT) of the switching mainframe. Note that with the default trigger settings of the switching mainframe, line #1 is an input and line #2 is an output.

Figure 9-8 Trigger link connections



For this example, Model 6514 and switching mainframe are configured as follows:

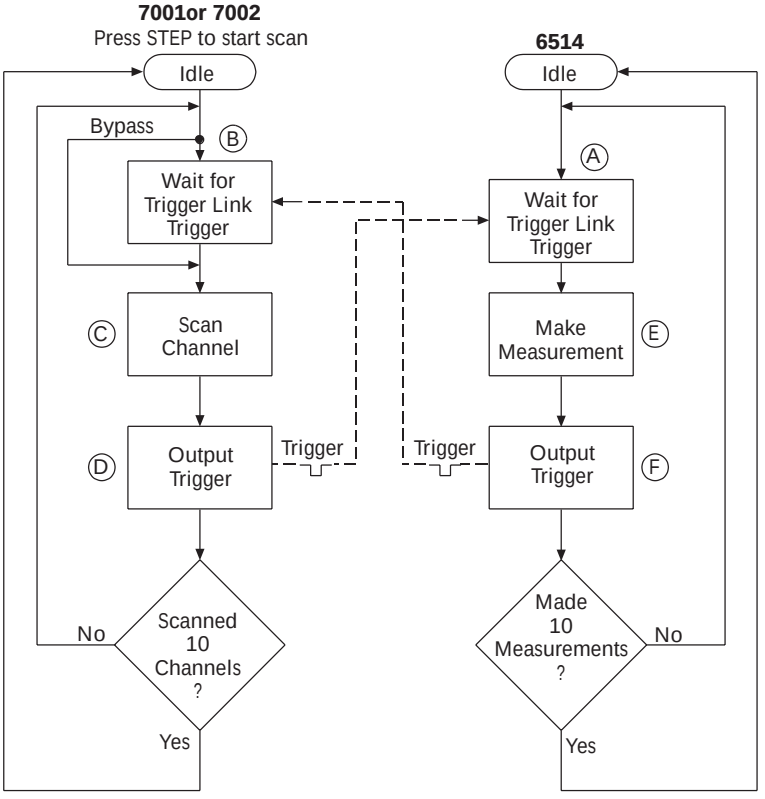
Model 6514	**Switching Mainframe**
Factory Defaults Restored	Factory Defaults Restored
Trig-In Event = TLink	Scan List = 1!1-1!10
Trigger Input Line = #2	Number of Scans 1
Trigger Output Line = #1	Channel Spacing = TrigLink
Trigger Output Event = ON	
Trigger Count = 10	
Trigger Delay = Auto	

To store readings in Model 6514 buffer, press STORE and set the buffer size to 10. When ENTER is pressed, the asterisk (*) annunciator turns on to indicate the buffer is enabled (see Section 8 for details on buffer operation).

To start the test, press STEP on the switching mainframe to take it out of idle and start the scan. The switching mainframes output pulse triggers Model 6514 to take a reading and store it. Model 6514 then sends an output trigger pulse to the switching mainframe to close the next channel. This process continues until all 10 channels are scanned, measured and stored.

Details of this testing process are explained in the following paragraphs and are referenced to the operation model shown in Figure 9-9.

Figure 9-9
Operation model for triggering example



a. Operation of Model 6514 starts at point A in the flowchart, where it waits for an external trigger.

b. Pressing STEP takes Model 7001/2 out of idle and places operation at point B in the flowchart.

c. For the first pass through Model, the scanner does not wait at point B. Instead, it closes the first channel (point C).

d. After the relay settles, Model 7001/2 outputs a trigger pulse. Since the instrument is programmed to scan 10 channels, operation loops back to point B, where it waits for an input trigger.

e. and f. With Model 6514 at point A, the output trigger pulse from Model 7001/2 triggers a measurement of DUT #1 (point E). After the measurement is complete, Model 6514 outputs a trigger pulse and then loops back to point A, where it waits for another input trigger.

The trigger applied to Model 7001/2 from Model 6514 closes the next channel in the scan, which then triggers Model 6514 to measure that DUT. This process continues until all 10 channels are scanned and measured.

10
Limit Tests

- **Limit testing** — Explains the basic Limit 1 and Limit 2 testing operations.
- **Binning** — Explains how to use a component handler to perform binning operations.
- **Front panel operation** — Explains how to configure and run tests from the front panel.
- **SCPI programming** — Covers the SCPI commands for remote operation.

Limit testing

As shown in Figure 10-1, there are two limit tests that can be performed on a DUT. Limit 1 is used as the wide pass band and Limit 2 is used as the narrow pass band. It is up to the user to specify limits that conform to this pass band relationship.

Figure 10-1
Limit tests

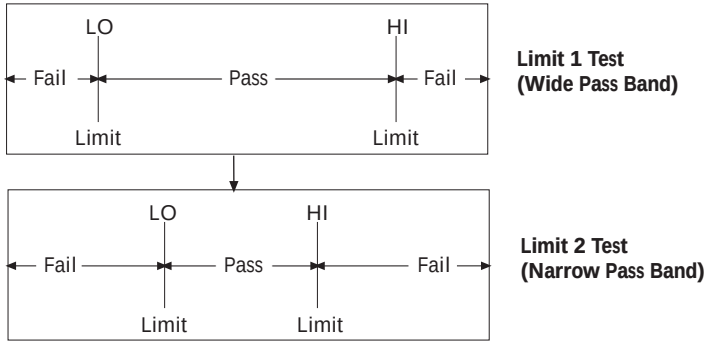
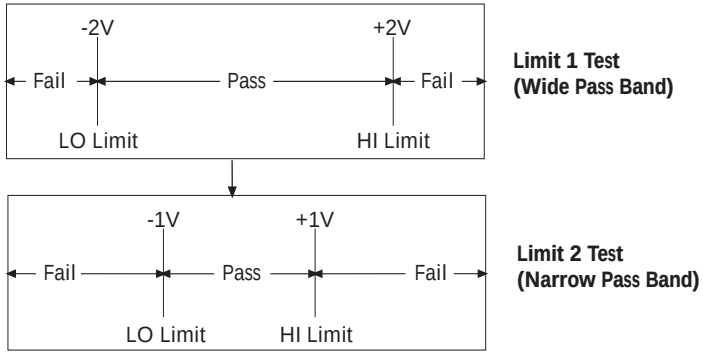


Figure 10-2 shows an example where the HI and LO limits for limit 1 are ±2V, and the Hi and LO limits for limit 2 are ±1V. A 0V reading passes both limit 1 and limit 2 tests. A +1.5V reading passes limit 1 but fails limit 2. A +2.5V reading fails both limit 1 and limit 2.

Figure 10-2
Limit tests example



The 2-stage limit testing process is shown in Figure 10-3. If limit 1fails, the “L1” message is displayed and the test is finished. Limit 2 is not tested because the pass band relationship between the two stages implies that if limit 1 fails, limit 2 must also fail. If limit 1 passes, the limit 2 test is performed. If limit 2 fails, the “L2” message is displayed. If both limit 1 and limit 2 pass, the “OK” message is displayed. The display messages for limit tests are summarized in Table 10-1.

A test is only performed if it is enabled. Therefore, you can perform a single-stage test or a 2-stage test. In the flowchart (Figure 10-3), operation simply proceeds through a disabled test.

Figure 10-3
Operation model for limit test

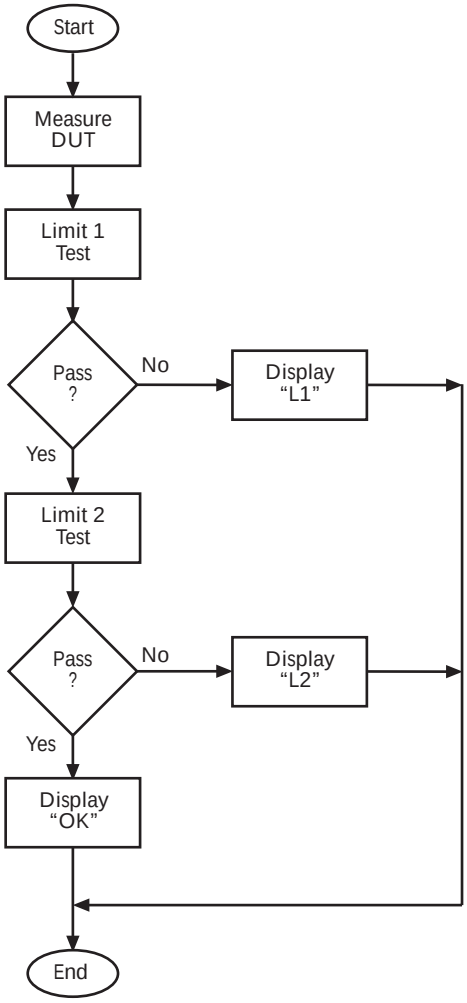


Table 10-1
Test limit display messages

Display Message	**Limit 1 Test Result**	**Limit 2 Test Result**
:OK	Pass	Pass
:L1	Fail	Not Performed
:L2	Pass	Fail

NOTES *Display messages indicate which test or tests have failed, but they do not indicate which limit (HI or LO) has failed. When using remote operation, you can determine which limit failed by reading the measurement event register. See Ref B for the FAIL? commands in Table 10-2.*

Relative (Rel), mX+b and percent can be used with limit testing. The tests will be done on the result of the math operation (not the input values). These math operations are covered in Section 7.

Application — A typical application for a 2-stage limit test is to sort a batch of DUT according to tolerance. For example, you may want to sort resistors (all having the same nominal value) into three groups, 1%, 5%, and >5%. The limits for limit 1 would be the 5% tolerances, and the limits for limit 2 would be the 1% tolerances. If a resistor passes both tests, it belongs in the 1% group. If it passes limit 1, but fails limit 2, it belongs in the 5% group. If it fails both tests, it belongs in the >5% group.

Binning

Even though no additional equipment is required to perform limit tests on the DUT, Model 6514 can be used with a component handler to perform binning operations. Based on the outcome of a test, the component handler will place the DUT in the assigned bin.

Figure 10-4 shows a basic binning system. After all programmed testing on the DUT is completed, the appropriate digital output pattern is sent to the component handler, which then places the DUT in the appropriate bin. The component handler selects the next DUT, and the testing process is repeated.

Figure 10-4
Binning system

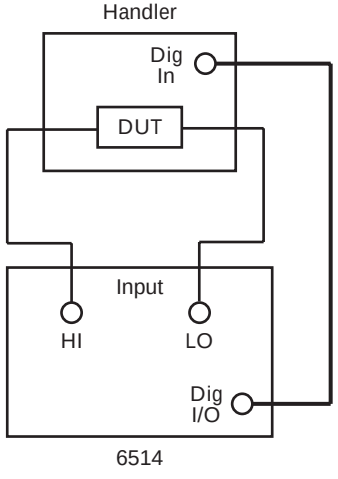
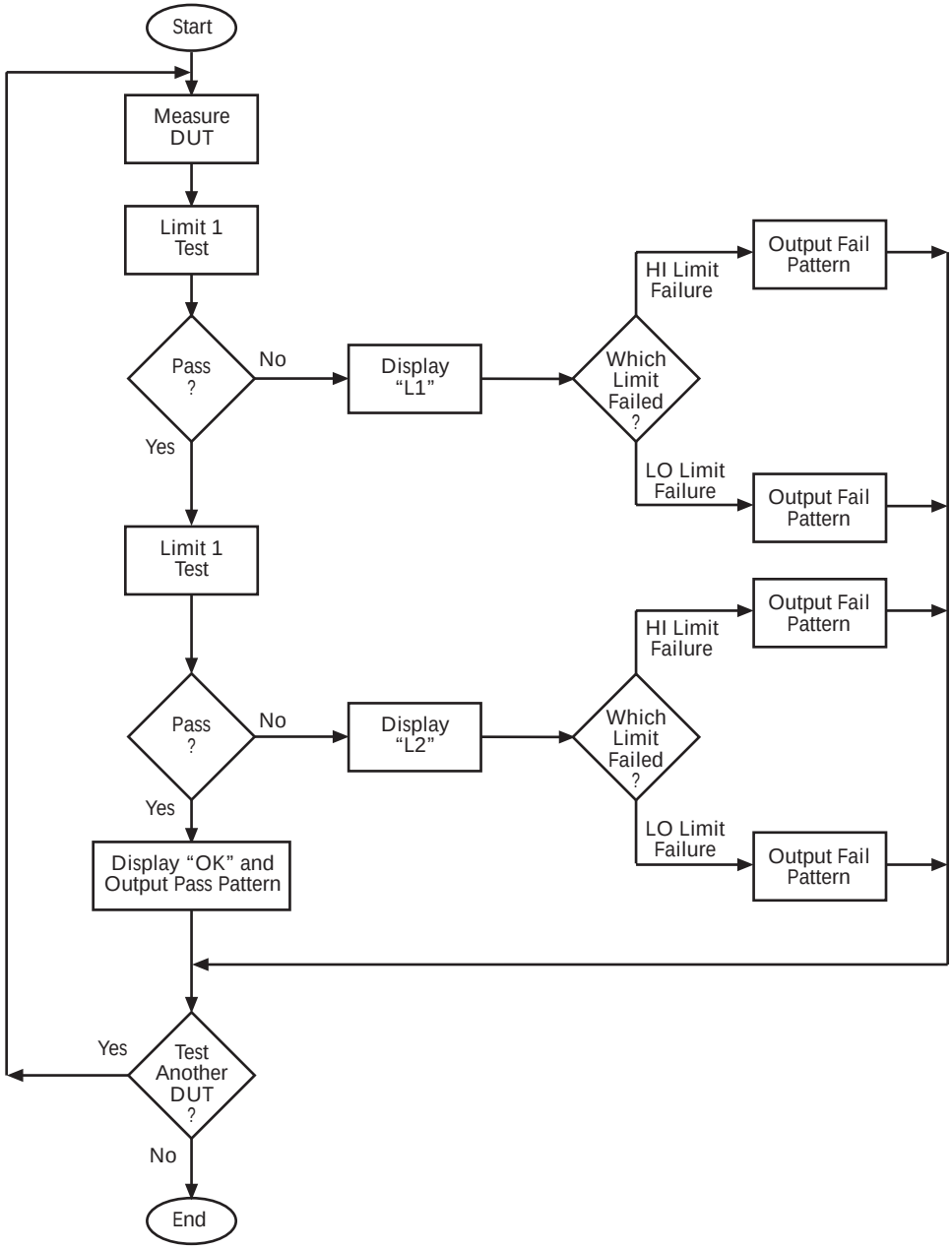


Figure 10-5 shows the basic limit testing flowchart expanded to include binning. Notice that there are five possible output patterns (one pass pattern and four fail patterns), but only one will be sent to the component handler for each DUT that is tested.

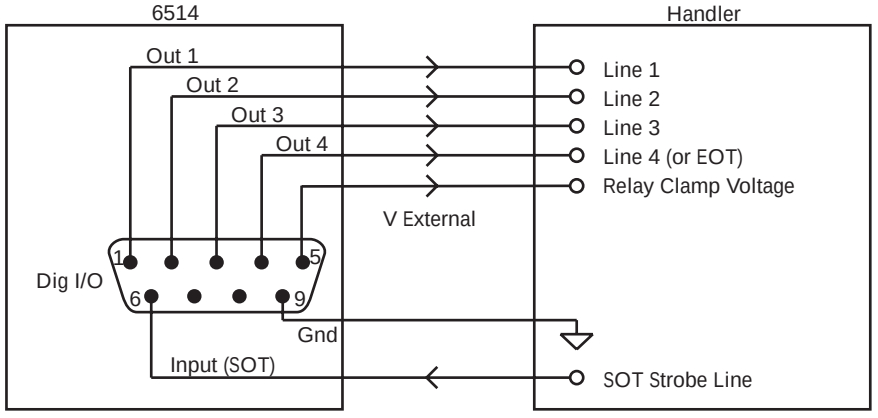
Figure 10-5
Operation model for limit testing with binning



Component handler interface

Model 6514 is interfaced to a component handler via the Digital I/O port as shown in Figure 10-6. The I/O port has four lines for output signals and one line for input signals. The input line is used to start the test and the output lines are used to send the test pass/fail signal(s) to the component handler to perform the binning operation.

Figure 10-6 Handler interface connections



The digital I/O lines are available at the DB-9 connector on the rear panel of Model 6514. A custom cable using a standard female DB-9 connector is required for connection to Model 6514.

Start of test

The SOT (start of test) line of the Digital I/O is used to control the start of the testing process. When /STest is the selected arm-in event for the arm layer of the trigger model, the testing process will start when the SOT line is pulled low. When test is the selected arm-in event, the test will start when the SOT line is pulled high. Section 9 provides details on trigger model configuration.

NOTE *If you do not wish to use the SOT line to start the test, you can use the immediate arm-in event. The testing process will start as soon as the LIMIT key is pressed (assuming one or both limit tests are enabled).*

The component handler will either maintain the SOT line high or low. This is its “not ready” condition. When the component handler is ready (DUT properly position in the handler), it will either pull the SOT line low or high to start the test.

Digital output patterns

Model 6514 uses digital output bit patterns to communicate test results to the component handler. For each limit test, unique fail patterns are used for the HI and LO limits. A pass pattern is used to indicate that there were no errors. After a test is finished, the appropriate output pattern is sent to the component handler. The handler decodes the bit pattern and places the DUT in the appropriate bin.

Model 6514 can be used with either of the two basic types of handlers. When used with a category pulse handler, Model 6514 pulses one of the four handler lines. The handler then places the DUT into the bin assigned to the pulsed line.

When used with a category register handler, Model 6514 outputs a bit pattern to three handler lines. After Model 6514 sends the end-of-test (EOT) strobe pulse to the fourth handler line, the handler places the DUT into the bin assigned to that bit pattern.

Component handler types

Model 6514 can accommodate two different types of component handlers; category pulse, and category register.

Category pulse component handler

When using this type of handler, Model 6514 pulses one of the four handler lines when a pass or fail condition occurs. The handler then places the DUT in the bin assigned to that pulsed line. When interfacing to this type of handler, a maximum of four component handler bins are supported.

If the handler requires low-going pulses, then the four digital output lines of Model 6514 must be initially set to high. This initial HI, HI, HI, HI clear pattern on the output lines represents a "no action" condition for the handler since it is waiting for one of the lines to go low. A line goes low when the defined fail or pass pattern sets it low. For example, if you want a particular test failure to pulse line #4 of the handler, the defined fail pattern has to be HI, HI, HI, LO. When the failure occurs, line #4 will be pulled low, and the DUT will be placed in the bin assigned to that pulsed line.

If the handler requires a high-going pulse, the four digital output lines of Model 6514 must initially be set low. The LO, LO, LO, LO clear pattern represents the "no action" condition for the handler. When one of those lines are pulled high by a defined pass or fail bit pattern (i.e., LO, LO, LO, HI), the DUT will be placed in the bit assigned to that pulsed line.

Category register component handler

When using this type of handler, Model 6514 sends a bit pattern to three handler lines when a pass or fail condition occurs. This bit pattern determines the bin assignment for the DUT. With the pass/fail pattern on the output, line #4 is then pulsed. This EOT (end-of-test) pulse latches the bit pattern into the register of the handler, which places the DUT in the assigned bin. When interfacing to this type of handler, a maximum of eight component handler bins are supported.

If the handler requires a low-going EOT pulse, line #4 of the digital output must initially be set high. When the EOT line is pulsed low, the binning operation occurs. When using the CONFIG LIMITS MENU to define pass/fail bit patterns, line #4 must be set low. If, for example, the required fail pattern by the handler is HI, LO, HI, then you must define the fail pattern of the test to be HI, LO, HI, LO. When the test fails, the HI, LO, HI bit pattern is sent to the handler. When line #4 goes LO, the bit pattern is latched into the register of the handler, and the binning operation occurs.

Conversely, if the handler requires a high-going EOT pulse, the EOT line of the digital output must initially be set low (off). When the EOT line is pulsed high, the binning operation occurs.

Line 4 mode

When using a category pulse component handler, Model 6514 must be set to the Busy or /Busy mode. In the Busy mode, the idle state for line 4 is LO. When the test starts (SOT line pulsed), line 4 goes HI (busy state). After the test is finished, it goes back to LO. For the /Busy mode, the idle state for line 4 is HI and busy state is LO.

When using a catagory register component handler, Model 6514 must be set for the End of Test mode. In this mode, Model 6514 sends the EOT pulse to the component handler as previously explained.

Digital output clear pattern

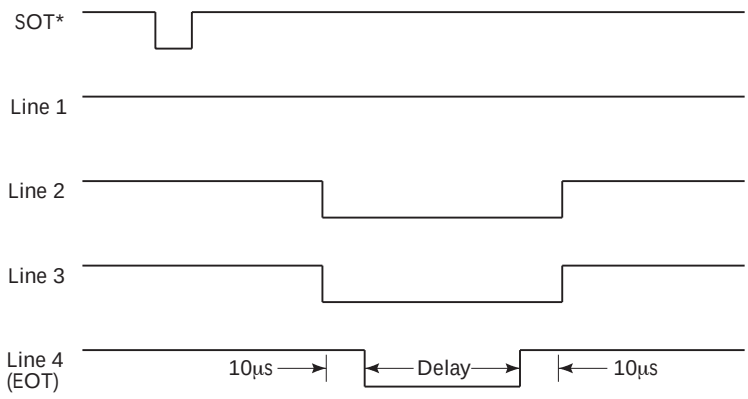
After every binning operation, the digital output needs to be reset to a clear pattern, which serves as a "no action" condition for the component handler.

Model 6514 can be programmed to automatically clear the digital output after the pass or fail pattern is sent. With auto-clear, you must specify the required pulse width (delay) for the pass or fail pattern. When not using auto-clear, you must return the digital output to its clear pattern.

NOTE *With the Busy line 4 mode selected, the clear state of line 4 is LO, regardless of the configured clear pattern. With the /Busy mode selected, the clear state of line 4 is HI.*

Auto-Clear timing — The following example timing diagram (Figure 10-7) and discussion explain the relationship between the digital output lines for auto-clear.

Figure 10-7 Digital output auto-clear timing example



* With the SOT line being pulsed low (as shown), /START TEST must be the selected arm event for the trigger model. If the SOT line is instead pulsed high by the handler, START TEST must be the selected arm event.

Initially, the four digital output lines are cleared (in this case, they are all set high). Limit tests start when the start-of-test (SOT) pulse is received from the component handler. When the testing process is finished, the pass or fail pattern is applied to the digital output. As shown in the diagram, lines 2, 3, and 4 go low while line 1 remains high.

The pulse width (delay) of the pass/fail pattern can be set from 0 to 60 sec (10µsec resolution) as required by the component handler. Note that the delay specifies the pulse width of line 4. The pulse width of lines 1, 2, and 3 is actually 20µsec longer. Line 4 is skewed because it is used as the end-of-test (EOT) strobe by category register component handlers. Lines 1, 2, and 3 establish the bit pattern and then 10µsec later the SOT strobe "tells" the handler to read the bit pattern and perform the binning operation. This 10µsec offset is used to make sure the correct bit pattern is read by the handler.

After the pass/fail is read by the handler, the digital output returns to the clear pattern.

Front panel operation

Limit test configuration

Most aspects of limit testing are configured from the limit configuration menu. When using a component handler, the "start of test" (/STest, Test or Immediate) option is set from the arm layer configuration menu.

Once in a menu structure, use the ▲ and ▼ keys to display menu items. Use the cursor ◀ and ▶ and the ▲ and ▼ keys to key in values. To change polarity of a value, place the cursor on "+" or "-" and press ▲ and ▼. To change range for the value, place the cursor on the range symbol and use the ▲ and ▼ keys (P = pico, $_N$ = nano, μ = micro, m = milli, ^ = x1, K = kilo, M = mega, G = giga, T = tera). A menu item or value is selected by pressing ENTER.

Digital output bit patterns — An output pattern is set by selecting a decimal value (0 to 15) that corresponds to the 4-bit BCD pattern of the output. To determine the output pattern value, add up the decimal weight values for the desired HI lines:

Output HI Line:	Out 4	Out 3	Out 2	Out 1
Decimal Weight:	8	4	2	1

For example, to set an output pattern to 0101 (lines 3 and 1 HI), set the output value to 5 (4 +1).

Limits configuration menu

The configuration menu for limits is structured as follows. Bullets denote the main items of the menu. To access the menu, press SHIFT and then CONF-LIM.

- **LIMIT 1** — Configure limit 1 test:
  CONTROL — Enable or disable limit 1 test.
  HILIM — Set the HI limit (-9.999999T to +9.999999T), and set the "fail" digital output bit pattern (0 to 15).
  LOLIM — Set the LO limit (-9.999999T to +9.999999T), and set the "fail" digital output bit pattern (0 to 15).
- **LIMIT 2** — Configure limit 2 test:
  CONTROL — Enable or disable limit 2 test.
  HILIM — Set the HI limit (-9.999999T to +9.999999T), and set the "fail" digital output bit pattern (0 to 15).
  LOLIM — Set the LO limit (-9.999999T to +9.999999T), and set the "fail" digital output bit pattern (0 to 15).
- **PASS** — Set the digital output bit pattern for the "all tests pass" condition (0 to 15).
- **DIG CLR** (Digital Clear):
  AUTO CLR — Enable or disable auto-clear for the digital output.
  DEL (Delay) — Set the pass/fail pattern pulse width (0 to 60 sec with 10μsec resolution).
  DIGOUT — Set the digital output clear pattern (0 to 15).

- **LIN4MOD** (Line 4 Mode):
  ENDOFTST (End of Test) — With this mode, Model 6514 will pulse the EOT line when the test is finished. Use with catagory register component handlers.
  /BUSY and **BUSY** — Pulls line 4 LO (/Busy) or HI (Busy) while the test is in process. Use with catagory pulse component handlers.

Arm layer configuration menu

When using a component handler, the "start of test" option is selected from the Arm-In menu item of the arm layer configuration menu. To access the menu, press SHIFT and then CONF-ARM.

- **ARM-IN** — Select the "start of test" option:
  IMM (Immediate) — Test starts when LIMIT key is pressed.
  TEST — Test starts when the handler pulls the SOT line of the Digital I/O high.
  /STEST — Test starts when the handler pulls the SOT line of the Digital I/O low.

NOTE *The other arm-in control sources are seldom used with component handlers, but are available.*

Perform limit tests

Step 1 Configure test system

As previously explained, testing the system could be as simple as connecting a DUT to Model 6514 or could employ the use of a component handler for binning operations.

Step 2 Configure measurement

Configure Model 6514 for the desired measurement as covered in the previous sections of this manual.

Step 3 Configure limit tests

Configure Model 6514 for the limit tests as explained in "Limit Test Configuration".

Step 4 Start testing process

To enable the limit tests, press the LIMIT key. If the SOT line of the Digital I/O port is being used by a component handler, the test process will not start until the handler pulses the SOT line. Otherwise, the testing process will start when LIMIT is pressed.

Step 5 Stop testing process

The testing process can be terminated at any time by again pressing the LIMIT key. When using a component handler, the testing process will stop after the last DUT is tested.

SCPI programming

Table 10-2
SCPI commands — limit tests

Command	Description	Default	Ref
:CALCulate2	CALCulate2 Subsystem:		
:FEED <name>	Select input path for limit testing; CALCulate[1] or SENSe[1].	SENS	A
:LIMit[1]	Limit 1 Testing:		
:UPPer	Configure upper limit:		
[:DATA] <n>	Set limit; -9.99999e20 to 9.99999e20.	1.0	
:SOURce2 <NDN> or <NRf>	Specify 4-bit output “fail” pattern.	15	B
:LOWer	Configure lower limit:		
[:DATA] <n>	Set limit; -9.99999e20 to 9.99999e20.	-1.0	
:SOURce2 <NDN> or <NRf>	Specify 4-bit output “fail” pattern.	15	B
:STATe <b>	Enable or disable Limit 1 test.	OFF	
:FAIL?	Return result of Limit 1 test; 0 (pass) or 1(fail).		C
:LIMit2	Limit 2 Testing:		
:UPPer	Configure upper limit:		
[:DATA] <n>	Set limit; -9.99999e20 to 9.99999e20.	1.0	
:SOURce2 <NDN> or <NRf>	Specify 4-bit output “fail” pattern.	15	B
:LOWer	Configure lower limit:		
[:DATA] <n>	Set limit; -9.99999e20 to 9.99999e20.	-1.0	
:SOURce2 <NDN> or <NRf>	Specify 4-bit output “fail” pattern.	15	
:STATe <b>	Enable or disable Limit 2 test.	OFF	
:FAIL?	Return result of Limit 2 test; 0 (pass) or 1(fail).		C
:CLIMits	Composite Limits:		
:CLEar	Clear I/O port and restore it back to SOURce2:TTL settings:		
[:IMMediate]	Clears I/O port immediately.		
:AUTO <b>	When enabled, I/O port clears when :INITiate sent.	ON	
:PASS	Define “pass” digital output pattern.		
:SOURce2 <NDN> or <NRf>	Specify 4-bit pass pattern (no failures).	15	B
:NULL	Configure and control Rel:		Sec 7
:OFFSet <NRf>	Specify Rel value; -9.999999e20 to 9.999999e20.	0.0	
:STATe <b>	Enable or disable Rel.	OFF	
:DATA?	Return CALC2 reading(s) triggered by INITiate.		D
:LATest?	Return last (latest) CALC2 reading.		D

Table 10-2 (cont.)
SCPI commands — limit tests

Command	Description	Default	Ref
:SOURce2	SOURce2 Subsystem:		
:TTL <NDN> or <NRf>	Specify 4-bit digital output clear pattern.	15	B
:CLEar	Clear I/O port (return output to TTL pattern):		
[:IMMediate]	Clear I/O port immediately.		
:AUTO <b>	Enable or disable auto-clear.	OFF	
:DELay <n>	Specify delay (pulse-width) for pass/fail pattern; 0 to 60 (sec).	0.0001	
:TTL4	Line 4 Mode configuration:		
:MODE <name>	Select output line 4 mode; EOTest or BUSY.	EOT	
:BSTate <ttl>	Select active TTL level for busy; 1 (HI) or 0 (LO).	0	
	Trigger Subystem:		Sec 9
ARM	Arm Layer:		
:SOURce <name>	Select control source; NSTest, PSTest or IMMediate.	IMM	E
INITiate	Initiation one trigger cycle.		D
FORMat	FORMat subsystem:		
:SOURce2 <name>	Select data format for reading output patterns:	ASC	
	<name> = ASCii — Decimal format		
	HEXadecimal — Hexadecimal format		
	OCTal — Octal format		
	BINary — Binary format		

A) FEED <name>

Name parameters:

- CALCulate1 — Limit tests will be performed on the result of a math calculation (mX+b or percent).
- SENSe — Limit tests will be performed on the input signal. Note however, that Rel can be used on the result of a math calculation as well as the input signal. Limit tests will be performed on the result of the Rel operation (see CALCulate2:NULL). Details on relative, mX+b and percent are provided in Section 7.

B) <NDN> and <NRf> parameters

<NDN>	= #Bxxxx	Binary format (each x = 1 or 0)
	= #Hx	Hexadecimal format (x = 0 to F)
	= #Qxx	Octal format (x = 0 to 17)
<NRf>	= 0 to 15	Decimal format

An output pattern is set by sending a parameter value that corresponds to the 4-bit BCD pattern of the output. The parameter value can be sent in the binary, decimal, hexadecimal, or octal format. For example, if you wish to set lines 4, 2, and 1 HI, the binary parameter value would

be 1011. To use one of the other formats, convert the binary number to its decimal, hexadecimal, or octal equivalent:

Binary 1011 = Decimal 11 = Hexadecimal B = Octal 13

The <NDN> (non-decimal numeric) parameter type is used to send non-decimal values. These values require a header (#B, #H or #Q) to identify the data format being sent. The letter in the header can be upper or lower case. The <NRf> (numeric representation format) parameter type is used to send decimal values and does not use a header.

The following examples show the proper parameter syntax to set an output pattern to 1101 (lines 4, 3 and 1 set HI):

#b1101	Binary format (<NDN> parameter type)
#hD	Hexadecimal format (<NDN> parameter type)
#q15	Octal format (<NDN> parameter type)
13	Decimal format (<NRf> parameter type)

NOTE *When a query command to read a programmed output pattern (i.e., CALC2:LIM:UPP:SOUR2?) is sent, the format for the returned value is determined by the presently selected response message format for output patterns (see FORMat:SOURce2 command in Table 10-2).*

C) FAIL?

In the event of a failure, you can read the measurement event register to determine which limit (upper or lower) failed. See Section 13 to program and read the measurement event register.

D) DATA?

The INITiate command must be sent to perform the programmed number of measurements. If the instrument is programmed to perform a finite number of measurements, the :DATA? command will return all the CALC2 readings after the last reading is taken. The :DATA:LATest? command will only return the last (latest) CALC2 reading.

If the instrument is programmed to perform an infinite number of measurements (arm count or trigger count set to infinite), you cannot use the :DATA? command to return CALC2 readings. However, you can use the :DATA:LATest? command to return the last CALC2 reading after aborting the measurement process. After sending the INITiate command to start the measurement process, use the ABORt command to abort the measurement process, then use :DATA:LATest? to return the last CALC2 reading.

Sending :DATA? or :DATA:LATest? without first sending INITiate will return “old” readings, or cause an error (-220) if limit is not enabled or there are no readings available.

E) ARM:SOURce <name>

Typical “start of test” options:

- IMMediate — Test starts when LIMIT key is pressed.
- NSTest — Test starts when component handler pulls the SOT line low.
- PSTest — Test starts when component handler pulls the SOT line high.

Programming example

The following command sequence will test DUT using the limit tests example shown in Figure 10-2.

```
*RST                    ' Restore RST defaults (Volts function).
CALC2:LIM:UPP 2         ' Set upper limit for Limit 1 (2V).
CALC2:LIM:LOW -2        ' Set lower limit for Limit 1 (-2V).
CALC2:LIM:STAT ON       ' Enable Limit 1 test.
CALC2:LIM2:UPP 1        ' Set upper limit for Limit 2 (1V).
CALC2:LIM2:LOW -1       ' Set lower limit for Limit 2 (-1V).
CALC2:LIM2:STAT ON      ' Enable Limit 2 test.
                        ' Connect DUT to input.
INIT                    ' Perform tests on DUT (one measure-
                         ment).
CALC2:LIM:FAIL?         ' Return result of Limit 1 test.
CALC2:LIM2:FAIL?        ' Return result of Limit 2 test.
```

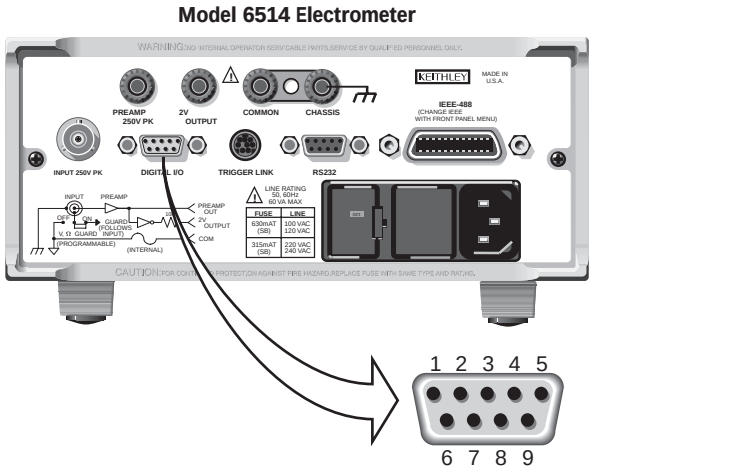
11
Digital I/O, Analog Outputs, and External Feedback

- **Digital I/O port** — Explains how to use the digital I/O port to control external circuitry.
- **Analog outputs** — Covers the 2V analog output and preamp out.
- **External feedback** — Explains how to use the external feedback mode to perform charge and current measurements.

Digital I/O port

Model 6517A's Digital I/O port is a male DB-9 connector located on the rear panel. The ports location and pin designations are shown in Figure 11-1. The four active-low, digital output lines and one input line are used to control external circuitry.

Figure 11-1
Digital I/O port



1 = Digital Output #1
2 = Digital Output #2
3 = Digital Output #3
4 = Digital Output #4 (EOT*)
5 = VEXT
6 = SOT*
7 = Not Used
8 = Not Used
9 = Digital Ground

* Start of Test (SOT) and End of Test (EOT) are used for Limit Tests (see Section 10).

Typical applications for the digital I/O port include the following:

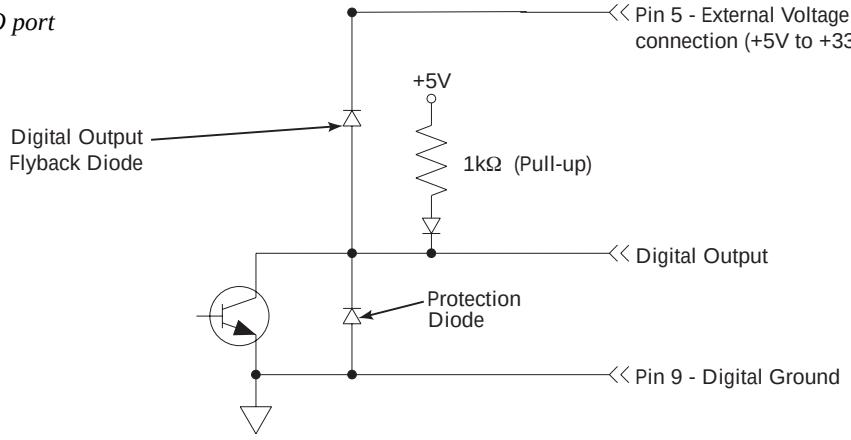
- **Component handler control** — When performing limit tests, a component handler can be used to sort DUT into bins. The digital I/O of Model 6514 serves as the interface between the limit tests and the component handler. Via the digital input line (pin 6), the component handler can tell Model 6514 when it is ready for the test. Via the digital output lines, Model 6514 sends digital output patterns to the component handler and tells it when the test is finished. A digital output pattern determines which bin the DUT belongs in.

NOTE *Information on using the digital I/O to control a component handler for limit tests is provided in Section 10.*

- **External device control** — Each digital output can be used as a control switch for an external device (i.e. relay) circuit. Each output line can sink up to 500mA. Drive voltage is provided by an external source (+5V to +33V).
- **Logic Control** — The four digital outputs can be used as inputs to logic devices.

The simplified schematic for the digital outputs are shown in Figure 11-2. Note that this illustration shows the schematic for one digital output. All four digital output circuits are identical.

Figure 11-2 Digital I/O port simplified schematic



Sink mode — controlling external devices

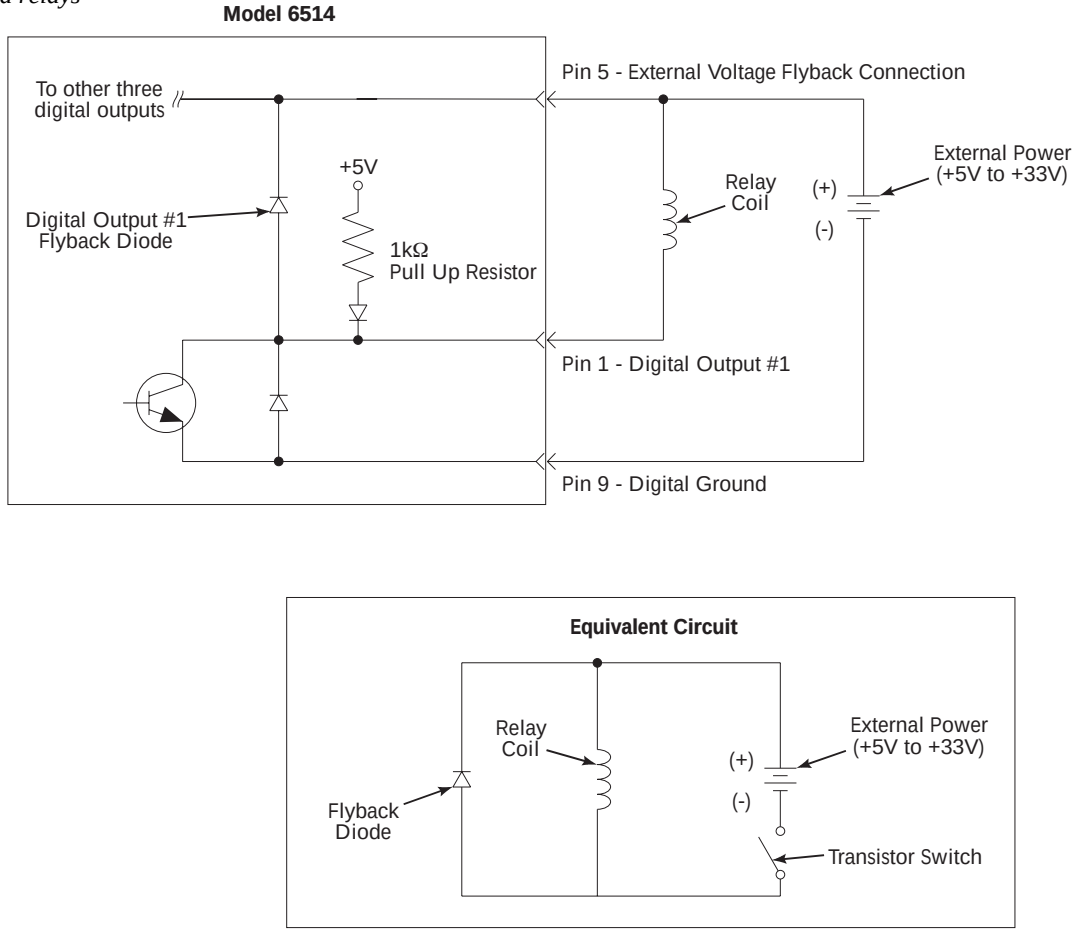
Each output can be operated from an external supply (voltage range from +5V to +33V applied through the external device being driven). The high current sink capacity of the output driver allows direct control of relays, solenoids, and lamps (no additional circuitry needed).

As shown in Figure 11-2, each of the four digital, open-collector outputs includes a built-in pull up resistor to +5V. The output transistor is capable of sinking 500mA from voltages up to +33V. Each output channel contains a fly-back diode for protection when switching inductive loads (such as a low power solenoid or relay coils). To use these fly-back diodes, connect the external supply voltage to pin 5 of the digital I/O port. Make sure the external supply voltage is between +5V and +33V and the current required by the device does not exceed 500mA.

CAUTION **Do not exceed +33V maximum voltage on pin 5 of the digital I/O port, and do not use any output line to sink >500mA. Exceeding these limits may cause damage to the instrument that is not covered by the warranty.**

An externally powered relay connected to the digital output port is shown in Figure 11-3. Other externally powered devices can be similarly connected by replacing the relay with the device. When the output line is set LO (0V), the output transistor sinks current through the external device. In the HI state, the output transistor is off (transistor switch open). This interrupts current flow through the external device.

Figure 11-3
Controlling externally powered relays



Source mode — logic control

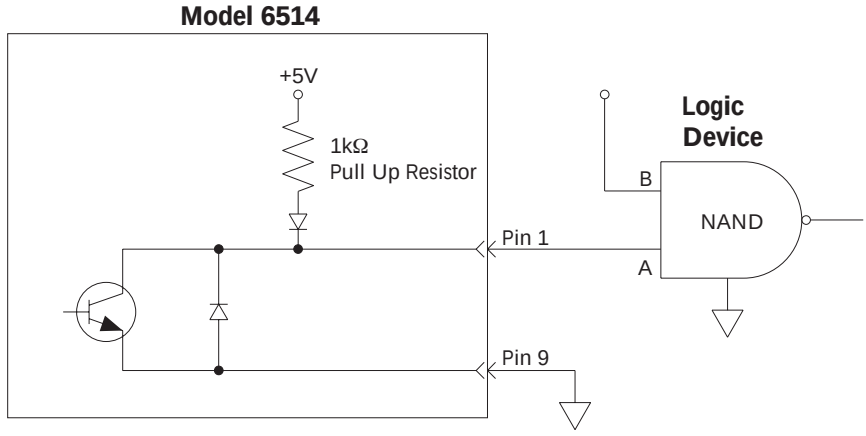
The digital outputs can be used as logic inputs to active TTL, low-power TTL, or CMOS inputs. For this mode of operation, the output lines can source up to 2mA.

CAUTION **Each output line can source up to 2mA. Exceeding 2mA may cause damage to Model 6514 that is not covered by the warranty.**

Figure 11-4 shows how to connect a logic device to one of the output lines. When the output line is set HI, the transistor will turn off (transistor switch open) to provide a reliable logic high output (>3.75V). When the output line is set LO, the transistor turns on (transistor switch closed) to route current to digital ground. As a result, a low logic output (0V) is provided at the output.

If the second input (B) of the NAND gate is connected to another output line of the port, the output of the NAND gate will go to logic 0 when both digital outputs are set HI.

Figure 11-4
NAND gate control



Setting digital output lines

Digital output lines are set by selecting a decimal value (0 to 15) that corresponds to the 4-bit BCD pattern of the output. To determine the value, add up the decimal weight values for the desired HI lines:

Output HI Line:	Out 4	Out 3	Out 2	Out 1
Decimal Weight:	8	4	2	1

For example, to set output lines 3 and 1 HI (0101 bit pattern), set the output value to 5 (4 +1).

Perform the following steps to set the digital output pattern from the front panel:

1. Press SHIFT and then CONF-LIM to access the limits menu.
2. Press the ▲ or ▼ until "LIMIT:PASS" is displayed.
3. Press ENTER. The present digital output pattern value will be displayed.
4. Use the ◄, ►, ▲ and ▼ keys to display the desired output pattern value (0 to 15), and press ENTER.
5. Press EXIT to return to the normal display state.

SCPI programming — digital output pattern

Table 11-1
SCPI commands — digital outputs

Command	Description	Default
SOURce2	SOURce2 Subsystem:	
:TTL <NRf> or <NDN>	Specify 4-bit digital output pattern (see "Parameter Values").	15
:TTL?	Query the digital output pattern. The value returned is in the decimal format.	
Parameter Values (see Note):		
<NRf> = 0 to 15	Decimal format	
<NDN> = #Bxxxx	Binary format (each x = 1 or 0)	
= #Hx	Hexadecimal format (x = 0 to F)	
= #Qxx	Octal format (x = 0 to 17)	

Note: The <NDN> parameter type can be used to set the output pattern using non-decimal values. Convert the decimal value to its binary, hexadecimal or octal equivalent and include the appropriate header (#B, #H or #Q). For example, to set output lines 4 and 2 HI using the binary format, send SOURce2:TTL #B1010. More information about the <NDN> parameter type is provided in Section 13 (see "Programming Enable Registers").

Programming example

The following command sequence sets output lines 4 and 2 HI, and output lines 3 and 1 LO.

```
SOUR2:TTL 10              ' Set output lines 4 and 2 HI.
SOUR2:TTL?                ' Request output pattern value.
```

Analog outputs

Model 6514 has two analog outputs on the rear panel. The 2V ANALOG OUTPUT provides a scaled ±2V output with a value of ±2V corresponding to full-range input. The PREAMP OUT is especially useful in situations requiring buffering. These two analog outputs are discussed in the following paragraphs.

WARNING **When floating input low above 30V RMS from earth ground, hazardous voltage will be present at the analog outputs. Hazardous voltage may also be present when the input voltage exceeds 30V RMS in the volts function, or when input currents exceed 30pA in the amps function.**

CAUTION **Connecting PREAMP OUT, COMMON, or 2V ANALOG OUTPUT to earth while floating the input may damage the instrument.**

2V analog output

The 2V analog output provides a scaled ±2V output that is non-inverting in the volts mode. Connections for using this output are shown in Figure 11-5. For a full-range input (i.e. 2V on the 2V range), the output will be 2V. Example analog outputs are listed in Table 11-2.

The 2V analog output signal is not corrected during calibration. Gain errors of up to 15% may appear at this output, depending on function and range.

The output impedance is 10kΩ. To minimize the effects of loading, the input impedance of the device connected to the 2V analog output should be as high as possible. For example, for a device that has an input impedance of 10MΩ, the error due to loading will be approximately 0.1%.

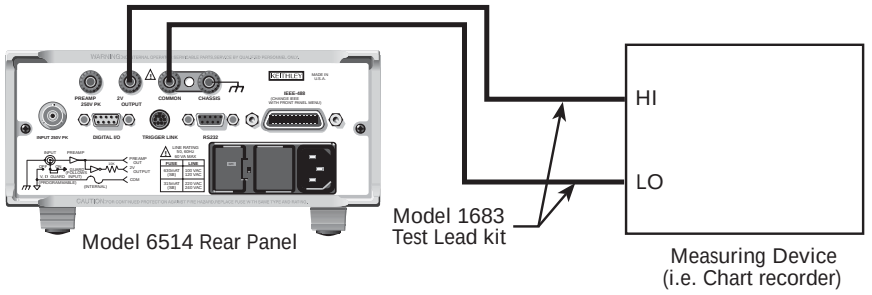
NOTE *Rel and the result of mX+b or percent have no affect on the analog output. The 2V analog output is scaled only to the actual input.*

Table 11-2
Example 2V analog output values

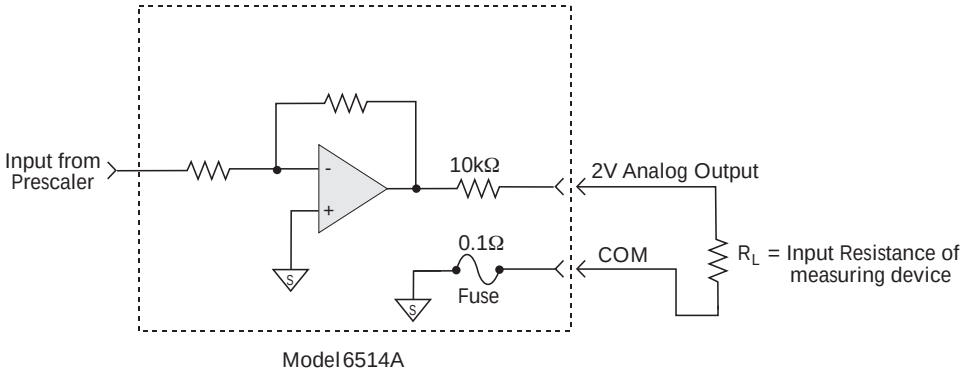
Range	Applied signal	Analog output value (nominal)*
20pA	10.5pA	-1.05V
2uA	-1.65µA	1.65V
200mV	140mV	1.4V
200V	-36V	-0.36V
200kΩ	175kΩ	1.75V
20nC	19nC	-1.9V

* Output values are within ±15% of nominal value.

Figure 11-5
Typical 2V analog output connections



A. Connections

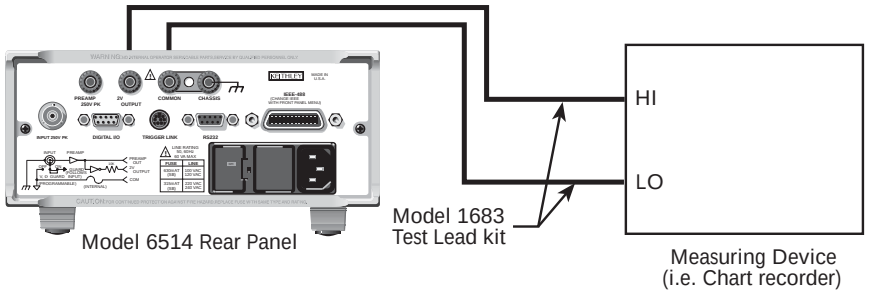


B. Equivalent Circuit

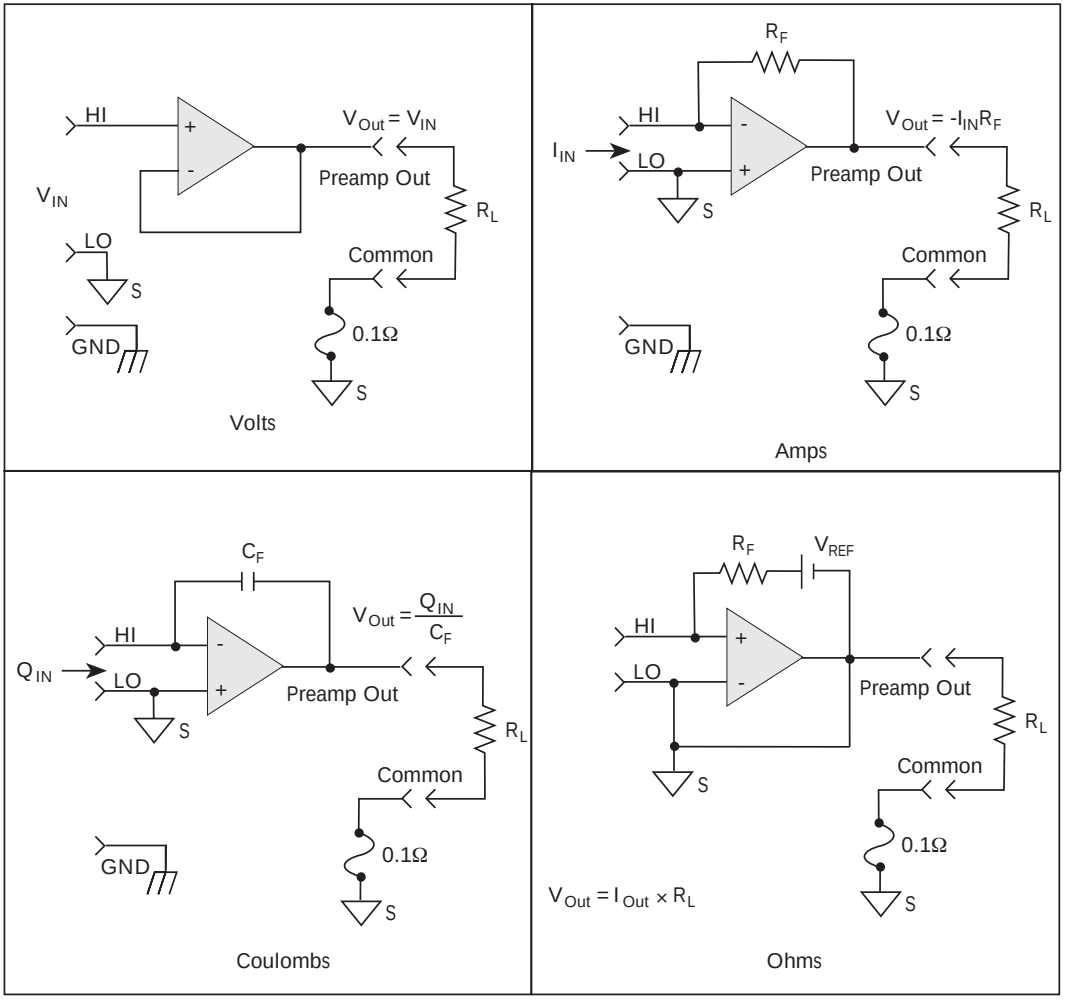
Preamp out

The preamp output of Model 6514 follows the signal amplitude applied to the input terminal The preamp output provides a guard output for volts measurements. It can be used as an inverting output or with external feedback in the amps and coulombs modes. Connections and equivalent circuits for the preamp output are shown in Figure 11-6. Full-range outputs for the various functions and ranges are listed in Table 11-3.

Figure 11-6 Typical preamp out connections



A. Connections



B. Equivalent Circuit

Since the preamp output signal is not corrected during calibration, gain error of up to 15% may appear at this output, depending on function and range selection. For all volts ranges, preamp output accuracy is typically 10ppm.

WARNING **High voltage may be present between the preamp output and common terminals depending on the input signal (see Table 11-3).**

CAUTION **Connecting preamp output, common, or 2V analog output to earth while floating the input may damage the instrument**.

Table 11-3
Full-range preamp out values

Function	Range	Full-range value
Volts	2V	2V
	20V	20V
	200V	200V
Amps	2nA, 2µA, 2mA	2V
	20pA, 20nA, 20µA, 20mA	20V
	200pA, 200nA, 200µA	200V
Ohms	2kΩ, 2MΩ, 2GΩ	2V
	20kΩ, 20MΩ, 20GΩ	20V
	200kΩ, 200MΩ, 200GΩ	200V
Coulombs	20nC, 2µC	20V
	200nC, 20µC	200V

Note that the preamp out output resistance is 1Ω. The output resistance appears between input low and analog output low to keep the resistor out of the loop when using external feedback elements. To keep loading errors under 0.1%, the device connected to the preamp output should have a minimum input impedance of 100k.

CAUTION **To prevent damage to Model 6514, do not connect a device to preamp out that will draw more than ±100µA. For example, at 200V, the impedance connected to preamp out must be at least 2MΩ (200V/100µA = 2MΩ).**

External feedback

The external feedback function provides a means to extend the capabilities of Model 6514 electrometer to such uses as logarithmic currents, non-decade current ranges, as well as non-standard coulombs ranges. The following paragraphs discuss the basic electrometer input circuitry and methods to implement these functions.

Electrometer input circuitry

A simplified diagram of the electrometer input in the external feedback mode is shown in Figure 11-7. An input current applied to the inverting (-) input of the op amp is nulled by a current feedback through the internal feedback network made up of R_{FB} and C_{FB}. Because the output of the op amp appears at the preamp out, this internal network can be replaced by an external network connected between the preamp output and input HI connections. When using external feedback, the following factors must be taken into account:

1. The maximum current value that can be supplied by the preamp output is 20mA in amps and ohms (1mA in volts). The maximum voltage span in external feedback is ±20V.
2. The input impedance in the external feedback mode is given by the relationship $Z_{IN} = Z_{FB}/A_V$, where: Z_{FB} is the impedance of the external feedback network, and A_V is the open-loop gain of the electrometer (typically greater than 55×10^6). Note that the input impedance is $Z_{IN} = 10M\Omega \parallel Z_{FB}$ when zero check is enabled.
3. The voltage at the preamp out terminal is given by the formula:

   V = -IZFB

4. Any feedback elements should be housed in a suitable shielded enclosure (see “Shielded Fixture Construction” below). Insulators connected to input HI should be made of Teflon or other high-quality insulating material and should be thoroughly cleaned to maintain the high input impedance and low input current of Model 6514. If these insulators become contaminated, they can be cleaned with methanol and then with clean, pressurized air.

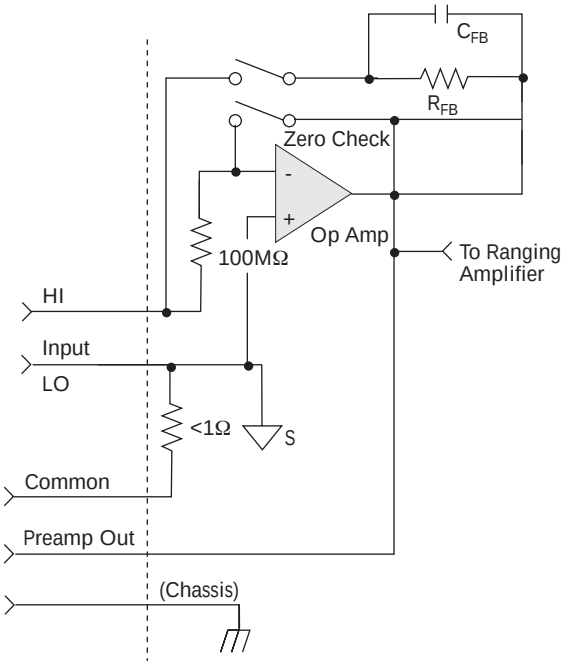


Figure 11-7
Electrometer input circuitry (external feedback mode)

Shielded fixture construction

Since shielding is so critical for proper operation of external feedback, it is recommended that a shielded fixture similar to the one shown in Figure 11-8 be used to house the feedback element. The fixture is constructed of a commercially available shielded fixture modified with the standard BNC connectors replaced with triaxial female connectors. For convenience, a banana jack can be mounted on the box to make the necessary preamp out connection.

Alternately, a wire could be run through a rubber grommet mounted in a hole in the side of the box. Note that input low is connected to chassis ground within the shielded box. This connection can be made by using a small solder lug secured with a screw.

Non-standard coulombs ranges

The Model 6514 has four coulombs ranges allowing it to measure charge between 10fC and 20µC. Charge measurements greater than 20µC can be obtained by placing the instrument in the external feedback mode and measuring the voltage across an external feedback capacitor. See the following subheading "External feedback procedure" for instructions.

Charge is related to capacitance and voltage by the formula:

$Q = CV$

where: Q = the charge in coulombs
C = the capacitance in farads
V = the voltage in volts.

Model 6514 display will read the charge directly in units determined by the value of C. For example, a 10µF capacitor will result in a displayed reading of 10µC/V.

In practice, the feedback capacitor should be greater than 100pF for feedback stability and of suitable dielectric material to ensure low leakage and low dielectric absorption. Polystyrene, polypropylene, and Teflon dielectric capacitors are examples of capacitor types with these desirable characteristics. The capacitor should be mounted in a shielded fixture like the one in Figure 11-8.

To discharge the external feedback capacitor, enable zero check. The discharge time constant will be given by: $t = (10M\Omega)(C_{FB})$. Allow five time constants for discharge to within 1% of final value.

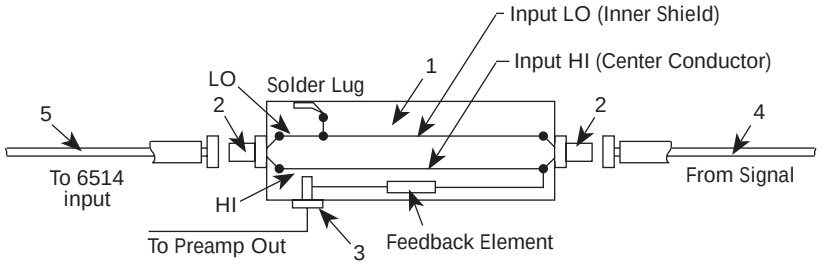
External feedback procedure

Use the following procedure to operate Model 6514 in the external feedback mode.

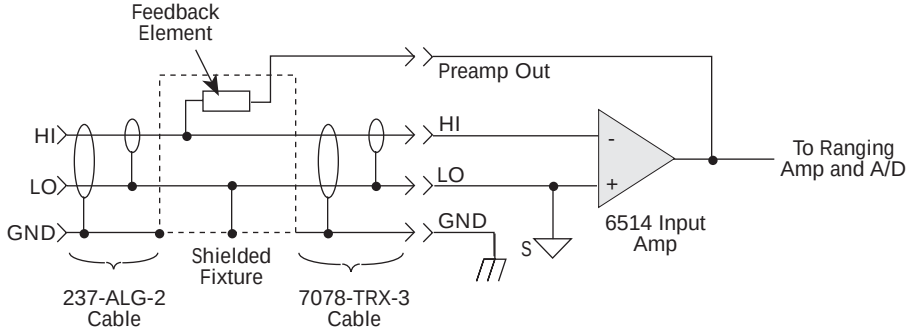
1. Enable zero check.
2. Connect the feedback element between the preamp out terminal and the input HI terminal.
3. Enable external feedback as follows:
   a. Press the XFBK key to access the external feedback menu.
   b. Press the ▲ or ▼ key to select ON and press ENTER.
4. Press the V key to select the volts function.
5. Disable zero check. The "XF" message will be displayed to indicate that the instrument is in the external feedback mode. The display will show the voltage measured at the output of the input preamplifier (PREAMP OUT).

NOTE *To disable external feedback, press XFBK and select the OFF option.*

Figure 11-8
Shielded fixture construction



A. Construction



B. Equivalent Circuits

Parts List		
Item	Description	MFR Part Number
1	Shielded Fixture	Pomona #2390
2	Female Triaxial	Keithley 7078-TRX-TBC
3	Banana Jack	Keithley BI-9-2
4	Triaxial Cable	Keithley 237-ALG-2
5	Triaxial Cable	Keithley 7078-TRX-3

Logarithmic currents

The use of a diode junction in the external feedback path permits a logarithmic current-to-voltage conversion. This relationship for a junction diode is given by the equation:

$V = mkT/q \ln(I/I_O) + I_{RB}$

where; q = unit of charge (1.6022×10^{-19})
k = Boltzmann's constant (1.3806×10^{-23})
T = temperature (K).

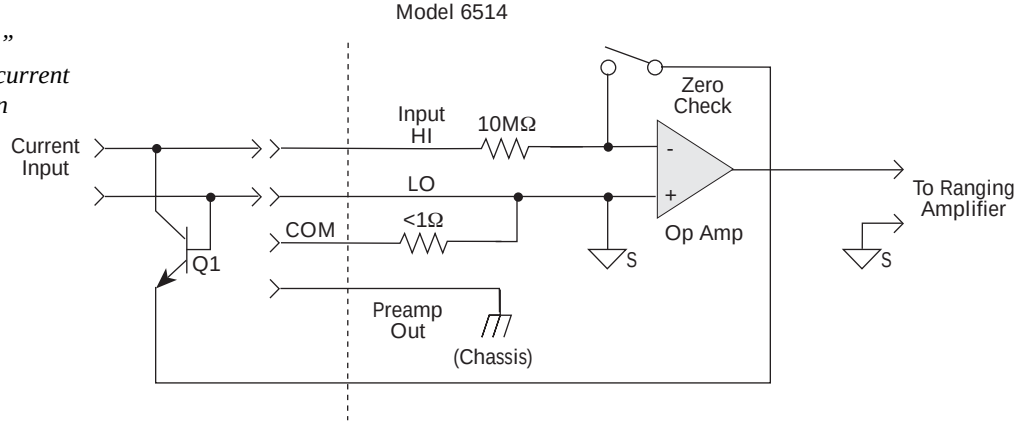
The limitations in this equation center on the factors I_O, m, and RB. I_O is the extrapolated current for V_O. An empirical proportional constant, m, accounts for the different character current conduction (recombination and diffusion mechanisms) within the junction, typically varying between 1 and 2. Finally, RB constitutes the ohmic bulk resistance of the diode junction material. I_O and RB limit the usefulness of the junction diode at low and high currents respectively. The factor m introduces non-linearity's between those two extremes. Because of these limitations, most diodes have a limited range of logarithmic behavior.

A solution to these constraints is to use a transistor configured as a "transdiode" in the feedback path, as shown in Figure 11-9. Analyzing the transistor in this configuration leads to the relationship:

$V = kT/q[\ln(I/I_O) - \ln(h_{FE}/(1 + h_{FE}))]$

where; h_{FE} is the current gain of the transistor.

Figure 11-9
"Transdiode" logarithmic current configuration



From this equation, proper selection of Q1 would require a device with high current gain (h_{FE}), which is maintained over a wide range of emitter currents. Suitable devices for this application include Analog Devices AD812 and Precision Monolithics MAT-01. Use the enclosure in Figure 11-8 to shield the device.

Frequency compensation/stabilization is accomplished by adding a feedback capacitor, C_{FB}. The value of this capacitor depends on the particular transistor being used and the maximum current level expected. Compensation at maximum current is required because the dynamic impedance will be minimum at this point. It should be noted that the response speed at lower currents will be compromised due to the increasing dynamic impedance, which is given by the following formula:

Using the above transistors, a minimum RC time constant of 100µsec at maximum input current would be used. At I_{IN} (max) of 100µA, this value would correspond to 0.4µF. Note that at 100nA, this value would increase the RC response time constant to 100msec. A minimum capacitance of 100pF is recommended.

Although the input signal to this particular circuit is assumed to be a current, conversion to voltage input could be performed by placing a shunt resistor across the input. However, the nominal voltage burden of 1mV must be considered as an error signal that must be taken into account.

Further processing of the current response can be achieved by using the suppress feature. For example, REL could be enabled with a reference input current applied. For all subsequent currents, the natural logarithm of the ratio of the measured current to the suppressed current would then be displayed:

$$\begin{aligned} V_{DISP} &= V_{REL}\ kT/q\ (\ln (I_{READ}/I_O) - \ln (I_{REL}/I_O)) \\ &= kT/q\ (\ln (I_{READ}/I_{REL})) \\ &= 0.26/I\ (\ln (I_{READ}/I_{REL}))\ @\ 25^{\circ}C \end{aligned}$$

NOTE *The circuit topology of Figure 11-9 works for positive input currents only. For bipolar input signals, an external offset bias must be applied, or use a PNP transistor for Q1.*

Non-decade current gains

Model 6514 electrometer input uses internal decade resistance feedback networks for the current ranges. In some applications, non-decade current gains may be desirable. As shown in Figure 11-10, an external feedback resistor, R_{FB}, can be used to serve this purpose. Limitations on the magnitude of the feedback current require that the value of R_{FB} be greater than $10^2\Omega$.

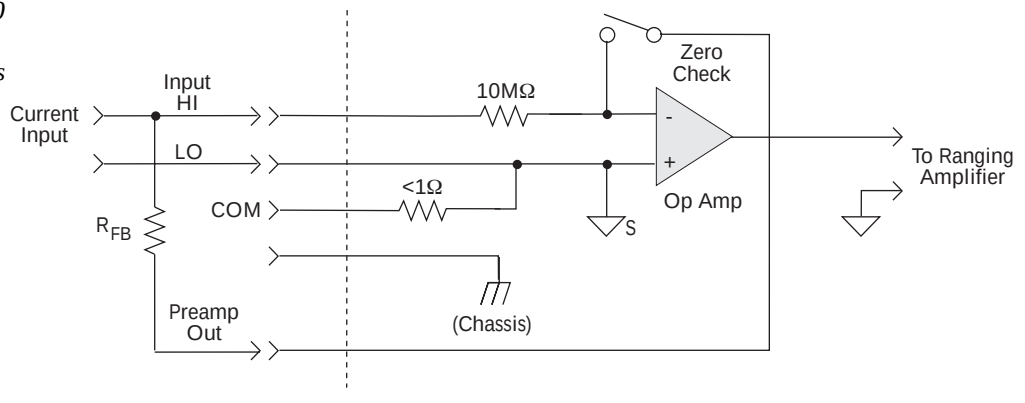


Figure 11-10 Non-decade current gains

SCPI programming — external feedback

Table 11-4
SCPI commands — external feedback

Commands	Description	Ref	Default
[SENSe]	SENSe Subsystem:		
:VOLTage	Volts configuration:		
:XFEedback <b>	Enable or disable external feedback.		Off
:FUNCtion VOLTage	Select Volts function.	Sec 3	
SYSTem	SYSTem Subsystem:		
:ZCHeck <b>	Enable or disable zero check.	Sec 2	On

Programming example — external feedback

The following command sequence configures Model 6514 to perform measurements using the external feedback mode:

```
SYST:ZCH ON          ' Enable zero check.
VOLT:XFE ON          ' Enable external feedback.
FUNC 'VOLT'          ' Select Volts function.
SYST:ZCH OFF         ' Disable zero check.
READ?                ' Trigger measurement(s) and request
                      reading(s).
```

12
Remote Operation

- **Selecting and configuring an interface** — Explains how to select and configure an interface; GPIB or RS-232.
- **GPIB operation and reference** — Covers the following GPIB topics:
  GPIB Bus Standards
  GPIB Bus Connections
  Primary Address Selection
  General Bus Commands
  Front Panel GPIB Operation
  Programming Syntax
- **RS-232 interface reference** — Provides basic reference information for the RS-232 interface and explains how to make connections to the computer.

Selecting and configuring an interface

Interfaces

Model 6514 supports two built-in remote interfaces:

- GPIB interface
- RS-232 interface

You can use only one interface at a time. At the factory, the GPIB bus is selected. You can select the interface only from the front panel. The interface selection is stored in non-volatile memory; it does not change when power has been off or after a remote interface reset.

GPIB interface — The GPIB is the IEEE-488 interface. Model 6514 must be assigned to unique address. At the factory the address is set to 14, but can be set to any value from 0 to 30. However, the address must not conflict with the address assigned to other instruments in the system. You can use either the SCPI or DDC language to program the instrument.

RS-232 interface — When using the RS-232 interface, you must set baud rate, data bits, parity, terminator and flow control. For the RS-232 interface, you can only use the SCPI language to program the instrument.

Languages

For the GPIB interface, there are two programming languages to choose from:

- SCPI language
- DDC language

NOTE *For the RS-232 interface, only the SCPI language can be used to program the instrument. When the RS-232 interface is selected, it automatically defaults to SCPI.*

SCPI language — Standard Commands for Programmable Instrument (SCPI) is fully supported by the GPIB and RS-232 interfaces. Always calibrate Model 6514 using the SCPI language.

DDC language — Model 6514 implements most DDCs (device-dependent commands) available in the Keithley Models 6512, 617, and 617 HIQ electrometers. The commands are provided in Appendix D. See the appropriate instruction manual for details on operation.

Interface selection and configuration procedures

When you select (enable) the GPIB interface, the RS-232 interface disables. Conversely, selecting (enabling) the RS-232 interface disables the GPIB interface.

NOTE When an interface is enabled (on) or disabled (off), the instrument will exit from the menu structure and perform the power-on sequence.

GPIB interface

The GPIB interface is selected and configured from the GPIB menu structure. From this menu, you can enable or disable the GPIB interface, and check or change the following settings:

- Primary address (0 to 30)
- Language (SCPI or DDC)

Selecting GPIB interface — Press SHIFT and then GPIB to access the GPIB menu. The present status (on or off) of the GPIB interface is displayed. If the GPIB is already enabled (on), proceed to step 1 of "Checking/Changing GPIB Settings" to check and/or change the settings. Perform the following steps to enable (select) the GPIB interface:

1. Place the cursor on the OFF setting by pressing the ◄ or ► key.
2. Press the ▲ or ▼ key to toggle the setting to ON.
3. Press ENTER. The instrument will exit the menu structure and perform the power-on sequence.

Checking/changing GPIB settings — Press SHIFT and then GPIB to access the GPIB menu and perform the following steps:

1. Use the ▲ or ▼ key to display the present address (ADDR) and language (LANG) settings. If these settings are correct, press EXIT to exit the menu. Otherwise, continue on to change one or both settings.
2. Use ▲ or ▼ to display the primary address (ADDR). To retain this address, press ENTER. To change the GPIB address:
   a. Press the ◄ or ► key to move the cursor over to the address value field.
   b. Use the ◄, ►, ▲ and ▼ keys to display a valid address value (0 to 30).
   c. Press ENTER. The present programming language setting is then displayed.
3. To retain the displayed programming language (LANG), press ENTER. To change the programming language:
   a. Press ◄ or ► to move the cursor over to the language setting.
   b. Press ▲ or ▼ to display the desired language setting (SCPI or DDC).
   c. Press ENTER. The unit will reset.

RS-232 interface

The RS-232 interface is selected and configured from the RS-232 menu structure. From this menu, you can enable or disable the RS-232 interface, and check or change the following settings:

- Baud rate (57.6K, 38.4k, 19.2k, 9600, 4800, 2400, 1200, 600 or 300)
- Data bits (7 or 8)
- Parity (none, odd or even)
- Terminator (CR, LF, CRLF or LFCR)
- Flow control (none or Xon/Xoff)

NOTE See "RS-232 Interface Reference" (located at the end of this section) for information on these settings and connections to the computer.

Selecting RS-232 interface — Press SHIFT and then RS-232 to access the RS-232 menu. The present status (on or off) of the RS-232 interface is displayed. If it is already enabled (on), proceed to step 1 of "Checking/Changing RS-232 Settings" to check and/or change the settings. Perform the following steps to enable (select) the RS-232 interface:

1. Place the cursor on the OFF setting by pressing the ◄ or ► key.
2. Press the ▲ or ▼ key to toggle the setting to ON.
3. Press ENTER. The instrument will exit the menu structure and perform the power-on sequence.

Checking/changing RS-232 settings — Press SHIFT and then RS-232 to access the RS-232 menu and perform the following steps:

1. Use the ▲ or ▼ key to display the RS-232 settings. If these settings are correct, press EXIT to exit the menu. Otherwise, continue on to change one or more settings.
2. Use the ▲ or ▼ key to display the baud rate (BAUD). To retain this baud rate, press ENTER. To change the baud rate:
   a. Press the ◄ or ► key to move the cursor over to the baud rate value.
   b. Use the ▲ or ▼ key to display the desired baud rate (300 to 57.6k).
   c. Press ENTER. The data bits setting is then displayed.
3. To retain the displayed data bits setting (BITS), press ENTER. To change the data bits setting:
   a. Press the ◄ or ► key to move the cursor over to the data bits value.
   b. Use the ▲ or ▼ key to display the desired number of data bits (8 or 7).
   c. Press ENTER. The parity setting is then displayed.
4. To retain the displayed parity setting (PARITY), press ENTER. To change the parity setting:
   a. Press ◄ or ► to move the cursor over to the parity setting.
   b. Use ▲ or ▼ to display the desired parity (NONE, ODD or EVEN).
   c. Press ENTER. The terminator is then displayed.
5. To retain the displayed terminator (TX TERM), press ENTER. To change the terminator:
   a. Press ◄ or ► (to move the cursor over to the terminator setting.
   b. Use ▲ or ▼ to display the desired terminator (LFCR, CR, CRLF or LF).
   c. Press ENTER. The flow control setting is then displayed.
6. To retain the displayed flow control setting (FLOW), press ENTER. To change the flow control setting:
   a. Press ◄ or ► to move the cursor over to the flow control setting.
   b. Use ▲ or ▼ to display the desired flow control setting (NONE or XonXoff).
   c. Press ENTER.

NOTE Only the SCPI language can be used with the RS-232 interface. The instrument defaults to the SCPI language when the RS-232 interface is selected (enabled).

GPIB operation and reference

GPIB bus standards

The GPIB bus is the IEEE-488 instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975. Model 6514 conforms to these standards:

- IEEE-488.1-1987
- IEEE-488.2-1992

This standard defines a syntax for sending data to and from instruments, how an instrument interprets this data, what registers should exist to record the state of the instrument, and a group of common commands.

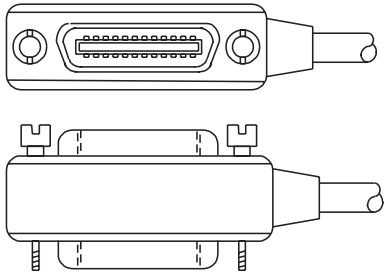
- SCPI 1996.0 (Standard Commands for Programmable Instruments)

This standard defines a command language protocol. It goes one step further than IEEE-488.2-1992 and defines a standard set of commands to control every programmable aspect of an instrument.

GPIB bus connections

To connect Model 6514 to the GPIB bus, use a cable equipped with standard IEEE-488 connectors as shown in Figure 12-1.

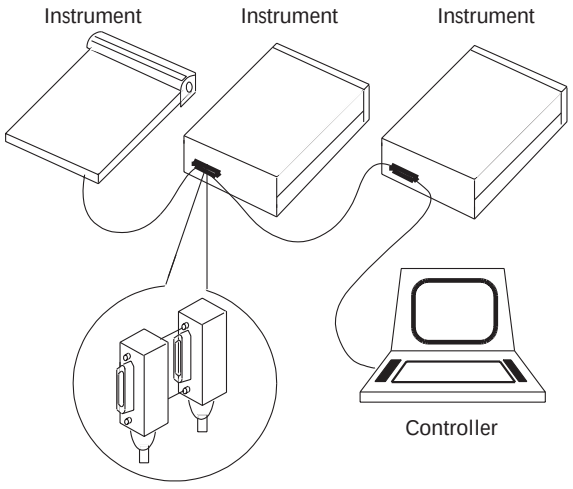
Figure 12-1
IEEE-488 connector



To allow many parallel connections to one instrument, stack the connector. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, which are identified with dark-colored screws. Earlier versions had different screws, which were silver-colored. Do not use these types of connectors on Model 6514, because it is designed for metric threads.

Figure 12-2 shows a typical connecting scheme for a multi-unit test system.

Figure 12-2
IEEE-488 connections



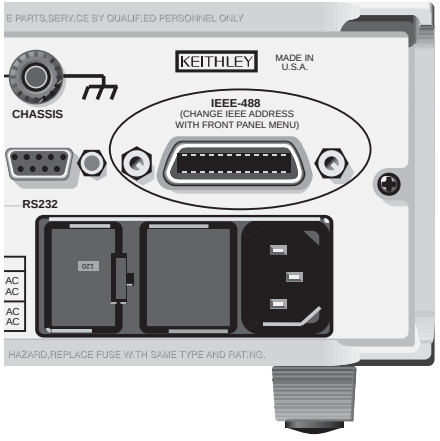
To avoid possible mechanical damage, stack no more than three connectors on any one unit.

NOTE *To minimize interference caused by electromagnetic radiation, use only shielded IEEE-488 cables. Available shielded cables from Keithley are Models 7007-1 and 7007-2.*

To connect Model 6514 to the IEEE-488 bus, follow these steps:

1. Line up the cable connector with the connector located on the rear panel. The connector is designed so that it will fit only one way. Figure 12-3 shows the location of the IEEE-488 connector.

Figure 12-3
IEEE-488 connector location



2. Tighten the screws securely, making sure not to over tighten them.
3. Connect any additional connectors from other instruments as required for your application.
4. Make sure that the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. See your controllers instruction manual for information about properly connecting to the IEEE-488 bus.

NOTE *You can only have 15 devices connected to an IEEE-488 bus, including the controller. The maximum cable length is either 20 meters or two meters times the number of devices, whichever is less. Not observing these limits may cause erratic bus operation.*

Primary address selection

Model 6514 ships from the factory with a GPIB address of 14. When the instrument powers up, it momentarily displays the primary address. You can set the address to a value of 0-30. Do not assign the same address to another device or to a controller that is on the same GPIB bus.

Usually controller addresses are 0 or 21, but see the controllers instruction manual for details. Make sure the address of the controller is the same as that specified in the controllers programming language.

The primary address is checked or changed from the GPIB menu, which is accessed by pressing SHIFT and then GPIB. Press the ▲ or ▼ key to display the present address (i.e. ADDR: 14).

To change the GPIB address:

1. Press SHIFT and then GPIB to access the GPIB configuration menu.
2. Use the ▲ or ▼ key to display the present address (i.e. ADDR: 14).
3. Use the ◀, ▶, ▲ and ▼ keys to display a valid address value and press ENTER.
4. Return to the main display by pressing EXIT.

General bus commands

Commands and associated statements

General commands are those commands, such as DCL, that have the same general meaning regardless of the instrument. Table 12-1 lists the general bus commands.

Table 12-1
General bus commands

Command	Effect on Model 6514
REN	Goes into remote when next addressed to listen.
IFC	Reset interface; all devices go into talker and listener idle states.
LLO	LOCAL key locked out.
GTL	Cancel remote; restore front panel operation for Model 6514.
DCL	Return all devices to known conditions.
SDC	Returns Model 6514 to known conditions.
GET	Initiates a trigger.
SPE, SPD	Serial polls Model 6514.

REN (remote enable)

The remote enable command is sent to Model 6514 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Simply setting REN true does not actually place the instrument in the remote state. You must address the instrument to listen after setting REN true before it goes into remote.

Note that the instrument does not have to be in remote to be a talker.

Also, note that all front panel controls except for LOCAL and POWER are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL key.

IFC (interface clear)

The IFC command is sent by the controller to place all instruments on the bus in the local, talker, listener idle states. Model 6514 responds to the IFC command by canceling front panel TALK or LSTN lights, if the instrument was previously placed in one of those states. Note that this command does not affect the status of the instrument; settings, data, and event registers are not changed.

To send the IFC command, the controller must set the IFC line true for a minimum of 100µs.

LLO (local lockout)

Use the LLO command to prevent local operation of the instrument. After the unit receives LLO, all its front panel controls except the POWER are inoperative. In this state, pressing the LOCAL will not restore control to the front panel. The GTL command restores control to the front panel.

GTL (go to local)

Use the GTL command to put a remote mode instrument into local mode. The GTL command also restores front panel key operation.

DCL (device clear)

Use the DCL command to clear the GPIB interface and return it to a known state. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously.

When Model 6514 receives a DCL command, it clears the input buffer and output queue, cancels deferred commands, and clears any command that prevents the processing of any other device command. A DCL does not affect instrument settings and stored data.

SDC (selective device clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL.

GET (group execute trigger)

GET is a GPIB trigger that is used as an event to control operation. Model 6514 reacts to this trigger if it is the programmed control source. The control source is programmed from the SCPI TRIGger subsystem.

SPE, SPD (serial polling)

Use the serial polling sequence to obtain Model 6514 serial poll byte. The serial poll byte contains important information about internal functions. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from Model 6514.

Front panel GPIB operation

The following paragraphs describe aspects of the front panel that are part of GPIB operation, including messages, status indicators, and the LOCAL key.

Error and status messages

See Appendix B for a list of error and status messages associated with IEEE-488 programming. The instrument can be programmed to generate an SRQ, and command queries can be performed to check for specific error conditions.

GPIB status indicators

The REM (remote), TALK (talk), LSTN (listen), and SRQ (service request) annunciators show the GPIB bus status. Each of these indicators is described below.

- REM — This indicator shows when the instrument is in the remote state. REM does not necessarily indicate the state of the REM line, as the instrument must be addressed to listen with REM true before the REM indicator turns on. When the instrument is in remote, all front panel keys, except for the LOCAL key, are locked out. When REM is turned off, the instrument is in the local state, and front panel operation is restored.
- TALK — This indicator is on when the instrument is in the talker active state. Place the unit in the talk state by addressing it to talk with the correct MTA (My Talk Address) command. TALK is off when the unit is in the talker idle state. Place the unit in the talker idle state by sending a UNT (Untalk) command, addressing it to listen, or sending the IFC (Interface Clear) command.
- LSTN — This indicator is on when Model 6514 is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. LSTN is off when the unit is in the listener idle state. Place the unit in the listener idle state by sending UNL (Unlisten), addressing it to talk, or sending the IFC (Interface Clear) command over the bus.
- SRQ — You can program the instrument to generate a service request (SRQ) when one or more errors or conditions occur. When this indicator is on, a service request has been generated. This indicator stays on until the serial poll byte is read or all the conditions that caused SRQ have ceased to exist.

LOCAL key

The LOCAL key cancels the remote state and restores local operation of the instrument. Pressing the LOCAL key also turns off the REM indicator and returns the display to normal if a user-defined message was displayed.

If the LLO (Local Lockout) command is in effect, the LOCAL key is also inoperative.

Programming syntax

The following paragraphs cover syntax for both common commands and SCPI commands. For more information, see the IEEE- 488.2 and SCPI standards.

Command words

Program messages are made up of one or more command words.

Commands and command parameters

Common commands and SCPI commands may or may not use a parameter. The following are some examples:

*SAV <NRf>	Parameter (NRf) required.
*RST	No parameter used.
:DISPlay:ENABle <b>	Parameter <b> required.
:SYSTem:PRESet	No parameter used.

Put at least one space between the command word and the parameter.

- Brackets [ ] — Some command words are enclosed in brackets ([ ]). These brackets are used to denote an optional command word that does not need to be included in the program message. For example:

  :INITiate[:IMMediate]

  These brackets indicate that :IMMediate is implied (optional) and does not have to be used. Thus, the above command can be sent in one of two ways:

  :INITiate or :INITiate:IMMediate

  Notice that the optional command is used without the brackets. When using optional command words in your program, do not include the brackets.

- Parameter types — The following are some of the common parameter types:

  <b> Boolean — Used to enable or disable an instrument operation. 0 or OFF disables the operation, and 1 or ON enables the operation.

  :DISPlay:ENABle ON Enable the display

  <name> Name parameter — Select a parameter name from a listed group.

  <name> = NEVer
  = NEXT

  :CALCulate:FORMat MXB Select Mx + B calculation

  <NRf> Numeric representation format — A number that can be expressed as an integer (e.g., 8) a real number (e.g., 23.6) or an exponent (2.3E6).

  :TRACe:POINts 20 Set buffer size to 20

<NDN> Non-decimal numeric — A non-decimal value that can be used to program status enable registers. A unique header identifies the format; #B (binary), #H (hexadecimal) and #Q (octal). See “Programming Enable Registers” in Section 13 for details.

*SRE #B10001	Set bits B0 and B4 of Service Request Enable Register

<n> Numeric value — Can consist of an NRf number or one of the following name parameters: DEFault, MINimum, or MAXimum. When the DEFault parameter is used, the instrument is programmed to the *RST default value. When the MINimum parameter is used, the instrument is programmed to the lowest allowable value. When the MAXimum parameter is used, the instrument is programmed to the largest allowable value.

:ARM:TIMer 0.1	Sets timer to 100 msec.
:ARM:TIMer DEFault	Sets timer to 0.1 sec.
:ARM:TIMer MINimum	Sets timer to 1 msec.
:ARM:TIMer MAXimum	Sets timer to 999999.999 sec.

- Angle brackets < > — Used to denote a parameter type. Do not include the brackets in the program message.

  :DISPlay:ENABle <b>

  The <b> indicates that a Boolean type parameter is required. Thus, to enable the display, you must send the command with the ON or 1 parameter as follows.

  :DISPlay:ENABle ON or 1

Query commands

The query command requests the presently programmed status. It is identified by the question mark (?) at the end of the fundamental form of the command. Most commands have a query form.

:ARM:TIMer?	Queries the timer interval

Most commands that require a numeric parameter (<n>) can also use the DEFault, MINimum, and MAXimum parameters for the query form. These query forms are used to determine the *RST default value and the upper and lower limits for the fundamental command.

:ARM:TIMer? DEFault	Queries the *RST default value
:ARM:TIMer? MINimum	Queries the lowest allowable value
:ARM:TIMer? MAXimum	Queries the largest allowable value

Case sensitivity

Common commands and SCPI commands are not case sensitive. You can use upper or lower case and any case combination. Examples:

```
*RST              = *rst
:DATA?            = :data?
:SYSTem:PRESet    = :system:preset
```

Long-form and short-form versions

A SCPI command word can be sent in its long-form or short-form version. The command tables in this manual use the long-form version. However, the short-form version is indicated by upper case characters.

:SYSTem:PRESet	long-form
:SYST:PRES	short form
:SYSTem:PRES	long-form and short-form combination

Note that each command word must be in either long-form or short-form. For example, :SYSTe:PRESe is illegal and will generate an error. The command will not be executed.

Short-form rules

Use the following rules to determine the short-form version of any SCPI command:

- If the length of the command word is four letters or less, no short form version exists.

  :auto = :auto

These rules apply to command words that exceed four letters:

- If the fourth letter of the command word is a vowel, delete it and all the letters after it.

  immediate = :imm

- If the fourth letter of the command word is a consonant, retain it but drop all the letters after it.

  :format = :form

- If the command contains a question mark (?) or a non-optional number included in the command word, you must include it in the short-form version.

  :delay? = :del?

- Command words or characters that are enclosed in brackets ([ ]) are optional and need not be included in the program message.

Program messages

A program message is made up of one or more command words sent by the computer to the instrument. Each common command is simply a three letter acronym preceded by an asterisk (*). The following SCPI commands from the STATus subsystem are used to help explain how command words are structured to formulate program messages.

Command structure	
:STATus	Path (Root)
:OPERation	Path
:ENABle <NRf>	Command and parameter
:ENABle?	Query command
:PRESet	Command

Single command messages

The above command structure has three levels. The first level is made up of the root command (:STATus) and serves as a path. The second level is made up of another path (:OPERation) and a command (:PRESet). The third path is made up of one command for the :OPERation path. The three commands in this structure can be executed by sending three separate program messages as follows:

```
:stat:oper:enab <NRf>
:stat:oper:enab?
:stat:pres
```

In each of the above program messages, the path pointer starts at the root command (:stat) and moves down the command levels until the command is executed.

Multiple command messages

You can send multiple command messages in the same program message as long as they are separated by semicolons (;). The following is an example showing two commands in one program message:

```
:stat:oper; :stat:oper:enab <NRf>
```

When the above is sent, the first command word is recognized as the root command (:stat). When the next colon is detected, the path pointer moves down to the next command level and executes the command. When the path pointer sees the colon after the semicolon (;), it resets back to the root level and starts over.

Commands that are on the same command level can be executed without having to retype the entire command path. Example:

```
:stat:oper:enab <NRf>; enab?
```

After the first command (:enab) is executed, the path pointer is at the third command level in the structure. Since :enab? is also on the third level, it can be entered without repeating the entire path name. Notice that the leading colon for :enab? is not included in the program message. If a colon were included, the path pointer would reset to the root level and expect a root command. Since :enab? is not a root command, an error would occur.

Command path rules

- Each new program message must begin with the root command, unless it is optional (e.g., [:SENSe]). If the root is optional, simply treat a command word on the next level as the root.
- The colon (:) at the beginning of a program message is optional and need not be used.

  :stat:pres = stat:pres

- When the path pointer detects a colon (:), it moves down to the next command level. An exception is when the path pointer detects a semicolon (;), which is used to separate commands within the program message.
- When the path pointer detects a colon (:) that immediately follows a semicolon (;), it resets to the root level.
- The path pointer can only move down. It cannot be moved up a level. Executing a command at a higher level requires that you start over at the root command.

Using common commands and SCPI commands in the same message

Both common commands and SCPI commands can be used in the same message as long as they are separated by semicolons (;). A common command can be executed at any command level and will not affect the path pointer.

:stat:oper:enab <NRf>; *ESE <NRf>

Program Message Terminator (PMT)

Each program message must be terminated with an LF (line feed), EOI (end or identify), or an LF+EOI. The bus will hang if your computer does not provide this termination. The following example shows how a program message must be terminated:

:trac:poin 10 <PMT>

Command execution rules

- Commands execute in the order that they are presented in the program message.
- An invalid command generates an error and, of course, is not executed.
- Valid commands that precede an invalid command in a multiple command program message are executed.
- Valid commands that follow an invalid command in a multiple command program message are ignored.
- For fastest command execution:
  1. Do not use optional command words (i.e., [:SENSE [1]]).
  2. Do not use the colon (:) at the beginning of a program message.
  3. Always use the short-form versions of commands and parameters.
  4. Minimize the amount of “white” space in command strings.
  5. Keep numeric parameters simple (i.e., 1 vs. 1.000e + 00).
  6. Use all upper-case.

Response messages

A response message is the message sent by the instrument to the computer in response to a query command program message.

Sending a response message

After sending a query command, the response message is placed in the output queue. When Model 6514 is addressed to talk, the response message is sent from the output queue to the computer.

Multiple response messages

If you send more than one query command in the same program message (see "Multiple Command Messages"), the multiple response messages for all the queries is sent to the computer when Model 6514 is addressed to talk. The responses are sent in the order that the query commands were sent and are separated by semicolons (;). Items within the same query are separated by commas (,). The following example shows the response message for a program message that contains four single item query commands:

0; 1; 1; 0

Response Message Terminator (RMT)

Each response is terminated with an LF (line feed) and EOI (end or identify). The following example shows how a multiple response message is terminated:

0; 1; 1; 0; <RMT>

Message exchange protocol

Two rules summarize the message exchange protocol:

Rule 1. Always tell Model 6514 what to send to the computer.
The following two steps must always be performed to send information from the instrument other computer:
1. Send the appropriate query command(s) in a program message.
2. Address Model 6514 to talk.

Rule 2. The complete response message must be received by the computer before another program message can be sent to Model 6514.

RS-232 interface reference

Sending and receiving data

The RS-232 interface transfers data using seven or eight data bits and one stop bit. Parity selections include none, odd or even.

RS-232 settings

The procedure to select and configure the RS-232 interface is provided in "Selecting and Configuring an Interface" located at the beginning of this section. Make sure the controller you connect to Model 6514 also uses these settings.

NOTE *You can break data transmissions by sending a ^C or ^X character string to Model 6514. This clears any pending operation and discards any pending output.*

Baud rate

The baud rate is the rate at which Model 6514 and the programming terminal communicate. You can choose from one of the following rates: 57.6k, 38.4k, 19.2k, 9600, 4800, 2400, 1200, 600 or 300.

Make sure that the programming terminal that you are connecting to Model 6514 can support the baud rate you selected. Both Model 6514 and the other device must be configured for the same baud rate.

Data and stop bits

The RS-232 can be set to transfer data using seven or eight data bits and one stop bit.

Parity

Parity for the RS-232 interface can be set to none, even or odd.

Terminator

Model 6514 can be configured to terminate each program message that it transmits to the controller with any of the following combinations of <CR> and <LF>:

- LF line feed
- CR carriage return
- LFCR line feed, carriage return
- CRLF carriage return, line feed

Flow control (signal handshaking)

Signal handshaking between the controller and the instrument allows the two devices to communicate to each other regarding being ready or not ready to receive data. Model 6514 does not support hardware handshaking (flow control).

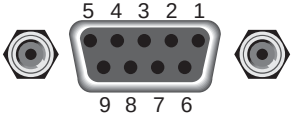
Software flow control is in the form of X_ON and X_OFF characters and is enabled when XonXoFF is selected from the RS232 FLOW menu. When the input queue of Model 6514 becomes more than 3/4 full, the instrument issues an X_OFF command. The control program should respond to this and stop sending characters until Model 6514 issues the X_ON, which it will do once its input buffer has dropped below half-full. Model 6514 recognizes X_ON and X_OFF sent from the controller. An X_OFF will cause Model 6514 to stop outputting characters until it sees an X_ON. Incoming commands are processed after the <CR> character is received from the controller.

If NONE is the selected flow control, then there will be no signal handshaking between the controller and Model 6514. Data will be lost if transmitted before the receiving device is ready.

RS-232 connections

The RS-232 serial port can be connected to the serial port of a controller (i.e., personal computer) using a straight through RS-232 cable terminated with DB-9 connectors. **Do not use a null modem cable**. The serial port uses the transmit (TXD), receive (RXD), and signal ground (GND) lines of the RS-232 standard. It does not use the hardware handshaking lines CTS and RTS. Figure 12-4 shows the rear panel connector for the RS-232 interface, and Table 12-2 shows the pinout for the connector.

Figure 12-4
RS-232 interface connector



RS232
Rear Panel Connector

If your computer uses a DB-25 connector for the RS-232 interface, you will need a cable or adapter with a DB-25 connector on one end and a DB-9 connector on the other, wired straight through (not null modem). Table 12-3 provides pinout identification for the 9-pin (DB-9) or 25-pin (DB-25) serial port connector on the computer (PC).

Table 12-2
RS-232 connector pinout

Pin number	Description
1	DCD, data carrier detect
2	TXD, transmit data
3	RXD, receive data
4	DTR, data terminal ready
5	GND, signal ground
6	DSR, data set ready
7	RTS, ready to send
8	CTS, clear to send
9	No connections

RTS and CTS are tied together.
DCD, DTR, and DSR are tied together.

Table 12-3
PC serial port pinout

Signal	DB-9 pin number	DB-25 pin number
DCD, data carrier detect	1	8
RXD, receive data	2	3
TXD, transmit data	3	2
DTR, data terminal ready	4	20
GND, signal ground	5	7
DSR, data set ready	6	6
RTS, request to send	7	4
CTS, clear to send	8	5
RI, ring indicator	9	22

Error messages

See Appendix B for RS-232 error messages.

13
Status Structure

- **Overview** — Provides an operational overview of the status structure for Model 6514.
- **Clearing registers and queues** — Covers the actions that clear (reset) registers and queues.
- **Programming and reading registers** — Explains how to program enable registers and read any register in the status structure.
- **Status byte and service request (SRQ)** — Explains how to program the status byte to generate service requests (SRQs). Shows how to use the serial poll sequence to detect SRQs.
- **Status register sets** — Provides bit identification and command information for the four status register sets; standard event status, operation event status, measurement event status, and questionable event status.
- **Queues** — Provides details and command information on the output queue and error queue.

Overview

Model 6514 provides a series of status registers and queues allowing the operator to monitor and manipulate the various instrument events. The status structure is shown in Figure 13-1. The heart of the status structure is the status byte register. This register can be read by the users test program to determine if a service request (SRQ) has occurred, and what event caused it.

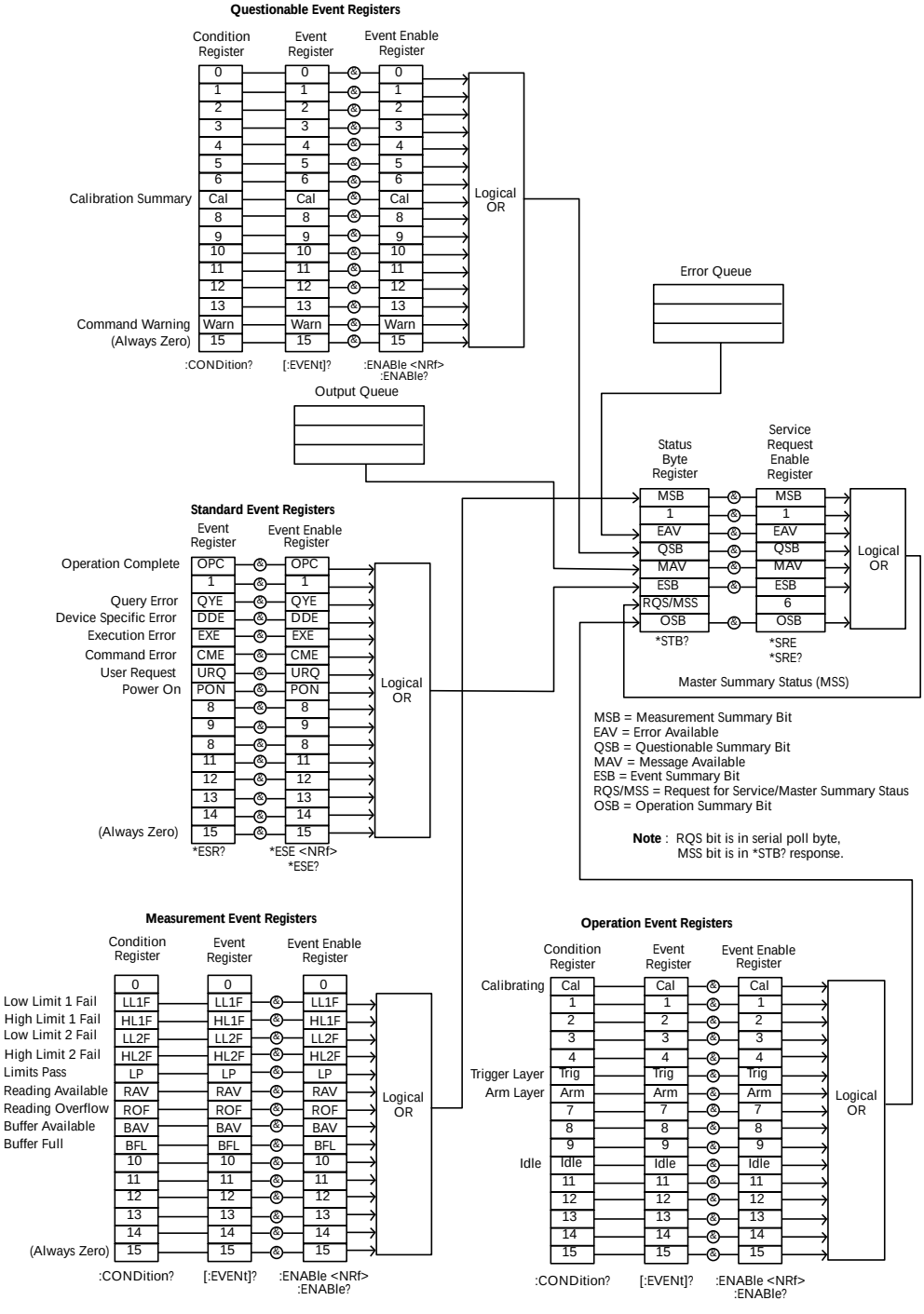
Status byte and SRQ — The status byte register receives the summary bits of four status register sets and two queues. The register sets and queues monitor the various instrument events. When an enabled event occurs, it sets a summary bit in the status byte register. When a summary bit of the status byte is set and its corresponding enable bit is set (as programmed by the user), the RQS/MSS bit will set to indicate that an SRQ has occurred.

Status register sets — A typical status register set is made up of a condition register, an event register and an event enable register. A condition register is a read-only register that constantly updates to reflect the present operating conditions of the instrument.

When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. When an event register bit is set and its corresponding enable bit is set (as programmed by the user), the output (summary) of the register will set to 1, which in turn sets the summary bit of the status byte register.

Queues — Model 6514 uses an output queue and an error queue. The response messages to query commands are placed in the output queue. As various programming errors and status messages occur, they are placed in the error queue. When a queue contains data, it sets the appropriate summary bit of the status byte register.

Figure 13-1
6514 status mode structure



Clearing registers and queues

When Model 6514 is turned on, the bits of all registers in the status structure are clear (reset to 0) and the two queues are empty. Commands to reset the event and event enable registers, and the error queue are listed in Table 13-1. In addition to these commands, any enable register can be reset by sending the 0 parameter value with the individual command to program the register.

*NOTE SYSTem:PRESet and *RST have no effect on status structure registers and queues.*

Table 13-1
Common and SCPI commands — reset registers and clear queues

Commands	Description	Ref
To reset registers:		
*CLS	Reset all bits of the following event registers to 0: Standard event register Operation event register Measurement event register Questionable event register	Note 1
STATus	STATus subsystem:	
:PRESet	Reset all bits of the following enable registers to 0: Operation event enable register Measurement event enable register Questionable event enable register	Note 1
To clear error queue:		
*CLS	Clear all messages from error queue	Note 2
STATus	STATus subsystem:	
:QUEue	Error queue:	
:CLEar	Clear messages from error queue	Note 3
SYSTem	SYSTem subsystem:	
:ERRor	Error queue:	
:CLEar	Clear messages from error queue	Note 3

Notes:
1. The standard event enable register is not reset by STATus:PRESet or *CLS. Send the 0 parameter value with *ESE to reset all bits of that enable register to 0 (see “Status Byte and Service Request commands”).
2. STATus:PRESet has no effect on the error queue.
3. Use either of the two clear commands to clear the error queue.

Programming and reading registers

Programming enable registers

The only registers that can be programmed by the user are the enable registers. All other registers in the status structure are read-only registers. The following explains how to ascertain the parameter values for the various commands used to program enable registers. The actual commands are covered later in this section (see Tables 13-3 and 13-6).

A command to program an event enable register is sent with a parameter value that determines the desired state (0 or 1) of each bit in the appropriate register. An enable register can be programmed using any of the following data formats for the parameter value; binary, decimal, hexadecimal, or octal.

The bit positions of the register (see Figure 13-2) indicate the binary parameter value. For example, if you wish to sets bits B4, B3, and B1, the binary value would be 11010 (where B4=1, B3=1, B1=1 and all other bits are 0). When you use one of the other formats, convert the binary number to its decimal, hexadecimal, or octal equivalent:

Binary 11010 = Decimal 26 = Hexadecimal 1A = Octal 32

Note that Figure 13-2 includes the decimal weight for each register bit. To set bits B4, B3 and B1, the decimal parameter value would be the sum of the decimal weights for those bits (16+8+2 = 26).

The <NDN> (non-decimal numeric) parameter type is used to send non-decimal values. These values require a header (#B, #H or #Q) to identify the data format being sent. The letter in the header can be upper or lower case. The <NRf> (numeric representation format) parameter type is used to send decimal values, and does not use a header. The following examples show the proper parameter syntax for setting bits B5, B3, and B2:

#b101100	Binary format (<NDN> parameter type)
#h2C	Hexadecimal format (<NDN> parameter type)
#q54	Octal format (<NDN> parameter type)
44	Decimal format (<NRf> parameter type)

Valid characters for the non-decimal parameter values are shown as follows:

<NDN> Format	Valid Characters
Binary	1's and 0's
Hexadecimal	0 through 9 and A through F
Octal	0 through 7

Figure 13-2
16-bit status register

A. Bits 0 through 7

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Binary Value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal Weights	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)

B. Bits 8 through 15

Bit Position	B15	B14	B13	B12	B11	B10	B9	B8
Binary Value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal Weights	32768 (2^{15})	16384 (2^{14})	8192 (2^{13})	4096 (2^{12})	2048 (2^{11})	1024 (2^{10})	512 (2^9)	256 (2^8)

Reading registers

Any register in the status structure can be read by using the appropriate query (?) command. The following explains how to interpret the returned value (response message). The actual query commands are covered later in this section (see Tables 13-3 through 13-6).

The response message will be a value that indicates which bits in the register are set. That value (if not already binary) will have to be converted to its binary equivalent. For example, for a binary value of 100101, bits B5, B3, and B0 are set.

The returned value can be in the binary, decimal, hexadecimal, or octal format. The FORMat:SREGister command is used to select the data format for the returned value (see Table 13-2).

For non-decimal formats, one of the following headers will accompany the returned value to indicate which format is selected:

#B = Header for binary values
#H = Header for hexadecimal values
#Q = Header for octal values

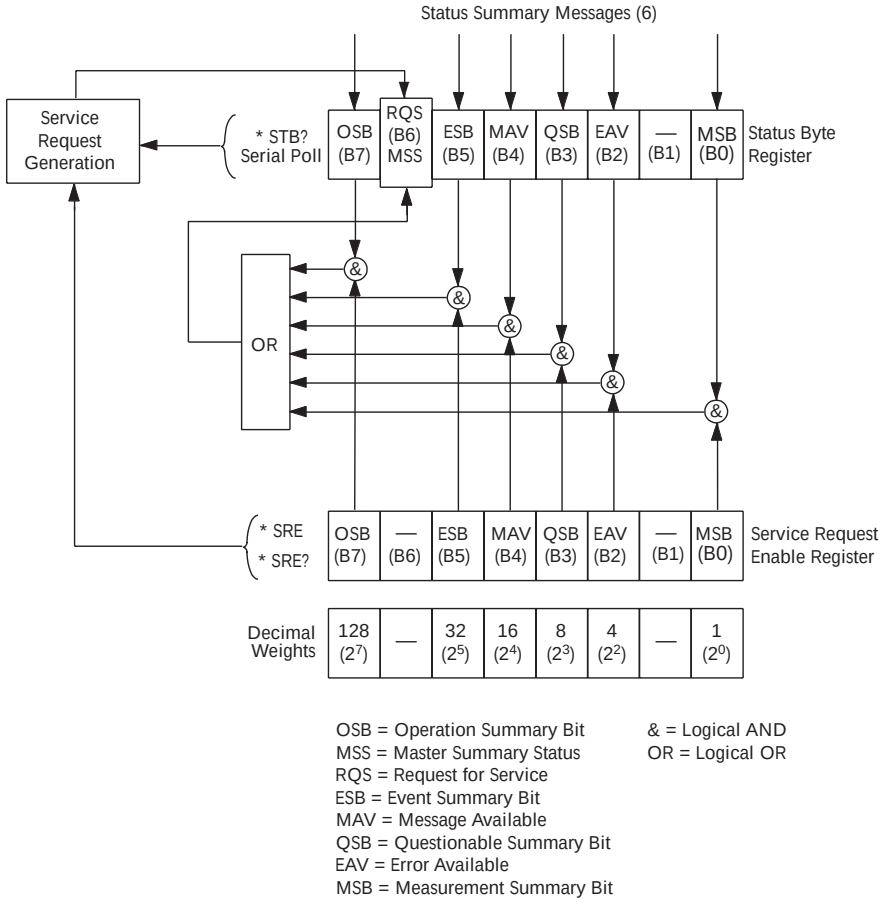
Table 13-2
SCPI command — data formats for reading status registers

Command	Description	Default
:FORMat	FORMat subsystem	
:SREGister <name>	Select data format for reading status registers: <name> = ASCii — Decimal format HEXadecimal — Hexadecimal format OCTal — Octal format BINary — Binary format	ASCii

Status byte and service request (SRQ)

Service request is controlled by two 8-bit registers; the status byte register and the service request enable register. Figure 13-3 shows the structure of these registers.

Figure 13-3
Status byte and service request



Status byte register

The summary messages from the status registers and queues are used to set or clear the appropriate bits (B0, B2, B3, B4, B5, and B7) of the status byte register. These summary bits do not latch, and their states (0 or 1) are solely dependent on the summary messages (0 or 1). For example, if the standard event register is read, its register will clear. As a result, its summary message will reset to 0, which in turn will reset the ESB bit in the status byte register.

The bits of the status byte register are described as follows:

- **Bit B0, measurement status (MSB)** — Set summary bit indicates that an enabled measurement event has occurred.
- **Bit B1** — Not used.
- **Bit B2, error available (EAV)** — Set summary bit indicates that an error or status message is present in the error queue.
- **Bit B3, questionable summary bit (QSB)** — Set summary bit indicates that an enabled questionable event has occurred.
- **Bit B4, message available (MAV)** — Set summary bit indicates that a response message is present in the output queue.
- **Bit B5, event summary bit (ESB)** — Set summary bit indicates that an enabled standard event has occurred.
- **Bit B6, request service (RQS)/master summary status (MSS)** — Set bit indicates that an enabled summary bit of the status byte register is set.
- **Bit B7, operation summary (OSB)** — Set summary bit indicates that an enabled operation event has occurred.

Depending on how it is used, bit B6 of the status byte register is either the request for service (RQS) bit or the master summary status (MSS) bit:

- When using the serial poll sequence of Model 6514 to obtain the status byte (a.k.a. serial poll byte), B6 is the RQS bit. See “serial polling and SRQ” for details on using the serial poll sequence.
- When using the *STB? command (see Table 13-3) to read the status byte, B6 is the MSS bit.

Service request enable register

The generation of a service request is controlled by the service request enable register. This register is programmed by you and is used to enable or disable the setting of bit B6 (RQS/MSS) by the status summary message bits (B0, B2, B3, B4, B5, and B7) of the status byte register. As shown in Figure 13-3, the summary bits are logically ANDed (&) with the corresponding enable bits of the service request enable register. When a set (1) summary bit is ANDed with an enabled (1) bit of the enable register, the logic “1” output is applied to the input of the OR gate and, therefore, sets the MSS/RQS bit in the status byte register.

The individual bits of the service request enable register can be set or cleared by using the *SRE common command. To read the service request enable register, use the *SRE? query command. The service request enable register clears when power is cycled or a parameter value of 0 is sent with the *SRE command (i.e. *SRE 0). The commands to program and read the SRQ enable register are listed in Table 13-6.

Serial polling and SRQ

Any enabled event summary bit that goes from 0 to 1 will set bit B6 and generate an SRQ (service request). In your test program, you can periodically read the status byte to check if an SRQ has occurred and what caused it. If an SRQ occurs, the program can, for example, branch to an appropriate subroutine that will service the request.

Typically, SRQs are managed by the serial poll sequence of Model 6514. If an SRQ does not occur, bit B6 (RQS) of the status byte register will remain cleared, and the program will simply proceed normally after the serial poll is performed. If an SRQ does occur, bit B6 of the status byte register will set, and the program can branch to a service subroutine when the SRQ is detected by the serial poll.

The serial poll automatically resets RQS of the status byte register. This allows subsequent serial polls to monitor bit B6 for an SRQ occurrence generated by other event types. After a serial poll, the same event can cause another SRQ, even if the event register that caused the first SRQ has not been cleared.

The serial poll does not clear MSS. The MSS bit stays set until all status byte summary bits are reset.

SPE, SPD (serial polling)

The SPE, SPD general bus command is used to serial poll Model 6514. Serial polling obtains the serial poll byte (status byte). Typically, serial polling is used by the controller to determine which of several instruments has requested service with the SRQ line.

Status byte and service request commands

The commands to program and read the status byte register and service request enable register are listed in Table 13-3. For details on programming and reading registers, see “Programming enable registers” and “Reading registers”.

NOTE *To reset the bits of the service request enable register to 0, use 0 as the parameter value for the *SRE command (i.e. *SRE 0).*

Table 13-3
Common commands — status byte and service request enable registers

Command	Description	Default
*STB?	Read status byte register.	
*SRE <NDN> or <NRf>	Program the service request enable register: <NDN> = #Bxx…x Binary format (each x = 1 or 0) = #Hx Hexadecimal format (x = 0 to FF) = #Qx Octal format (x = 0 to 377) <NRf> = 0 to 255 Decimal format	(Note)
*SRE?	Read the service request enable register	

Note: *CLS and STATus:PRESet have no effect on the service request enable register.

Programming example — set MSS (B6) when error occurs

The first command of the following sequence enables EAV (error available). When an invalid command is sent (line 4), bits B2 (EAV) and B6 (MSS) of the status byte register set to 1. The last command reads the status byte register using the binary format (which directly indicates which bits are set). The command to select format (FORMat:SREGister) is documented in Table 13-2. To determine the exact nature of the error, you will have to read the error queue (see "Queues").

```
*CLS                    ' Clear Error Queue.
*SRE 4                  ' Enable EAV.
FORM:SREG BIN           ' Select binary format.
BadCommand              ' Generate error.
*STB?                   ' Read Status Byte Register.
```

NOTE *An example program to demonstrate serial polling (Generating SRQ on buffer full) is provided in Appendix E.*

Status register sets

As shown in Figure 13-1, there are four status register sets in the status structure of Model 6514; standard event status, operation event status, measurement event status, and questionable event status.

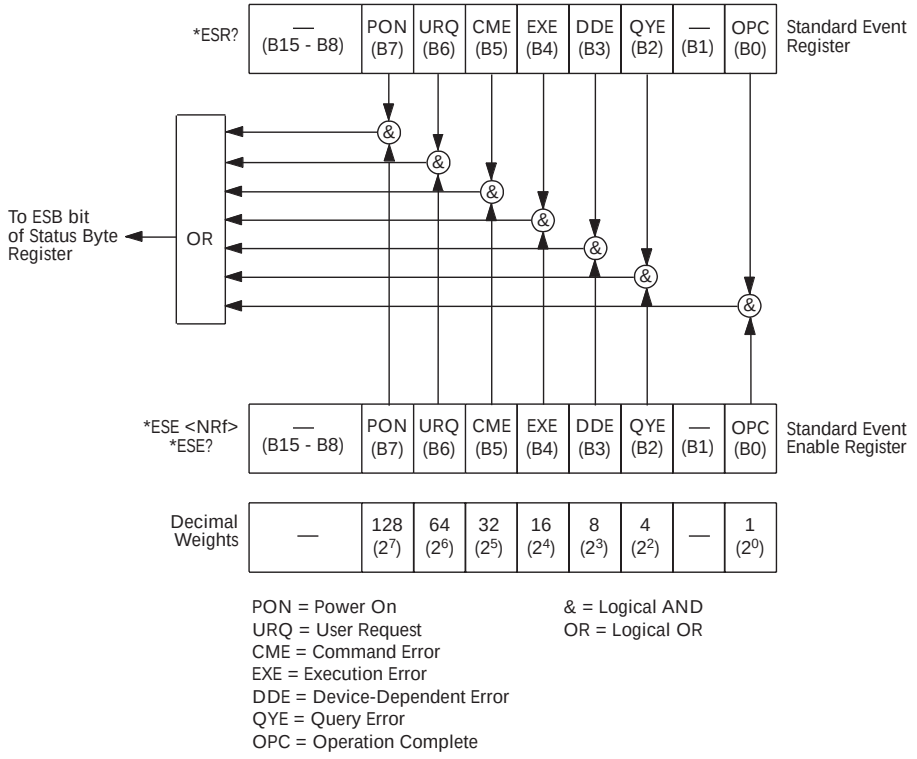
Register bit descriptions

Standard event status

The used bits of the standard event register (shown in Figure 13-4) are described as follows:

- **Bit B0, operation complete** — Set bit indicates that all pending selected device operations are completed and Model 6514 is ready to accept new commands. This bit only sets in response to the *OPC? query command. See Section 14 for details on *OPC and *OPC?.
- **Bit B2, query error (QYE)** — Set bit indicates that you attempted to read data from an empty output queue.
- **Bit B3, device-dependent error (DDE)** — Set bit indicates that an instrument operation did not execute properly due to some internal condition.
- **Bit B4, execution error (EXE)** — Set bit indicates that Model 6514 detected an error while trying to execute a command.
- **Bit B5, command error (CME)** — Set bit indicates that a command error has occurred. Command errors include:
  - → IEEE-488.2 syntax error — Model 6514 received a message that does not follow the defined syntax of the IEEE-488.2 standard.
  - → Semantic error — Model 6514 received a command that was misspelled or received an optional IEEE-488.2 command that is not implemented.
  - → The instrument received a Group Execute Trigger (GET) inside a program message.
- **Bit B6, user request (URQ)** — Set bit indicates that the LOCAL key on Model 6514 front panel was pressed.
- **Bit B7, power ON (PON)** — Set bit indicates that Model 6514 has been turned off and turned back on since the last time this register has been read.

Figure 13-4
Standard event status

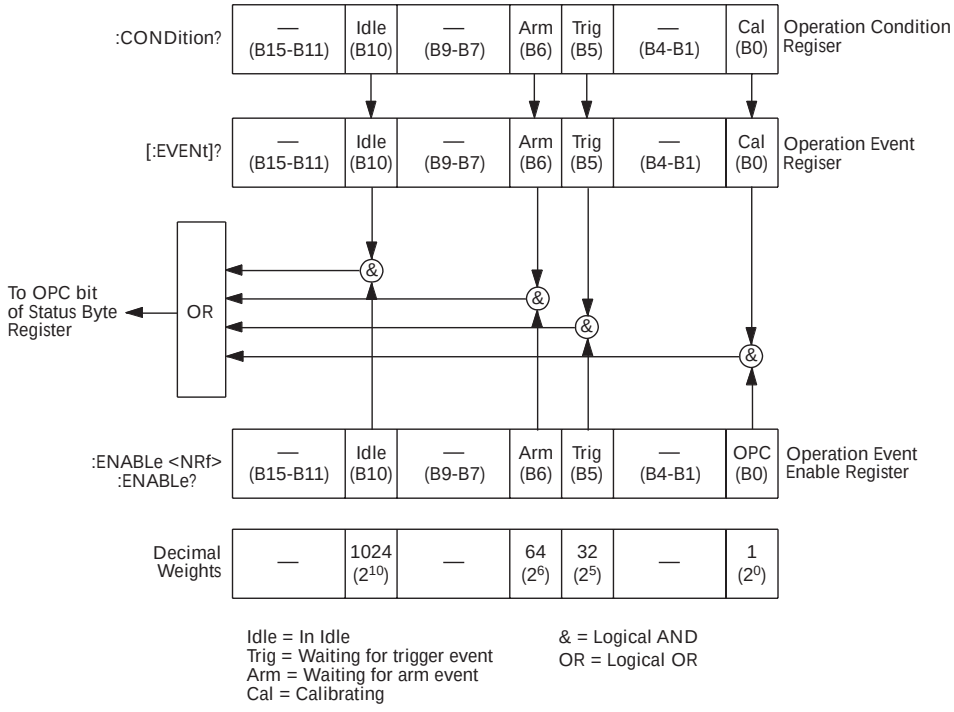


Operation event status

The used bits of the operation event register (shown in Figure 13-5) are described as follows:

- **Bit B0, calibrating** — Set bit indicates that Model 6514 is calibrating.
- **Bit B5, waiting for trigger event (Trig)** — Set bit indicates that Model 6514 is in the trigger layer waiting for a TLINK trigger event to occur.
- **Bit B6, waiting for arm event (Arm)** — Set bit indicates that Model 6514 is in the arm layer waiting for an arm event to occur.
- **Bit B10, idle state (Idle)** — Set bit indicates Model 6514 is in the idle state.

Figure 13-5
Operation event status

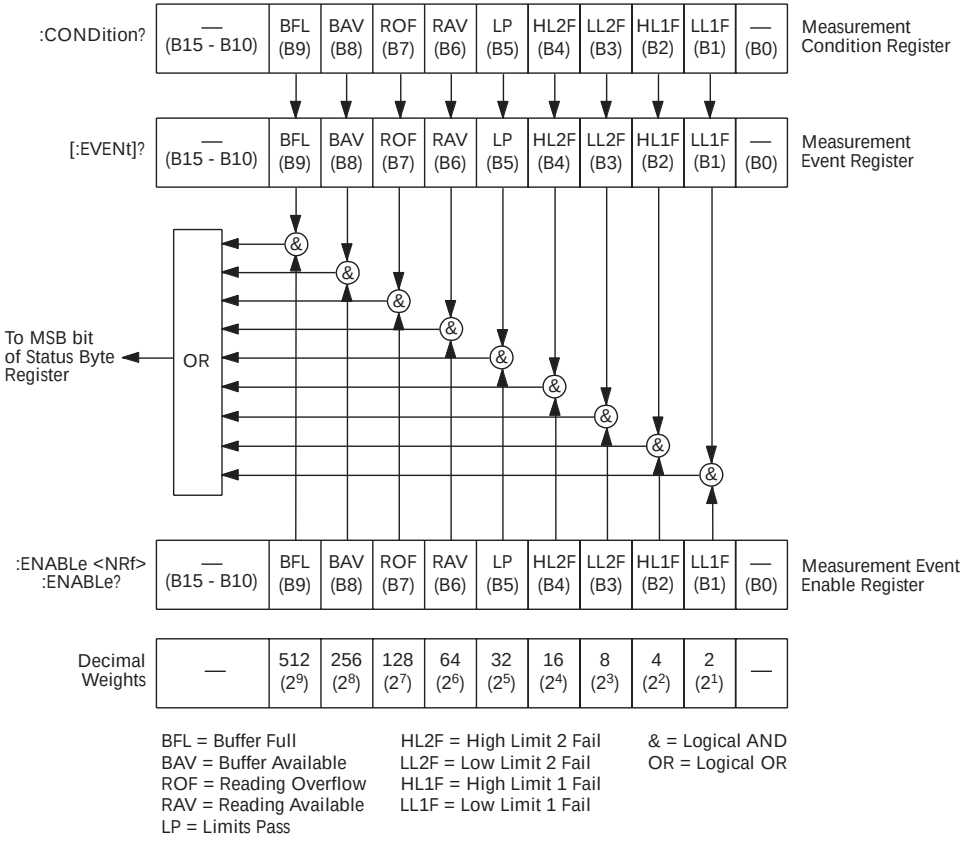


Measurement event status

The used bits of the measurement event register (shown in Figure 13-6) are described as follows:

- **Bit B1, low limit 1 fail (LL1F)** — Set bit indicates that the low limit 1 test has failed.
- **Bit B2, high limit 1 fail (HL1F)** — Set bit indicates that the high limit 1 test has failed.
- **Bit B3, low limit 2 fail (LL2F)** — Set bit indicates that the low limit 2 test has failed.
- **Bit B4, high limit 2 fail (HL2F)** — Set bit indicates that the high limit 2 test has failed.
- **Bit B5, limits pass (LP)** — Set bit indicates that all limit tests passed.
- **Bit B6, reading available (RAV)** — Set bit indicates that a reading was taken and processed.
- **Bit B7, reading overflow (ROF)** — Set bit indicates that the volts, amps, ohms or coulombs reading exceeds the selected measurement range of Model 6514.
- **Bit B8, buffer available (BAV)** — Set bit indicates that there are at least two readings in the buffer.
- **Bit B9, buffer full (BFL)** — Set bit indicates that the buffer is full.

Figure 13-6 Measurement event status

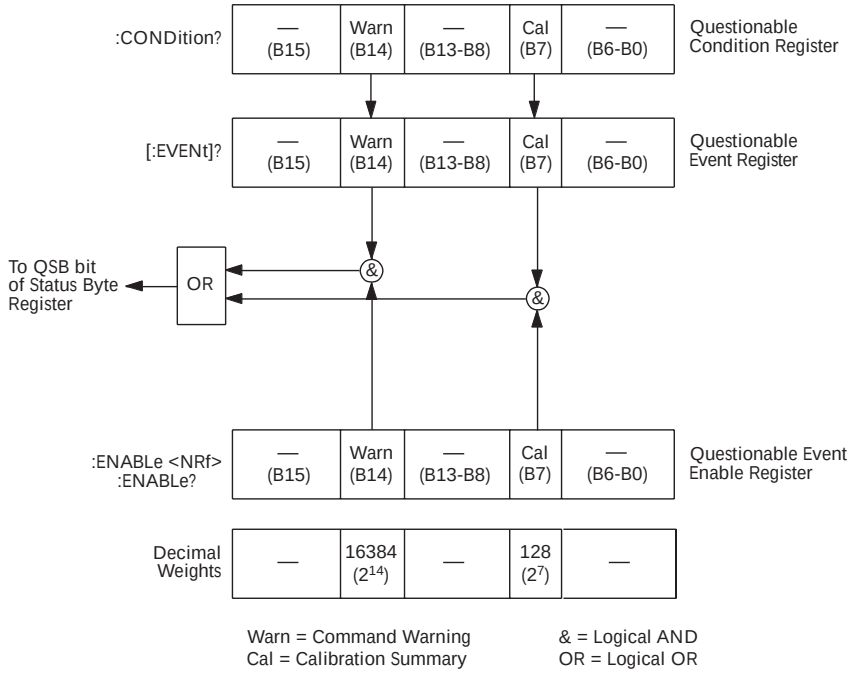


Questionable event status

The used bits of the questionable event register (shown in Figure 13-7) are described as follows:

- **Bit B7, calibration summary (Cal)** — Set bit indicates that an invalid calibration constant was detected during the power-up sequence. This error will clear after successful calibration of Model 6514.
- **Bit B14, command warning (Warn)** — Set bit indicates that a signal oriented measurement command parameter has been ignored.

Figure 13-7
Questionable event status



Condition registers

As Figure 13-1 shows, each status register set (except the standard event register set) has a condition register. A condition register is a real-time, read-only register that constantly updates to reflect the present operating conditions of the instrument. For example, while Model 6514 is in the idle state, bit B10 (Idle) of the operation condition register will be set. When the instrument is taken out of idle, bit B10 clears.

The commands to read the condition registers are listed in Table 13-4. For details on reading registers, see “Reading registers”.

Table 13-4
Common and SCPI commands — condition registers

Command	Description
STATus	STATus subsystem:
:OPERation:CONDition?	Read operation condition register.
:MEASurement:CONDition?	Read measurement condition register.
:QUEStionable:CONDition?	Read questionable condition register.

Event registers

As Figure 13-1 shows, each status register set has an event register. When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. Reading an event register clears the bits of that register. *CLS resets all four event registers.

The commands to read the event registers are listed in Table 13-5. For details on reading registers, see “Reading registers”.

Table 13-5
Common and SCPI commands — event registers

Command	Description
*ESR?	Read standard event status register.
STATus	STATus subsystem:
:OPERation:[:EVENt]?	Read operation event register.
:MEASurement:[:EVENt]?	Read measurement event register.
:QUEStionable:[:EVENt]?	Read questionable event register.

Note: Power-up and *CLS resets all bits of all event registers to 0. STATus:PRESet has no effect.

Event enable registers

As Figure 13-1 shows, each status register set has an enable register. Each event register bit is logically ANDed (&) to a corresponding enable bit of an enable register. Therefore, when an event bit is set and the corresponding enable bit is set (as programmed by the user), the output (summary) of the register will set to 1, which in turn sets the summary bit of the status byte register.

The commands to program and read the event enable registers are listed in Table 13-6. For details on programming and reading registers, see "Programming enable registers" and "Reading registers".

NOTE *The bits of any enable register can be reset to 0 by sending the 0 parameter value with the appropriate enable command (i.e. STATus:OPERation:ENABle 0).*

Table 13-6
Common and SCPI commands — event enable registers

Command	**Description**
*ESE <NDN> or <NRf>	Program standard event enable register (see "*Parameters*").
*ESE?	Read standard event enable register.
STATus	STATus subsystem:
:OPERation	Operation event enable register:
:ENABle <NDN> or <NRf>	Program enable register (see "*Parameters*").
:ENABle?	Read enable register.
:MEASurement	Measurement event enable register:
:ENABle <NDN> or <NRf>	Program enable register (see "*Parameters*").
:ENABle?	Read enable register.
:QUEStionable	Questionable event enable register:
:ENABle <NDN> or <NRf>	Program enable register (see "*Parameters*").
:ENABle?	Read measurement event enable register:
Parameters:	
<NDN> = #Bxx…x	Binary format (each x = 1 or 0)
= #Hx	Hexadecimal format (x = 0 to FFFF)
= #Qx	Octal format (x = 0 to 177777)
<NRf> = 0 to 65535	Decimal format

Note: Power-up and STATus:PRESet resets all bits of all enable registers to 0. *CLS has no effect.

Programming example — program and read registers

This command sequence programs and reads the measurement registers. Registers are read using the binary format (which directly indicates which bits are set). The command to select format (FORMat:SREGister) is documented in Table 13-2.

```
FORM:SREG BIN          ‘ Select binary format to read registers.
STAT:MEAS:ENAB 512     ‘ Enable BFL (buffer full).
STAT:MEAS:COND?        ‘ Read Measurement Condition Register.
STAT:MEAS?             ‘ Read Measurement Event Register.
```

Queues

Model 6514 uses two queues, which are first-in, first-out (FIFO) registers:

- Output queue — Used to hold reading and response messages.
- Error queue — Used to hold error and status messages.

Model 6514 status model (Figure 13-1) shows how the two queues are structured with the other registers.

Output queue

The output queue holds data that pertains to the normal operation of the instrument. For example, when a query command is sent, the response message is placed in the output queue.

When data is placed in the output queue, the message available (MAV) bit in the status byte register sets. A data message is cleared from the output queue when it is read. The output queue is considered cleared when it is empty. An empty output queue clears the MAV bit in the status byte register.

A message is read from the output queue by addressing Model 6514 to talk after the appropriate query is sent.

Error queue

The error queue holds error and status messages. When an error or status event occurs, a message that defines the error/status is placed in the error queue.

When a message is placed in the error queue, the error available (EAV) bit in the status byte register is set. An error/status message is cleared from the error queue when it is read. The error queue is considered cleared when it is empty. An empty error queue clears the EAV bit in the status byte register.

The error queue holds up to 10 error/status messages. The commands to read the error queue are listed in Table 13-7. When you read a single message in the error queue, the "oldest" message is read and then removed from the queue. If the queue becomes full, the message "350, 'queue overflow'" will occupy the last memory location. On power-up, the error queue is empty. When empty, the message "0, No Error" is placed in the queue.

Messages in the error queue are preceded by a code number. Negative (-) numbers are used for SCPI defined messages, and positive (+) numbers are used for Keithley defined messages. The messages are listed in Appendix B. As shown in Table 13-7, there are commands to read the entire message (code and message) or the code only.

On power-up, all error messages are enabled and will go into the error queue as they occur. Status messages are not enabled and will not go into the queue. As listed in Table 13-7, there are commands to enable and/or disable messages. For these commands, the <list> parameter is used to specify which messages to enable or disable. The messages are specified by their codes. The following examples show various forms for using the <list> parameter.

<list>	=	(-110)	Single message
	=	(-110:-222)	Range of messages (-110 through -222)
	=	(-110:-222, -220)	Range entry and single entry (separated by a comma)

When you enable messages, messages not specified in the list are disabled. When you disable messages, each listed message is removed from the enabled list.

NOTE *To prevent all messages from entering the error queue, send the enable command along with the null list parameter as follows: STATus:QUEue:ENABle ().*

Table 13-7
SCPI commands — error queue

Command	Description	Default
STATus	STATus subsystem:	
:QUEue	Read error queue:	(Note 1)
[:NEXT]?	Read and clear oldest error/status (code and message).	
:ENABle <list>	Specify error and status messages for error queue.	(Note 2)
:ENABle?	Read the enabled messages.	
:DISable <list>	Specify messages not to be placed in queue.	(Note 2)
:DISable?	Read the disabled messages.	
:CLEar	Clear messages from error queue.	
SYSTem	SYSTem subsystem:	
:ERRor	Read error queue:	(Note 1)
[:NEXT]?	Read and clear oldest error/status (code and message).	
:ALL?	Read and clear all errors/status (code and message).	
:COUNt?	Read the number of messages in queue.	
:CODE	Code numbers only:	
[:NEXT]?	Read and clear oldest error/status (code only).	
:ALL?	Read and clear all errors/status (codes only).	
:CLEar	Clear messages from error queue.	

Notes:
1. Power-up and *CLS empties the error queue. STATus:PRESet has no effect.
2. Power-up enables error messages and disables status messages. *CLS and STATus:PRESet have no effect.

Programming example — read error queue

The following command reads the error queue:

```
STAT:QUE?                ' Read Error Queue.
```

14
Common Commands

Common commands (summarized in Table 14-1) are device commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard.

Table 14-1
IEEE-488.2 common commands and queries

Mnemonic	Name	Description	Ref
*CLS	Clear status	Clears all event registers and error queue.	Sec 13
*ESE <NRf>	Event enable command	Program the standard event enable register.	Sec 13
*ESE?	Event enable query	Read the standard event enable register.	Sec 13
*ESR?	Event status register query	Read the standard event enable register and clear it.	Sec 13
*IDN?	Identification query	Returns the manufacturer, model number, serial number, and firmware revision levels of the unit.	A
*OPC	Operation complete command	Set the operation complete bit in the standard event register after all pending commands have been executed.	B
*OPC?	Operation complete query	Places an ASCII "1" into the output queue when all pending selected device operations have been completed.	B
*OPT?	Option query	The value 5156 is returned if the Model 5156 calibration source is connected to the Model 6514. The value 0 is returned if the Model 5156 is not connected.	
*RCL <NRf>	Recall command	Returns Model 6514 to the user-saved setup.	C
*RST	Reset command	Returns Model 6514 to the *RST default conditions.	D
*SAV <NRf>	Save command	Saves the present setup as the user-saved setup.	C
*SRE <NRf>	Service request enable command	Programs the service request enable register.	Sec 13
*SRE?	Service request enable query	Reads the service request enable register.	Sec 13
*STB?	Status byte query	Reads the status byte register.	Sec 13
*TRG	Trigger command	Sends a bus trigger to Model 6514.	E
*TST?	Self-test query	Performs a checksum test on ROM and returns the result.	F
*WAI	Wait-to-continue command	Wait until all previous commands are executed.	G

A) IDN? — identification query

Reads identification code

The identification code includes the manufacturer, model number, serial number, and firmware revision levels and is sent in the following format:

KEITHLEY INSTRUMENTS INC., MODEL 6514, xxxxxxx, yyyyy/zzzzz/w

Where: xxxxxxx is the serial number.
yyyyy/zzzzz is the firmware revision levels of the digital board ROM and display board ROM. Note that yyyyy also provides build date and time information.
w is the board revision level.

B) OPC — operation complete — Sets OPC bit
OPC? — operation complete query — Places a "1" in output queue

When *OPC is sent, the OPC bit in the standard event register will set after all pending command operations are complete. When *OPC? is sent, an ASCII "1" is placed in the output queue after all pending command operations are complete.

Typically, either one of these commands is sent after the INITiate command. The INITiate command is used to take the instrument out of idle in order to perform measurements. While operating within the trigger model layers, all sent commands (except DCL, SDC, IFC, SYSTem:PRESet, *RST, GET and ABORt) will not execute.

After all programmed operations are completed, the instrument returns to the idle state at which time all pending commands (including *OPC and/or *OPC?) are executed. After the last pending command is executed, the OPC bit and/or an ASCII "1" is placed in the output queue.

Programming example — The following command sequence will perform 10 measurements. After the measurements are completed (in approximately 10 seconds), an ASCII "1" will be placed in the output queue.

```
*RST                    ' Return 6514 to RST defaults (idle).
TRIG:DEL 1              ' Set trigger delay for 1 second.
ARM:COUN 10             ' Program for 5 measurements and stop.
INIT                    ' Start measurements.
*OPC?                   ' Send *OPC?.
```

C) SAV <NRf> — save — Save present setup in memory
RCL <NRf> — recall — Return to setup stored in memory

Parameters
0 = Memory location 0
1 = Memory location 1
2 = Memory location 2

Use the *SAV command to save the present instrument setup configuration in memory for later recall. Any control affected by *RST can be saved by the *SAV command. The *RCL command is used to restore the instrument to the saved setup configuration. Three setup configurations can be saved and recalled.

Model 6514 ships from the factory with SYSTem:PRESet defaults loaded into the available setup memory. If a recall error occurs, the setup memory defaults to the SYSTem:PRESet values.

Programming example:

```
*SAV 2   ' Save present setup in memory location 2.
*RST     ' Set 6514 to RST defaults.
*RCL 2   ' Return (recall) 6514 to setup stored in memory location 2.
```

D) RST — reset — Return Model 6514 to RST defaults

When the *RST command is sent, Model 6514 performs the following operations:

1. Returns Model 6514 to the RST default conditions (see "Default" column of SCPI tables).
2. Cancels all pending commands.
3. Cancels response to any previously received *OPC and *OPC? commands.

E) TRG — trigger

Send bus trigger to Model 6514

Use the *TRG command to issue a GPIB trigger to Model 6514. It has the same effect as a group execute trigger (GET).

Use the *TRG command as an event to control operation. Model 6514 reacts to this trigger if BUS is the programmed arm control source. The control source is programmed from the TRIGger subsystem.

NOTE Details on triggering are covered in Section 9.

Programming example — The following command sequence configures Model 6514 to be controlled by bus triggers. The last line, which sends a bus trigger, triggers one measurement. Each subsequent bus trigger will also trigger a single measurement.

```
*RST                    ' Restore RST defaults.
ARM:SOUR BUS            ' Select BUS control source.
ARM:COUN INF            ' Set arm layer count to infinite.
INIT                    ' Take 6514 out of idle.
*TRG                    ' Trigger one measurement.
```

F) TST? — self-test query

Run self test and read result

Use this query command to perform a checksum test on ROM. The command places the coded result (0 or 1) in the output queue. When Model 6514 is addressed to talk, the coded result is sent from the output queue to the computer.

A returned value of zero (0) indicates that the test passed, and a value of one (1) indicates that the test failed.

G) WAI — wait-to-continue

Wait until previous commands are completed

Effectively, the *WAI command is a No-Op (no operation) for Model 6514 and thus, does not need to be used.

Two types of device commands exist:

- Sequential commands — A command whose operations are allowed to finish before the next command is executed.
- Overlapped commands — A command that allows the execution of subsequent commands while device operations of the overlapped command are still in progress.

The *WAI command is used to suspend the execution of subsequent commands until the device operations of all previous overlapped commands are finished. The *WAI command is not needed for sequential commands.

15
SCPI Signal Oriented Measurement Commands

The signal oriented measurement commands are used to acquire readings. You can use these high level instructions to control the measurement process. These commands are summarized in Table 15-1.

NOTE The readings acquired by these commands depend on which data elements are selected (see "FORMat Subsystem" in Section 16 for details).

Table 15-1
Signal oriented measurement command summary

Command	Description	Ref
CONFigure:<function>	Places Model 6514 in a "one-shot" measurement mode for the specified function.	A
CONFigure?	Queries the selected function.	
FETCh?	Requests the latest reading(s).	B
READ?	Performs an INITiate and a :FETCh?.	C
MEASure[:<function>]?	Performs a CONFigure:<function>, and a :READ?.	D

A) CONFigure:<function> Configure Model 6514 for "one-shot" measurements

<function> =	VOLTage[:DC]	Configure voltage
	CURRent[:DC]	Configure current
	RESistance	Configure resistance
	CHARge	Configure charge

This command configures the instrument for "one-shot" measurements on the specified function. Each subsequent READ? command will then trigger a single measurement and acquire the reading (see READ? for details).

If the instrument is in idle, this command will execute immediately. If the instrument is not in idle, execution of the command will execute when the operation returns to the idle state.

When this command is executed, Model 6514 will be configured as follows:

- The specified function is selected.
- All controls related to the selected function are defaulted to the *RST values.
- The event control sources of the trigger model are set to immediate.
- The arm and trigger count values of the trigger model are set to one.
- The delay of the trigger model is set to zero.
- Model 6514 is placed in the idle state.
- All math calculations are disabled.
- Buffer operation is disabled. A storage operation presently in process will be aborted.
- Autozero is enabled.

This command is automatically asserted when the :MEASure? command is sent.

Programming example — The following command sequence selects and configures Model 6514 for "one-shot" measurements. Each subsequent READ? triggers a single measurement and requests the reading.

```
CONF:VOLT                ' Perform CONFigure operations.
READ?                    ' Trigger measurement and request reading.
```

B) FETCh? Request latest reading

This command requests the latest post-processed readings. After sending this command and addressing Model 6514 to talk, the readings are sent to the computer. This command does not affect the instrument setup.

This command does not trigger a measurement. The command simply requests the last group of readings. Note that this command can repeatedly return the same readings. Until there is a new reading(s), this command continues to return the old reading(s). If your application requires a "fresh" reading, use the :READ? command.

This command is automatically asserted when the :READ? or :MEASure? command is sent.

C) READ? Trigger measurement(s) and request reading(s)

This command is used to trigger and acquire readings. The number of readings depends on how the trigger model is configured. For example, if configured for 20 measurements (arm count 1, trigger count 20), 20 sets of readings will be acquired.

When this command is sent, the following commands execute in the order they are presented:

- INITiate
- FETCh?

If the instrument is in the idle state, INITiate takes the instrument out of idle to perform the programmed number measurements. If the instrument is not in the idle state, execution of this command will wait until it goes back into idle.

The FETCh? command is executed to acquire the reading(s). The readings are sent to the computer when Model 6514 is addressed to talk.

NOTE *If the instrument is programmed to perform an infinite number of measurements (arm count or trigger count set to infinite), you cannot use the READ? command to trigger and acquire readings. Use INITiate to start (trigger) the measurement process, send ABORt to abort the measurement process, and then use SENSe:DATA[:LATest]? to return the last (latest) reading.*

D) MEASure[:<function>]? Configure and perform "one-shot" measurement

<function> =	VOLTage[:DC]	Measure voltage
	CURRent[:DC]	Measure current
	RESistance	Measure resistance
	CHARge	Measure charge

This command combines all of the other signal oriented measurement commands to perform a "one-shot" measurement and acquire the reading.

When this command is sent, the following commands execute in the order that they are presented.

- CONFigure:<function>
- READ?

When :CONFigure is executed, the instrument goes into a "one-shot" measurement mode. See CONFigure for details.

When READ? is executed, its operations will then be performed. In general, an INITiate is executed to perform the measurement and a FETch? is executed to acquire the reading. See :READ? for details.

NOTE *If you send MEASure? (no measurement function specified), the operations of CONFigure will apply to the presently selected function.*

16
DISPlay, FORMat, and SYSTem

- **DISPlay subsystem** — Covers the SCPI commands that are used to control the display.
- **FORMat subsystem** — Covers the SCPI commands to configure the format that readings are sent over the bus.
- **SYSTem subsystem** — Covers miscellaneous SCPI commands.

DISPlay subsystem

Table 16-1
SCPI commands — display

Command	Description	Default	Ref
:DISPlay			
:DIGits <n>	Set display resolution; 4 to 7.	6	Sec 6
:ENABle <b>	Turn front panel display on or off.	(see Note)	A
[:WINDow[1]]	Path to control user text messages:		
:TEXT		(see Note)	
[:DATA] <a>	Define ASCII message "a" (up to 12 characters).		B
:STATe <b>	Enable or disable text message mode.		C

Note: *RST and SYSTem:PRESet have no effect on the display circuitry and user-defined text messages.

A) DISPlay:ENABle <b>

With front panel circuitry turned off, the instrument operates at a higher speed. While disabled, the display is frozen and all front panel controls (except LOCAL) are disabled. Normal display operations can be resumed by using :ENABle to enable the display, pressing the LOCAL key, or cycling power.

B) DISPlay:TEXT[:DATA] <a>

Message Types:	String	'aa…a' or "aa…a"
	Indefinite Block	#0aa…a
	Definite Block	#XYaa…a

where; Y = number of characters in message (up to 12)
X = number of digits that make up Y (1 or 2)

The display message can be up to 12 characters (ASCII) long. A space is counted as a character. Excess message characters result in an error. Note that for the string type, the message must be enclosed by single or double quotes.

An indefinite block message must be the only command in the program message, or the last command in the program message. If you include a command after an indefinite block message (on the same line), it will be treated as part of the message and is displayed instead of executed.

C) DISPlay:TEXT:STATe <b>

When the text message mode is enabled, a defined message is displayed. When disabled, the message is removed from the display.

GPIB operation — A user-defined message remains displayed only as long as the instrument is in remote. Taking the instrument out of remote (by pressing LOCAL or sending the GTL (go to local) command) or cycling power cancels the message and disables the text message mode.

RS-232 operation — A user-defined message can be cancelled by sending SYSTem:LOCal, pressing LOCAL, or cycling power.

FORMat subsystem

The commands in this subsystem are used to select the format for transferring data over the bus.

Table 16-2
SCPI commands — data format

Command	Description	Default	Ref
:FORMat			
[:DATA] <type>[,<length>]	Specify data format; ASCii, REAL, 32 or SREal.	ASCii	A
:ELEMents <item list>	Specify data elements; READing, TIME, and STATus.	All 3	B
:BORDer <name>	Specify byte order; NORMal or SWAPped.	(see Note)	C
:SREGister <name>	Select data format for reading status registers; ASCii, HEXadecimal, OCTal, or BINary.	ASC	Sec 13
:SOURce2 <name>	Select data format for reading output patterns: ASCii, HEXadecimal, OCTal, or BINary.	ASC	Sec 10

Note: *RST default is NORMal. SYSTem:PRESet default is SWAPped.

A) FORMat[:DATA] <type>[,<length>]

Parameters

ASCii	=	ASCII format
REAL, 32	=	Binary IEEE-754 single precision format
SREal	=	Binary IEEE-754 single precision format

NOTE *<length> is not used for the ASCii or SREal parameters. It is optional for the REAL parameter. If you do not use <length> with REAL, <length> defaults to 32 (single precision format). The double precision format (<length> = 64) is not supported by Model 6514.*

The response to READ?, FETCh?, MEASure?, TRACe:DATA?, CALC1:DATA? or CALC2:DATA? over the GPIB can be returned in either the ASCii or binary format. All other queries are returned in ASCii, regardless of the selected format. Over the RS-232 interface, only the ASCII format is allowed.

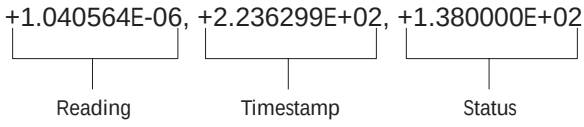
NOTE *Regardless of which data format for output strings is selected, the instrument will only respond to input commands using the ASCII format.*

ASCII data format

The ASCII data format is in a direct readable form for the operator. Most BASIC languages easily convert ASCII mantissa and exponent to other formats. However, some speed is compromised to accommodate the conversion. Figure 16-1 shows an example ASCII string that includes all the data elements. See :ELEMents for information on the data elements.

Figure 16-1 also shows the byte order of the data string. Data elements not specified by the :ELEMents command are simply not included in the string.

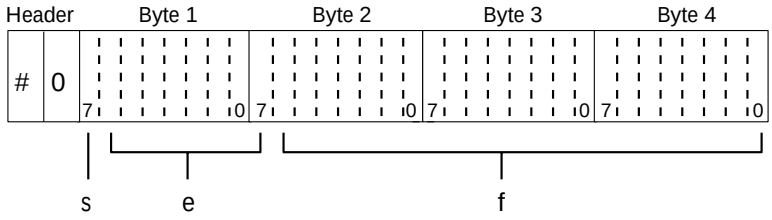
Figure 16-1
ASCII data format



IEEE-754 single precision format

REAL 32 or SREal will select the binary IEEE-754 single precision data format. Figure 16-2 shows the normal byte order format for each data element. For example, if all three data elements are selected, the data string for each reading conversion is made up of three 4-byte data blocks. Note that the data string for each reading conversion is preceded by a 2-byte header that is the binary equivalent of an ASCII # sign and 0. Figure 16-2 does not show the byte for the terminator that is attached to the end of each data string. Note that the byte order of the data string can be sent in reverse order (see :BORDer).

Figure 16-2
IEEE-754 single precision data format (32 data bits)



s = sign bit (0 = positive, 1 = negative)
e = exponent bits (8)
f = fraction bits (23)

Normal byte order shown. For swapped byte order, bytes sent in reverse order: Header, Byte 4, Byte 3 Byte 2, Byte 1.

The header and terminator are sent only once for each READ?.

During binary transfers, never un-talk Model 6514 until after the data is read (input) to the computer. Also, to avoid erratic operation, the readings of the data string (and terminator) should be acquired in one piece. The header (#0) can be read separately before the rest of the string.

The number of bytes to be transferred can be calculated as follows:

Bytes = 2 + (Rdgs x 4) + 1

where; 2 is the number of bytes for the header (#0).
Rdgs is the product of the number of selected data elements, arm count and trigger count.
4 is the number of bytes for each reading.
1 is the byte for the terminator.

For example, assume the instrument is configured to perform 10 measurements and send them to the computer using the binary format:

Bytes = 2 + (10 x 4) + 1
= 43

B) FORMat:ELEMents <item list>

Parameters

READing	=	Voltage, current, resistance or charge reading
TIME	=	Timestamp
STATus	=	Status information

The specified elements are included in the data string in response to :FETch?, :READ?, :MEASure? and :TRACe:DATA?. Note that each element in the item list must be separated by a comma (i.e. send ":ELEMents READing, TIME, STATus" to include all elements in the data string. The elements for the ASCii format are shown in Figure 16-1.

An overflow reading is returned as +9.9E37. When a specified data element has invalid data associated with it, NAN (Not A Number) will be the response. NAN is returned as +9.9E37.

Timestamp — Timestamp references the returned data string to a point in time. The timestamp operates as a timer that starts at zero seconds when the instrument is turned on, or when the timestamp is reset (SYSTem:TIME:RESet). After 99,999.99 seconds, the timer resets back to zero and starts over.

For buffer readings, timestamp can be referenced to the first reading stored in the buffer (absolute format) which is timestamped at 0 seconds, or to the time between each stored reading (delta format). The TRACe:TSTamp:FORMat command is used to select the timestamp format.

Status — The status word provides information about Model 6514 operation. The 16-bit status word is sent in decimal form. The decimal value has to be converted to the binary equivalent to determine the state of each bit in the word. For example, if the returned status value is 9, the binary equivalent is 00000001001. Bits 0 and 3 are set. The bits are explained as follows:

Bit 0 (OFLO) - Set to 1 if measurement performed while in over-range (overflowed reading).
Bit 1 (Filter) - Set to 1 when measurement performed with the averaging filter enabled.
Bit 2 (Math) - Set to 1 when measurement performed with CALC1 enabled.
Bit 3 (Null) - Set to 1 if null for CALC2 is enabled.
Bit 4 (Limits) - Set to 1 if a limit test (CALC2) is enabled.
Bits 5 and 6 (Limit Results) - Provides limit test results:

Bit 6	Bit 5	
0	0	All limit tests passed
0	1	CALC2:LIM1 test failed
1	0	CALC2:LIM2 test failed

Bits 7 and 8 (Measure) - Provides measurement status:

Bit 8	Bit 7	
0	0	Voltage function selected
0	1	Current function selected
1	0	Resistance function selected
1	1	Charge function selected

Bit 9 (Zero Check) - Set to 1 when zero check is enabled.

Bit 10 (Zero Correct) - Set to 1 when zero correct is enabled.

Example — The ASCII data string in Figure 16-1 contains all three data elements. The status value of 138 has a binary equivalent of 01001010, which indicates that bits B1, B3, and B7 are set. Therefore, the reading is 1.04056uA with null (REL) and the AVG filter enabled. The reading was taken 223.6299 seconds after the instrument was turned on.

C) FORMat:BORDer <name>

Parameters

NORMal	=	Normal byte order for IEEE-754 binary format
SWAPped	=	Reverse byte order for IEEE-754 binary format

For normal byte order, the data format for each element is sent as follows:

Byte 1 Byte 2 Byte 3 Byte 4

For reverse byte order, data is sent as follows:

Byte 4 Byte 3 Byte 2 Byte 1

The "#0" header (see Figure 16-2) is not affected by this command. The header is always sent at the beginning of the data string for each measurement conversion.

The ASCII data format can only be sent in the normal byte order. The SWAPped selection is ignored when the ASCII format is selected.

NOTE The SWAPped byte order must be used when transmitting binary data to any IBM PC.

SYSTem subsystem

Table 16-3
SCPI commands — system

Command	Description	Default	Ref
:SYSTem			
:ZCHeck <b>	Enable or disable zero check.	ON	Sec 2
:ZCORrect	Zero correct:		Sec 2
[:STATe] <b>	Enable or disable zero correct.	OFF	
:ACQuire	Acquire a new zero correct value.		
:PRESet	Return to SYSTem:PRESet defaults.		A
:LFRequency <freq>	Select power line frequency; 50 or 60 (Hz).		Sec 1
:AZERo	Path to control autozero:		Sec 2
[:STATe] <b>	Enable or disable autozero.	ON	
:TIME	Timestamp:		
:RESet	Reset timestamp to 0 seconds.		B
:POSetup <name>	Select power-on setup; RST, PRESet or SAVx (where x = 0 to 4).		C
:VERSion?	Query SCPI revision level.		D
:ERRor	Read messages in error queue:	(see Note)	Sec 13
[:NEXT]?	Return and clear oldest error (code and message).		
:ALL?	Return and clear all errors (code and message).		
:COUNt?	Return the number of errors.		
:CODE	Error code numbers only:		
[:NEXT]?	Return and clear oldest error (code only).		
:ALL?	Return and clear all errors (codes only).		
:CLEar	Clear messages from error queue.		Sec 13
:KEY <NRf>	Simulate key-press; see Figure 16-3.		E
	RS-232 interface:		Sec 12
:LOCal	Take Model 6514 out of remote (RS-232 only).		
:REMote	Put Model 6514 in remote (RS-232 only).		
:RWLock	Enable or disable local lockout (RS-232 only).		

Note: Clearing the error queue - power-up and *CLS clears the error queue. *RST, SYSTem:PRESet, and STATus:PRESet have no effect on the error queue.

A) SYSTem:PRESet

Returns the instrument to states optimized for front panel operation. SYSTem:PRESet defaults are listed in the SCPI tables in Section 17.

B) SYSTem:TIME:RESet

Resets the absolute timestamp to 0 seconds. The timestamp also resets when power is cycled, or after the instrument is on for 99,999.99 seconds. The TRACe:TSTamp:FORMat command is used to select the absolute timestamp. See Section 8 (Buffer) for details.

C) SYSTem:POSetup <name>

Parameters		
	RST	Power-up to *RST defaults
	PRESet	Power-up to SYSTem:PRESet defaults
	SAVx	Power-up to setup stored in memory (x = memory location 0, 1, 2, 3 or 4)

The *RST and SYSTem:DEFaults are listed in the SCPI tables in the Section 17. A setup is saved in memory using the *SAV command. See Section 14 (Common Commands) for details.

D) SYSTem:VERSion

Read the version of the SCPI standard being used by Model 6514. Example response message: 1996.0.

E) SYSTem:KEY <NRf>

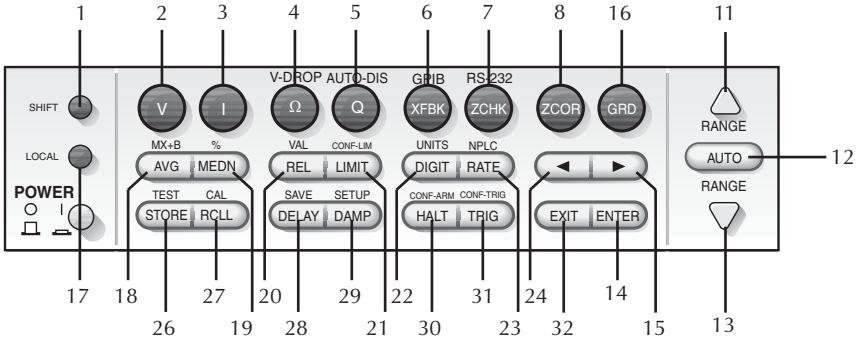
Parameters

1	=	SHIFT key		17	=	LOCAL key	
2	=	V key		18	=	AVG key	
3	=	I key		19	=	MEDIAN key	
4	=	Ω key		20	=	REL key	
5	=	Q key		21	=	LIMIT key	
6	=	XFDBK key		22	=	DIGIT key	
7	=	ZCHECK key		23	=	RATE key	
8	=	ZCOR key		24	=	Cursor left arrow key	
9	=	-------		25	=	-------	
10	=	-------		26	=	STORE key	
11	=	RANGE up arrow key		27	=	RECALL key	
12	=	AUTO key		28	=	DELAY key	
13	=	RANGE down arrow key		29	=	DAMP key	
14	=	ENTER key		30	=	HALT key	
15	=	Cursor right arrow key		31	=	TRIG key	
16	=	GRD key		32	=	EXIT key	

This command is used to simulate front panel key presses. For example, to select the volts measurement function, send the following command to simulate pressing the “V” key: SYSTem:KEY 2. The key-press codes are also shown in Figure 16-3.

The queue for the :KEY? query command can only hold one key-press. When :KEY? is sent and Model 6514 is addressed to talk, the key-press code number for the last key pressed (either physically or with :KEY) is sent to the computer.

Figure 16-3
Key-press codes



17
SCPI Reference Tables

- **Table 17-1** — CALCulate command summary
- **Table 17-2** — DISPlay command summary
- **Table 17-3** — FORMat command summary
- **Table 17-4** — SENSe command summary
- **Table 17-5** — SOURce command summary
- **Table 17-6** — STATus command summary
- **Table 17-7** — SYSTem command summary
- **Table 17-8** — TRACe command summary
- **Table 17-9** — TRIGger command summary

General notes

- Brackets ([ ]) are used to denote optional character sets. These optional characters do not have to be included in the program message. Do not use brackets in the program message.
- Angle brackets (< >) are used to indicate parameter type. Do not use angle brackets in the program message.
- The Boolean parameter (<b>) is used to enable or disable an instrument operation. 1 or ON enables the operation, and 0 or OFF disables the operation.
- Upper case characters indicated the short-form version for each command word.
- Default parameter — Listed parameters are both the *RST and SYSTem:PRESet defaults, unless noted otherwise. Parameter notes are located at the end of each table.
- Ref — Refers you to the section (Sec) that provides operation information for that command or command subsystem.
- SCPI — A checkmark (√) indicates that the command and its parameters are SCPI confirmed. An unmarked command indicates that it is a SCPI command, but does not conform to the SCPI standard set of commands. It is not a recognized command by the SCPI consortium. SCPI confirmed commands that use one or more non-SCPI parameters are explained by notes.

Table 17-1
CALCulate command summary

Command	Description	Default parameter	Ref	SCPI
:CALCulate[1]	Path to configure and control CALC1 calculations.		Sec 7	√
:FORMat <name>	Select math format; MXB or PERCent.	MXB		√
:FORMat?	Query math format.			√
:KMATh	Configure math calculations:			
:MMFactor <NRf>	Set “m” for mX+b calculation; -9.99999e20 to 9.99999e20.	1.0		
:MMFactor?	Query “m” factor.			
:MBFactor <NRf>	Set “b” for mX+b calculation; -9.99999e20 to 9.99999e20.	0.0		
:MBFactor?	Query “b” factor.			
:MUNits <name>	Specify units for mX+b result; 3 letters (A - Z).	“MXB”		
:MUNits?	Query units.			
:PERCent	Configure percent math calculation:			
[:REFerence] <NRf>	Specify reference value; -9.99999e20 to 9.99999e20.	1.0		
:ACQuire	Use input signal as reference value.			
:PERCent?	Query reference value.			
:STATe <b>	Enable or disable CALC1 calculation.	OFF		√

Table 17-1 (cont.)
CALCulate command summary

NOTE The <NDN> and <NRf> parameter values for the :SOURce2 command are provided at the end of this table.

Command	Description	Default parameter	Ref	SCPI
:STATe?	Query state of CALC1 calculation.			√
:DATA?	Return all CALC1 results triggered by INITiate.			√
:LATest?	Return last (latest) reading.			
:CALCulate2	Path to configure and control limit testing (CALC2):		Sec 10	√
:FEED <name>	Select input path for limit testing; CALCulate[1] or SENSe[1].	SENS		√
:FEED?	Query input path for limit tests.			√
:LIMit[1]	Limit 1 Testing:			√
:UPPer	Configure upper limit:			√
[:DATA] <n>	Set limit; -9.99999e20 to 9.99999e20.	1.0		√
[:DATA]?	Query upper limit.			√
:SOURce2 <NDN> or <NRf>	Specify 4-bit output “fail” pattern.	15		√
:SOURce2?	Query output pattern value.			√
:LOWer	Configure lower limit:			√
[:DATA] <n>	Set limit; -9.99999e20 to 9.99999e20.	-1.0		√
[:DATA]?	Query lower limit.			√
:SOURce2 <NDN> or <NRf>	Specify 4-bit output “fail” pattern.	15		√
:SOURce2?	Query output pattern value.			√
:STATe <b>	Enable or disable limit 1 test.	OFF		√
:STATe?	Query state of limit 1 test.			√
:FAIL?	Return result of limit 1 test; 0 (pass) or 1 (fail).			√
:LIMit2	Limit 2 Testing:			√
:UPPer	Configure upper limit:			√
[:DATA] <n>	Set limit; -9.99999e20 to 9.99999e20.	1.0		√
[:DATA]?	Query upper limit.			√
:SOURce2 <NDN> or <NRf>	Specify 4-bit output “fail” pattern.	15		√
:SOURce2?	Query output pattern value.			√
:LOWer	Configure lower limit:			√
[:DATA] <n>	Set limit; -9.99999e20 to 9.99999e20.	-1.0		√
[:DATA]?	Query lower limit.			√
:SOURce2 <NDN> or <NRf>	Specify 4-bit output “fail” pattern.	15		√

Table 17-1 (cont.)
CALCulate command summary

Command	Description	Default parameter	Ref	SCPI
:SOURce2?	Query output pattern value.			√
:STATe <b>	Enable or disable limit 2 test.	OFF		√
:STATe?	Query state of limit 2 test.			√
:FAIL?	Return result of limit 2 test; 0 (pass) or 1 (fail).			√
:CLIMits	Composite Limits:			
:CLEar	Clear I/O port and restore it back to SOURce2:TTL settings:			
[:IMMediate]	Clears I/O port immediately.			
:AUTO <b>	When enabled, I/O port clears when :INITiate sent.	ON		
:AUTO?	Query state of auto-clear.			
:PASS	Define “pass” digital output pattern.			
:SOURce2 <NDN> or <NRf>	Specify 4-bit pass pattern (no failures).	15		
:SOURce2?	Query “pass” output pattern.			
:NULL	Configure and control Rel:			√
:ACQuire	Use input signal as Rel value.			
:OFFSet <NRf>	Specify Rel value; -9.999999e20 to 9.999999e20.	0.0		√
:OFFSet?	Query Rel value.			√
:STATe <b>	Enable or disable Rel.	OFF		√
:STATe?	Query state of Rel.			√
:DATA?	Return all CALC2 readings triggered by INITiate.			√
:LATest?	Return only the last (latest) reading.			
:CALCulate3	Path to configure and control CALC3 calculations on buffer data:		Sec 8	√
:FORMat <name>	Select buffer statistic; MEAN, SDEViation, Maximum, MINimum or PKPK.	MEAN		√
:FORMat?	Query selected statistic.			√
:DATA?	Read the selected buffer statistic.			√

:SOURce2 <NDN> and <NRf> parameters:

<NDN> = #Bxxxx	Binary format (each x = 1 or 0)
= #Hx	Hexadecimal format (x = 0 to F)
= #Qxx	Octal format (x = 0 to 17)
<NRf> = 0 to 15	Decimal format

Table 17-2
DISPlay command summary

Command	Description	Default parameter	Ref	SCPI
:DISPlay			Sec 16	
:DIGits <n>	Set display resolution; 4 to 7.	6	Sec 6	
:DIGits?	Query display resolution.			
:ENABle <b>	Turn front panel display on or off.	(Note 1)		√
:ENABle?	Query display state.			√
[:WINDow[1]]	Path to control user text messages:			√
:TEXT		(Note 2)		√
[:DATA] <a>	Define ASCII message “a” (up to 12 characters).			√
[:DATA]?	Read text message.			√
:STATe <b>	Enable or disable text message mode.	(Note 3)		√
:STATe?	Query state of text message mode.			√

Notes:
1. *RST and SYSTem:PRESet have no effect on the display circuitry. Pressing LOCAL or cycling power enables (ON) the display circuit.
2. *RST and SYSTem:PRESet have no effect on a user-defined message. Pressing LOCAL or cycling power cancels all user-defined messages.
3. *RST and SYSTem:PRESet have no effect on the state of the message mode. Pressing LOCAL or cycling power disables (OFF) the message mode.

Table 17-3
FORMat command summary

Command	Description	Default parameter	Ref	SCPI
:FORMat			Sec 16	
[:DATA] <type>[,<length>]	Specify data format; ASCii, REAL, 32, or SREal.	ASC		√
[:DATA]?	Query data format.			√
:ELEMents <item list>	Specify data elements; READing, TIME, and STATus.	All 3		
:ELEMents?	Query data format elements.			
:BORDer <name>	Specify byte order; NORMal or SWAPped.	(see Note)		√
:BORDer?	Query byte order.			√
:SREGister <name>	Select data format for reading status registers; ASCii, HEXadecimal, OCTal, or BINary.	ASC	Sec 13	
:SREGister?	Query format for reading event registers.			
:SOURce2 <name>	Select data format for reading output patterns: ASCii, HEXadecimal, OCTal, or BINary.	ASC	Sec 10	
:SOURce2?	Query format for reading output patterns.			

Note: *RST default is NORMal. SYSTem:PRESet default is SWAPped.

Table 17-4
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
[:SENSe[1]]				
:FUNCtion <name>	Select function; 'VOLTage[:DC]', 'CURRent[:DC]', 'RESistance' or 'CHARge'.	'VOLT'	Secs 3, 4, 5	√
:FUNCtion?	Query measurement function.			√
:DATA	Path to return instrument readings:		Secs 3, 4, 5	√
[:LATest]?	Return the last instrument reading.			√
:VOLTage[:DC]	Path to configure volts function:			√
:NPLCycles <NRf>	Set integration rate in line cycles (PLC); 0.01 to 10.	6 (60Hz) 5 (50Hz)	Sec 6	√
:NPLCycles?	Query NPLC.			√
:RANGe	Configure measurement range:		Sec 6	√
[:UPPer] <NRf>	Select range; -210 to 210 (volts).	21		√
[:UPPer]?	Query range value.			√
:AUTO <b>	Enable or disable autorange.	(see Note)		√
:ULIMit <NRf>	Select autorange upper limit; -210 to 210 (volts).	210		
:ULIMit?	Query upper limit for autorange.			
:LLIMit <NRf>	Select autorange lower limit; -210 to 210 (volts).	2.1		
:LLIMit?	Query lower limit for autorange.			
:AUTO?	Query state of autorange.			√
:GUARd <b>	Enable or disable driven guard.	OFF	Sec 3	
:GUARd?	Query state of driven guard.			
:XFEedback <b>	Enable or disable external feedback.	OFF	Sec 11	
:XFEedback?	Query state of external feedback.			
:CURRent[:DC]	Path to configure amps function:			√
:NPLCycles <NRf>	Set integration rate in line cycles (PLC); 0.01 to 10.	6 (60Hz) 5 (50Hz)	Sec 6	√
:NPLCycles?	Query NPLC.			√
:RANGe	Configure measurement range:		Sec 6	√
[:UPPer] <NRf>	Select range; -0.021 to 0.021 (amps).	2.1e-4		√
[:UPPer]?	Query range value.			√
:AUTO <b>	Enable or disable autorange.	(see Note)		√

Table 17-4 (cont.)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:ULIMit <NRf>	Select autorange upper limit; -0.021 to 0.021 (amps).	2.1e-2		
:ULIMit?	Query upper limit for autorange.			
:LLIMit <NRf>	Select autorange lower limit; -0.021 to 0.021 (amps).	2.1e-11		
:LLIMit?	Query lower limit for autorange.			
:AUTO?	Query state of autorange.			√
:DAMPing <b>	Enable or disable current damping.	OFF	Sec 4	
:DAMPing?	Query state of damping			
:RESistance	Path to configure ohms function:			√
:NPLCycles <NRf>	Set integration rate in line cycles (PLC); 0.01 to 10.	6 (60Hz) 5 (50Hz)	Sec 6	√
:NPLCycles?	Query NPLC.			√
:RANGe	Configure measurement range:		Sec 6	√
[:UPPer] <NRf>	Select range; 0 to 2.1e11 (ohms).	2.1e5		√
[:UPPer]?	Query range value.			√
:AUTO <b>	Enable or disable autorange.	(see Note)		√
:ULIMit <NRf>	Select autorange upper limit; -2.1e11 to 2.1e11 (ohms).	2.1e11		
:ULIMit?	Query upper limit for autorange.			
:LLIMit <NRf>	Select autorange lower limit; -2.1e11 to 2.1e11 (ohms).	2.1e3		
:LLIMit?	Query lower limit for autorange.			
:AUTO?	Query state of autorange.			√
:GUARd <b>	Enable or disable driven guard.	OFF	Sec 3	
:GUARd?	Query state of driven guard.			
:CHARge	Path to configure coulombs function:			√
:NPLCycles <NRf>	Set integration rate in line cycles (PLC); 0.01 to 10.	6 (60Hz) 5 (50Hz)	Sec 6	√
:NPLCycles?	Query NPLC.			√
:RANGe	Configure measurement range:		Sec 6	√
[:UPPer] <NRf>	Select range; -21e-6 to 21e-6 (coulombs).	2.1e-6		√
[:UPPer]?	Query range value.			√
:AUTO <b>	Enable or disable autorange.	(see Note)		√

Table 17-4 (cont.)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:LGRoup <name>	Specify autorange limit; HIGH or LOW.	HIGH		
:LGRoup?	Query upper limit for autorange.			
:AUTO?	Query state of autorange.			√
:ADIScharge	Path for auto discharge:		Sec 5	
:LEVel <NRf>	Set auto discharge level; -21e-6 to 21e-6.	2e-6		
:LEVel?	Query auto discharge level.			
[:STATe] <b>	Enable or disable auto discharge.	OFF		
[:STATe]?	Query state of auto discharge.			
:AVERage	Path to control the Digital Filter:		Sec 6	
:TCONtrol <name>	Select filter control; MOVing or REPeat.	REP		
:TCONtrol?	Query filter control.			
:COUNt <n>	Specify filter count; 2 to 100.	10		
:COUNt?	Query filter count.			
[:STATe] <b>	Enable or disable digital filter.	OFF		
[:STATe]?	Query state of digital filter.			
:MEDian	Path to control median filter:		Sec 6	
:RANK <NRf>	Specify “n” for rank; 1 to 5 (rank = 2n+1).	1		
:RANK?	Query rank.			
[:STATe] <b>	Enable or disable median filter.	OFF		
[:STATe]?	Query state of median filter.			

Note: *RST default is ON and SYSTem:PRESet default is OFF.

Table 17-5
SOURce command summary

Command	Description	Default parameter	Ref	SCPI
:SOURce2			Sec 10	
:TTL	Program I/O port:			
[:LEVel] <NDN> or <NRf>	Specify 4-bit digital output pattern.	15		
[:LEVel]?	Query output value.			
:CLEar	Clear I/O port (return output to TTL pattern):			
[:IMMediate]	Clear I/O port immediately.			
:AUTO <b>	Enable or disable auto-clear.	OFF		
:AUTO?	Query state of auto-clear.			
:DELay <n>	Specify delay (pulse-width) for pass/fail pattern; 0 to 60 (sec).	0.0001		
:DELay?	Query delay.			
:TTL4	Line 4 mode configuration:			
:MODE <name>	Select output line 4 mode; EOTest or BUSY.	EOT		
:MODE?	Query line 4 mode.			
:BSTate <ttl>	Select active TTL level for busy; 1 (HI) or 0 (LO).	0		
:BSTate?	Query busy level.			
<NDN> and <NRf> parameters:				
<NDN> = #Bxxx	Binary format (each x = 1 or 0)			
= #Hx	Hexadecimal format (x = 0 to F)			
= #Qx	Octal format (x = 0 to 17)			
<NRf> = 0 to 15	Decimal format			

Table 17-6
STATus command summary

Command	Description	Default parameter	Ref	SCPI
:STATus		(Note 1)	Sec 13	√
:MEASurement	Measurement event registers:			
[:EVENt]?	Read the event register.	(Note 2)		
:ENABle <NDN> or <NRf>	Program the enable register.	(Note 3)		
:ENABle?	Read the enable register.			
:CONDition?	Read the condition register.			
:OPERation	Operation event registers:			√
[:EVENt]?	Read the event register.	(Note 2)		√

Table 17-6 (cont.)
STATus command summary

Command	Description	Default parameter	Ref	SCPI
:ENABle <NDN> or <NRf>	Program the enable register.	(Note 3)		√
:ENABle?	Read the enable register.			√
:CONDition?	Read the condition register.			√
:QUEStionable	Questionable event registers:			√
[:EVENt]?	Read the event register.	(Note 2)		√
:ENABle <NDN> or <NRf>	Program the enable register.	(Note 3)		√
:ENABle?	Read the enable register.			√
:CONDition?	Read the condition register.			√
:PRESet	Return status registers to default states.			√
:QUEue	Read error queue:			√
[:NEXT]?	Read and clear oldest error/status (code and message).	(Note 4)		√
:ENABle <list>	Specify error and status messages for error queue.	(Note 5)		√
:ENABle?	Read the enabled messages.			√
:DISable <list>	Specify messages not to be placed in queue.	(Note 5)		
:DISable?	Read the disabled messages.			
:CLEar	Clear messages from error queue.			

Parameters:

<NDN> =	#Bxx…x	Binary format (each x = 1 or 0)
=	#Hx	Hexadecimal format (x = 0 to FFFF)
=	#Qx	Octal format (x = 0 to 177777)
<NRf> =	0 to 65535	Decimal format
<list> =	(100:200, -224)	Example of a range and single entry (+100 through +200 and -224)

Notes:
1. Commands in this subsystem are not affected by *RST or SYSTem:PRESet. The effects of cycling power, *CLS and STATus:PRESet are explained by the following notes.
2. Event registers — Power-up and *CLS clears all bits. STATus:PRESet has no effect.
3. Enable registers — Power-up and STATus:PRESet clears all bits. *CLS has no effect.
4. Error queue — Power-up and *CLS empties the error queue. STATus:PRESet has no effect.
5. Error queue messages — Power-up enables error messages and disables status messages. *CLS and STATus:PRESet have no effect.

Table 17-7
SYSTem command summary

Command	Description	Default parameter	Ref	SCPI
:SYSTem			Sec 16	
:ZCHeck <b>	Enable or disable zero check.	ON	Sec 2	
:ZCHeck?	Query state of zero check.			
:ZCORrect	Zero correct:		Sec 2	
[:STATe] <b>	Enable or disable zero correct.	OFF		
[:STATe]?	Query state of zero correct.			
:ACQuire	Acquire a new zero correct value.			
:PRESet	Return to SYSTem:PRESet defaults.			√
:LFRequency <freq>	Select power line frequency; 50 or 60 (Hz).		Sec 1	
:LFRequency?				
:AZERo	Path to control autozero:		Sec 2	√
[:STATe] <b>	Enable or disable autozero.	ON		√
[:STATe]?	Query state of autozero.			√
:TIME	Timestamp:			
:RESet	Reset timestamp to 0 seconds.			
:POSetup <name>	Select power-on setup; RST, PRESet, or SAVx (where x = 0 to 4).			
:POSetup?	Query power-on setup.			
:VERSion?	Query SCPI revision level.			√
:ERRor	Read error queue:	(see Note)	Sec 13	√
[:NEXT]?	Read and clear oldest error/status (code and message).			
:ALL?	Read and clear all errors/status (code and message).			
:COUNt?	Read the number of messages in queue.			
:CODE	Code numbers only:			
[:NEXT]?	Read and clear oldest error/status (code only).			
:ALL?	Read and clear all errors/status (codes only).			
:CLEar	Clear messages from error queue.		Sec 13	
:KEY <NRf>	Simulate key-press; see Figure 16-3.			√
:KEY?	Query the last “pressed” key.			√

Table 17-7 (cont.)
SYSTem command summary

Command	Description	Default parameter	Ref	SCPI
	RS-232 interface:		Sec 12	
:LOCal	Take Model 6514 out of remote (RS-232 only).			
:REMote	Put Model 6514 in remote (RS-232 only).			
:RWLock	Enable or disable local lockout (RS-232 only).			

Note: Clearing the error queue - Power-up and *CLS clears the error queue. *RST, SYSTem:PRESet, and STATus:PRESet have no effect on the error queue.

Table 17-8
TRACe command summary

Command	Description	Default parameter	Ref	SCPI
:TRACe|:DATA	Use :TRACe or :DATA as root command.	(see Note)	Sec 8	√
:DATA?	Read the contents of the buffer (data store).			√
:CLEar	Clear readings from buffer.			
:FREE?	Query bytes available and bytes in use.			√
:POINts <n>	Specify size of buffer; 1 to 2500.	100		√
:ACTual?	Query number of readings stored in buffer.			
:POINts?	Query buffer size.			√
:FEED <name>	Select source of readings for buffer; SENSe[1], CALCulate[1], or CALCulate2.	SENS1		√
:CONTrol <name>	Select buffer control mode; NEXT or NEVer.	NEV		√
:CONTrol?	Query buffer control mode.			√
:FEED?	Query source of readings for buffer.			√
:TSTamp	Timestamp:			
:FORMat <name>	Select timestamp format; ABSolute or DELta.	ABS		
:FORMat?	Query timestamp format.			

Note: SYSTem:PRESet and *RST have no effect on the commands in this subsystem. The listed defaults are power-on defaults.

Table 17-9
TRIGger command summary

Command	Description	Default parameter	Ref	SCPI
:INITiate	Path to initiate measurement cycle(s):		Sec 9	√
[:IMMediate]	Initiate one trigger cycle.			√
:ABORt	Reset trigger system (goes to idle state).			√
:ARM[:SEQuence[1]]	Path to configure arm layer:			√
[:LAYer[1]]				
:SOURce <name>	Select control source; IMMediate, TIMer, BUS, TLINk, STESt, PSTest, NSTest, BSTest, or MANual.	IMMediate		√
:SOURce?	Query arm control source.			√
:COUNt <n>	Set measure count; 1 to 2500, or INF (infinite).	1		√
:COUNt?	Query measure count.			√
:TIMer <n>	Set timer interval; 0.001 to 99999.999 (sec).	0.100		√
:TIMer?	Query timer interval.			√
[:TCONfigure]				√
:DIRection <name>	Enable (SOURce) or disable (ACCeptor) bypass.	ACCeptor		√
:DIRection?	Query arm source bypass.			√
[:ASYNchronous]	Configure input/output triggers:			
:ILINe <NRf>	Select input trigger line; 1, 2, 3, 4, 5, or 6.	1		
:ILINe?	Query input trigger line.			
:OLINe <NRf>	Select output trigger line; 1, 2, 3, 4, 5, or 6.	2		
:OLINe?	Query output trigger line.			
:OUTPut <name>	Output trigger (TRIGger) or not at all (NONE).	NONE		
:OUTPut?	Query output trigger status.			
:TRIGger[:SEQuence[1]]	Path to configure trigger layer:			√
:SOURce <name>	Select control source; IMMediate or TLINk.	IMMediate		√
:SOURce?	Query trigger control source.			√
:COUNt <n>	Set measure count; 1 to 2500, or INF (infinite).	1		√
:COUNt?	Query measure count.			√
:DELay <n>	Set trigger delay; 0 to 999.9999 (sec).	0.0		√
:AUTO <b>	Enable or disable auto delay.	OFF		√
:AUTO?	Query state of auto delay.			√
:DELay?	Query delay value.			√

Table 17-9 (cont.)
TRIGger command summary

Command	Description	Default parameter	Ref	SCPI
:TRIGger:CLEar	Clear input triggers immediately.			
[:TCONfigure]				√
:DIRection <name>	Enable (SOURce) or disable (ACCeptor) bypass.	ACCeptor		√
:DIRection?	Query trigger source bypass.			√
[:ASYNchronous]	Configure input/output triggers:			
:ILINe <NRf>	Select input trigger line; 1, 2, 3, 4, 5, or 6.	1		
:ILINe?	Query input trigger line.			
:OLINe <NRf>	Select output trigger line; 1, 2, 3, 4, 5, or 6.	2		
:OLINe?	Query output trigger line.			
:OUTPut <name>	Output trigger after measurement (SENSe) or not at all (NONE).	NONE		
:OUTPut?	Query output trigger status.			

18
Performance Verification

Introduction

Use the procedures in this section to verify that Model 6514 accuracy is within the limits stated in the instrument's one-year accuracy specifications. You can perform these verification procedures:

- When you first receive the instrument make sure that it was not damaged during shipment.
- Verify that the unit meets factory specifications.
- Determine if calibration is required.
- Following calibration, make sure it was performed properly.

WARNING **The information in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so. Some of these procedures may expose you to hazardous voltages, which could cause personal injury or death if contacted. Use standard safety precautions when working with hazardous voltages.**

NOTE *If the instrument is still under warranty, and its performance is outside specified limits, contact your Keithley representative, or the factory, to determine the correct course of action.*

Verification test requirements

Be sure that you perform the verification tests:

- Under the proper environmental conditions.
- After the specified warm-up period.
- Using the correct line voltage.
- Using the proper test equipment.
- Using the specified test signals and reading limits.

Environmental conditions

Conduct your performance verification procedures in a test environment with:

- An ambient temperature of (18-28˚C) 65-82˚F.
- A relative humidity of less than 70% unless otherwise noted.

Warm-up period

Allow Model 6514 to warm up for at least one hour before conducting the verification procedures. If the instrument has been subjected to temperature extremes (those outside the ranges stated above), allow additional time for the instrument's internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is (10˚C) 18˚F outside the specified temperature range.

Allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

Model 6514 requires a line voltage of 100/120 VAC or 220/240 VAC at a line frequency of 50 or 60Hz. Verification tests must be performed within this range.

Recommended test equipment

Table 18-1 summarizes recommended verification equipment. You can use alternate equipment, but keep in mind that test equipment accuracy will add to the uncertainty of each measurement. Generally, the test equipment should have accuracy or uncertainty at least four times better than corresponding Model 6514 specifications.

Table 18-1
Recommended verification equipment

Description	**Manufacturer/model**	**Specifications**
Calibrator	Fluke 5700A	DC voltage:[1] 2V: 7ppm 20V: 5ppm 200V: 7ppm DC current:[1] 20µA: 550ppm 200µA: 100ppm 2mA: 55ppm 20mA: 55ppm
Resistance calibrator	Fluke 5450A	Nominal resistance:[1] 1.9kΩ: 8ppm 19kΩ: 7.5ppm 190kΩ: 8.5ppm 1.9MΩ: 11.5ppm 19MΩ: 30ppm 100MΩ: 120ppm
Electrometer calibration standard	Keithley Model 5156	Nominal resistance:[2] 100MΩ: 200ppm 1GΩ: 300ppm 10GΩ: 400ppm 100GΩ: 500ppm Nominal capacitance:[2] 1nF: 1,000ppm 100nF: 1,000ppm

Notes:
1. 90-day, 23˚ ±5˚C full-range accuracy specifications shown,
2. 23˚ ±3˚C accuracy of characterization.
3. Connect red and black clips to make triax short.

Table 18-1 (cont.)
Recommended verification equipment

Description	Manufacturer/model	Specifications
Triax cable	Keithley 7024-3	
Low-noise coax cable	Keithley 4801	
Triax-to-alligator clip cable[3]	Keithley 237-ALG-2	
Triax-to-BNC adapter	Keithley 7078-TRX-BNC	
Triax shielding cap	Keithley CAP-31	
BNC-to-double banana plug adapter	Pomona 1269	

Notes:
1. 90-day, 23˚ ±5˚C full-range accuracy specifications shown,
2. 23˚ ±3˚C accuracy of characterization.
3. Connect red and black clips to make triax short.

Verification limits

The verification limits stated in this section have been calculated using only Model 6514 one-year accuracy specifications, and they do **not** include test equipment uncertainty. If a particular measurement falls outside the allowable range, recalculate new limits based on Model 6514 specifications and corresponding test equipment specifications.

Example reading limits calculation

As an example of how verification limits are calculated, assume you are testing the 20V range using a 20V input value. Using Model 6514 20V range accuracy specification of ±(0.025% of reading + 3 counts), the calculated reading limits are:

Reading limits = 20V ±[(20V × 0.025%) + 300μV]
= 20V ±(0.005 + 0.0003)
= 20V ±0.0053V
= 19.9947V to 20.0053V

Recalculating resistance reading limits

When verifying resistance measurement accuracy, it will probably be necessary to recalculate resistance limits based on the actual resistance values. You can calculate new reading limits in the same manner described above, but be sure to use the actual calibration resistance values and Model 6514 ohms accuracy specifications for your calculations.

As an example, assume that you are testing the 20kΩ range, and that the actual value of the nominal 19kΩ calibrator resistor is 19.1kΩ. Using Model 6514 20kΩ range accuracy specifications of ±(0.15% of reading + 3 counts), the recalculated reading limits are:

Reading limits = 19.1kΩ ±[(19.1kΩ × 0.15%) + 0.3Ω]
= 19.1kΩ ±29Ω
= 19.0710kΩ to 19.1290kΩ

Calibrator voltage calculations

When verifying the 20pA-2µA current ranges and all charge ranges, you must calculate the actual calibrator voltages from the desired current or charge values and the characterized Model 5156 Calibration Standard resistor and capacitor values.

Current calculations

Calibrator voltages required for verification currents are calculated as follows:

$$V = IR$$

Where: V = required calibrator voltage
I = verification current
R = actual standard resistor value

For example, assume you are calibrating the 20pA range using an actual 100.5GΩ standard resistor value. The actual calibrator voltage is: 20pA × 100.5GΩ = 2.01V.

Charge calculations

Calibrator voltages for verification charge values are calculated as follows:

$$V = Q/C$$

Where: V = required calibrator voltage
Q = verification current
C = actual standard resistor value

For example, the required calibrator voltage for a 200nC range verification charge value with a 99.5nF standard capacitance value is: 200nC/99.5nF = 2.01005V.

Performing the verification test procedures

Test summary

- Volts measurement accuracy
- Amps measurement accuracy
- Ohms measurement accuracy
- Coulombs measurement accuracy

If Model 6514 is not within specifications and not under warranty, see the calibration procedures in Section 19 for information on calibrating the unit.

Test considerations

When performing the verification procedures:

- Restore Model 6514 factory front panel defaults and perform input bias current and voltage offset calibration as outlined below.
- Make sure that the test equipment is properly warmed up and properly connected to Model 6514 INPUT jack.
- Be sure test equipment is set up for the proper function and range.
- Allow the input signal to settle before making a measurement.
- Do not connect test equipment to Model 6514 through a scanner, multiplexer, or other switching equipment.

WARNING **The maximum common-mode voltage (voltage between analog common and chassis ground) is 500V peak, DC to 60Hz sine wave. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.**

CAUTION **The maximum input voltage is 250V peak, DC to 60Hz sine wave. Exceeding this voltage may result in instrument damage.**

Restoring factory defaults

Before performing *each* verification procedure, restore the instrument to its factory front panel defaults as follows:

1. Press SHIFT then SETUP. The instrument will display the following prompt:
   RESTORE: FACT
2. Using either RANGE key, select FACT, then restore the factory default conditions by pressing ENTER.

NOTE *You can use either RANGE key to select among FACT, GPIB, and USR setups. Be sure to use FACT defaults for the verification procedures.*

Input bias current and offset voltage calibration

Before performing the performance verification procedures, perform input bias current and offset voltage calibration as outlined below. Note that these offsets will be lost if power is cycled unless you save them first.

Offset voltage calibration

1. From the calibration menu, use the down RANGE key to display the following:
   CAL: VOFFSET
2. Press ENTER. The instrument will prompt for a short:
   INPUT SHORT
3. Connect the triax short (triax cable with red and alligator black clips connected together) to the rear panel INPUT jack.
4. Press ENTER to complete offset voltage calibration. The unit will display the following message:
   CALIBRATING

Input bias current calibration

1. Turn on the power, and allow a one-hour warm-up period before calibrating input bias current or offset voltage.
2. Restore factory defaults as outlined above.
3. Press SHIFT then CAL, and note that the unit displays the following:
   CAL: RUN
4. Use the down RANGE key to display the following:
   CAL: IOFFSET
5. Press ENTER. The instrument will prompt for an open input:
   INPUT CAP

6. Connect the triax shielding cap to the rear panel INPUT jack.
7. Press ENTER to complete input bias current calibration. The unit will display the following message: CALIBRATING

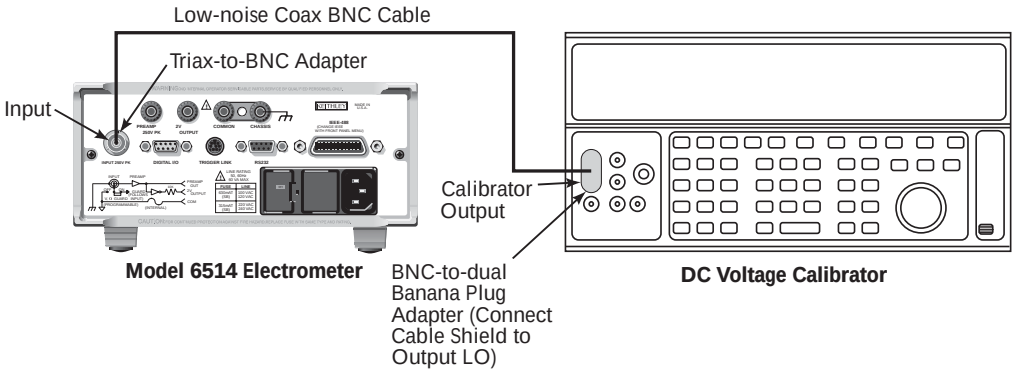
Volts measurement accuracy

Follow the steps below to verify that Model 6514 volts function measurement accuracy is within specified limits. The test involves applying accurate DC voltages and then verifying that Model 6514 voltage readings are within required limits.

WARNING **Hazardous voltages are used in the following procedures. Always place the calibrator in standby before changing test connections.**

1. With the power off, connect the voltage calibrator to Model 6514 INPUT jack, as shown in Figure 18-1. Use the appropriate triax-to-BNC, low-noise coaxial cable, and BNC-to-dual banana plug adapters where shown.

Figure 18-1 Connections for volts verification



2. Turn on the power and allow a one-hour warm-up period. Restore factory defaults and perform offset calibration as outlined above.
3. Select the DC volts function on Model 6514 by pressing the V key, and set the calibrator to output DC volts.
4. Select Model 6514 2V range with the down RANGE key.
5. Make sure zero check is enabled (press ZCHECK), then zero correct the instrument with ZCOR. Disable zero check.
6. Set the calibrator voltage to 0.0000V, and turn on the output.
7. Enable REL on Model 6514. Leave REL enabled for the remainder of the test.

8. Verify voltage measurement accuracy for each of the voltages listed in Table 18-2. For each test point:
   - Select the correct Model 6514 measurement range.
   - Set the calibrator voltage to the indicated value.
   - Verify that Model 6514 voltage reading is within the limits given in the table.
9. Repeat the procedure for negative source voltages with the same magnitudes as those listed in Table 18-2.

Table 18-2
Voltage measurement accuracy reading limits

Model 6514 range	**Calibrator voltage**	**Model 6514 volts reading limits (1 Year, 18˚C-28˚C)**
2V	2.00000V	1.99946 to 2.00054V
20V	20.0000V	19.9947 to 20.0053V
200V	200.000V	199.877 to 200.123V

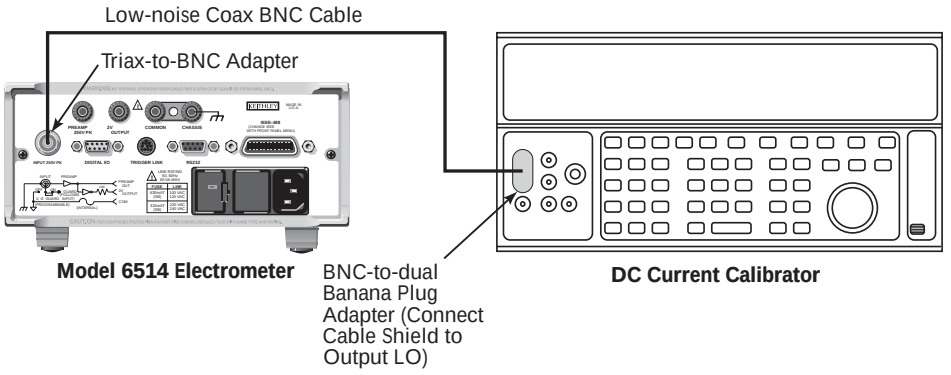
Amps measurement accuracy

Follow the steps below to verify that Model 6514 amps function measurement accuracy is within specified limits. The test involves applying accurate DC currents and then verifying that Model 6514 current readings are within required limits.

20µA-20mA range accuracy

1. Connect the current calibrator to Model 6514 INPUT jack, as shown in Figure 18-2. Use the appropriate triax-to-BNC, low-noise coaxial cable, and BNC-to-dual banana plug adapters where shown.

Figure 18-2 Connections for 20µA-20mA range verification



2. Select Model 6514 DC amps function with the I key, and set the calibrator to output DC current.
3. Set Model 6514 to the 20µA range using the up or down RANGE key.
4. With zero check enabled, zero correct Model 6514, then disable zero check.
5. Set the calibrator current to 0.0000µA, and make sure the output is turned on.
6. Enable Model 6514 REL mode. Leave REL enabled for the remainder of the test.
7. Verify current measurement accuracy for each of the currents listed in Table 18-3. For each test point:
   - Select the correct Model 6514 measurement range.
   - Set the calibrator current to the indicated value.
   - Verify that Model 6514 current reading is within the limits given in the table.

8. Repeat the procedure for negative source currents with the same magnitudes as those listed in Table 18-3.

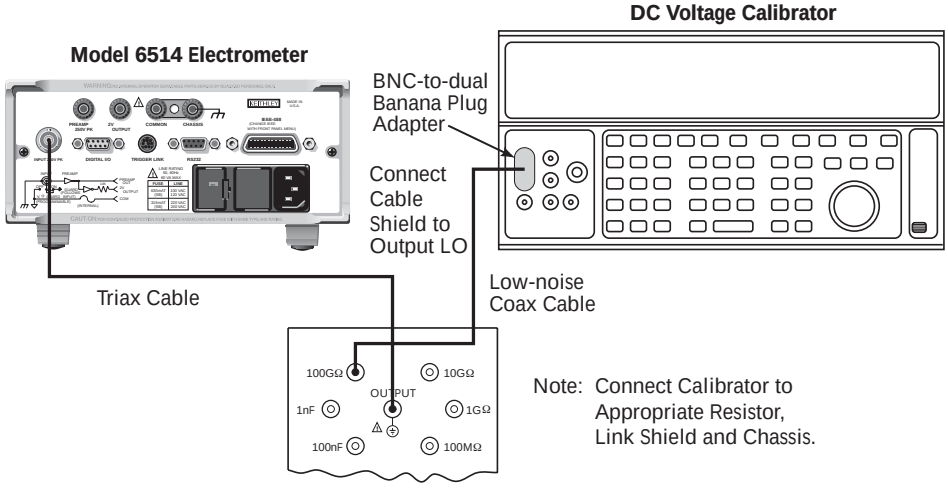
Table 18-3
20µA-20mA range current measurement accuracy reading limits

Model 6514 range	Calibrator current	Model 6514 amps reading limits (1 Year, 18˚C-28˚C)
20µA	20.0000µA	19.9795 to 20.0205µA
200µA	200.000µA	199.795 to 200.205µA
2mA	2.00000mA	1.99790 to 2.00210mA
20mA	20.0000mA	19.9795 to 20.0205mA

20pA-2µA range accuracy

1. Connect the voltage calibrator and Model 5156 Electrometer Calibration Standard to Model 6514 INPUT jack, as shown in Figure 18-3. Initially make connections to the 100GΩ resistor in the calibration standard.

Figure 18-3
Connections for 20pA-20µA range verification



2. Select the DC amps function on Model 6514, and set the calibrator to output DC voltage.
3. Set Model 6514 to the 20pA range.
4. With zero check enabled, zero correct the instrument, then disable zero check.
5. Set the calibrator voltage to 0.0000V, and make sure the output is turned on.
6. Enable Model 6514 REL mode. Leave REL enabled for the remainder of the test.

7. Verify current measurement accuracy for each of the currents listed in Table 18-4. For each test point:
   - Make connections to the indicated calibration standard resistor.
   - Select the correct Model 6514 measurement range.
   - Calculate the actual required calibrator voltage: V = IR, where I is the desired applied current, and R is the actual standard resistor value.
   - Set the calibrator to the calculated voltage.
   - Verify that Model 6514 current reading is within the reading limits listed in the table.
8. Repeat the procedure for negative source currents with the same magnitudes as those listed in Table 18-4.

Table 18-4
20pA-2µA range current measurement accuracy reading limits

Model 6514 range	**Nominal calibrator voltage**	**Calibration standard resistor[1]**	**Applied current**	**Actual voltage[2]**	**Model 6514 amps reading limits (1 Year, 18˚C-28˚C)**
20pA	2V	100GΩ	20.0000pA	_____V	19.7970 to 20.2030pA
200pA	2V	10GΩ	200.000pA	_____V	197.995 to 202.005pA
2nA	2V	1GΩ	2.00000nA	_____V	1.99570 to 2.00430nA
20nA	2V	100MΩ	20.0000nA	_____V	19.9595 to 20.0405nA
200nA	20V	100MΩ	200.000nA	_____V	199.595 to 200.405nA
2µA	200V	100MΩ	2.00000µA	_____V	1.99790 to 2.00210µA

[1] Nominal resistance values shown. Use actual characterized value for calculations.
[2] Calculate actual calibrator voltage as follows: V = IR, where I is desired applied current, and R is actual standard resistance value.

Ohms measurement accuracy

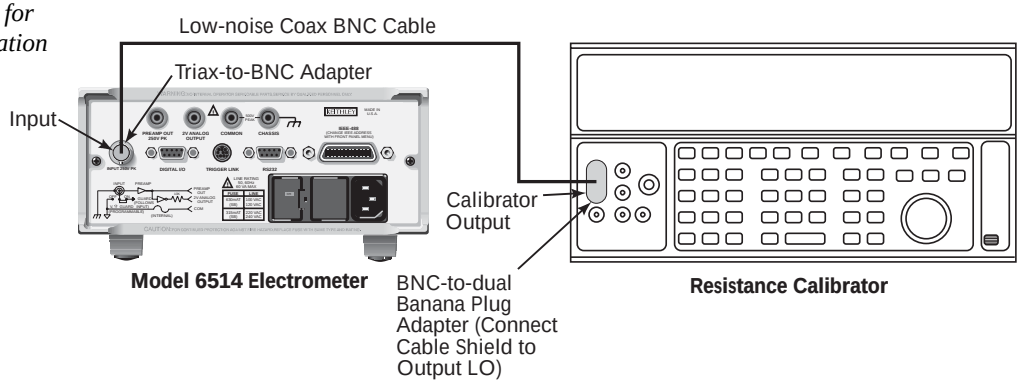
Follow the steps below to verify that Model 6514 ohms function measurement accuracy is within specified limits. This procedure involves applying accurate resistances from a resistance calibrator or standard and then verifying that Model 6514 resistance measurements are within required limits.

WARNING **With the ohms function selected, the Model 6514 can output an open-circuit voltage up to 250V. Place the unit in zero check when leads are not connected.**

2kΩ-20MΩ range accuracy

1. Connect the resistance calibrator to Model 6514 INPUT jack, as shown in Figure 18-4.

Figure 18-4 Connections for ohms verification (2kΩ-20MΩ ranges)



2. Select Model 6514 ohms function by pressing the Ω key, and set the calibrator to the resistance function.
3. With zero check enabled, zero correct the instrument, then disable zero check.
4. Output 0Ω from the calibrator, and then press REL.

5. Verify resistance measurement accuracy for the 2kΩ-20MΩ ranges as listed in Table 18-5. For each test point:

   - Select the correct Model 6514 measurement range.
   - Set the calibrator resistance to the indicated value.
   - If the calibrator resistance differs from the nominal value, recalculate new reading limits based on the resistance and Model 6514 accuracy specifications.
   - Verify that Model 6514 resistance reading is within the required reading limits.

Table 18-5
2kΩ-20MΩ range resistance measurement accuracy limits

Model 6514 range	**Calibrator resistance[1]**	**Model 6514 ohms reading limits (1 Year, 18˚C-28˚C)[2]**
2kΩ	1.9kΩ	1.89610 to 1.90390kΩ
20kΩ	19kΩ	18.9712 to 19.0288kΩ
200kΩ	190kΩ	189.522 to 190.478kΩ
2MΩ	1.9MΩ	1.89525 to 1.90475MΩ
20MΩ	19MΩ	18.9617 to 19.0383MΩ

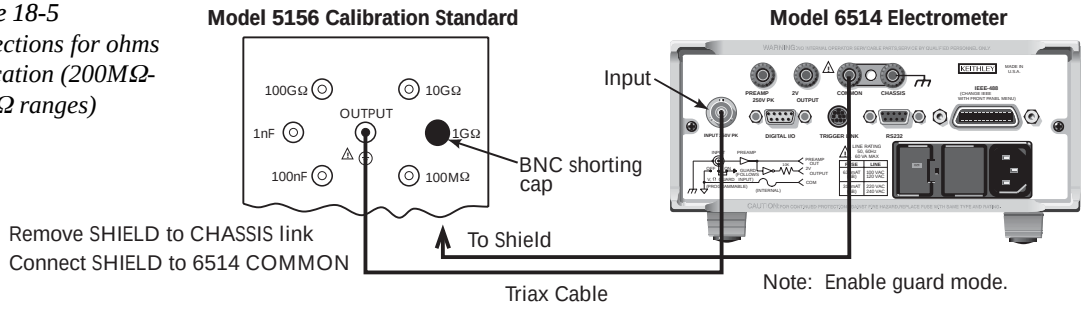
[1] Nominal resistance values.
[2] Reading limits based on Model 6514 accuracy specifications and nominal resistance values. If actual resistance values differ from nominal values shown, recalculate reading limits using actual calibrator resistance values and Model 6514 one-year accuracy specifications. See *Verification limits* earlier in this section for details.

200MΩ-200GΩ range accuracy

1. Connect Model 5156 Electrometer Calibration Standard to Model 6514, as shown in Figure 18-5. Initially, connect the BNC shorting cap to the 100MΩ resistance jack. Be sure to remove the link between SHIELD and CHASSIS, and connect Model 5156 CHASSIS jack to Model 6514 COMMON terminal.

WARNING **Hazardous voltage may be present on Model 5156 SHIELD and OUTPUT jacks.**

Figure 18-5
Connections for ohms verification (200MΩ-200GΩ ranges)



2. Select Model 6514 ohms function with the Ω key.
3. Using the GRD key, enable Model 6514 guard mode.
4. Verify resistance measurement accuracy for the 200MΩ-200GΩ ranges as listed in Table 18-6. For each test point:
   - Select the correct Model 6514 measurement range.
   - Connect the BNC shorting cap to select the appropriate standard resistor.
   - If the standard resistance differs from the nominal value, recalculate new reading limits based on the resistance and Model 6514 accuracy specifications.
   - Verify that Model 6514 resistance reading is within the required reading limits.

Table 18-6
200MΩ-200GΩ resistance measurement accuracy limits

Model 6514 range	Standard resistance[1]	Model 6514 ohms reading limits (1 Year, 18˚C-28˚C)[2]
200MΩ	100MΩ	99.697 to 100.303MΩ
2GΩ	1GΩ	0.98496 to 1.01504GΩ
20GΩ	10GΩ	9.8497 to 10.1503GΩ
200GΩ	100GΩ	98.497 to 101.503GΩ

[1] Nominal resistance values.

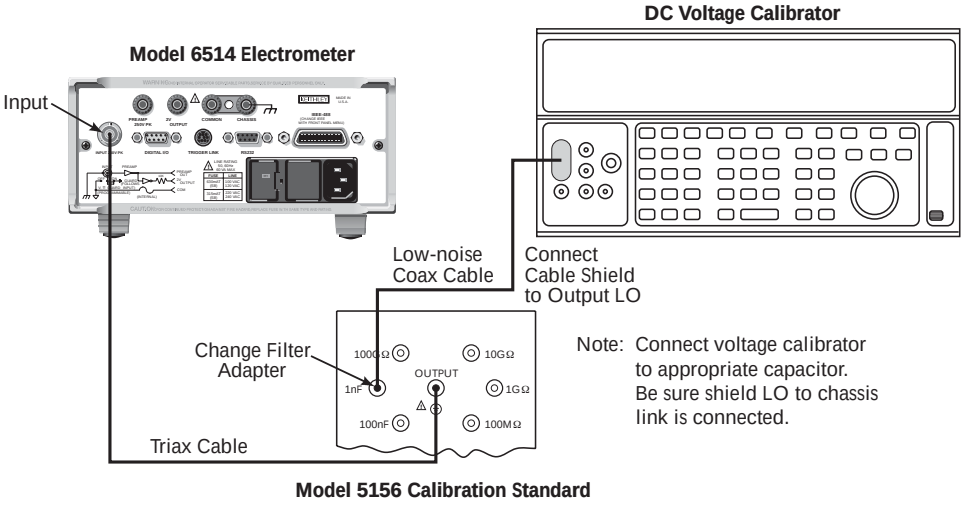
[2] Reading limits based on Model 6514 accuracy specifications and nominal resistance values. If actual resistance values differ from nominal values shown, recalculate reading limits using actual standard resistance values and Model 6514 one-year accuracy specifications. See *Verification limits* earlier in this section for details.

Coulombs measurement accuracy

Follow the steps below to verify that Model 6514 coulombs function measurement accuracy is within specified limits. The test involves applying accurate charge values and then verifying that Model 6514 readings are within required limits.

1. Connect the voltage calibrator and Model 5156 Electrometer Calibration Standard to Model 6514 INPUT jack, as shown in Figure 18-6. Be sure to use the charge filter as indicated. Initially, make connections to the 1nF capacitor, and be sure the link between SHIELD and CHASSIS is installed.

Figure 18-6 Connections for coulombs verification



2. Using the GRD key, make sure Model 6514 guard mode is disabled.
3. Select Model 6514 coulombs function by pressing the Q key, and set the calibrator to the DC volts function.
4. With zero check enabled, zero correct the instrument, then disable zero check.
5. Set the calibrator voltage to 0.0000V, and turn on its output.
6. Enable the REL mode, and leave REL enabled for the remainder of the test.

7. Verify charge measurement accuracy for each of the values listed in Table 18-7. For each test point:
   - Select the correct Model 6514 measurement range.
   - Make connections to the correct standard capacitor.
   - Calculate the required voltage from the desired charge and actual standard capacitance value: V = Q/C.
   - Disable zero check.
   - Set the calibrator voltage to the calculated value.
   - Verify that Model 6514 charge reading is within the required limits.
   - Enable zero check to discharge the capacitor.

Table 18-7
Coulombs measurement accuracy reading limits

Model 6514 range	**Nominal calibrator voltage**	**Standard capacitor[1]**	**Applied charge**	**Actual voltage[2]**	**Model 6514 coulombs reading limits (1 Year, 18˚C-28˚C)**
20nC	20V	1nF	20.0000nC	_____V	19.9915 to 20.0805nC
200nC	200V	1nF	200.000nC	_____V	199.195 to 200.805nC
2µC	20V	100nF	2.00000µC	_____V	1.97995 to 202.02005µC
20µC	200V	100nF	20.0000µC	_____V	19.7995 to 20.2005µC

[1] Nominal values.
[2] Calculate actual voltage from applied charge and actual capacitance value: V = Q/C.

19
Calibration

Introduction

Use the procedures in this section to calibrate Model 6514. These procedures require accurate test equipment to source precise DC voltages, currents, resistances and charge values.

WARNING **The information in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so. These procedures may expose you to hazardous voltages which could cause severe injury or death.**

Environmental conditions

Temperature and relative humidity

Conduct the calibration procedures at an ambient temperature of 18-28˚C (65-82˚F) with relative humidity of less than 70% unless otherwise noted.

Warm-up period

Allow Model 6514 to warm up for at least one hour before performing calibration.

If the instrument has been subjected to temperature extremes (those outside the ranges stated above), allow additional time for the instrument's internal temperature to stabilize. Typically, allow one extra hour to stabilize a unit that is 10˚C (18˚F) outside the specified temperature range.

Also, allow the test equipment to warm up for the minimum time specified by the manufacturer.

Line power

Model 6514 requires a line voltage of 100/120 VAC or 220/240 VAC at a line frequency of 50 or 60Hz. The instrument must be calibrated while operating from a line voltage within this range.

Calibration considerations

When performing the calibration procedures:

- Make sure that the test equipment is properly warmed up and connected to Model 6514 INPUT jack.
- Always allow the source signal to settle before calibrating each point.
- Do not connect test equipment to Model 6514 through a scanner or other switching equipment.
- If an error occurs during calibration, Model 6514 will generate an appropriate error message.

WARNING **The maximum common-mode voltage (voltage between common and chassis ground) is 500V peak. DC to 60Hz sine wave. Exceeding this value may cause a breakdown in insulation, creating a shock hazard.**

CAUTION **The maximum input voltage is 250V peak, DC to 60Hz sine wave. Exceeding this voltage may result in instrument damage.**

Calibration cycle

Perform calibration at least once a year to ensure the unit meets or exceeds its specifications.

Recommended calibration equipment

Table 19-1 lists the recommended equipment for the calibration procedures. You can use alternate equipment, but keep in mind that test equipment uncertainty will affect calibration accuracy. Calibration equipment should have accuracy specifications at least four times better than corresponding Model 6514 specifications.

Table 19-1
Recommended calibration equipment

Description	**Manufacturer/model**	**Specifications**
Calibrator	Fluke 5700A	DC voltage:[1] 2V: 7ppm 20V: 5ppm 200V: 7ppm DC current:[1] 20µA: 550ppm 200µA: 100ppm 2mA: 55ppm 20mA: 55ppm
Resistance calibrator	Fluke 5450A	Nominal resistance:[1] 1.9kΩ: 8ppm 1.9MΩ: 11.5ppm
Calibration standard	Keithley Model 5156	Nominal resistance:[2] 100MΩ: 200ppm 1GΩ: 300ppm 10GΩ: 400ppm 100GΩ: 500ppm Nominal capacitance:[2] 1nF: 1,000ppm 100nF: 1,000ppm
Triax cable	Keithley 7024-3	
Low-noise coax cable	Keithley 4801	
Triax-to-alligator clip cable[3]	Keithley 237-ALG-2	
Triax-to-BNC adapter	Keithley 7078-TRX-BNC	
Triax shielding cap	Keithley CAP-31	
BNC-to-double banana plug adapter	Pomona 1269	

[1] 90-day, 23˚ ±5˚C full-range accuracy specifications shown.
[2] 23˚ ±3˚C accuracy of characterization.
[3] Short red and black clips to make triax short.

Calibration errors

Model 6514 checks for errors after each calibration step, minimizing the possibility that improper calibration may occur due to operator error. If an error is detected during calibration, the instrument will display an appropriate error message. The unit will then prompt you to repeat the calibration step that caused the error.

Calibration menu

You can access the calibration menu by pressing SHIFT then CAL. The various selections are summarized in Table 19-2. Use the up or down RANGE key to scroll through these selections.

Table 19-2
Calibration menu

Menu item*	**Description**
RUN	Calibrates present function and range.
COUNT	Displays calibration count.
IOFFSET	Performs input bias current calibration.
VOFFSET	Performs offset voltage calibration.
DATES	Displays calibration and due dates.
UNLOCK	Unlocks calibration using code.
LOCK	Locks cal, exits to the main menu.
SAVE	Saves calibration constants.

* Press SHIFT then CAL to access. Use up or down RANGE to scroll through selections.

Aborting calibration

You can abort the calibration procedure at any time by pressing the EXIT key.

Current and charge calculations

When calibrating the 20pA-2μA current ranges and all charge ranges, you must calculate the actual current or charge values from the applied calibrator voltages and the characterized Model 5156 Calibration Standard resistor and capacitor values. You can either calculate these values manually (as in this section) or automatically as covered below.

Manual calculations

Current calculations

Calibration currents are calculated as follows:

$I = V/R$

Where: I = calibration current
V = calibrator voltage
R = actual standard resistor value

For example, assume you are calibrating the 20pA range using a 2V calibrator voltage with an actual 100.5GΩ standard resistor value. The actual calibration current is: 2V/100.5GΩ = 19.9004pA.

Charge calculations

Calibration charge values are calculated as follows:

$Q = CV$

Where: Q = calibration charge
C = actual standard capacitance value
V = calibrator voltage

For example, the 200nC range calibration charge value using 2V with a 99.5nF standard capacitance value is: 2V × 99.5nF = 199nC.

Automatic calculations

As an alternative to manual calculations, you can use a computer to read the standard values from Model 5156 via remote programming commands, and then have the computer perform the calculations. See Appendix H for details. Note that you can use the *OPT? command (Section 14) to determine if the Model 5156 is properly connected.

Calibration procedure

The calibration procedure should be performed in the following order:

- Preparing for calibration
- Offset voltage and input bias current calibration
- Volts calibration
- Amps calibration
- Coulombs calibration
- Ohms calibration
- Entering calibration dates and saving calibration
- Locking out calibration

NOTE Ohms calibration must be done last to allow charge to bleed off internal insulators.

Preparing for calibration

1. Turn on Model 6514 and the calibrator, and allow them to warm up for at least one hour before performing calibration.
2. Press SHIFT then CAL. The instrument will display the following:
   CAL: RUN
3. Use the up or down RANGE key to display the following:
   CAL: UNLOCK
4. Press ENTER. The instrument will prompt for the calibration code:
   CODE?
5. Enter the current calibration code on the display. (Factory default: 006514.) Use the up and down RANGE keys to select the letter or number, and use the left and right arrow keys to choose the position. Press ENTER to complete the process, and the unit will display:
   NEW CODE? N
6. With N displayed, press ENTER.

Input bias current and offset voltage calibration

Before performing the remaining calibration steps, perform input bias current and offset voltage calibration as outlined below.

Offset voltage calibration

1. From the calibration menu, use the up or down RANGE key to display the following:
   CAL: VOFFSET
2. Press ENTER. The instrument will prompt for a short:
   INPUT SHORT

3. Connect the triax short (triax cable with red and black alligator clips connected together) to the rear panel INPUT jack.
4. Press ENTER to complete offset voltage calibration.

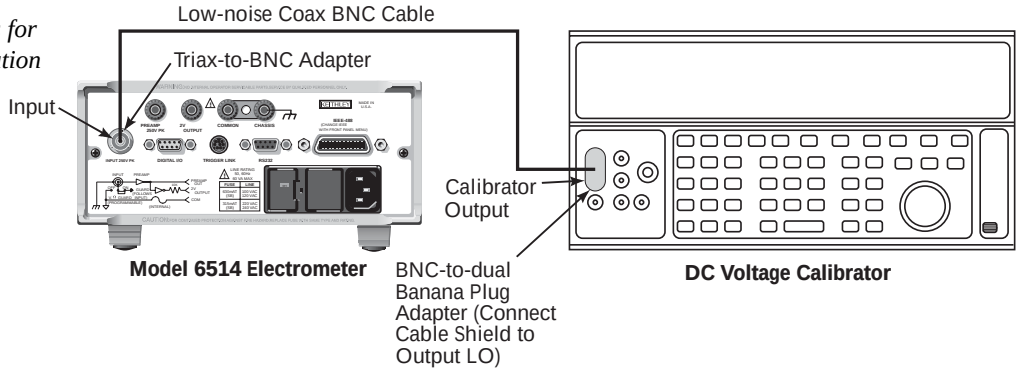
Input bias current calibration

1. From the calibration menu, use the down RANGE key to display the following:
   CAL: IOFFSET
2. Press ENTER. The instrument will prompt for an open input:
   INPUT CAP
3. Connect the triax shielding cap to the rear panel INPUT jack.
4. Press ENTER to complete input bias current calibration.

Volts calibration

1. Connect the voltage calibrator to Model 6514 INPUT jack, as shown in Figure 19-1. Be sure to use the low-noise coaxial cable and appropriate adapters as shown.

Figure 19-1
Connections for volts calibration



2. Select Model 6514 volts function by pressing the V key, and set the calibrator to output DC volts.
3. Select Model 6514 2V range and make sure the calibrator output is turned on.
4. Press SHIFT then CAL to access the calibration menu. The unit will display the following:
   CAL:RUN
5. Press ENTER. The unit will prompt for the zero calibration point:
   2V ZERO
6. Connect a triax short to the INPUT jack, and then press ENTER.
7. The unit will prompt for the +2V cal point:
   +2V CAL

8. Press ENTER. The unit will display the following for the positive full-scale calibration voltage:
   2.000000 DCV
9. Set the calibrator output voltage to +2.000000V, then adjust Model 6514 display to agree with that value.

NOTE *If your calibrator cannot source the recommended calibration values, use the closest values, then set Model 6514 display to agree with the calibrator signal levels. Use the up and down RANGE keys to select the digit value, and use the left and right arrow keys to choose the digit position.*

10. Press ENTER. The unit will prompt for the negative full-scale calibration point:
    -2V CAL
11. Press ENTER. The Model 6514 will prompt for the negative full-scale calibration voltage:
    -2.000000 VDC
12. Set the calibrator output voltage to -2.000000V, then adjust the display to agree with the calibrator voltage. Press ENTER to complete calibration of the present range.
13. Press EXIT to return to normal display.
14. Repeat steps 3 through 13 for the 20V and 200V ranges using Table 19-3 as a guide.

Table 19-3
Volts calibration summary

Model 6514 range	**Calibrator voltages***
2V	Triax short
	+2.000000V
	-2.000000V
20V	Triax short
	+20.00000V
	-20.00000V
200V	Triax short
	+200.0000V
	-200.0000V

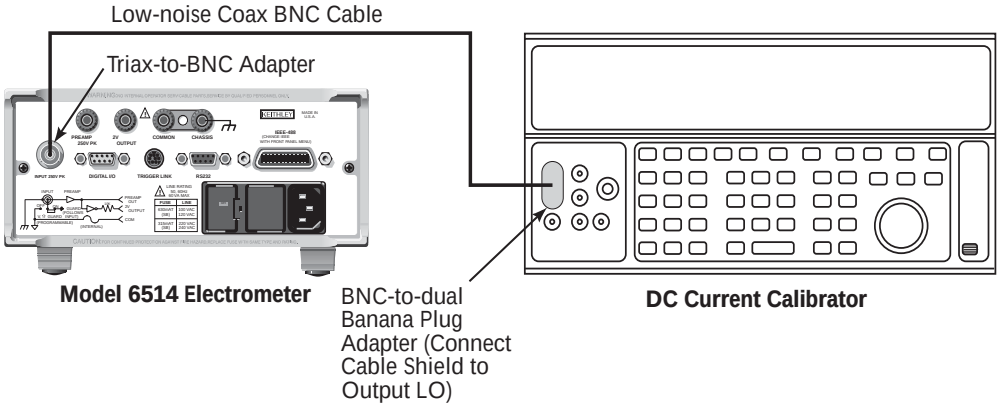
* Calibrate zero, positive full-scale, and negative full-scale for each range.

Amps calibration

20µA-20mA range calibration

1. Connect the triax shielding cap to the Model 6514 INPUT jack.

Figure 19-2 Connections for 20µA-20mA range calibration



2. Select Model 6514 amps function by pressing the I key, and set the calibrator to output DC current.
3. Select Model 6514 20µA range, and make sure the calibrator output is turned on.
4. Press SHIFT then CAL, then press ENTER at the CAL: RUN prompt. The unit will prompt for the zero calibration point:

   20µA ZERO
5. Connect the triax shielding cap to the INPUT jack, allow 15 seconds for settling, and then press ENTER.
6. Connect the current calibrator to the Model 6514 INPUT jack, as shown in Figure 19-2.
7. The unit will prompt for the positive full-scale cal point:

   +20µA CAL
8. Press ENTER. The unit will prompt for the positive full-scale current:

   20.00000 µA
9. Set the calibrator current to +20.00000µA, then adjust the display to agree with the calibrator current. Allow 15 seconds for settling.
10. Press ENTER. The unit will prompt for the negative full-scale calibration point:

    -20µA CAL
11. Press ENTER. Model 6514 will prompt for the negative full-scale calibration current:

    -20.00000 µA
12. Set the calibrator output to —20.00000µA, then adjust the display to agree with the calibrator value. Allow 15 seconds for settling, then press ENTER to complete calibration of the present range.
13. Press EXIT to return to normal display.
14. Repeat steps 1 through 13 for the 200µA through 20mA ranges using Table 19-4 as a guide.

Table 19-4
*20*µA-20mA range amps calibration summary

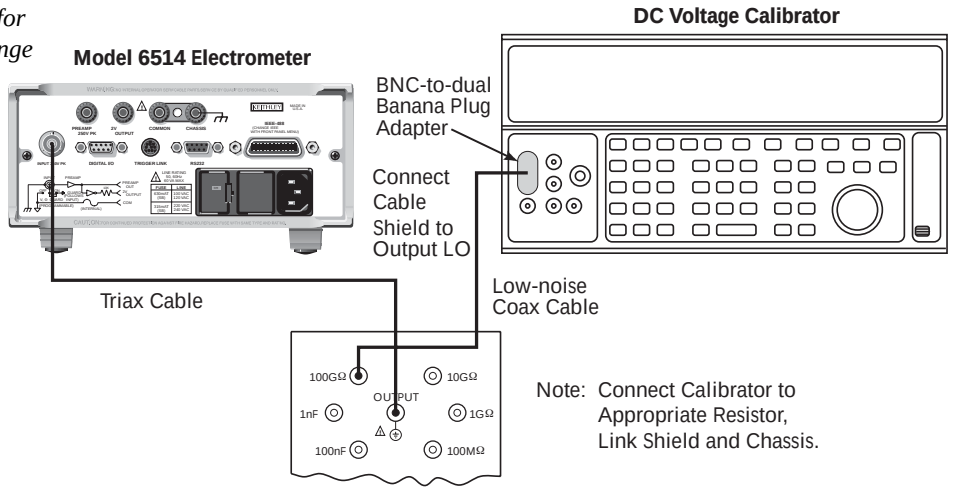
Model 6514 range	Calibrator currents*	Settling time**
20µA	0µA	>15 sec.
	+20.00000µA	>15 sec.
	-20.00000µA	>15 sec.
200µA	0µA	>15 sec.
	+200.0000µA	>15 sec.
	-200.0000µA	>15 sec.
2mA	0mA	>15 sec.
	+2.000000mA	>15 sec.
	-2.000000mA	>15 sec.
20mA	0mA	>15 sec.
	+20.00000mA	>15 sec.
	-20.00000mA	>15 sec.

* Calibrate zero, positive full-scale, and negative full-scale for each range. Triax cap used for zero cal points.
** Allow calibration signal to settle for indicated time before calibrating each point.

20pA-2µA range calibration

1. Connect the triax shielding cap to the Model 6514 INPUT jack.

Figure 19-3
Connections for 20pA-2µA range calibration



2. Select the amps function on Model 6514.
3. Select Model 6514 20pA range.
4. Press SHIFT then CAL, then press ENTER at the CAL: RUN prompt. The unit will prompt for the zero calibration point:

   20PA ZERO
5. Allow the settling time listed in Table 19-5, then press ENTER.
6. The instrument will prompt for the positive full-scale calibration point:

   +20PA CAL
7. Connect the voltage calibrator and Model 5156 Electrometer Calibration standard to the Model 6514 INPUT jack, as shown in Figure 19-3. Initially, make connections to the 100GΩ resistance.
8. Press ENTER. The instrument will prompt a full-scale calibration current:

   20.00000 PA
9. Set the calibrator voltage to +2.000000V. Calculate the actual calibration current from the calibrator voltage and the actual standard resistor value: I = V/R. Adjust Model 6514 display to agree with the calculated current. Allow the settling time listed in Table 19-5, then press ENTER.
10. Model 6514 will prompt for the negative full-scale calibration point:

    -20PA CAL
11. Press ENTER. The instrument will prompt for the negative full-scale current:

    -20.00000 PA
12. Set the calibrator output voltage to -2.000000V, then calculate the calibration current from the calibrator voltage and standard resistor value: I = V/R. Adjust Model 6514 display to agree with the calculated current. Allow the settling time listed in Table 19-5, then press ENTER to complete calibration of the present range.
13. Press EXIT to return to normal display.
14. Repeat steps 1 through 13 for the 200pA through 2μA ranges using Table 19-5 as a guide. Be sure to make connections to the correct standard resistor.

Table 19-5
20pA-2µA range amps calibration summary

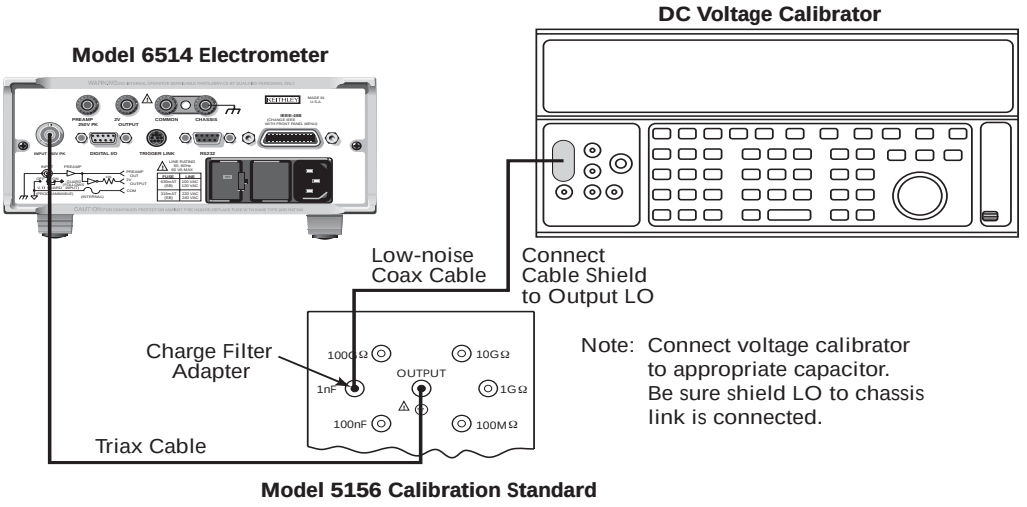
Model 6514 range	Calibrator voltages	Standard resistor[1]	Calibration currents[2]	Settling time[3]
20pA		100GΩ	0pA	> 2 min.
	+2.000000V	100GΩ	+20pA	> 2 min.
	-2.000000V	100GΩ	-20pA	> 2 min.
200pA		10GΩ	0pA	> 2 min.
	+2.000000V	10GΩ	+200pA	> 2 min.
	-2.000000V	10GΩ	-200pA	> 2 min.
2nA		1GΩ	0nA	> 15 sec.
	+2.000000V	1GΩ	+2nA	> 15 sec.
	-2.000000V	1GΩ	-2nA	> 15 sec.
20nA		1GΩ	0nA	> 15 sec.
	+20.00000V	1GΩ	+20nA	> 15 sec.
	-20.00000V	1GΩ	-20nA	> 15 sec.
200nA		100MΩ	0nA	> 15 sec.
	+20.00000V	100MΩ	+200nA	> 15 sec.
	-20.00000V	100MΩ	-200nA	> 15 sec.
2µA		100MΩ	0µA	> 15 sec.
	+200.0000V	100MΩ	+2µA	> 15 sec.
	-200.0000V	100MΩ	-2µA	> 15 sec.

[1] Nominal resistance values.
[2] Nominal currents. Calculate actual currents from calibrator voltage and actual standard resistor value: I = V/R. Calibrate zero, positive full-scale, and negative full-scale for each range. Triax cap used for zero cal points.
[3] Allow calibration signal to settle for indicated time before calibrating each point.

Coulombs calibration

1. Connect the voltage calibrator and Model 5156 Calibration Standard to Model 6514 INPUT jack, as shown in Figure 19-4. Initially, make connections to the 1nF capacitor. Also be sure to connect the link between SHIELD and CHASSIS.

Figure19-4 Connections for coulombs



2. Select Model 6514 coulombs function by pressing the Q key, and set the calibrator to output volts.
3. Using the GRD key, disable Model 6514 guard mode.
4. Select Model 6514 20nC range, make sure the calibrator output is turned on and set the output to 0V.
5. Press SHIFT then CAL, then press ENTER at the CAL: RUN prompt. The unit will prompt for the positive full-scale calibration point:

   +20nC CAL

6. Press ENTER. The unit will prompt for the positive full-scale calibration value:

   20.0000nC

7. Set the calibrator voltage to +20.00000V. Compute the actual charge from the calibrator voltage and actual capacitance value: Q = CV. Adjust Model 6514 display to agree with that charge value, then press ENTER.
8. Model 6514 will prompt for the zero calibration point:

   2nC ZERO

9. Press ENTER to complete zero calibration for the present range and then set the calibrator to output 0V. Model 6514 will next prompt for the negative full-scale calibration point:

   -20nC CAL

10. Press ENTER. Model 6514 will prompt for the negative full-scale charge value: -20.0000nC
11. Set the calibrator output voltage to -20.00000V. Calculate the actual charge from the calibrator voltage and actual standard capacitor value: Q = CV. Adjust Model 6514 display to agree with the calculated charge value, then press ENTER to complete calibration of the present range.
12. Press EXIT to return to normal display.
13. Repeat steps 4 through 12 for the 200nC through 20µC ranges using Table 19-6 as a guide.

Table 19-6
Coulombs calibration summary

Model 6514 range	**Calibrator voltage**	**Standard capacitance[1]**	**Calibration charge[2]**
20nC	+20.00000V	1nF	+20nC
	-20.00000V	1nF	-20nC
200nC	+200.0000V	1nF	+200nC
	-200.0000V	1nF	-200nC
2µC	+20.00000V	100nF	+2µC
	-20.00000V	100nF	-2µC
20µC	+200.0000V	100nF	+20µC
	-200.0000V	100nF	-20µC

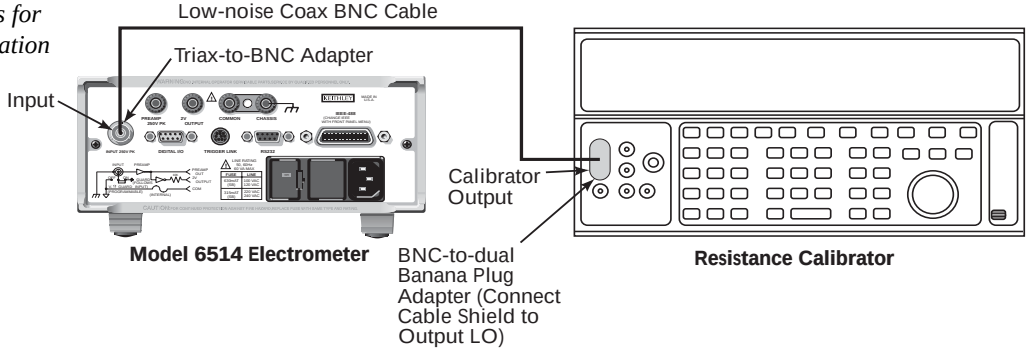
[1] Nominal value.
[2] Based on nominal capacitance values. Calculate actual charge from calibrator voltage and actual standard capacitance value: Q = CV. Calibrate positive full-scale, and negative full-scale values for each range.

Ohms calibration

NOTE Calibration is required only for the 2kΩ, 2MΩ, and the 2GΩ ranges. However, other ranges may also be calibrated using appropriate calibration resistances if desired. Volts should be calibrated before ohms.

1. Connect the triax short to the INPUT jack (triax alligator cable with red and black leads connected together).

Figure 19-5 Connections for ohms calibration (2kΩ and 2MΩ ranges)



2. Select Model 6514 ohms function by pressing the Ω key.
3. Select Model 6514 2kΩ range.
4. Press SHIFT then CAL. At the CAL:RUN prompt, press ENTER. The unit will prompt as follows:

   2KOHM ZERO

NOTE Zero calibration is performed only on the 2kΩ range.

5. Press ENTER. The unit will prompt for the calibration resistance:

   INPUT 2KOHM

6. Press ENTER. The unit will prompt for the actual resistance:
   2.000000KOHM
7. Connect the resistance calibrator to the Model 6514 INPUT jack, as shown in Figure 19-5.
8. Select the 1.9kΩ calibrator resistance.
9. Adjust Model 6514 display to agree with the actual calibration resistance, then press ENTER to complete calibration of the present range.
10. Press EXIT to return to normal display.
11. Repeat steps 3 through 10 for the 2MΩ range using the 1.9MΩ calibrator resistance. (See Table 19-7.)

12. Disconnect the resistance calibrator, and connect the 1GΩ calibration standard resistor to Model 6514 INPUT jack, as shown in Figure 19-6. Be sure to remove the link between Model 5156 SHIELD and CHASSIS terminals. Also connect Model 5156 CHASSIS terminal to Model 6514 COMMON jack.

WARNING **Hazardous voltages may be present on Model 5156 SHIELD and OUTPUT terminals.**

13. Using the GRD key, enable Model 6514 guard mode.
14. Repeat steps 3 through 10 for the 2GΩ range. Be sure to set Model 6514 display to the actual standard resistance value.

Figure 19-6
Connections for ohms calibration (2GΩ range)

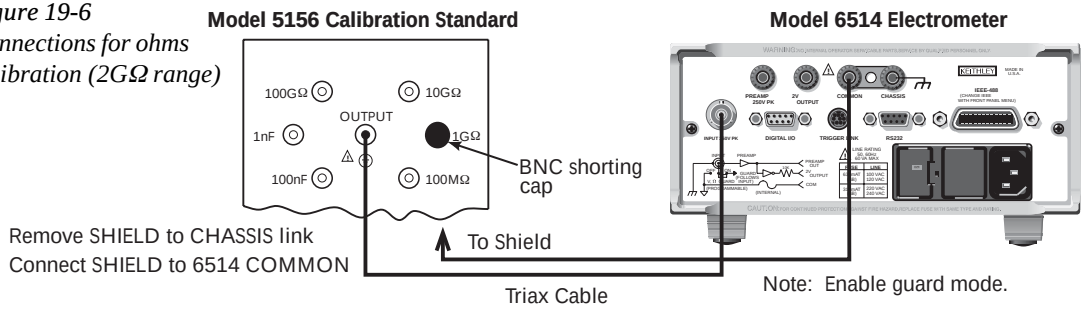


Table 19-7
Ohms calibration summary

Model 6514 range	Calibration resistance*
2kΩ**	1.9kΩ
2MΩ	1.9MΩ
2GΩ	1GΩ

* Nominal values. Use actual values for calibration. Use resistance calibrator for 2kΩ and 2MΩ ranges. Use calibration standard resistor for 1GΩ range.

** Zero also calibrated on 2kΩ range.

Entering calibration dates and saving calibration

NOTE *For temporary calibration without saving new calibration constants, proceed to Locking out calibration.*

1. Press SHIFT then CAL to access the calibration menu.
2. Use either RANGE key to display the following:
   CAL: DATES
3. Press ENTER. The unit will display:
   DATE: 06/15/98
4. Use the arrow and RANGE keys to set the date, then press ENTER. The unit will then prompt for the calibration due date:
   NDUE: 06/15/99
5. Set the due date as desired, then press ENTER.
6. Select CAL: SAVE from the calibration menu, then press ENTER. The unit will prompt as follows:
   SAVE CAL?YES
7. With the YES prompt displayed, press ENTER to save and lock out calibration. The unit will display:
   CAL SAVED

NOTE *Calibration will also be locked out once saved.*

Locking out calibration

Use the following procedure to lock out calibration without saving new calibration constants:

1. Press SHIFT then CAL, then use the up RANGE key to display the following:
   CAL: LOCK
2. Press ENTER. The instrument will display the following message:
   CAL LOCKED.

Changing the calibration code

Follow the steps below to change the calibration code:

1. Press SHIFT then CAL. The instrument will display the following:
   CAL: RUN
2. Use the up or down RANGE key to display the following:
   CAL: UNLOCK
3. Press ENTER. The instrument will prompt for the present calibration code:
   CODE?

4. Enter the present calibration code on the display. (Factory default: 006514.) Use the up and down RANGE keys to select the letter or number, and use the left and right arrow keys to choose the position. Press ENTER to complete the process, and the unit will display:
   NEW CODE? Y/N
5. Select Y, then press ENTER. The unit will prompt for the new code:
   CODE? 000000
6. Enter the new code, then press ENTER.
7. Using the LOCK selection in the calibration menu, lock out calibration after changing the code.

Resetting the calibration code

If you forget the calibration code, you can unlock calibration by shorting together the CAL pads, which are located on the display circuit board inside the unit. Doing so will also reset the code to the factory default (006514).

Displaying calibration dates

To display calibration dates at any time:

1. From normal display, press SHIFT then CAL. The unit will display the following:
   CAL: RUN
2. Use either RANGE key to select CAL: DATES, then press ENTER. Model 6514 will display the last calibration date, for example:
   DATE: 06/15/98
3. Press ENTER to view the calibration due date, for example:
   NDUE: 06/15/99
4. Press EXIT to return to normal display.

Displaying the calibration count

To display the calibration count at any time:

1. From normal display, press SHIFT then CAL. The unit will display the following:
   CAL: RUN
2. Use either RANGE key to select CAL:COUNT from the calibration menu, then press ENTER. For example:
   COUNT: 1
3. Press EXIT to return to normal display.

20
Routine Maintenance

Introduction

The information in this section deals with routine type maintenance that can be performed by the operator and includes procedures for setting the line voltage and replacing the line fuse, and running the front panel tests.

Setting line voltage and replacing line fuse

WARNING **Disconnect the line cord at the rear panel, and remove all test leads connected to the instrument (front and rear) before replacing the line fuse.**

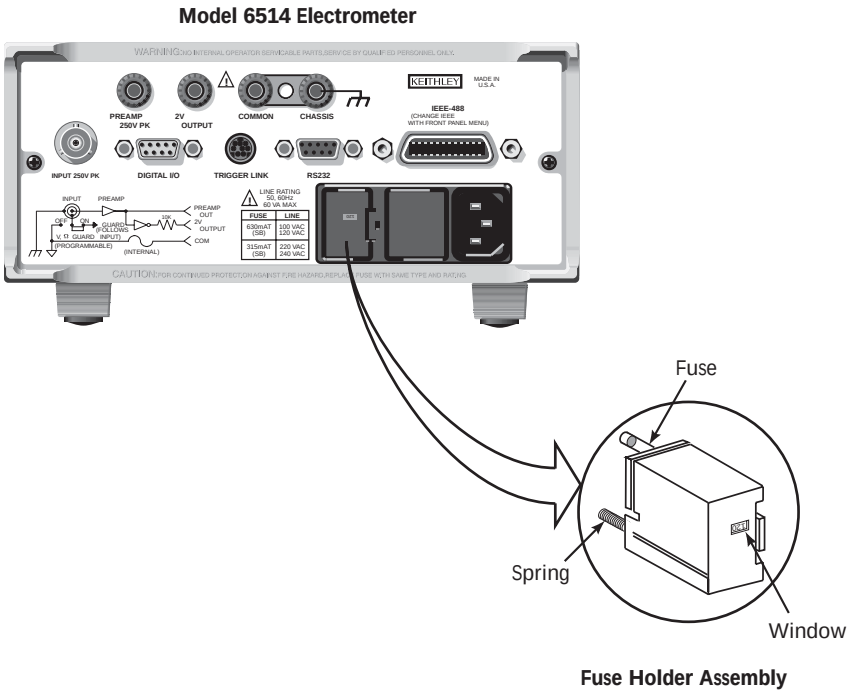
The power line fuse is located in the power module next to the AC power receptacle (see Figure 20-1). If the line voltage must be changed, or if the line fuse requires replacement, perform the following steps:

1. Place the tip of a flat-blade screwdriver into the power module by the fuse holder assembly (see Figure 20-1). Gently push in and to the left. Release pressure on the assembly, and its internal spring will push it out of the power module.
2. Remove the fuse, and replace it with the type listed in Table 20-1.

CAUTION **For continued protection against fire or instrument damage, replace the fuse only with the type and rating listed. If the instrument repeatedly blows fuses, it will require servicing.**

3. If configuring the instrument for a different line voltage, remove the line voltage selector from the assembly, and rotate it to the proper position. When the selector is installed into the fuse holder assembly, the correct line voltage appears inverted in the window.
4. Install the fuse holder assembly into the power module by pushing it in until it locks in place.

Figure 20-1
Power module



Fuse Holder Assembly

Table 20-1
Power line fuse

Line voltage	**Rating**	**Keithley part no.**
100/120V	0.63A, 250V, 5x20mm, slow blow	FU-106-.630
220/240V	0..315A, 250V, 5x20mm, slow-blow	FU-106-.315

Front panel tests

The front panel tests are summarized in Table 20-2. To run a test, simply press SHIFT then TEST, then scroll through the menu choices and press ENTER.

Table 20-2
Front panel tests

Test	Description
DISP	Test display
KEY	Test front panel keys

DISP test

The display test allows you to verify that each segment and annunciator in the vacuum fluorescent display is working properly. Perform the following steps to run the display test:

1. Press SHIFT and then TEST to access the self-test options.
2. Use the up or down RANGE key to display "TEST: DISP".
3. Press ENTER to start the test. There are four parts to the display test. Each time ENTER is pressed, the next part of the test sequence is selected. The four parts of the test sequence are as follows:
   - All annunciators are displayed.
   - The segments of each digit are sequentially displayed.
   - The 12 digits (and annunciators) are sequentially displayed.
   - The annunciators located at either end of the display are sequentially displayed.
4. When finished, abort the display test by pressing EXIT. The instrument returns to normal operation.

KEY test

The KEY test allows you to check the functionality of each front panel key. Perform the following steps to run the KEY test:

1. Press SHIFT and then TEST to access the self-test options.
2. Use the up or down RANGE key to display "TEST: KEY".
3. Press ENTER to start the test. When a key is pressed, the label name for that key is displayed to indicate that it is functioning properly. When the key is released, the message "NO KEY PRESS" is displayed.
4. Pressing EXIT tests the EXIT key. However, the second consecutive press of EXIT aborts the test and returns the instrument to normal operation.

A
Specifications

VOLTS

RANGE	5½ DIGIT RESOLUTION	ACCURACY (1 Year)[1] 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C
2 V	10 µV	0.025 + 4	0.003 + 2
20 V	100 µV	0.025 + 3	0.002 + 1
200 V	1mV	0.06 + 3	0.002 + 1

Note:
[1] When properly zeroed, 5½-digit. Rate: Slow (100ms integration time).

NMRR: 60dB on 2V, 20V, >55dB on 200V, at 50Hz or 60Hz ±0.1%.

CMRR: >120dB at DC, 50Hz or 60Hz.

INPUT IMPEDANCE: >200TΩ in parallel with 20pF, < 2pF guarded (10MΩ with zero check on).

SMALL SIGNAL BANDWIDTH AT PREAMP OUTPUT: Typically 100kHz (–3dB).

AMPS

RANGE	5½ DIGIT RESOLUTION	ACCURACY (1 Year)[1] 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C
20 pA	100 aA[2]	1 + 30	0.1 + 5
200 pA	1 fA[2]	1 + 5	0.1 + 1
2 nA	10 fA	0.2 + 30	0.1 + 2
20 nA	100 fA	0.2 + 5	0.03 + 1
200 nA	1 pA	0.2 + 5	0.03 + 1
2 µA	10 pA	0.1 + 10	0.005 + 2
20 µA	100 pA	0.1 + 5	0.005 + 1
200 µA	1 nA	0.1 + 5	0.005 + 1
2 mA	10 nA	0.1 + 10	0.008 + 2
20 mA	100 nA	0.1 + 5	0.008 + 1

Notes:
[1] When properly zeroed, 5½-digit. Rate: Slow (100ms integration time).
[2] aA =10^{-18}A, fA=10^{-15}A.

INPUT BIAS CURRENT: <3fA at T_{CAL} (user adjustable). Temperature coefficient = 0.5fA/°C .

INPUT BIAS CURRENT NOISE: <750aA p-p (capped input), 0.1Hz to 10Hz bandwidth, damping on. Digital filter = 40 readings.

INPUT VOLTAGE BURDEN at T_{CAL} ±1°C (user adjustable)**:**

<20µV on 20pA, 2nA, 20nA, 2µA, 20µA ranges.
<100µV on 200pA, 200nA, 200µA ranges.
<2mV on 2mA range.
<4mV on 20mA range.

TEMPERATURE COEFFICIENT OF INPUT VOLTAGE BURDEN: <10µV/°C on pA, nA, µA ranges.

PREAMP SETTLING TIME (to 10% of final value): 2.5s typical on pA ranges, damping off, 3s typical on pA ranges damping on, 15ms on nA ranges, 5ms on µA and mA ranges.

NMRR: >95dB on pA, 60dB on nA, µA, and mA ranges at 50Hz or 60Hz ±0.1%. Digital Filter = 40.

OHMS

RANGE	5½-DIGIT RESOLUTION	ACCURACY (1Year)[1] 18°–28°C ±(% rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(% rdg+counts)/°C	TEST CURRENT (nominal)
2 kΩ	10 mΩ	0.20+ 10	0.01 + 2	0.9 mA
20 kΩ	100 mΩ	0.15+ 3	0.01 + 1	0.9 mA
200 kΩ	1 Ω	0.25+ 3	0.01 + 1	0.9 mA
2 MΩ	10 Ω	0.25+ 4	0.02 + 2	0.9 µA
20 MΩ	100 Ω	0.25+ 3	0.02 + 1	0.9 µA
200 MΩ	1 kΩ	0.30+ 3	0.02 + 1	0.9 µA
2 GΩ	10 kΩ	1.5 + 4	0.04 + 2	0.9 nA
20 GΩ	100 kΩ	1.5 + 3	0.04 + 1	0.9 nA
200 GΩ	1 MΩ	1.5 + 3	0.04 + 1	0.9 nA

[1] When properly zeroed, 5½ digit. Rate: Slow (100ms integration time).

MAXIMUM OPEN CIRCUIT VOLTAGE: 250VDC.

PREAMP SETTLING TIME (To 10% of final reading with <100pF input capacitance): 2kΩ through 200kΩ: 2ms; 20MΩ through 200MΩ: 90ms. 2GΩ through 200GΩ: 1s.

COULOMBS

RANGE	6½ DIGIT RESOLUTION	ACCURACY (1 Year)[1,2] 18°–28°C ±(%rdg+counts)	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C
20 nC	10 fC	0.4 + 50	0.04 + 10
200 nC	100 fC	0.4 + 50	0.04 + 10
2 µC	1 pC	1 + 50	0.05 + 10
20 µC	10 pC	1 + 50	0.05 + 10

Notes:

[1] Charge acquisition time must be <1000s, derate 2% for each additional 10,000s.

[2] When properly zeroed, 6½ digit. Rate: Slow (100ms integration time).

INPUT BIAS CURRENT: <4fA at T_{CAL}. Temperature coefficient = 0.5fA/°C.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

IMPLEMENTATION: SCPI (IEEE-488.2, SCPI-1996.0); DDC (IEEE-488.1).

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Function, Range, Zero Check, Zero Correct, EOI (DDC mode only), Trigger, Terminator (DDC mode only), Data Storage 2500 Storage, Calibration (SCPI mode only), Display Format, SRQ, REL, Output Format, Guard, V-offset Cal, I-offset Cal.

ADDRESS MODES: TALK ONLY and ADDRESSABLE.

LANGUAGE EMULATION: 6512, 617, 617HIQ emulation via DDC mode.

TRIGGER TO READING DONE: 150ms typical, with external trigger.

RS-232 IMPLEMENTATION:

Supports: SCPI 1996.0.
Baud Rates: 300, 600, 1200, 2400, 4800, 9600, 19.2k, 38.4k, 57.6k.
Protocols: Xon/Xoff, 7 or 8 bit ASCII, parity-odd/even/none.
Connector: DB-9 TXD/RXD/GND.

GENERAL

DISPLAY: 6½-digit vacuum fluorescent.

OVERRANGE INDICATION: Display reads "OVRFLOW".

RANGING: Automatic or manual.

CONVERSION TIME: Selectable 0.01 PLC to 10 PLC.

PROGRAMS: Provide front panel access to IEEE address, choice of engineering units or scientific notation, and digital calibration.

MAXIMUM INPUT: 250V peak, DC to 60Hz sine wave; 10s per minute maximum on mA ranges.

MAXIMUM COMMON MODE VOLTAGE (DC to 60Hz sine wave): Electrometer, 500V peak;

ISOLATION (Meter COMMON to chassis): Typically $10^{10}\Omega$ in parallel with 500pF.

INPUT CONNECTOR: Three lug triaxial on rear panel.

2V ANALOG OUTPUT: 2V for full range input. Inverting in Amps and Coulombs mode. Output impedance 10kΩ.

PREAMP OUTPUT: Provides a guard output for Volts measurements. Can be used as an inverting output or with external feedback in Amps and Coulombs modes.

DIGITAL INTERFACE:
Handler Interface: Start of test, end of test, 3 category bits.
Digital I/O: 1 Trigger input, 4 outputs with 500mA sink capability.
Connector: 9 Pin D subminiature, male pins.

EMC: Conforms with European Union Directive 89/336/EEC EN55011, EN50082-1, EN61000-3-2, EN61000-3-3, FCC part 15 class B.

SAFETY: Conforms with European Union Directive 73/23/EEC EN61010-1.

GUARD: Switchable voltage and ohm guard available.

TRIGGER LINE: Available, see manual for usage.

READING STORAGE: 2500 readings.

READING RATE:

To internal buffer	1200 readings/second[1]
To IEEE-488 bus	500 readings/second[1,3]
To front panel	17 readings/second at 60Hz;[2]
	15 readings/second at 50Hz[2]

Notes:
[1] 0.01 PLC, digital filters off, front panel off, auto zero off.
[2] 1.00 PLC, digital filters off.
[3] Binary transfer mode.

DIGITAL FILTER: Median and averaging (selectable from 2 to 100 readings).

DAMPING: User selectable on Amps function.

ENVIRONMENT:
Operating: 0°–50°C; relative humidity 70% non-condensing, up to 35°C.
Storage: –25° to +65°C.

WARM-UP: 1 hour to rated accuracy (see manual for recommended procedure).

POWER: 90–125V or 210–250V, 50–60Hz, 60VA.

PHYSICAL:
Case Dimensions: 90mm high × 214mm wide × 369mm deep (3½ in. × 8⅜ in. × 14⁹⁄₁₆ in.).
Working Dimensions: From front of case to rear including power cord and IEEE-488 connector: 15.5 inches.
Net Weight: <4.6 kg (<10.1 lbs).
Shipping Weight: <9.5 kg (<21 lbs).

B
Status and Error Messages

Table B-1
Status and error messages

Number	Description	Event
-440	Query unterminated after indefinite response	EE
-430	Query deadlocked	EE
-420	Query unterminated	EE
-410	Query interrupted	EE
-363	Input buffer overrun	EE
-362	Framing error in program message	EE
-361	Parity error in program message	EE
-360	Communications error	EE
-350	Queue overflow	SYS
-330	Self-test failed	EE
-314	Save/recall memory lost	EE
-315	Configuration memory lost	EE
-285	Program syntax error	EE
-284	Program currently running	EE
-282	Illegal program name	EE
-281	Cannot create program	EE
-260	Expression error	EE
-241	Hardware missing	EE
-230	Data corrupt or stale	EE
-225	Out of memory	EE
-224	Illegal parameter value	EE
-223	Too much data	EE
-222	Parameter data out of range	EE
-221	Settings conflict	EE
-220	Parameter error	EE
-215	Arm deadlock	EE
-214	Trigger deadlock	EE
-213	Init ignored	EE
-212	Arm ignored	EE
-211	Trigger ignored	EE
-210	Trigger error	EE
-202	Settings lost due to rtl	EE
-201	Invalid while in local	EE
-200	Execution error	EE
-178	Expression data not allowed	EE
-171	Invalid expression	EE
-170	Expression error	EE
-168	Block data not allowed	EE
-161	Invalid block data	EE
-160	Block data error	EE

Table B-1 (cont.)
Status and error messages

Number	Description	Event
-158	String data not allowed	EE
-154	String too long	EE
-151	Invalid string data	EE
-150	String data error	EE
-148	Character data not allowed	EE
-144	Character data too long	EE
-141	Invalid character data	EE
-140	Character data error	EE
-128	Numeric data not allowed	EE
-124	Too many digits	EE
-123	Exponent too large	EE
-121	Invalid character in number	EE
-120	Numeric data error	EE
-114	Header suffix out of range	EE
-113	Undefined header	EE
-112	Program mnemonic too long	EE
-111	Header separator error	EE
-110	Command header error	EE
-109	Missing parameter	EE
-108	Parameter not allowed	EE
-105	GET not allowed	EE
-104	Data type error	EE
-103	Invalid separator	EE
-102	Syntax error	EE
-101	Invalid character	EE
-100	Command error	EE
+000	No error	SE
	Measurement events:	
+101	Low limit 1 failed	SE
+102	High limit 1 failed	SE
+103	Low limit 2 failed	SE
+104	High limit 2 failed	SE
+105	Active limit tests passed	SE
+106	Reading available	SE

Table B-1 (cont.)
Status and error messages

Number	Description	Event
+107	Reading overflow	SE
+108	Buffer available	SE
+109	Buffer full	SE
	Standard events:	
+200	Operation complete	SE
	Operation events:	
+300	Device calibrating	SE
+303	Device sweeping	SE
+305	Waiting in trigger layer	SE
+306	Waiting in arm layer	SE
+310	Re-entering the idle layer	SE
	Questionable events:	
+408	Questionable calibration	SE
+414	Command warning	SE
	Calibration errors:	
+500	Date of calibration not set	EE
+501	Next date of calibration not set	EE
+502	Calibration data invalid	EE
+507	Measurement offset data invalid	EE
+508	Measurement gain data invalid	EE
+509	Not permitted with cal locked	EE
+510	Not permitted with cal un-locked	EE
+511	Voltage offset not converging	EE
+512	Current offset not converging	EE
	Lost data errors:	
+602	GPIB address lost	EE
+603	Power-on state lost	EE
+604	DC calibration data lost	EE
+605	Calibration dates lost	EE
+606	GPIB communication language lost	EE
	Communication errors:	
+700	Invalid system communication	EE
+701	ASCII only with RS-232	EE

Table B-1 (cont.)
Status and error messages

Number	Description	Event
	Additional (more informative) command execution errors:	
+800	Illegal with storage active	EE
+801	Insufficient vector data	EE
+804	Expression list full	EE
+805	Undefined expression exists	EE
+806	Expression not found	EE
+807	Definition not allowed	EE
+808	Expression cannot be deleted	EE
+811	Not an operator or number	EE
+812	Mismatched parentheses	EE
+813	Not a number of data handle	EE
+814	Mismatched brackets	EE
+815	Too many parentheses	EE
+816	Entire expression not parsed	EE
+817	Unknown token	EE
+818	Error parsing mantissa	EE
+819	Error parsing exponent	EE
+820	Error parsing value	EE
+821	Invalid data handle index	EE
+830	Invalid with INFinite ARM:COUNT	EE
+831	Invalid with INFinite TRIG:COUNT	EE
+900	Internal system error	EE
	DDC Status Model:	
+950	Rdg overflow	SE
+951	Rdg ready	SE
+952	Buffer full	SE
+953	IDDC error	EE
+954	IDDCO error	EE
+955	Trig overrun	EE
+956	No remote	EE
+957	Number error	EE
+958	DDC ready	SE
+960	DDC Mode IDDC Error	EE
+961	DDC Mode IDDCO Error	EE

Table B-1 (cont.)
Status and error messages

Number	Description	Event
	Keithley 6512 Serial Poll Byte Events:	
+962	DDC Ready	SE
+963	DDC Reading Done	SE
+965	DDC Buffer Full	SE
+966	DDC Reading overflow	SE

EE = error event
SE = status event
SYS = system error event
NOTE: Errors and status messages with a positive number are instrument-dependent. Negative errors are reserved by SCPI.

NOTE: SCPI-confirmed messages are described in Volume 2: Command Reference of the Standard Commands for Programmable Instruments. Refer to the :SYSTem:ERRor? command.

C
General Measurement Considerations

Measurement considerations

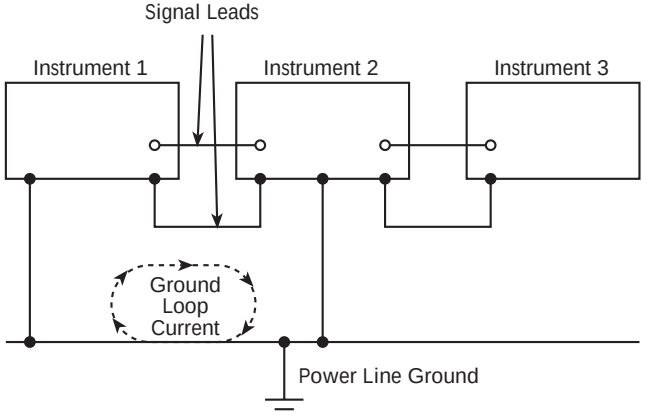
The following measurement considerations apply to all precision measurements. Measurement considerations that are unique to a particular measurement function are covered in Sections 3, 4, and 5. Table 2-5 (located at the end of Section 2) lists all measurement considerations, and indicates where to find detailed information on them.

For comprehensive information on all measurement considerations, refer to the Low Level Measurements handbook, which is available from Keithley.

Ground loops

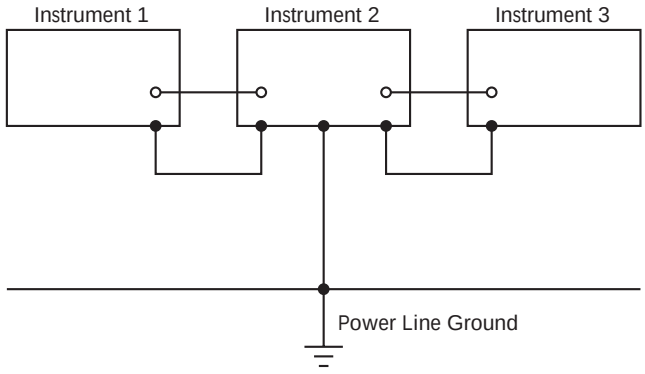
Ground loops that occur in multiple-instrument test setups can create error signals that cause erratic or erroneous measurements. The configuration shown in Figure C-1 introduces errors in two ways. Large ground currents flowing in one of the wires will encounter small resistances, either in the wires, or at the connecting points. This small resistance results in voltage drops that can affect the measurement. Even if the ground loop currents are small, magnetic flux cutting across the large loops formed by the ground leads can induce sufficient voltages to disturb sensitive measurements.

Figure C-1
Power line ground loops



To prevent ground loops, instruments should be connected to ground at only a single point, as shown in Figure C-2. Note that only a single instrument is connected directly to power line ground. Experimentation is the best way to determine an acceptable arrangement. For this purpose, measuring instruments should be placed on their lowest ranges. The configuration that results in the lowest noise signal is the one that should be used.

Figure C-2
Eliminating ground loops



Triboelectric effects

Triboelectric currents are generated by charges created between a conductor and an insulator due to friction. Here, free electrons rub off the conductor and create a charge imbalance that causes the current flow. For example, bending a triaxial cable causes friction between the center conductor (HI) and its surrounding insulator resulting in triboelectric currents. Triboelectric currents can be minimized as follows:

- Use “low noise” cables. These cables are specially designed to minimize charge generation and use graphite to reduce friction. The Keithley Model 7078-TRX triax cables are low noise.
- Use the shortest cables possible, and secure them (i.e., taping or tying) to a non-vibrating surface to keep them from moving.

Piezoelectric and stored charge effects

Piezoelectric currents are generated when mechanical stress is applied to certain insulating materials (i.e., crystalline). In some plastics, pockets of stored charge cause the material to behave in a similar manner.

When building test fixtures, choose good insulating materials and make connecting structures as rigid as possible. Make sure there are no mechanical stresses on the insulators.

Electrochemical effects

Error currents also arise from electrochemical effects when ionic chemicals create weak batteries on a circuit board. These batteries could generate a few nanoamps of current between conductors. Ionic contamination may be the result of body oils, salts or solder flux. The problem is further enhanced by high humidity (moisture) that decreases insulation resistance.

When building test fixtures, select insulators that resist water absorption, and use the fixture in a moderate humidity environment. Also, be sure that all insulators are kept clean and free of contamination. See “Handling and Cleaning Test Fixtures” in Section 2 for cleaning tips.

Humidity

Excess humidity can reduce insulation resistance on PC boards and in test connection insulators. Reduction in insulation resistance can, of course, seriously affect high-impedance measurements. Also, humidity (moisture) can combine with contaminants to produce offset currents caused by electrochemical effects (see (Electrochemical Effects). To minimize the effects of moisture, keep humidity to a minimum (ideally <50%), and keep components and connectors in the test system clean. See “Handling and Cleaning Test Fixtures” in Section 2 for cleaning tips.

Light

Some components, such as semiconductor junctions and MOS capacitors on semiconductor wafers, are excellent light detectors. Consequently, these components must be tested in a light-free environment. While many test fixtures provide adequate light protection, others may allow sufficient light penetration to affect the test results. Areas to check for light leaks include doors and door hinges, tubing entry points, and connectors or connector panels.

Electrostatic interference

Electrostatic interference occurs when a electrically charged object is brought near an uncharged object, thus inducing a charge on the previously uncharged object. Usually, effects of such electrostatic action are not noticeable because low impedance levels allow the induced charge to dissipate quickly. However, the high impedance levels of many measurements do not allow these charges to decay rapidly, and erroneous or unstable readings may result. These erroneous or unstable readings may be caused in the following ways:

1. DC electrostatic field can cause undetected errors or noise in the reading.
2. AC electrostatic fields can cause errors by driving the input preamplifier into saturation, or through rectification that produces DC errors.

Electrostatic interference is first recognizable when hand or body movements near the experiment cause fluctuations in the reading. Pick-up from AC fields can also be detected by observing the electrometer preamp output on an oscilloscope. Line frequency signals on the output are an indication that electrostatic interference is present. Means of minimizing electrostatic interference include:

1. Shielding. Possibilities include: a shielded room, a shielded booth, shielding the sensitive circuit, and using shielded cable. The shield should always be connected to a solid connector that is connected to signal low. If circuit low is floated above ground, observe safety precautions, and avoid touching the shield. Meshed screen or loosely braided cable could be inadequate for high impedances, or in string fields. Note, however, that shielding can increase capacitance in the measuring circuit, possibly slowing down response time.
2. Reduction of electrostatic fields. Moving power lines or other sources away from the experiment reduces the amount of electrostatic interference seen in the measurement.

Magnetic fields

A magnetic field passing through a loop in a test circuit will generate a magnetic EMF (voltage) that is proportional to the strength of the field, the loop area, and the rate at which these factors are changing. Magnetic fields can be minimized by following these guidelines:

- Locate the test circuit as far away as possible from such magnetic field sources as motors, transformers and magnets.
- Avoid moving any part of the test circuit within the magnetic field.
- Minimize the loop area by keeping leads as short as possible and twisting them together.

Electromagnetic Interference (EMI)

The electromagnetic interference characteristics of the Model 6514 comply with the electromagnetic compatibility (EMC) requirements of the European Union as denoted by the CE mark. However, it is still possible for sensitive measurements to be affected by external sources. In these instances, special precautions may be required in the measurement setup.

Sources of EMI include:

- Radio and TV broadcast transmitters.
- Communications transmitters, including cellular phones and handheld radios.
- Devices incorporating microprocessors and high-speed digital circuits.
- Impulses sources as in the case of arcing in high-voltage environments.

The effect on instrument performance can be considerable if enough of the unwanted signal is present. The effects of EMI can be seen as an unusually large offset, or, in the case of impulse sources, erratic variations in the displayed reading.

The instrument and experiment should be kept as far away as possible from any EMI sources. Additional shielding of the instrument, experiment and test leads will often reduce EMI to an acceptable level. In extreme cases, a specially constructed screen room may be required to sufficiently attenuate the troublesome signal.

External filtering of the input signal path may be required. In some cases, a simple one-pole filter may be sufficient. In more difficult situations, multiple notch or band-stop filters, tuned to the offending frequency range, may be required. Connecting multiple capacitors of widely different values in parallel will maintain a low impedance across a wide frequency range. Keep in mind, however, that such filtering may have detrimental effects (such as increased response time) on the measurement.

D
DDC Emulation Commands

DDC language

The Model 6514 can be configured to accept device-dependent commands (DDCs) of the Keithley Model 6512, 617, or 617 HIQ electrometer. The commands for controlling the Model 6514 with the DDC language are provided in Table D-1. For details on Model 6512, 617, and 617 HIQ operation, refer to the appropriate instruction manual.

Since the architecture of the Model 6514 differs from that of the other electrometers, some commands are different and cannot be used. Be sure to refer to the notes at the end of the table for information on command restrictions.

CAUTION **The DDC language is intended to be used only over the IEEE-488 bus. Using front panel controls in conjunction with this language may cause erratic operation. In this case, results cannot be guaranteed.**

Table D-1
Device dependent command summary

Mode	Command	Description	Note
Calibration Value	none	A (calibration) commands not supported	
Reading Mode	B0	Electrometer	
	B1	Buffer reading	
	B2	Maximum reading	
	B3	Minimum reading	
Zero Check	C0	Zero Check off	
	C1	Zero Check on	
Function	F0	Volts	
	F1	Amps	
	F2	Ohms	
	F3	Coulombs	
	F4	External Feedback	
Data Format	G0	Reading with prefix (NDCV-1.23456E+00)	
	G1	Reading without prefix (-1.23456E+00)	
	G2	Reading with prefix and buffer suffix (if in B1) (NDCV-1.23456E+00+00,012)	
Hit Key	H0	Manual trigger	
	Hn	Hit front panel key, where “n” = 1 to 32 (see Figure 16-3 for key press codes)	A
Buffer Size	In	Set buffer size, where “n” = 1 to 2500.	B

Table D-1 (cont.)
Device dependent command summary

Mode	Command	Description	Note
EOI and Bus Hold-off	K0	Enable both EOI and bus hold-off on X	
	K1	Disable EOI, enable bus hold-off on X	
	K2	Enable EOI, disable bus hold-off on X	
	K3	Disable both EOI and bus hold-off on X	
Store Calibration	none	L1 (store calibration) command not supported	
SRQ	M0	Disable SRQ	
	M1	Reading overflow	
	M2	Buffer full	
	M8	Reading done	
	M16	Ready	
	M32	Error	
Baseline Suppression (Rel)	N0	Suppression (Rel) disabled	
	N1	Suppression (Rel) enabled	
Digital Filter	P0	Filter off	
	P1	Filter off	
	Pn	Repeat Filter on, where filter size “n” = 2 to 100	C
Data Store (Buffer)	Q0	Conversion rate	
	Q1	One reading per second	
	Q2	One reading every 10 seconds	
	Q3	One reading per minute	
	Q4	One reading every 10 minutes	
	Q5	One reading per hour	
	Q6	Trigger mode	
	Q7	Disabled	

Table D-1 (cont.)
Device dependent command summary

Mode	Command	Description					Note
Range		**V**	**A**	**Ω**	**Q**	**XFdbk**	
	R0	Auto	Auto	Auto	Auto	Auto	
	R1	2V	20pA	2kΩ	20nC	2V	
	R2	2V	20pA	20kΩ	20nC	2V	
	R3	20V	200pA	200kΩ	20nC	20V	
	R4	200V	2nA	2MΩ	200nC	200V	
	R5	200V	20nA	20MΩ	2µC	200V	
	R6	200V	200nA	200MΩ	20µC	200V	
	R7	200V	2uA	2GΩ	20µC	200V	
	R8	200V	20uA	20GΩ	20µC	200V	
	R9	200V	200uA	200GΩ	20µC	200V	
	R10	200V	2mA	200GΩ	20µC	200V	
	R11	200V	20mA	200GΩ	20µC	200V	
	R12	Cancel Auto range for all functions					
Trigger Mode	T0	Continuous, triggered by talk					
	T1	One-shot, triggered by talk					
	T2	Continuous, triggered by GET					
	T3	One-shot, triggered by GET					
	T4	Continuous, triggered by X					
	T5	One-shot, triggered by X					
	T6	Continuous, triggered by External Trigger					
	T7	One-shot, triggered by External Trigger					
Status Word	U0	Return status word: FRRCZNT0BG0QMMKYY* *YY: := LFCR =: CRLF :0 LF =0 CR 00 None					D
	U1	Send error conditions					
	U2	Send data conditions					E
	U3	Buffer size and readings stored					F
Execute	X	Execute other device-dependent commands					F

Table D-1 (cont.)
Device dependent command summary

Mode	Command	Description	Note
Terminator	Y0	LFCR (line feed, carriage return)	D
	Y1	CRLF (carriage return, line feed)	
	Y2	LF (line feed)	
	Y3	CR (carriage return)	
	Y4	None	
Zero Correct	Z0	Zero Correct disabled	
	Z1	Zero Correct enabled	

A. The hit key command (Hn) is not used by the Models 6512, 617, and 617 HIQ. The hit command is similar to the SCPI SYSTem:KEY command (see Section 16 for details).
B. The buffer size command (In) is not used by the Models 6512, 617, and 617 HIQ. The buffer size command is similar to the SCPI TRACe:POINts command (see Section 8 for details).
C. The moving filter cannot be selected from the DDC language.
D. For the Models 6512, 617, and 617 HIQ, the terminator commands (Y) to set the terminator are different from the Y commands used by the Models 6512, 617, and 617 HIQ. Also note that the "YY" response to the U0 command is different.
E. For the Model 6514, the Buffer Full bit in the U2X status word does not get cleared until either the buffer is resized or buffer storage is reactivated. Note that requesting a buffer reading does not clear the U2 Buffer Full bit.
F. The U3 status command is not used by the Models 6512, 617, and 617 HIQ. The response message indicates the buffer size (In) and the actual number of readings stored in the buffer.

E
Example Programs

Programming examples

All examples assume QuickBASIC version 4.5 or higher and a CEC IEEE-488 interface card with CEC driver version 2.11 or higher, with the Model 6514 at address 14 on the IEEE-488 bus.

Changing function and range

The Model 6514 has independent range control for each of its four measurement functions. This means, for example, that autorange can be turned on for Volts while leaving it off for the rest of the functions.

Another difference is in the parameter for the range command. The parameter value for the :RANGe command is given as "the maximum value to measure". The instrument interprets this parameter and goes to the appropriate range. When you query the range with :RANGe?, the instrument sends back the full scale value of its present range.

Note that the Model 6514 rounds the range parameter to an integer before choosing the appropriate range. Sending VOLTage:RANGe 21.6 will set the Volts function to the 200V range. The parameter 21.6 is rounded to 22, which exceeds the 20V range.

The following program demonstrates range and function changes. A measurement will be taken while on the Amps and Ohms function:

```
  ‘ For QuickBASIC 4.5 and CEC PC488 interface card, edit the follow-
ing
  ‘ line where the QuickBASIC libraries are on your computer:
       ‘$INCLUDE: ‘c:\qb45\ieeeqb.bi’

  ‘ Initialize the CEC interface as address 21:
       CALL initialize(21, 0)

  ‘ Restore RST defaults:
       CALL SEND(14, “*rst”, status%)

  ‘ Set Amps for 20uA range and Ohms for 2MW range:
       CALL SEND(14, “curr:rang 20e-6”, status%)
       CALL SEND(14, “res:rang 2e6”, status%)
  ‘ Switch to Amps function and take reading. Each READ?
  ‘ will trigger one reading:
       CALL SEND(14, “func ‘curr’”, status%)
       CALL SEND(14, “read?”, status%)
       reading%$ = SPACE$(80)
       CALL ENTER(reading$, length%, 14, status%)
       PRINT reading$

  ‘ Switch to Ohms function and take reading:
       CALL SEND(14, “func ‘res’”, status%)
       CALL SEND(14, “read?”, status%)
       reading%$ = SPACE$(80)
       CALL ENTER(reading$, length%, 14, status%)
       PRINT reading$
```

One-shot triggering

Other instruments generally have two types of triggering: one-shot and continuous. In one-shot, each activation of the selected trigger source causes one reading. In continuous, the instrument is idle until the trigger source is activated, at which time it begins taking readings at a specified rate. Typical trigger sources are:

- IEEE-488 talk
- IEEE-488 Group Execute Trigger (GET)
- "X" command
- External trigger (rear panel BNC)

Arming the instrument to respond to triggers is implicit in the non-SCPI voltmeters. Sending a command to a non-SCPI voltmeter to change any of the trigger controls causes the instrument to arm itself for triggers.

The SCPI trigger model implemented in the Model 6514 gives:

- Explicit control over the trigger source (the TRIGger subsystem).
- A way for completely disabling triggers.

Changing any of the settings in the TRIGger subsystem does not automatically arm the Model 6514 for triggers.

The following program sets up the Model 6514 to take one reading each time it receives an external trigger pulse.

```
' For QuickBASIC 4.5 and CEC PC488 interface card, edit
' the following line where the QuickBASIC libraries are
' on your computer:
' $INCLUDE: 'c:\qb45\ieeeqb.bi'

' Initialize the CEC interface as address 21:
CALL initialize(21, 0)

' Puts trigger model in idle state and configure for
' one-shot ' triggering:
CALL SEND(14, "*rst", status%)
CALL SEND(14, "trig:sour tlin; coun inf", status%)

' Take 6514 out of idle (ready for external input triggers):
CALL SEND(14, "init", status%)
```

After the Model 6514 receives the INITiate command, it stops at the control source in the trigger model, waiting for a trigger pulse. Each time a pulse arrives at the Trigger Link connector, the Model 6514 takes one reading. Because TRIGger:COUNt has been set to INFinity, the instrument never enters the idle state. You can send the ABORt command to put the instrument in the idle state, disabling triggers until another INITiate command is sent.

Generating SRQ on buffer full

When your program must wait until the Model 6514 has completed an operation, it is more efficient to program the 6514 to assert the IEEE-488 SRQ line when it is finished, rather than repeatedly serial polling the instrument. An IEEE-488 controller will typically address the instrument to talk and then unaddress it each time it performs a serial poll. Repeated polling of the Model 6514 will generally reduce its overall reading throughput. Therefore, use the srq%() function call.

The Model 6514 provides a status bit for almost every operation it performs. It can be programmed to assert the IEEE-488 SRQ line whenever a status bit becomes true or false. The IEEE-488 controller (your computer) can examine the state of the SRQ line without performing a serial poll, thereby detecting when the 6514 has completed its task without interrupting it in the process.

The following example program segment sets up the Model 6514 to assert SRQ when the reading buffer has completely filled and then arms the reading buffer, initiates readings, and waits for the Model 6514 to indicate that the buffer is full.

This is not a complete program. The commands to configure the trigger model and the reading buffer (see the next example) are not shown. The example shown here can be modified for any event in the Model 6514 status reporting system.

```
‘ For QuickBASIC 4.5 and CEC PC488 interface card, edit
‘ the following line where the QuickBASIC libraries are
‘ on your computer:
‘ $INCLUDE: ‘c:\qb45\ieeeqb.bi’

‘ Initialize the CEC interface as address 21:
CALL initialize(21, 0)

‘ Reset STATus subsystem (not affected by *RST)
CALL SEND(14, "stat:pres;*cls", status%)

CALL SEND(14, "stat:meas:enab 512", status%)  'enable BFL
CALL SEND(14, "*sre 1"' status%)              'enable MSB
CALL SEND(14, "trac:feed:cont next", status%)

‘ Start everything
CALL SEND(14, "init", status%)

WaitSRQ:
IF (NOT(srq%()) THEN GOTO WaitSRQ
CALL SPOLL(14, poll%, status%)
IF (poll% AND 64)=0 THEN GOTO WaitSRQ
```

After the program has detected an asserted SRQ line, it serial polls the Model 6514 to determine if it is the device requesting service. This is necessary for two reasons:

- Serial polling the Model 6514 causes it to stop asserting the SRQ line.
- In test systems that have more than one IEEE-488 instrument programmed to assert SRQ, your program must determine which instrument is actually requesting service.

Once an event register has caused a service request, it cannot cause another service request until you clear it by reading it (in this case using STATus:MEASurement[:EVENt]?) or by sending the *CLS command.

Storing readings in buffer

The reading buffer in the Model 6514 is flexible and capable. It has three controls, which are found in the TRACe susbsystem. There are commands to control:

- The size of the buffer (in readings).
  `TRACe:POINts <NRf>` Store up to 2000 readings.
- Where the data is coming from.
  `TRACe:FEED SENSe1` Store unprocessed readings.
  `TRACe:FEED CALCulate1` Store CALC1 (KMATh) results.
  `TRACe:FEED CALCulate2` Store CALC2 (limits) readings.
- Select buffer control mode.
  `TRACe:FEED:CONTrol NEVer` Immediately stop storing readings.
  `TRACe:FEED:CONTrol NEXT` Arm buffer, stop when buffer is full.

The following example program sets up the Model 6514 to take 20 readings as fast as it can into the buffer, and then reads the data back after the buffer has filled.

```
' Example program to demonstrate the reading buffer
' For QuickBASIC 4.5 and CEC PC488 interface card

' Edit the following line to where the QuickBASIC
' libraries are on your computer
' $INCLUDE: 'c:\qb45\ieeeqb.bi'

' Initialize the CEC interface as address 21
CALL initialize(21, 0)

' Reset controls and put trigger model in IDLE state
CALL SEND(14, "*rst", status%)

' Reset STATus subsystem (not affected by *RST)
CALL SEND(14, "stat:pres;*cls", status%)
CALL SEND(14, "stat:meas:enab 512", status%)  'enable BFL
CALL SEND(14, "*sre 1", status%)              'enable MSB
CALL SEND(14, "trig:coun 20", status%)

' TRACe subsystem is not affected by *RST
CALL SEND(14, "trac:poin 20", status%)
CALL SEND(14, "trac:feed sens1;feed:cont next", status%)

' Start everything
CALL SEND(14, "init", status%)

' Initialize reading$ while the 6514 is busy taking readings
reading$ = SPACE$(4000)

WaitSRQ:
IF (NOT(srq%)) THEN GOTO WaitSRQ
CALL SPOLL(14, poll%, status%)
```

```
IF (poll% AND 64)=0 THEN GOTO WaitSRQ

CALL SEND(14, "stat:meas?", status%)
CALL ENTER(S$, length%, 14, status%)

CALL SEND(14, "trac:data?", status%)
CALL ENTER(reading$, length%, 14, status%)
PRINT reading$
```

NOTE: To repeat buffer storage, send the following command and then repeat the steps following the 'Start everything comment in the above example.

```
CALL SEND(14, "feed:cont next", status%)
```

Taking readings using the :READ? command

This programming example demonstrates a simple method for taking and displaying (on the computer CRT) a specified number of readings. The product of the arm count and trigger count determines the number of readings to take. The *RST default for both counters is one. Therefore, READ? will trigger and return one reading (1 × 1 = 1). If, for example, you want to take 10 readings, you can set one of the counters to 10, while keeping the other counter set to one. READ? will trigger and return 10 readings (10 × 1 = 10).

The following program takes 10 readings on the Volts function and displays them on the computer CRT.

```
' For QuickBASIC 4.5 and CEC PC488 interface card
' edit the following line to where the QuickBASIC libraries are
' on your computer
' $INCLUDE: 'c:\qb45\ieeeqb.bi

' Initialize the CEC interface as address 21
CALL initialize(21, 0)

' Reset controls, clear buffer and place 2182 in idle
CALL SEND(14, "*rst", status%)
CALL SEND(14, "trac:cle", status%)

CALL SEND(14, "trig:coun 10", status%)
CALL SEND(14, "form:elem read", status%)
CALL SEND(14, "read?", status%)
reading$ = SPACE$ (300)
CALL ENTER(reading$, length%, 14, status%)
PRINT reading$
```

Controlling the Model 6514 via the RS-232 COM2 port

This example program illustrates the use of the Keithley Model 6514 interfaced to the RS-232 COM2 port. The Model 6514 is set up to take 100 readings at the fastest possible rate. The readings are taken, sent across the serial port, and displayed on the screen.

```
' Example program controlling the Model 6514 via the RS-232 COM2 port
' For QuickBASIC 4.5 and CEC PC488 interface card
RD$=SPACE$(1500)              ' Set string space
CLS                           ' CLear screen
PRINT "Set COM2 baud rate to 19200"
PRINT "Set 8 data bits, no parity, no flow control, and CR as Termina-
tor"

' Configure serial port parameters
ComOpen$="COM2:19200,N,8,1,ASC,CD0,CS0,DS0,LF,OP0,RS,TB8192,RB8192"
OPEN ComOpen$ FOR RANDOM AS #1

' Model 6514 setup commands
' Note Serial communications only operate with SCPI mode....
PRINT #1, "*RST"                ' RST defaults
PRINT #1, "*CLS"                ' Clear registers
PRINT #1, "VOLT:RANG 10"        ' 10V range
PRINT #1, "SYST:AZER OFF"       ' Disable autozero
PRINT #1, "AVER OFF"            ' Disable average filter
PRINT #1, "DISP:DIG 4"          ' 3½-digit resolution
PRINT #1, "FORM:ELEM READ"      ' Reading only
PRINT #1, "VOLT:NPLC 0.01"      ' NPLC = 0.01
PRINT #1, "TRIG:COUN 100"       ' 100 readings
PRINT #1, "DISP:ENAB OFF"       ' Turn off display
PRINT #1, "INIT"                ' Take 6514 out of idle
SLEEP 1                         ' Wait one second
PRINT #1, "READ?"               ' Perform measurements
LINE INPUT #1, RD$              ' Get data
PRINT RD$                       ' Display data on CRT
PRINT #1, "DISP:ENAB ON"        ' Turn on display
PRINT #1, "SYST:AZER ON"        ' Enable autozero

' Clean up and quit:
CLOSE #1                        ' Close file
CLEAR                           ' Clear interface
END
```

F
IEEE-488 Bus Overview

Introduction

The IEEE-488 bus is a communication system between two or more electronic devices. A device can be either an instrument or a computer. When a computer is used on the bus, it serves as a supervisor of the communication exchange between all the devices and is known as the controller. Supervision by the controller consists of determining which device will talk and which device will listen. As a talker, a device will output information and as a listener, a device will receive information. To simplify the task of keeping track of the devices, a unique address number is assigned to each.

On the bus, only one device can talk at a time and is addressed to talk by the controller. The device that is talking is known as the active talker. The devices that need to listen to the talker are addressed to listen by the controller. Each listener is then referred to as an active listener. Devices that do not need to listen are instructed to unlisten. The reason for the unlisten instruction is to optimize the speed of bus information transfer since the task of listening takes up bus time.

Through the use of control lines, a handshake sequence takes place in the transfer process of information from a talker to a listener. This handshake sequence helps ensure the credibility of the information transfer. The basic handshake sequence between an active controller (talker) and a listener is as follows:

1. The listener indicates that it is ready to listen.
2. The talker places the byte of data on the bus and indicates that the data is available to the listener.
3. The listener, aware that the data is available, accepts the data and then indicates that the data has been accepted.
4. The talker, aware that the data has been accepted, stops sending data and indicates that data is not being sent.
5. The listener, aware that there is no data on the bus, indicates that it is ready for the next byte of data.

Bus description

The IEEE-488 bus, which is also referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines

A typical setup for controlled operation is shown in Figure F-1. Generally, a system will contain one controller and a number of other instruments to which the commands are given. Device operation is categorized into three operators: controller, talker, and listener. The controller controls the instruments on the bus. The talker sends data while a listener receives data. Depending on the type of instrument, any particular device can be a talker only, a listener only, or both a talker and listener.

There are two categories of controllers: system controller and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

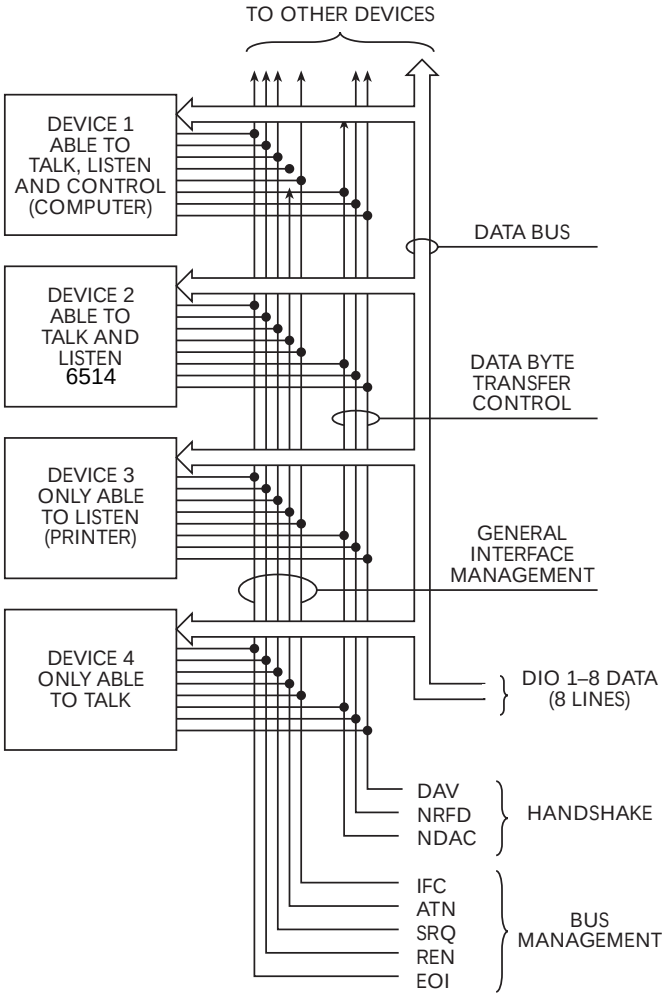
The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 31, and is generally set by rear panel DIP switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with $20. For example, if the primary address is $14, the actual listen address is $34 ($34 = $14 + $20). In a similar manner, the talk address is obtained by ORing the primary address with $40. With the present example, the talk address derived from a primary address of $14 would be $54 ($54 = $14 + $40).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of $60-$7F. Note, however, that many devices, including the Model 6514, do not use secondary addressing.

Once a device is addressed to talk or listen, the appropriate bus transactions take place. For example, if the instrument is addressed to talk, it places its data string on the bus one byte at a time. The controller reads the information, and the appropriate software can be used to direct the information to the desired location.

Figure F-1
IEEE-488 bus configuration



Bus lines

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines, and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the operation of these lines.

Data lines

The IEEE-488 bus uses eight data lines that transfer data one byte at a time. DIO1 (Data Input/Output) through DIO8 (Data Input/Output) are the eight data lines used to transmit both data and multiline commands and are bi-directional. The data lines operate with low true logic.

Bus management lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands.

ATN (Attention) — The ATN state determines how information on the data bus is to be interpreted.

IFC (Interface Clear) — The IFC line controls clearing of instruments from the bus.

REN (Remote Enable) — The REN line is used to place the instrument on the bus in the remote mode.

EOI (End or Identify) — The EOI line is used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request) — The SRQ line is used by devices when they require service from the controller.

Handshake lines

The bus handshake lines operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (DATA VALID) — The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

NRFD (Not Ready For Data) — The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence until the accepting device is ready.

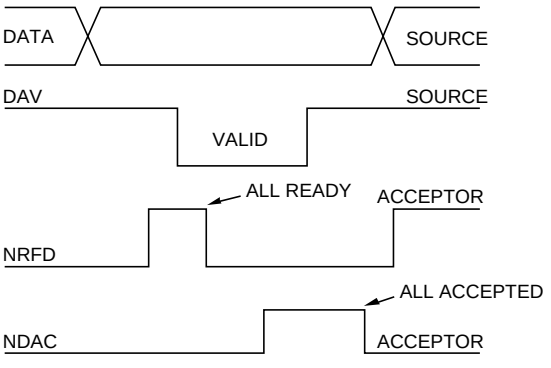
NDAC (Not Data Accepted) — NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

The complete handshake sequence for one data byte is shown in Figure F-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100ns after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

The previous sequence is used to transfer both data, talk and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses, or commands as described in the following paragraphs.

Figure F-2
IEEE-488 handshake sequence



Bus commands

The instrument may be given a number of special bus commands through the IEEE-488 interface. The following paragraphs briefly describe the purpose of the bus commands which are grouped into the following three categories.

1. Uniline commands — Sent by setting the associated bus lines true. For example, to assert REN (Remote Enable), the REN line would be set low (true).
2. Multiline commands — General bus commands which are sent over the data lines with the ATN line true (low).
3. Common commands — Commands that are common to all devices on the bus; sent with ATN high (false).
4. SCPI commands — Commands that are particular to each device on the bus; sent with ATN (false).

These bus commands and their general purpose are summarized in Table F-1.

Table F-1
IEEE-488 bus command summary

Command type	**Command**	**State of ATN line**	**Comments**
Uniline	REN (Remote Enable)	X	Set up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline Universal	LLO (Local Lockout)	Low	Locks our local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from the bus.
	UNT (Untalk)	Low	Removes any talkers from the bus.
Common	—	High	Programs IEEE-488.2 compatible instruments for common operations.
SCPI	—	High	Programs SCPI compatible instruments for particular operations.

Figure F-3 Command codes

D_7 D_6 D_5 D_4						X 0 0 0	Command	X 0 0 1	Command	X 0 1 0	Primary Address	X 0 1 1	Primary Address	X 1 0 0	Primary Address	X 1 0 1	Primary Address	X 1 1 0		X 1 1 1	
Bits	D_3 ↓	D_2 ↓	D_1 ↓	D_0 ↓	Column→ Row ↓	0 (A)	0 (B)	1 (A)	1 (B)	2 (A)	2 (B)	3 (A)	3(B)	4 (A)	4 (B)	5 (A)	5 (B)	6 (A)	6 (B)	7 (A)	7 (B)
	0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
	0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
	0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
	0	0	1	1	3	ETX		DC3		#	3	3	19	C	3	S	19	c		s	
	0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
	0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
	0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
	0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
	1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
	1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
	1	0	1	0	10	LF		SUB		•	10	:	26	J	10	Z	26	j		z	
	1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
	1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
	1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
	1	1	1	0	14	SO		RS		.	14	>	30	N	14	∩	30	n		≅	
	1	1	1	1	15	SI		US		/	15	?	UNL	O	15	—	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE) PPU (PARALLEL POLL UNCONFIGURE), and TCT (TAKE CONTROL) not implemented by Model 6514.

Note: D_0 = DIO1 ... D_7 = DIO8; X = Don't Care.

Addressed multiline commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands. Both the commands and the address preceding it are sent with ATN true.

SDC (Selective Device Clear) — The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local) — The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger) — The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

Address commands

Addressed commands include two primary command groups and a secondary address group. ATN is true when these commands are asserted. The commands include:

LAG (Listen Address Group) — These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group) — The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group) — Commands in this group provide additional addressing capabilities. Many devices (including the Model 6514) do not use these commands.

Unaddress commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten) — Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk) — Any previously commanded talkers will be placed in the talker idle state by the UNT command.

Common commands

Common commands are commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard.

Generally, these commands are sent as one or more ASCII characters that tell the device to perform a common operation, such as reset. The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

SCPI commands

SCPI commands are commands that are particular to each device on the bus. These commands are designated by the instrument manufacturer and are based on the instrument model defined by the Standard Commands for Programmable Instruments (SCPI) Consortium's SCPI standard.

Generally, these commands are sent as one or more ASCII characters that tell the device to perform a particular operation, such as setting a range or closing a relay. The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command codes

Command codes for the various commands that use the data lines are summarized in Figure F-3. Hexadecimal and the decimal values for the various commands are listed in Table F-2.

Table F-2
Hexadecimal and decimal command codes

Command	Hex value	Decimal value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SCG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Typical command sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table F-3 lists a typical bus sequence for sending the addressed multiline commands. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table F-3
Typical bus sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	.	2E	46
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 14.

Table F-4 gives a typical common command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the common command string.

Table F-4
Typical addressed command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	.	2E	46
3	Data	Set high	*	2A	42
4	Data	Stays high	R	52	82
5	Data	Stays high	S	53	83
6	Data	Stays high	T	54	84

*Assumes primary address = 14.

IEEE command groups

Command groups supported by the Model 6514 are listed in Table F-5. Common commands and SCPI commands are not included in this list.

Table F-5
IEEE command groups

HANDSHAKE COMMAND GROUP	
	NDAC = NOT DATA ACCEPTED NRFD = NOT READY FOR DATA DAV = DATA VALID
UNIVERSAL COMMAND GROUP	
	ATN = ATTENTION DCL = DEVICE CLEAR IFC = INTERFACE CLEAR REN = REMOTE ENABLE SPD = SERIAL POLL DISABLE SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP	
LISTEN	LAG = LISTEN ADDRESS GROUP MLA = MY LISTEN ADDRESS UNL = UNLISTEN
TALK	TAG = TALK ADDRESS GROUP MTA = MY TALK ADDRESS UNT = UNTALK OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP	
	ACG = ADDRESSED COMMAND GROUP GTL = GO TO LOCAL SDC = SELECTIVE DEVICE CLEAR
STATUS COMMAND GROUP	
	RQS = REQUEST SERVICE SRQ = SERIAL POLL REQUEST STB = STATUS BYTE EOI = END

Interface function codes

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual. The interface function codes for the Model 6514 are listed in Table F-6.

Table F-6
Model 6514 interface function codes

Code	Interface function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability
T5	Talker (basic talker, talk-only, serial poll, unaddressed to talk on LAG)
L4	Listener (basic listener, unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open collector bus drivers
TE0	No Extended Talker capability
LE0	No Extended Listener capability

The codes define Model 6514 capabilities as follows:

SH (Source Handshake Function) — SH1 defines the ability of the instrument to initiate the transfer of message/data over the data bus.

AH (Acceptor Handshake Function) — AH1 defines the ability of the instrument to guarantee proper reception of message/data transmitted over the data bus.

T (Talker Function) — The ability of the instrument to send data over the bus to other devices is provided by the T function. Instrument talker capabilities (T5) exist only after the instrument has been addressed to talk.

L (Listener Function) — The ability for the instrument to receive device-dependent data over the bus from other devices is provided by the L function. Listener capabilities (L4) of the instrument exist only after it has been addressed to listen.

SR (Service Request Function) — SR1 defines the ability of the instrument to request service from the controller.

RL (Remote-Local Function) — RL1 defines the ability of the instrument to be placed in the remote or local modes.

PP (Parallel Poll Function) — The instrument does not have parallel polling capabilities (PP0).

DC (Device Clear Function) — DC1 defines the ability of the instrument to be cleared (initialized).

DT (Device Trigger Function) — DTI defines the ability of the Model 6514 to have readings triggered.

C (Controller Function) — The instrument does not have controller capabilities (C0).

TE (Extended Talker Function) — The instrument does not have extended talker capabilities (TE0).

LE (Extended Listener Function) — The instrument does not have extended listener capabilities (LE0).

E (Bus Driver Type) — The instrument has open-collector bus drivers (E1).

G
IEEE-488 and SCPI Conformance Information

Introduction

The IEEE-488.2 standard requires specific information about how the Model 6514 implements the standard. Paragraph 4.9 of the IEEE-488.2 standard (Std 488.2-1987) lists the documentation requirements. Table G-1 provides a summary of the requirements and provides the information or references the manual for that information. Table G-2 lists the coupled commands used by the Model 6514.

The Model 6514 complies with SCPI version 1991.0. Tables 17-1 through 17-9 list the SCPI confirmed commands and the non-SCPI commands implemented by the Model 6514.

Table G-1
IEEE-488 documentation requirements

	Requirements	**Description or reference**
(1)	IEEE-488 Interface Function Codes.	See Appendix F.
(2)	Behavior of 6514 when the address is set outside the range 0-30.	Cannot enter an invalid address.
(3)	Behavior of 6514 when valid address is entered.	Address changes and bus resets.
(4)	Power-On Setup Conditions.	Determine by :SYSTem:POSetup (Section 16).
(5)	Message Exchange Options:	
(a)	Input buffer size.	2048 bytes.
(b)	Queries that return more than one response message unit.	None.
(c)	Queries that generate a response when parsed.	All queries (Common Commands and SCPI).
(d)	Queries that generate a response when read.	None.
(e)	Coupled commands.	See Table G-2.
(6)	Functional elements required for SCPI commands.	Contained in SCPI command subsystems tables (see Tables 17-1 through 17-9).
(7)	Buffer size limitations for block data.	Block display messages: 12 characters max,
(8)	Syntax restrictions.	See Programming Syntax in Section 12.
(9)	Response syntax for every query command.	See Programming Syntax in Section 12.
(10)	Device-to-device message transfer that does not follow rules of the standard.	None.
(11)	Block data response size.	See Display Subsystem in Section 16.
(12)	Common Commands implemented by 6514.	See Common Commands in Section 14.
(13)	Calibration query information.	Section 19
(14)	Trigger macro for *DDT.	Not applicable.

Table G-1 (cont.)
IEEE-488 documentation requirements

	Requirements	**Description or reference**
(15)	Macro information	Not applicable.
(16)	Response to *IDN (identification).	See Common Commands in Section 14.
(17)	Storage area for *PUD and *PUD?	Not applicable.
(18)	Resource description for *RDT and *RDT?	Not applicable.
(19)	Effects of *RST, *RCL and *SAV.	See Common Commands in Section 14.
(20)	*TST information.	See Common Commands in Section 14.
(21)	Status register structure.	See Status Structure in Section 13.
(22)	Sequential or overlapped commands.	All are sequential except :INIT which is overlapped.
(23)	Operation complete messages.	*OPC, *OPC? and *WAI; see Common Commands in Section 14.

Table G-2
Coupled commands

Sending	**Changes**	**To**
CALC1:FORM:KMAT:PERC:ACQ	CALC1:FORM:KMAT:PERC:REF <n>	Acquired value
CALC2:NULL:ACQ	CALC2:NULL:OFFS <n>	Acquired value
VOLT:RANG:UPP <n>	VOLT:RANG:AUTO <b>	OFF
CURR:RANG:UPP <n>	CURR:RANG:AUTO <b>	OFF
RES:RANG:UPP <n>	RES:RANG:AUTO <b>	OFF
CHAR:RANG:UPP <n>	CHAR:RANG:AUTO <b>	OFF
VOLT:NPLC <n>	CURR:NPLC <n>	Volts PLC value
	RES:NPLC <n>	Volts PLC value
	CHAR:NPLC <n>	Volts PLC value
CURR:NPLC <n>	VOLT:NPLC <n>	Amps PLC value
	RES:NPLC <n>	Amps PLC value
	CHAR:NPLC <n>	Amps PLC value
RES:NPLC <n>	VOLT:NPLC <n>	Ohms PLC value
	CURR:NPLC <n>	Ohms PLC value
	CHAR:NPLC <n>	Ohms PLC value
CHAR:NPLC <n>	VOLT:NPLC <n>	Charge PLC value
	CURR:NPLC <n>	Charge PLC value
	RES:NPLC <n>	Charge PLC value
TRAC:POIN <n>	TRAC:FEED:CONT <name>	NEV
TRAC:CLE	TRAC:FEED:CONT <name> TRAC:CLE	NEV
CHAR:RANG:AUTO:LGR <n> CHAR:RANG:AUTO ON	CHAR:RANG:UPP <n>	If autorange = ON then: 2µC if old range <2nC and LRG = UPPer or 200nC if old range >200nC and LGR = LOWer

H
Calibration Options

Introduction

This appendix contains information on reading Model 5156 Electrometer Calibration Standard values as well as a summary of Model 6514 remote calibration commands. See Section 19 for complete calibration information.

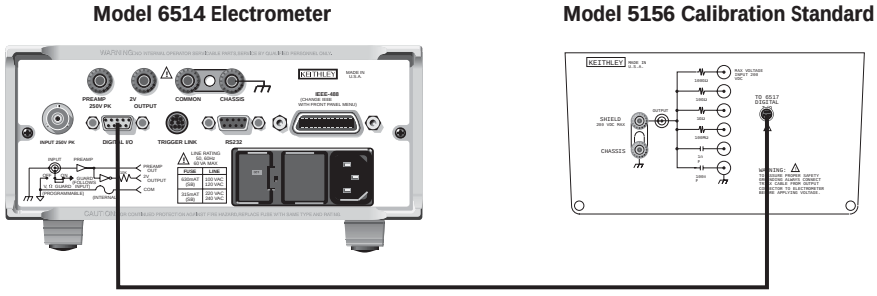
Reading calibration standard values

Instead of manually computing calibration currents and charge values, you can read out Model 5156 Electrometer Calibration standard values via remote, then use a computer to calculate those values.

Data transfer connections

Figure H-1 shows data transfer connections. Connect the Model 6514 DIGITAL I/O connector to the Model 5156 TO 6517 DIGITAL I/O connector using the optional Keithley CA-199-1A data transfer cable. Also connect the Model 6514 to the GPIB or RS-232 port of the host computer (not shown).

Figure H-1
Data transfer connections



Example program

The program below demonstrates how to read back and display calibration standard values. To use this program, you will need the following:

- IBM PC compatible computer.
- Microsoft QBasic (supplied with DOS 5 – 6.22).
- CEC or Keithley IEEE-488 interface card installed in the computer.
- Installed CECHP.EXE driver (supplied with above interface card).

```
' Program to read Model 5156 standard values via Model 6514.
' 6514 primary address = 14.
OPEN "IEEE" FOR OUTPUT AS #1              ' Open IEEE-488 output path.
OPEN "IEEE" FOR INPUT AS #2               ' Open IEEE-488 input path.
PRINT #1, "INTERM CRLF"                   ' Set input terminator.
PRINT #1, "OUTTERM LF"                    ' Set output terminator.
PRINT #1, "REMOTE 14"                     ' Put 6514 in remote.
CLS
PRINT "Model 5156 Calibration Standard values:"
PRINT #1, "OUTPUT 14;:CAL:UNPR:KI5156?"   ' Query 5156 standard values.
PRINT #1, "ENTER 14"
INPUT #2, R100G, R10G, R1G, R100M, C1NF, C100NF
PRINT #1, "LOCAL 14"
CLOSE
PRINT "100 G ohm value:"; R100G
PRINT "10 G ohm value:"; R10G
PRINT "1 G ohm value:"; R1G
PRINT "100 M ohm value:"; R100M
PRINT "1 nF value:"; C1NF
PRINT "100 nF value:"; C100NF
END
```

Remote calibration

Calibration commands

Table H-1 summarizes Model 6514 calibration commands.

Table H-1
Calibration commands

Command	Description
:CALibration	
:PROTected	
:CODE '<code>'	Eight character code/password used to enable or unlock calibration. (Default: KI006514.)
:CODE?	Calibration code query.
:LOCK	Lock out further calibration.
:LOCK?	Return 1 if calibration is locked, 0 otherwise.
:SENSe <NRf>	Calibrate active function and range.
:DATA?	Query measurement cal constants.
:SAVE	Save all calibration data to non-volatile memory.
:DATE <NRf, NRf, NRf>	Year, Month, Day when cal was last performed.
:DATE?	Query last cal date.
:NDUE <NRf, NRf, NRf>	Year, Month, Day when 6514 is due for re-cal.
:NDUE?	Query cal due date.
:COUNt?	Returns how many times a 6514 has been calibrated.
:UNPRotected	
:VOFFset	Voltage Offset correction.
:IOFFset	Current Offset correction.

Remote calibration overview

The steps below outline the general procedure for calibrating the Model 6514 using remote commands. Refer to Section 19 for details on calibration steps, calibration points, and test equipment connections.

1. Send the following command to unlock calibration:

   :CAL:PROT:CODE 'KI006514'

   Note that the above command uses the factory default code.

2. Perform current and voltage offset correction by sending the following commands:

   :CAL:UNPR:IOFF

   :CAL:UNPR:VOFF

   Be sure the appropriate connections are made to the INPUT jack before sending each command (cap for IOFF; short for VOFF).

3. Send the appropriate commands to select the function and range to be calibrated. For example, the following commands select the volts function and the 2V range:

   :SENS:FUNC 'VOLT'

   :SENS:VOLT:RANG 2

4. Make appropriate connections, then send the commands for each calibration point for the selected function and range. For example, send the following commands for the 2V range:

   :CAL:PROT:SENS 0

   :CAL:PROT:SENS 2

   :CAL:PROT:SENS –2

NOTE *Be sure the appropriate calibration signal is applied to the INPUT jack before sending the command for each calibration point. See Section 19 for details.*

5. Repeat steps 3 and 4 for each function and range.
6. After all functions and ranges are calibrated, send the commands to program the calibration dates; for example:

   :CAL:PROT:DATE 1998,12,15

   :CAL:PROT:NDUE 1999,12,15

7. Finally, send the following commands to save calibration constants and then lock out calibration:

   :CAL:PROT:SAVE

   :CAL:PROT:LOCK

Index

Numerics

20µA-20mA range accuracy 18-12
200MΩ-200GΩ range accuracy 18-17
20pA-2µA range accuracy 18-13
2kΩ-20MΩ range accuracy 18-15
2V analog output 11-7

A

Aborting calibration 19-5
Address commands F-9
Addressed multiline commands F-9
Amps calibration 19-10
Amps measurement accuracy 18-12
Amps measurement considerations 4-9
Amps measurement procedure 4-2
Amps Measurements 4-1
Analog outputs 11-7
Application 3-14, 5-7
Applications 4-13
Auto discharge 5-2
Automatic calculations 19-6
Autozero 2-2

B

Basic connections to DUT 2-6
Binning 10-4
Buffer 8-1
Buffer operations 8-2
Buffer statistics 8-3
Bus commands F-7
Bus description F-3
Bus lines F-5
Bus management lines F-5

C

Cable insulation resistance 4-14
Cable leakage resistance 3-9
Calibration 19-1
Calibration commands H-4
Calibration considerations 19-3
Calibration cycle 19-3
Calibration errors 19-5
Calibration menu 19-5
Calibration Options H-1
Calibration procedure 19-7
Calibrator voltage calculations 18-7
Capacitance measurements 5-7
Capacitor dielectric absorption 3-14
Capacitor leakage current 4-14
Changing function and range E-2
Changing the calibration code 19-18
Charge calculations 18-7
Clearing registers and queues 13-4
Command F-10
Command codes F-10
Common Commands 14-1, F-10
Component handler interface 10-6
Component handler types 10-7
Condition registers 13-15
Connection fundamentals 2-3
Contact information 1-2
Controlling the Model 6514 via the RS-232 COM2 port E-7
Coulombs calibration 19-14
Coulombs measurement accuracy 18-18
Coulombs measurement considerations 5-6
Coulombs measurement procedure 5-3
Coulombs Measurements 5-1
Current and charge calculations 19-6
Current calculations 18-7

D

Damping 4-4
Data lines F-5
Data transfer connections H-2
DDC Emulation Commands D-1
DDC language D-2
Default settings 1-12
Digital 6-9
Digital filter 6-9
Digital I/O port 11-2
Digital I/O, Analog Outputs, and External Feedback 11-1
Digital output clear pattern 10-8
Digits 6-4
Diode leakage current 4-13
DISP test 20-4
Display 1-12
DISPlay subsystem 16-2
DISPlay, FORMat, and SYSTem 16-1
Displaying calibration dates 19-19
Displaying the calibration count 19-20

E

Electrochemical effects C-4
Electromagnetic Interference (EMI) C-5
Electrometer input circuitry 11-11
Electrostatic interference C-4

Entering calibration dates and saving calibration 19-18
Environmental conditions 18-3, 19-2
Error messages 12-19
Error queue 13-19
Event enable registers 13-17
Event registers 13-16
Example program H-3
Example Programs E-1
Example reading limits calculation 18-6
External feedback 11-11
External feedback procedure 11-13
External trigger example 9-12
External triggering 9-11
External voltage source 5-6

F

Filters 6-8
Floating measurements 2-11
FORMat subsystem 16-4
Front and rear panel familiarization 1-5
Front panel 2-17
Front panel GPIB operation 12-10
Front panel operation 10-10
Front panel summary 1-5
Front panel tests 20-4

G

General bus commands 12-8
General information 1-2
General Measurement Considerations C-1
General notes 17-2
Generating SRQ on buffer full E-4
Getting Started 1-1
GPIB bus connections 12-5
GPIB bus standards 12-5
GPIB operation and reference. 12-5
Ground loops C-2
Guarding 3-2
Guarding input cable 3-12

H

Handshake lines F-6
High impedance measurement techniques 4-5
Humidity C-4

I

Idle and initiate 9-4
IEEE command groups F-12
IEEE-488 and SCPI Conformance Information G-1
IEEE-488 Bus Overview F-1
Input bias current 4-9, 5-6
Input bias current and offset voltage calibration 2-17, 18-9, 19-7
Input bias current calibration 18-9
Input cable leakage and capacitance 3-3
Input capacitance (settling time) 3-10
Input connector 2-3
Input protection 2-11
Input trigger requirements 9-11
Inspection 1-2
Interface function codes F-13
Interface selection and configuration procedures 12-2
Interfaces 12-2
Introduction 18-2, 19-2, 20-2, F-2, G-2, H-2

K

KEY test 20-4

L

Languages 12-2
Light C-4
Limit test configuration 10-10
Limit testing 10-2
Limit Tests 10-1
Line frequency selection 1-10
Line power 18-3, 19-2
Line power connection 1-10
Loading effects 3-9
Locking out calibration 19-18
Logarithmic currents 11-15
Low noise input cables 2-5

M

Magnetic fields C-5
Manual calculations 19-6
Measurement Concepts 2-1
Measurement considerations 2-19, C-2
Measurement overview 2-2, 3-2, 4-2, 5-2
Median filter 6-8
mX+b 7-4
mX+b and percent (%) 7-4

N

Noise 4-10
Non-decade current gains 11-16
Non-standard coulombs ranges 11-13

O

Offset voltage calibration 18-9
Ohms calibration 19-16
Ohms measurement accuracy 18-15
One-shot triggering E-3
Options and accessories 1-3
Output queue 13-18
Output trigger specifications 9-12
Overview 13-2

P

Percent (%) 7-5
Perform limit tests 10-11
Performance considerations 2-2
Performance Verification 18-1
Performing the verification test procedures 18-8
Piezoelectric and stored charge effects C-3
Power-up 1-10
Power-up sequence 1-11
Preparing for calibration 19-7
Primary address selection 12-7
Programming and reading registers 13-5
Programming enable registers 13-5
Programming example 3-8, 4-9, 5-6, 8-6, 9-10, 10-15
Programming examples E-2
Programming syntax 12-11

Q

Queues 13-18

R

Range 6-2
Range, units, and digits 6-2
Range, Units, Digits, Rate, and Filters 6-1
Rate 6-6
Reading calibration standard values H-2
Reading registers 13-6
Reading values H-2
Rear panel summary 1-8
Recalculating resistance reading limits 18-6
Recall 8-2
Recommended calibration equipment 19-3
Recommended test equipment 18-4
Register bit descriptions 13-11
Relative 7-1, 7-2
Relative, mX+b and Percent (%) 7-1
Remote calibration H-4
Remote calibration overview H-4
Remote Operation 12-1
Resetting the calibration code 19-19
Restoring factory defaults 18-9
Routine Maintenance 20-1
RS-232 connections 12-18
RS-232 interface reference 12-17
RS-232 settings 12-17

S

Safety symbols and terms 1-2
SCPI commands F-10
SCPI programming 1-15, 2-3, 2-18, 3-7, 4-8, 5-5, 8-4, 9-9, 10-12
SCPI programming — digital output pattern 11-6
SCPI programming — external feedback 11-17
SCPI programming — filters 6-10
SCPI programming — mX+b and percent 7-6
SCPI programming — range and digits 6-4
SCPI programming — rate 6-7
SCPI programming — relative 7-3
SCPI programming — zero check and zero correct 2-15
SCPI Reference Tables 17-1
SCPI Signal Oriented Measurement Commands 15-1
Selecting and configuring an interface 12-2
Sending and receiving data 12-17
Serial polling and SRQ 13-9
Service request enable register 13-8
Setting and controlling relative 7-2
Setting digital output lines 11-5
Setting line voltage and replacing line fuse 20-2
Shielded fixture construction 11-12
Sink mode — controlling external devices 11-3
Source mode — logic control 11-5
Specifications A-1
Status and Error Messages 1-12, B-1
Status byte and service request (SRQ) 13-7
Status byte and service request commands 13-9

Status byte register 13-7
Status register sets 13-11
Status Structure 13-1
Store 8-2
Storing readings in buffer E-5
Surface insulation resistance (SIR) 4-15
System electrometer features 1-4
SYSTem subsystem 16-8

T

Taking readings using the READ? command E-6
Temperature and relative humidity 19-2
Test circuit leakage 3-2
Test considerations 18-8
Test fixture 2-9
Test summary 18-8
Triboelectric effects C-3
Trigger model configuration — front panel 9-7
Trigger model operation 9-4
Trigger models 9-2
Triggering 9-1
Typical command sequences F-11

U

Unaddress commands F-9
Units 6-4

V

V-Drop and I-Source for ohms 3-6
Verification limits 18-6
Verification test requirements 18-3
Voltage burden 4-9
Volts and ohms measurement considerations 3-9
Volts and ohms measurement procedure 3-4
Volts and Ohms Measurements 3-1
Volts calibration 19-8
Volts measurement accuracy 18-10

W

Warm-up period 2-2, 18-3, 19-2
Warranty information 1-2

Z

Zero check 2-13
Zero check and zero correct 2-13
Zero check hop and auto discharge hop 5-7
Zero correct 2-14

Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

❑ Intermittent ❑ Analog output follows display ❑ Particular range or function bad; specify

_____

❑ IEEE failure ❑ Obvious problem on power-up ❑ Batteries and fuses are OK

❑ Front panel operational ❑ All ranges or functions are bad ❑ Checked all cables

Display or output (check one)

❑ Drifts ❑ Unable to zero ❑ Unstable

❑ Overload ❑ Will not read applied input

❑ Calibration only ❑ Certificate of calibration required ❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

_____

What power line voltage is used?_____ Ambient temperature? _____ °F

Relative humidity? _____Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

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Newtons4th Ltd

PSM1735

User Manual

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" Do not be hasty when making measurements."

The **PSM1735** is a precision instrument that provides you with the tools to make a wide variety of measurements accurately, reliably, and efficiently - but good metrology practice must be observed. Take time to read this manual and familiarise yourself with the features of the instrument in order to use it most effectively.

DANGER OF ELECTRIC SHOCK

Only qualified personnel should install this equipment, after reading and understanding this user manual. If in doubt, consult your supplier.

RISQUE D'ELECTROCUTION

L'installation de cet équipement ne doit être confiée qu'à un personnel qualifié ayant lu et compris le présent manuel d'utilisation. Dans le doute, s'adresser au fournisseur.

GEFAHR VON ELEKTRISCHEM SCHOCK

Nur entsprechend ausgebildetes Personal ist berechtigt, diese Ausrüstung nach dem Lesen und Verständnis dieses Anwendungshandbuches zu installieren. Falls Sie Zweifel haben sollten, wenden Sie sich bitte an Ihren Lieferanten.

RISCHIO DI SCARICHE ELETTRICHE

Solo personale qualificato può installare questo strumento, dopo la lettura e la comprensione di questo manuale. Se esistono dubbiconsultate il vostro rivenditore.

PELIGRO DE DESCARGA ELÉCTRICA

Solo personal cualificado debe instalar este instrumento, después de la lectura y comprensión de este manual de usuario. En caso de duda, consultar con su suministrador.

IMPORTANT SAFETY INSTRUCTIONS

This equipment is designed to comply with BSEN 61010-1 (Safety requirements for electrical equipment for measurement, control, and laboratory use) – observe the following precautions:

- Ensure that the supply voltage agrees with the rating of the instrument printed on the back panel ***before*** connecting the mains cord to the supply.
- This appliance ***must*** be earthed. Ensure that the instrument is powered from a properly grounded supply.
- The inputs must not be connected to signals greater than 10V peak.
- Keep the ventilation holes on the underneath and sides free from obstruction.
- Do not operate or store under conditions where condensation may occur or where conducting debris may enter the case.
- There are no user serviceable parts inside the instrument – do not attempt to open the instrument, refer service to the manufacturer or his appointed agent.

Note: Newtons4th Ltd. shall not be liable for any consequential damages, losses, costs or expenses arising from the use or misuse of this product however caused.

DECLARATION OF CONFORMITY

Manufacturer: Newtons4th Ltd.
Address: 1 Bede Island Road
Leicester
LE2 7EA

We declare that the product:

Description: Phase Sensitive Multimeter
Model: PSM1735

Conforms to the EEC Directives:

2014/30/EU relating to electromagnetic compatibility:
EN 61326-1:2013

2014/35/EU relating to Low Voltage Directive:
EN 61010-2-030:2010:

January 2017

Jigar Patel
(Senior Engineer Newtons4th Ltd.)

WARRANTY

This product is guaranteed to be free from defects in materials and workmanship for a period of 36 months from the date of purchase.

In the unlikely event of any problem within this guarantee period, first contact Newtons4th Ltd. or your local representative, to give a description of the problem. Please have as much relevant information to hand as possible – particularly the serial number and release numbers (press SYSTEM then LEFT).

If the problem cannot be resolved directly then you will be given an RMA number and asked to return the unit. The unit will be repaired or replaced at the sole discretion of Newtons4th Ltd.

This guarantee is limited to the cost of the PSM1735 itself and does not extend to any consequential damage or losses whatsoever including, but not limited to, any loss of earnings arising from a failure of the product or software.

In the event of any problem with the instrument outside of the guarantee period, Newtons4th Ltd. offers a full repair and re-calibration service. It is recommended that PSM1735 is re-calibrated annually.

Please contact your local Distributor or the N4L office for further details of N4L's instrument repair and re-calibration service.

ABOUT THIS MANUAL

The PSM1735 has a number of separate measurement functions that share common resources such as the keyboard and display.

Accordingly, this manual first describes the general features and specification of the instrument as a whole; and then describes the individual functions in detail.

Each function is described in turn, in its own chapter, with details of the principles on which it is based, how to use it, the options available, display options, specifications etc.

Detailed descriptions of the RS232 command set are given in the separate manual "PSM17xx communications manual".

Due to our policy of continuous product improvement, we reserve the right to change product specifications or designs at any time without notice and without incurring obligations. All Errors and omissions excepted (E&OE)

CONTENTS

1 Introduction – general principles of operation 1-1
1.1 Voltage inputs 1-4
2 Getting started 2-1
2.1 Unpacking 2-1
2.2 Keyboard and controls 2-3
2.3 Basic operation 2-4
2.4 Measurement Selectivity 2-5
3 Using the menus 3-1
3.1 Selection from a list 3-3
3.2 Numeric data entry 3-4
3.3 Text entry 3-5
4 Special functions 4-1
4.1 Display zoom 4-1
4.2 Program store and recall 4-2
4.3 Zero compensation 4-3
4.4 Alarm function 4-4
4.5 Analogue output 4-6
4.6 Data hold 4-7
4.7 Parallel port 4-8
4.8 Sweep results store and recall 4-9
5 Using remote control 5-1
5.1 Standard event status register 5-3
5.2 Serial Poll status byte 5-4
5.3 RS232 connections 5-5
5.4 Data streaming 5-6
6 System options 6-1
6.1 User data 6-3
7 Measurement options 7-1
7.1 ACQU - Acquisition options 7-1
7.2 Datalog 7-4
7.3 SWEEP - Frequency sweep options 7-6
7.4 TRIM - Trim function 7-8

8 Output control 8-1
8.1 Generator specifications 8-3
9 Input channels 9-1
9.1 Trimming x10 oscilloscope probes 9-5
10 True RMS Voltmeter 10-1
10.1 RMS voltmeter specification 10-4
11 Frequency response analyser 11-1
11.1 Frequency response analyser specification 11-5
12 Phase angle voltmeter (vector voltmeter) 12-1
12.1 Phase angle voltmeter specification 12-4
13 Power meter 13-1
13.1 Power meter specification 13-4
14 LCR meter 14-1
14.1 Applying Compensation 14-6
14.2 LCR meter specification 14-10
15 Harmonic analyser 15-1
15.1 Harmonic analyser specification 15-4
16 Transformer analyser 16-1
16.1 Turns ratio 16-3
16.2 Inductance & leakage inductance 16-4
16.3 AC resistance and Q factor 16-5
16.4 DC resistance 16-5
16.5 Interwinding capacitance 16-6
16.6 Magnetising current 16-7
16.7 Return loss 16-8
16.8 Insertion loss 16-9
16.9 Harmonics and distortion 16-11
16.10 Longitudinal balance 16-12

APPENDICES

Appendix A Accessories

Appendix B Serial command summary

Appendix C Available character set

Appendix D Configurable parameters

Appendix E Contact details

1 Introduction – general principles of operation

The PSM1735 is a self-contained test instrument, with one output and two inputs, which incorporates a suite of test functions.

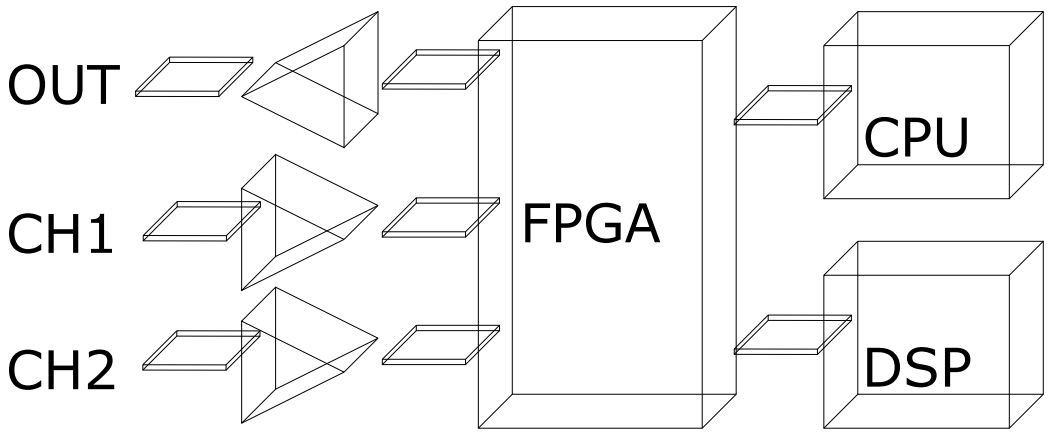
The PSM1735 has a wide bandwidth generator output that can be used as signal generator for sine or square waveforms. A dc offset may be added to the signal generator output.

The PSM1735 has two differential, high bandwidth, voltage inputs, which use direct digital analysis at low frequencies and a heterodyning technique to give high accuracy at high frequencies.

The PSM1735 has two processors:

a DSP (digital signal processor) for data analysis
a CPU (central processing unit) for control and display

At the heart of the system is an FPGA (field programmable gate array) that interfaces the various elements.



This general purpose structure provides a versatile hardware platform that can be configured by firmware to provide a variety of test functions, including:

signal generator
two channel true rms voltmeter
phase angle voltmeter (vector voltmeter)
frequency response analyser (gain/phase analyser)
harmonic analyser

With additional external interfaces, such as current shunts, other functions are possible:

true rms current meter
LCR meter
power meter

The programmable nature of the instrument means that new functions can be added as they become available, or existing functions can be enhanced, by simple firmware download.

The PSM1735 is configured to perform the required test function by simple user menus, or can be controlled remotely via a serial interface (RS232), or optionally LAN interface or GPIB interface.

The optional LAN interface sets a default IP address with the LAN chip expecting to be connected as a network client via DCHP so it is not usually necessary to set an IP address. If the IP address is not automatically assigned to your network address it can be manually changed using a program supplied by Lantronix. Please contact the N4L office for further information or assistance.

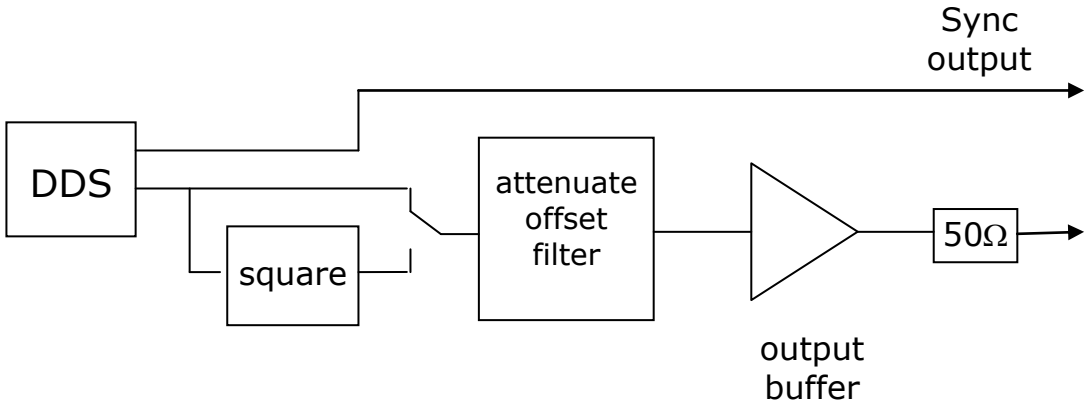
E-mail address: support@newtons4th.com

The PSMComm2 software will display all instruments connected to the same subnet allowing the appropriate instrument to be selected from the list.

Generator output

The output sinewave is generated by direct digital synthesis (DDS). Amplitude is set in 2 stages - a fine control and a coarse control to give excellent resolution over the whole range. The square wave is generated from the sinewave by a high speed comparator. The output has a variable offset added, is filtered and is buffered by a high speed, high current buffer. There is also a TTL Sync output for oscilloscope synchronization etc, constantly running at the selected generator frequency.

The DDS is clocked at 150 MHz.
The DAC resolution is 12 bit.
The fine amplitude control is 11 bit (0.05% fsd).
The coarse amplitude control is 8 bit.
The maximum output level is ±10V peak.
The maximum output current is ±200mA peak.
The 0V of the output is earthed.
The output impedance is 50Ω.
The output frequency range is 10uHz to 35MHz.
The Sync output is TTL level at generator frequency.

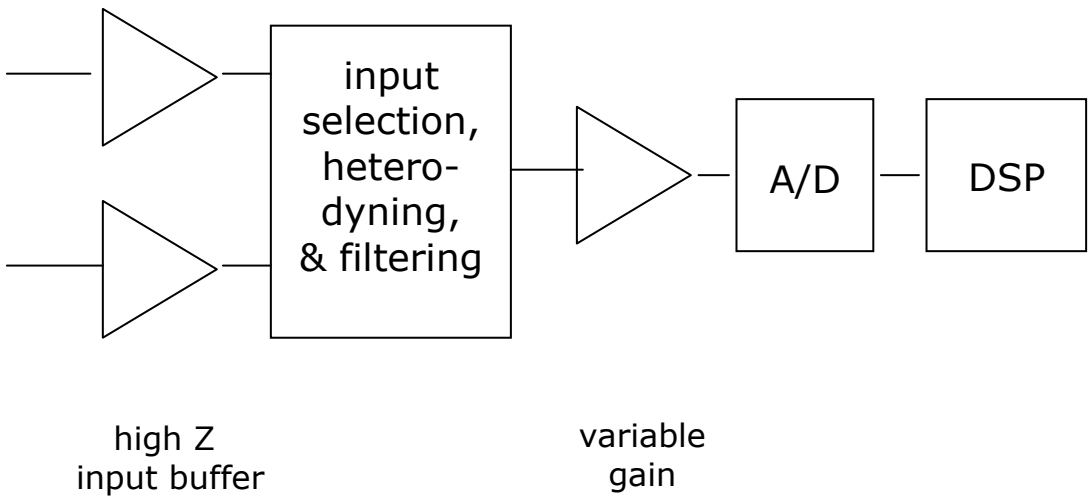


1.1 Voltage inputs

Each input consists of a pair of ac, or ac+dc, coupled high impedance buffers, one for the main input and one for the secondary. The main and secondary inputs can be selected independently, to multiplex two signals to the same input, or may be used as a single differential input, main - secondary. The secondary input has an adjustable gain, accessible from the front panel, to trim the CMRR.

After the selectable heterodyning and filtering, there is a series of gain stages leading to an A/D converter. Selection of the input gain, the heterodyning and the sampling of the A/D converter is under the control of the DSP. There is an autozero switch at the front end for dc accuracy.

The maximum input is ±10V peak.
The full scale of the lowest range is ±1mV peak.
The input frequency range is dc to 35 MHz.
The A/D converter resolution is 12 bit.
The A/D sample rate is variable to 500k samples/s.



2 Getting started

The PSM1735 is supplied ready to use – it comes complete with an appropriate power lead and a set of test leads. It is supplied calibrated and does not require anything to be done by the user before it can be put into service.

2.1 Unpacking

Please remove all contents from the carton and check each item against the packing list.

Having verified that everything on the packing list is present, it would be wise to verify that your PSM1735 operates correctly and has not been damaged in transit.

First, verify that the voltage rating on the rear of the PSM1735 is appropriate for the supply, then connect the mains cord to the inlet on the rear panel of the instrument and the supply outlet.

Switch on the PSM1735. The display should illuminate with the model name and the firmware version for a few seconds while it performs some initial tests. It should then default to the RMS voltmeter display. Note that the switch on message can be personalised – see the User Data section under System Options.

Note that if there are no leads connected, the rms display should read zero. If any test leads are connected then because of the high impedance of the inputs, the rms display may read some random values due to noise pick up. If the unit does display any values with no leads connected, give the unit thirty minutes to warm up then press ZERO.

Connect the output lead to the output BNC of the PSM1735 and two input probes to the + input BNCs of the two channels. Connect the output to both of the inputs by connecting the black clip on the output lead to the 0V clip on each of the input probes, and the red clip of the output lead to the input probes. Note that this is easiest to do by connecting across a resistor (any value above 1k).

Press the OUT key to invoke the output menu, then press the UP key to select the output on/off control then the RIGHT key to turn on the output.

Exit the menu by pressing the ENTER button or the HOME button *twice.*

The display should now indicate an rms value of about 1.4V on both channels, each of which should indicate the 3V range.

Press the FRA key to select the frequency response (gain phase) analyser function and check that the gain reads 0.000dB ±0.010dB, and that the phase reads 0.000° ±0.010°.

In the event of any problem with this procedure, please contact customer services at Newtons4th Ltd. or your local authorised representative: contact addresses and telephone numbers are given in the appendix at the back of this manual.

2.2 Keyboard and controls

The keyboard is divided into 5 blocks of keys:

- display control (5 keys top left)
- function keys (6 keys top right)
- setup keys (12 keys lower left)
- menu control keys (7 centre keys)
- action keys (4 keys lower right)

In normal operation, the cursor keys give one-touch adjustment of various parameters, such as generator amplitude and frequency, without having to access the menu system.

The setup keys provide access to the menus and are used for numeric data entry.

The function keys (FRA, PAV, LCR, RMS, POWER and HARM) are also used for entering the multipliers (G, M, k, m, u, n) for date entry and letters for text entry.

2.3 Basic operation

Once the unit has powered on and is displaying the default RMS voltmeter screen, the required function can be selected by pressing the function key, FRA, PAV, LCR, RMS, POWER, or HARM. Pressing the same function key again brings up the menu options specific to that function. For example, after the unit has powered on in RMS mode, press PAV to select phase angle voltmeter mode; press PAV again to gain access to the PAV specific menu options.

Alternatively, press MODE to bring up the function specific menus.

There are a number of menus available to configure the instrument. All of these menus are directly accessible with one press of the appropriate menu key. The cursor keys allow navigation around the menus and also control the generator when not accessing a menu.

For example, to turn on the output, press OUT to bring up the generator control menu, press UP to select the output on/off option, press RIGHT to turn on the output. Press ENTER, or HOME twice, to exit the menu. Press FRA to select frequency response analyser mode and the instrument will now display the gain and phase of the transfer function of the circuit under test at the spot frequency specified by the output control menu.

Press LEFT or RIGHT to adjust the frequency, Press UP or DOWN to adjust the amplitude (use the OUT menu to change the size of the steps).

Press START and the PSM1735 will start a frequency sweep over the specified range (set in the SWEEP menu); press TABLE to see the table of results, GRAPH to see a graph of the results and REAL TIME to return to the real time data.

2.4 Measurement Selectivity

In many applications that require frequency response analysis, it is common for the frequency of interest (sometimes referred to as the injected frequency) to be immersed in noise. It is therefore important that the FRA instrument being used is able to reject frequencies other than that of the signal of interest. This feature is usually described as the **measurement selectivity** of the instrument and in most cases; selectivity is increased as the measurement speed is slowed down.

N4L frequency response analysers incorporate analogue circuits with high common mode rejection and unique 'real time' DFT (Discrete Fourier transform) analysis to provide exceptional wideband frequency response measurements even when the signal of interest is immersed in noise. As a result of this design technique, users are not required to concern themselves with the careful choice of selectivity criteria to achieve stable measurements.

In most applications, the signal of interest is generated by the FRA itself. When using this normal mode of operation, PSM units from N4L will automatically analyse the measurement signal with a DFT algorithm running at exactly the same frequency as the injected signal. This process eliminates the problem of signal frequency detection.

Where an external signal source is used for signal injection, the PSM units will detect the injected frequency with a greater level of selectivity as the measurement speed is slowed down. The user need only select the measurement speed to achieve the optimum balance of speed and measurement stability.

While it is not required for the user to define the selectivity, nominal values used by the PSM units are defined in the following table:

speed	update rate	normal time constant	slow time constant	Measurement Selectivity
fast	1/20s	0.2s	0.8s	24Hz
medium	1/3s	1.5s	6s	3Hz
slow	2.5s	12s	48s	0.4Hz
very slow	10s	48s	192s	0.1Hz

NOTE:

Some FRA instrument manufacturers use the term 'IF Bandwidth'. While this term is usually used in general electronics to refer to the intermediate frequency of analogue RF circuits, in FRA applications the term actually relates to measurement selectivity.

3 Using the menus

The PSM1735 is a very versatile instrument with many configurable parameters. These parameters are accessed from the front panel via a number of menus.

Each of the main menus may be accessed directly from a specific key.

ACQU	data acquisition parameters such as speed and filtering
SWEEP	frequency sweep control
TRIM	generator trim control (amplitude compression)
COMMS	communications options (RS232 etc)
ALARM	control of audible alarm and analogue output
AUX	control of auxiliary devices connected to either the front AUX port or rear EXTENSION port
OUT	signal generator control
CH1	channel 1 input control
CH2	channel 2 input control
SYS	general system options such as phase convention, keyboard beep etc.
MODE	function control
PROG	recall/store/ delete of non-volatile programs

Each menu starts with the currently set parameters visible but no cursor. In this condition, pressing the menu key again or the HOME key aborts the menu operation and reverts back to normal operation.

To select any parameter, press the UP or DOWN key and a flashing box will move around the menu selecting each parameter. In this condition, the keys take on their secondary function such as numbers 0-9, multipliers n-G etc.

Pressing the HOME key first time reverts to the opening state where the parameters are displayed but the cursor is hidden. Pressing the HOME key at this point exits the menu sequence and reverts back to normal operation.

To abort the menu sequence, press the HOME key twice.

There are three types of data entry:

- selection from a list
- numeric
- text

3.1 Selection from a list

This data type is used where there are only specific options available such as the output may be ‘on’ or ‘off’, the graph drawing algorithm may use ‘dots’ or ‘lines’.

When the flashing cursor is highlighting the parameter, the RIGHT key steps forward through the list and the LEFT key steps backwards through the list. The number keys 0-9 step directly to that point in the list, which provides a quick way to jump through long lists. There is no need to press the ENTER key with this data type

For example, if the speed selection list comprises the options:

very slow	(item 0)
slow	(item 1)
medium	(item 2)
fast	(item 3)
window	(item 4)

and the presently selected option is “medium”, there are 3 ways to select “window”:

press RIGHT twice
press LEFT three times
press number 4

3.2 Numeric data entry

Parameters such as frequency and offset are entered as real numbers; frequency is an example of an unsigned parameter, offset is an example of a signed parameter.

Real numbers are entered using the number keys, multiplier keys, decimal point key, or +/- key (if signed value is permitted). When the character string has been entered, pressing the ENTER key sets the parameter to the new value. Until the ENTER key is pressed, pressing the HOME key aborts the data entry and restores the original number.

If a data value is entered that is beyond the valid limits for that parameter then a warning is issued and the parameter set as close to the requested value as possible. For example, the maximum amplitude of the PSM1735 generator is 10V peak; if a value of 15V is entered, a warning will be given and the amplitude set to the maximum of 10V.

When the parameter is first selected there is no character cursor visible – in this condition, a new number may be entered directly and will overwrite the existing number.

To edit a data value rather than overwrite it, press the RIGHT key and a cursor will appear. New characters are inserted at the cursor position as the keys are pressed, or the character before the cursor position can be deleted with the DELETE key.

Data values are always shown in engineering notation to at least 5 digits (1.0000-999.99 and a multiplier).

3.3 Text entry

There are occasions where it is useful to enter a text string; for example, a non-volatile program may have some text as a title.

Text is entered by selecting one of 6 starting characters using the main function keys on the top right hand side of the keyboard (FRA etc), then stepping forwards or backwards through the alphabet with the UP and DOWN keys.

The starting letters are A (FRA), E (PAV), I (LCR), O (RMS), U (POWER), or space (HARM).

Numbers can also be inserted using the number keys.

The UP and DOWN keys step forward and backwards using the ASCII character definitions – other printable characters such as # or ! can be obtained by stepping on from the space. The available character set is given in the Appendix.

When entering alphabetic characters, the ZOOM+ and ZOOM- keys select upper and lower case respectively for the character preceding the cursor and the next characters to be entered.

The editing keys, RIGHT, LEFT, DELETE and ENTER operate in the same way as for numeric entry.

4 Special functions

4.1 Display zoom

The PSM1735 normally displays many results on the screen in a combination of small font size (no zoom) and up to 4 values in a larger font size (first zoom level). There is also an even larger font for up to 4 selected values (second zoom level).

To set the data values for the larger font size, first return to no zoom by pressing ZOOM-, twice if necessary. Press ZOOM+ key to view the presently selected data, and press DELETE to clear the selection.

A flashing box surrounds the first available result. The flashing box is moved around the available results using the cursor keys, UP, DOWN, LEFT and RIGHT. Pressing the ENTER key selects the result for zoom and the box ceases to flash. Further results (up to four in total) can then be selected using the cursor keys in the same way – a solid box remains around the already selected item, and a new flashing box appears.

Having selected the desired results, pressing the ZOOM+ key invokes the first zoom level, pressing it again selects the higher level. Pressing ZOOM-, steps back down one level each time.

Note that any of the parameters selected for the zoom function can be used as the input for the alarm monitoring and analogue output.

4.2 Program store and recall

There are 100 non-volatile program locations where the settings for the entire instrument can be saved for recall at a later date. Each of the 100 locations has an associated name of up to 20 characters that can be entered by the user to aid identification.

Program number 1 (if not empty) is loaded when the instrument is powered on so that the PSM1735 can be set to a user defined state whenever it is switched on. This is particularly useful to set system options such as phase convention, GPIB address etc. If no settings have been stored in program 1 then the factory default settings are loaded (program number 0).

Program numbers 1-6 may be recalled with a single press of the function keys if the direct load option is selected in the system menu (see system options).

The instrument can be restored to the factory default settings at any time by recalling program number 0.

The program menu is accessed using the PROG key. The program location can be selected either by stepping through the program locations in turn to see the name or by entering the program number directly.

When storing a configuration in a program, there will be a slight pause (of about 1 second) if the program has previously been written or deleted. The process will be very quick if the location has not been used.

When supervisor mode is disabled (see system options), programs can only be recalled, not stored nor deleted, to avoid accidental modification.

4.3 Zero compensation

There are 3 levels of zero compensation:

Trim out the dc offset in the input amplifier chain.
Measure any remaining offset and compensate.
Measure parasitic external values and compensate.

The trim of the dc offset in the input amplifier chain is re-applied every time that the measurement function is changed or can be manually invoked with the ZERO key, or over the RS232 with the REZERO command.

The measurement of the remaining offset also happens when the offset is trimmed but is also repeated at regular intervals when using a measurement function that requires dc accuracy (such as the rms voltmeter). This is to compensate for any thermal drift in the amplifier chain. This repeated autozero function can be disabled via the SYSTEM OPTIONS menu.

The compensation for parasitic external values (for example to compensate for the capacitance of the test leads when measuring capacitance) is invoked manually by the ZERO key. Refer to each function section for the function specific operations.

Any single point compensation values are stored along with the instrument configuration when a program is stored.

To restore operation without function specific compensation press ZERO then select the clear option.

4.4 Alarm function

The PSM1735 has two independent alarms that can be read remotely or can generate an audible sound. Each of the alarms can be triggered by comparison to one or two thresholds:

sound the alarm if the value exceeds a threshold
sound the alarm if the value is below a threshold
sound the alarm if the value is outside a window
sound the alarm if the value is inside a window

Additionally, one of the alarms can be used to generate a sound which varies linearly between thresholds

The value to which each alarm is applied can be any of the measurements selected for zoom. The alarm status is also available as a logic output on the parallel port.

To program an alarm, first select the functions for the zoom; up to four measurements can be selected for the display, the alarm is applied to any of them; then press ALARM to invoke the alarm menu:

select which of the zoom functions is to be used
select the type of alarm
set the upper limit (if appropriate)
set the lower limit (if appropriate)
select whether the alarm is to be latched
select whether the alarm sounder is enabled

If the alarm latch is selected then the alarm will continue to sound even if the value returns to within the normal boundaries. To clear the alarm, press HOME.

The linear alarm option allows tests to be carried out even if it is not possible to see the display. Pressing ZERO in the alarm menu sets the upper and lower threshold to 4/3 and

1/3 of the measured value respectively. The repetition rate of the sounder then varies linearly as the value changes between these thresholds.

4.5 Analogue output

The analogue output is a 0 to 4V dc level that represents the selected measurement.

To program the analogue output, first select the functions for the zoom; up to four measurements can be selected for the display, the alarm is applied to any one of them; then press MONITOR to invoke the alarm and analogue output menu:

select which of the zoom functions is to be used
set the value for zero volts output
set the analogue scaling factor

The analogue output level is computed as:

output voltage = 4 * scale * (measurement – zero)

The output is updated whenever new data is available. For maximum update speed, select “fast analogue output” mode in the ACQU menu and enter a window value for 10ms or higher. When START is pressed, the instrument enters a special mode where all non-essential functions are suppressed (including the display). Press STOP to return to the normal display.

4.6 Data hold

When in real time display mode, the data on the display can be held at any time by pressing the REAL TIME key. When HOLD is activated a warning message is briefly displayed and the word HOLD appears in the top right hand corner of the display.

Press the REAL TIME key again or the HOME key or START key to release HOLD; in this case, HOME and START do not have their normal functions. Changing mode also releases hold.

When HOLD has been activated, the DSP continues to sample, compute and filter the results but the data is ignored by the CPU. When HOLD is released the display is updated with the next available value from the DSP.

4.7 Parallel port

The PSM1735 has a logic level parallel port with 8 output lines and 4 input lines, which can be used to interface with other parts of a test system or with a PLC.

The parallel port can be used either as a general purpose I/O port under communications control (see PPORT and PPORT? commands) or can be used as a status output:

7	6	5	4	3	2	1	0
				ALM2	ALM1	ERR	DAV

bit 0 DAV data available
bit 1 ERR data error (under or overrange)
bit 2 ALM1 alarm 1
bit 3 ALM2 alarm 2

The status output is enabled in the ALARM menu. By selecting appropriate alarm conditions, the status output can be used as a pass/fail indicator

Parallel port pin connections:

pin	function	
2-9	data out	D0 [pin 2] – D7 [pin 9]
10	data in	D2
11	data in	D3
12	data in	D0
13	+5V supply	50mA max.
15	data in	D1

4.8 Sweep results store and recall

There are 30 non-volatile storage locations that can store the results of frequency sweeps. Each location can store the sweep results for up to 50 points; larger sweeps can be stored in multiple locations:

frequency points in sweep	locations used per sweep	memory capacity
up to 50	1	30
51-100	2	15
101-150	3	10
151-200	4	7
201-250	5	6
251-500	8	3
501-1000	15	2
1001-2000	30	1

When storing a sweep, a text string may be entered to help identify the data.

Each stored sweep also saves the instrument configuration along with the sweep results (same as program store/recall), so that the instrument is restored to the same settings when the sweep is recalled.

The sweep data may be restored manually or via communications for download to a PC. To manually access the sweep data store, press PROG and select memory type “sweep”.

5 Using remote control

The PSM1735 is fitted with an RS232 serial communications port as standard and may have an IEEE488 (GPIB) interface or LAN interface fitted as an option, (Port No 10001). All the interfaces use the same ASCII protocol with the exception of the end of line terminators:

	Rx expects	Tx sends
RS232	carriage return (line feed ignored)	carriage return and line feed
LAN	carriage return (line feed ignored)	carriage return and line feed
IEEE488	carriage return or line feed or EOI	carriage return with EOI

All the functions of the PSM1735 can be programmed via either interface, and results read back. When the IEEE488 interface is set to 'remote' the RS232 port is ignored.

The commands are not case sensitive and white space characters are ignored (e.g. tabs and spaces). Replies from PSM1735 are always upper case, delimited by commas, without spaces.

Only the first six characters of any command are important – any further characters will be ignored. For example, the command to set the generator frequency is FREQUE but the full word FREQUENCY may be sent as the redundant NCY at the end will be ignored.

Fields within a command are delimited by a comma, multiple commands can be sent on one line delimited with a semi-colon eg.

AMPLIT,1.5;OUTPUT,ON

Mandatory commands specified in the IEEE488.2 protocol have been implemented, (e.g. *IDN?, *RST) and all

commands that expect a reply are terminated with a question mark.

The PSM1735 maintains an error status byte consistent with the requirements of the IEEE488.2 protocol (called the standard event status register) that can be read by the mandatory command *ESR? (see section 5.1).

The PSM1735 also maintains a status byte consistent with the requirements of the IEEE488.2 protocol, that can be read either with the IEEE488 serial poll function or by the mandatory command *STB? over RS232 or IEEE or LAN (see section 5.2).

The IEEE address defaults to 23 and can be changed via the COMMS menu.

The keyboard is disabled when the instrument is set to "remote" using the IEEE interface or if the command "KEYBOA,DISABL" is sent. Press HOME to return to "local".

RS232 data format is: start bit, 8 data bits (no parity), 1 stop bit. Flow control is RTS/CTS (see section 5.2), baud rate is selectable via the MONITOR menu.

A summary of the available commands is given in the Appendix. Details of each command are given in the communication command section of the manual.

Commands are executed in sequence except for two special characters that are immediately obeyed:

Control T (20) – reset interface (device clear)
Control U (21) – warm restart

To maintain compatibility with some communication systems, there is an optional "protocol 2" which requires a space between the command and any arguments.

5.1 Standard event status register

PON		CME	EXE	DDE	QYE		OPC

bit 0 OPC (operation complete)
cleared by most commands
set when data available or sweep complete
bit 2 QYE (unterminated query error)
set if no message ready when data read
bit 3 DDE (device dependent error)
set when the instrument has an error
bit 4 EXE (execution error)
set when the command cannot be executed
bit 5 CME (command interpretation error)
set when a command has not been recognised
bit 7 PON (power on event)
set when power first applied or unit has reset

The bits in the standard event status register except for OPC are set by the relevant event and cleared by specific command (*ESR?, *CLS, *RST). OPC is also cleared by most commands that change any part of the configuration of the instrument (such as MODE or START).

5.2 Serial Poll status byte

		ESB	MAV		FDV	SDV	RDV

bit 0 RDV (result data available)
set when results are available to be read as enabled by DAVER

bit 1 SDV (sweep data available)
set when sweep results are available to be read as enabled by DAVER

bit 2 FDV (fast data available (streaming))
set when data streaming results are available to be read as enabled by DAVER

bit 4 MAV (message available)
set when a message reply is waiting to be read

bit 5 ESB (standard event summary bit)
set if any bit in the standard event status register is set as well as the corresponding bit in the standard event status enable register (set by *ESE).

5.3 RS232 connections

The RS232 port on the PSM1735 uses the same pinout as a standard 9 pin serial port on a PC or laptop (9-pin male 'D' type).

Pin	Function	Direction
1	DCD	in (+ weak pull up)
2	RX data	in
3	TX data	out
4	DTR	out
5	GND	
6	DSR	not used
7	RTS	out
8	CTS	in
9	RI	not used

The PSM1735 will only transmit when CTS (pin 8) is asserted, and can only receive if DCD (pin 1) is asserted. The PSM1735 constantly asserts (+12V) DTR (pin 4) so this pin can be connected to any unwanted modem control inputs to force operation without handshaking. The PSM1735 has a weak pull up on pin 1 as many null modem cables leave it open circuit. In electrically noisy environments, this pin should be driven or connected to pin 4.

To connect the PSM1735 to a PC, use a 9 pin female to 9 pin female null modem cable:

1 & 6	-	4
2	-	3
3	-	2
4	-	1 & 6
5	-	5
7	-	8
8	-	7

5.4 Data streaming

The phase angle voltmeter and power meter modes have the option of high speed data streaming. In this operation, the window width for the measurement may be specified from 660us to 100ms and the data for each measurement window is transmitted over the communications in a continuous stream. The window is adjusted to synchronise to the measured frequency.

The PSM1735 buffers the data and transmits at the fastest rate that is possible. The buffer depth is over 8000 data values so more than 5 seconds of data can be captured at the fastest rate of 1500 readings per second even if the data is not read at all. If the window size is such that the data can be read out in real time then data streaming can continue indefinitely.

Once the data streaming window has been setup but before the streaming has been started, the display periodically shows the measured value. Once streaming has been started, the display is blanked to minimise processing overheads. Streaming can be stopped either immediately (ABORT) or may be stopped but remaining data continues to be transmitted until the buffer is empty (STOP).

STREAM,ENABLE,0.01
START
read data
STOP
continue to read stored data

6 System options

Press SYSTEM to access the system options.

Measurements of phase can be expressed in one of three conventional formats:

-180° to +180° (commonly used in circuit analysis)
0° to -360° (commonly used in power applications)
0° to +360°

The measurement is exactly the same it is only the way that it is expressed that changes.

Blanking can be applied to a number of measurements so that zero is shown when the measurement is below a certain level. This blanking can be disabled if desired.

The graphs on the display and printout may be made up of single points or lines.

Each key press is normally accompanied by an audible 'beep' as well as the tactile 'click'. The 'beep' can be disabled for quiet environments if the feel of the key is sufficient feedback

Regular autozero measurements can be suppressed.

Any measurements that are expressed in units of length (eg. LVDT) can be displayed in metres or inches.

The shunt value is usually selected automatically when changing the function to one that needs a current input such as power meter or LCR meter. If the shunt is set to 'manual' rather than 'default' then the shunt value will not be changed.

When stepping through frequency or amplitude using the cursor keys in real time mode, a message is usually

displayed showing the new value. This message can be disabled.

The 6 main function keys, FRA, PAV, LCR, RMS, POWER, HARM, can be used to load stored configurations as a "one-touch" way of configuring the instrument for specific applications. This is particularly useful in a production environment where an operator has a small number of specific tests to perform.

Levels are usually expressed in volts but can be set and displayed in dBm, which is a logarithmic scale referred to 1mW in 600Ω, often used when testing communications components.

To save these system settings as default, store the setup in program 1 so that they are reloaded on power on.

Pressing RIGHT from the SYSTEM OPTIONS menu selects the USER DATA screen.

Pressing LEFT from first SYSTEM OPTIONS menu displays the serial number, release versions, and calibration date.

6.1 User data

The PSM1735 can be personalised by entering up to 3 lines of user data as text (see section on text entry).

User data is displayed every time that the instrument is switched on to identify the instrument. The entered text may also be read over the communications to identify the instrument (see USER?).

A typical arrangement of the user data might be:

line 1 company name
line 2 department or individual name
line 3 unique identifying number (eg. asset number)

Any user data may be entered as required, as the lines are treated purely as text and are not interpreted by the PSM1735 at all.

For use in a production environment, The PSM1735 supports two modes of operation, supervisor and user. When supervisor mode is disabled, the stored programs can only be recalled, not changed. In user mode, the PSM1735 will also not accept any commands which could change the calibration data.

After changing the user data or supervisor status, execute ‘store’ to save the data in non-volatile memory.

7 Measurement options

7.1 ACQU - Acquisition options

In normal acquisition mode, the window over which the measurements are computed is adjusted to give an integral number of cycles of the input waveform. The results from each window are passed through a digital filter equivalent to a first order RC low pass filter.

There are four pre-set speed options - fast, medium, slow, and very slow – that adjust the nominal size of the window, and therefore the update rate and the time constant of the filter. Greater stability is obtained at the slower speed at the expense of a slower update rate.

Note that at low frequencies, the window is extended to cover a complete cycle of the input waveform even if this is a longer period than the nominal update rate.

There are two time constants for the filter, normal or slow, or the filter can be deselected. The filter applies an auto reset function to give a fast dynamic response to a change of measurement – this function can be deselected and the filter forced to operate with a fixed time constant for use with noisy signals.

The nominal values are:

speed	update rate	normal time constant	slow time constant
fast	1/20s	0.2s	0.8s
medium	1/3s	1.5s	6s
slow	2.5s	12s	48s
very slow	10s	48s	192s

There is also an option to set a specific size of the window to a value other than the preset options. In order to synchronise to an integral number of cycles, the window size is either reduced by up to 25% or increased as necessary.

The filter dynamics are usually set to "auto reset" where the filtering is reset in response to a significant change in data. This speeds up the response of the instrument to changing conditions. This function can be disabled so that the filtering has a fixed time constant, which would have an exponential response to a step change.

When the generator is not used and so the measurement is synchronised to the input frequency measured on CH1, there is a low frequency option that extends the frequency measurement down to 20mHz. This low frequency option also applies a digital filter, which can be useful when measuring in a low frequency, noisy environment.

The bandwidth of the instrument, usually set to "auto", can be forced to "wide" or "low". When not in auto selection, heterodyning is disabled and the bandwidth is either 1MHz (wide) or 50kHz (low) to minimise noise when making measurements at low frequencies.

There are three further modes apart from 'normal':

Data streaming is a special high speed mode for use with communications to a PC – see section on RS232. With data streaming, the approximate window size is entered and the nearest integral number of cycles is used as the window.

Fast analogue output mode suppresses the display in order to speed up the processing for analogue output update.

Single measurement mode makes individual measurements in response to a trigger – manually via the keypad or *TRG over the communications. After the measurement, the output can be specified to be switched off, left on, or left on with dc only. By setting the measurement window appropriately, this mode allows the output to be controlled so that it is only on for the duration of a single measurement. Note that the output will always be on for a longer duration than the window period because of settling and ranging time prior to starting the acquisition. The duration is typically 25% longer than the requested window for FRA and LCR measurement; RMS and POWER have an additional 1 second delay for dc settling.

7.2 Datalog

The PSM1735 can store and display measurements recorded at regular intervals over a time period. Each data record consists of the elapsed time and up to four data values selected by ZOOM. More than 8000 records can be stored if one value is selected; more than 3000 if four values are selected.

The actual interval between data points is governed by the measurement speed and the datalog interval. The PSM1735 stores the next available measurement after the datalog interval has elapsed: the actual elapsed time is attached to each datalog record, is displayed with the data on the table or each graph, and returned with each record over the communications (RS232, LAN or GPIB).

The data values may be stored to RAM or directly into non-volatile memory as each value becomes available. The non-volatile option is useful for acquiring data over long periods, to prevent the loss of data in the event of a power failure. Data that has been stored into RAM may be subsequently transferred to non-volatile memory using the PROG menu. In this mode, the data may be viewed in real time, as it is being acquired.

For high speed data acquisition, the datalog interval may be set to zero so that each measurement is stored. The measurement interval is controlled with the “speed” option in the ACQU menu. Using the “window” option for speed allows for greater control of the measurement interval. In this mode, the display flashes “DATALOG RUNNING” and only shows the acquisition time. The minimum datalog interval depends on the function but is typically 10ms.

Note that in all cases the measurement interval is necessarily adjusted to be an integral number of cycles of the measured waveform.

The datalog options are set up with the ACQU menu. The datalog is started with the START key and stopped with the STOP key unless the store becomes full first. The zero reference for the elapsed time is taken as the first data measurement after START.

The data can be viewed as a table or as individual graphs. Pressing GRAPH steps the graph through the stored parameters. If more than 250 records have been stored, the graph can show the data for the whole period or pressing ZOOM redraws the graph to show 250 records about the cursor. The cursor can be moved in single steps (LEFT or RIGHT) or large steps (UP or DOWN). Pressing UNZOOM shows the whole data gain. Movements of the cursor are synchronised in both the TABLE and GRAPH views.

7.3 SWEEP - Frequency sweep options

All ac measurements using the PSM1735 generator can be swept across a frequency range. The start frequency, stop frequency and number of steps up to 2000 can be specified. The measurements are subjected to the same speed constraints set in the ACQU menu, but the filtering does not apply on each measurement point. If continuous sweep is selected, then the filtering is applied to each successive sweep.

At the end of a sweep the generator may be set to be on, off, or dc only. The settings used are those in the normal generator menu.

The frequency steps may be set to be logarithmically or linearly spaced. Logarithmic spacing usually gives the clearest display of frequency dependent parameters but linear spacing can be useful in some applications.

The graph normally sets the y axis automatically to the extremes of the measurements (or in FRA mode to 20dB/decade of frequency) but the axis can be fixed if required. The graph of the second parameter (usually phase) can also be independently manually set.

A vertical marker can be placed on the graph to reference a specific frequency.

For visual comparison to a reference part with a known response, the reference response can be kept on the display drawn with a dotted line while new sweeps are made:

1. Set the graph scaling manually.
2. Perform a sweep with the reference part.
3. Press ZERO to set the reference display.
4. Perform a sweep with the part to be compared.

Each frequency point is an entirely new measurement and autoranging is restarted (if enabled). For the fastest possible sweeps, select manual ranging. As each frequency point is a new measurement, filtering has no effect on a single sweep, but fixed time filtering can be applied independently on each frequency point if repeat sweep in selected.

For maximum sweep speed, particularly when using a large number of points, there is a "fast sweep" mode which disables all non-essential functions, including the display, during the sweep. In this mode, the display is blank except for a flashing message "ACQUIRING SWEEP DATA" until the full sweep has been completed when normal display functions are restored. This mode is automatically selected when a user defined window of less than 100ms has been set.

Up to 30 sweeps may be stored in non-volatile memory using the PROG key. Sweeps are stored in blocks of 50 points, larger sweeps use contiguous blocks eg:

steps in sweep	blocks per sweep	max number of sweeps
2-50	1	30
51-100	2	15
101-150	3	10
151-200	4	7
201-250	5	6
251-500	8	3
501-1000	15	2
1001-2000	30	1

7.4 TRIM - Trim function

The trim function on the PSM1735 is a powerful and versatile feature that allows closed loop control of the generator amplitude. It allows a specific measurement to be programmed for either CH1 and CH2 and the generator output will be adjusted to maintain the measured voltage or current. This allows the excitation level to be controlled over changing conditions such as a frequency sweep.

At each measurement point, the measured level is checked against the specified level and tolerance; if an adjustment is needed the data is discarded and a new measurement made at the new output level. The user is alerted to the adjustment by an audible beep.

Particularly important in control loop analysis, where it is sometimes referred to as amplitude compression, it prevents the control loop being overdriven as the frequency changes.

It is also useful in a more general case where test levels are specified.

Note that when dBm mode level control is selected, the trim level is entered as dBm but the tolerance remains a linear percentage of the actual voltage, not the logarithmic dBm measure.

8 Output control

The output for the signal generator is digitally synthesised at an update rate of 150Msamples/s. With the output filtering, this gives a good sinewave waveform, even at 35MHz, while preserving very accurate frequency control.

The output amplitude is controlled in 2 stages – a fine control with 11 bit resolution, and a coarse control with 8 binary weighted steps. This gives 5mV resolution at high output levels and very fine resolution at low output levels.

Peak output level	resolution
5V - 10V	5mV
2.5V – 5V	2.5mV
1.25V – 2.5V	1.25mV
0.62V – 1.25V	0.62mV
0.31V – 0.62V	0.31mV
0.15 – 0.31V	0.15mV
75mV – 150mV	75uV
>75mV	40uV

The maximum output available from the generator is a function of frequency:

max frequency MHz	output level into 50Ω peak V	rms V
5	5	3.5
10	3	2
15	2	1.4
20	1.5	1
25	1.2	0.8
30	1	0.7
35	0.75	0.5

An offset may be added to any output to bias the signal or to null out any dc present with a resolution of +/-5mV.

The LEFT and RIGHT keys adjust the frequency of the generator by a fixed increment stored via the STEP menu; the UP and DOWN keys adjust the amplitude (except for the harmonic analyser and power analyser where UP and DOWN step the selected harmonic).

The generator output may be set to be on or off only.

There is a green LED to the right of the BNC Output connector. When extinguished the Output is switched off. When illuminated the Output is On.

8.1 Generator specifications

General	
Nominal Accuracy	frequency ±0.05% * amplitude ±10% < 10MHz, ±20% < 35MHz)
Nominal Accuracy (with trim)	amplitude ±1% < 10MHz, ±5% < 35MHz)
output impedance	50Ω ±2%
output voltage	±10V peak (Open Circuit) *
offset	±10V peak maximum
waveforms	sine, and square
frequency	10uHz to 35MHz
output control	5mV to 50uV steps
type	direct digital synthesis
update rate	150MHz
DAC resolution	12 bit
phase accumulator	48 bit

*The absolute amplitude of the generator signal is unimportant in FRA mode, it is only the relative magnitude between two measured inputs that is required, and the absolute amplitude is largely irrelevant in LCR mode, as it is only the relative magnitude/phase angle of two inputs that is required.

In the few applications in which generator accuracy becomes important, then the ability to use the TRIM function (See section 7.4) provides that ability.

9 Input channels

The two input channels each have two separate, ground referenced inputs that can be used independently or together as a differential input. The two channels are controlled independently but sampled synchronously.

Each input channel may be selected to use:
- single ended main input
- single ended secondary input
- differential main – secondary input

Each input channel may be selected to be:
- disabled
- voltage
- external shunt

If the external shunt option is selected, the data is scaled by the shunt value (entered under the relevant channel menu) and the units are displayed in Amps. Any resistor can be used as a shunt, or precision low inductance current shunts are available as accessories. Current transformers can be used if fitted with an appropriate burden resistor.

Note that the external shunt input polarity is reversed compared to that of the voltage input: ie the - input becomes non-inverting and the + input becomes inverting. This is to be consistent with other instruments having single inputs so that the capacitance to ground of the probe cable screen is driven with the lower source impedance in order to minimise errors at high frequency.

Note that some modes force the input channels to be voltage or current automatically, eg. the power meter defaults to channel 1 as voltage and channel 2 as current. This automatic selection can be overridden if required.

The input ranges have nominal full scale values set with a ratio of 1:√10 from 1mV to 10V. When the PSM1735 is using selective high frequency measurements (heterodyning) the ranges extend by approximately 50%. This gives the following ranges:

range	reference	nominal full scale	
		wideband	selective
1	1mV	1mV	1.5mV
2	3mV	3.16mV	5mV
3	10mV	10mV	15mV
4	30mV	31.6mV	50mV
5	100mV	100mV	150mV
6	300mV	316mV	500mV
7	1V	1V	1.5V
8	3V	3.16V	5V
9	10V	10V	10V

The maximum input signal that can be accurately measured varies with frequency:

frequency	max input level	
MHz	peak V	rms V
1	10	7
5	6	4
10	3	2
15	2	1.4
20	1.5	1
25	1.2	0.8
30	1	0.7
35	0.75	0.5

The input ranges may be selected manually, or by auto ranging (default). The start range for auto ranging may be selected if it is known that the signal will not be below a certain level.

There is also an option to auto range 'up only' so that a test may be carried out to find the highest range. Once the highest range has been determined, the range can be set to manual and the measurement made without losing any data due to range changing. Pressing the HOME key (or sending *TRG) restarts the auto ranging from the selected minimum range.

When in an input channel menu, the ZERO key provides a quick way to lock and unlock the range. When no flashing box is visible in the input channel menu and auto ranging is selected, pressing the ZERO key selects the range that the instrument is currently using and sets the auto ranging to manual, thus locking the range and preventing further auto ranging. Pressing the ZERO key again returns to full auto ranging from the bottom range.

For most measurement functions full auto ranging is the most suitable option but some applications, such as where transient events are occurring, are more reliable with manual ranging. Manual ranging (or up-only auto ranging) is essential for low frequency measurements.

There is a LED between the two BNC input connectors for each channel. These LED's change colour, the colour of the LED depends on the suitability of the selected range:

Green: Range selection is OK.
Orange: Under Ranging – select a lower range
Red: Over Ranging – Select a higher range.

For measuring signals that are biased on a dc level (such as an amplifier operating on a single supply or the output of a dc PSU), ac coupling can be used. AC+DC coupling is the normal option and should be used where possible.

Note AC only coupling should not be used below 20Hz as the results are not meaningful.

A scaling factor can be entered for each channel for use with attenuators such as x10 oscilloscope probes. A nominal value can be entered or the attenuation factor of the probe can be measured and the precise value entered. The measured voltage will be displayed after multiplication by the scale factor. The scale factor can be set automatically by pressing TRIG when in an input channel menu. For example, with a x10 oscilloscope probe on channel 1 input, a x1 probe on channel 2 input and both probes connected to the same voltage; press CH1 to invoke the input menu for channel 1 then press TRIG and the scale factor for channel 1 is computed so that channel 1 reads the same as channel 2. Note that when using external divider probes to increase the maximum input voltage it is important to use active probes if accurately measuring dc. This because the dc input impedance is different from the ac input impedance. When using passive probes the dc would read about 10% high.

If the channel has been set for use with an external shunt then the value of the shunt can be entered.

The secondary channel has a control to adjust the gain so that common mode rejection may be maximised when using oscilloscope probes.

9.1 Trimming x10 oscilloscope probes

To minimise the loading effects at high frequencies, x10 oscilloscope probes can be used with the PSM1735. For optimum performance, the probes need to be trimmed to match the input capacitance of the instrument and the probes need to be corrected for gain errors. A small plastic screwdriver is provided with each probe for this purpose. In all, there are three processes that must be carried out to optimise the performance:

probe trim
probe scaling (main inputs)
probe scaling (secondary inputs)

Connect the instrument output across a convenient resistor (anything above 1k) using the supplied BNC to crocodile clip output lead. Connect the four probes from CH1+, CH1-, CH2+ and CH2- also across the resistor. Observe the colour of which probe connects to each of the four input terminals for future use.

Press OUT and set the generator to 1kHz squarewave with 2V amplitude. Press HARM to invoke harmonic analyser mode and select third harmonic. Set all probes to x1.

To trim the probes connected to the main inputs. Select main voltage inputs in the CH1 and CH2 menu, the measured third harmonic should read 33.33% +/-0.05%. Select x10 on one of the probes and adjust the trimmer in the body of the probe until the third harmonic again reads the same value. Switch the probe back to x1 and verify that the third harmonic reads the same. Repeat the adjustment if necessary. Select x10 on the other probe and adjust in the same way. To verify the adjustment at higher frequency, select the 25^{th} harmonic for measurement. The reading should be 4.00% +/-0.5% in both x1 and x10 settings.

Repeat the procedure for the probes connected to the secondary inputs by selecting secondary voltage inputs in the CH1 and CH2 menu.

To adjust for the tolerance within the probes (typically 1%), the main inputs can be scaled and the secondary inputs can be adjusted. Press OUT and set 1kHz sinewave, 2V amplitude; and press FRA to invoke frequency response analyser.

To adjust for tolerance within the probes connected to the main inputs: select main voltage inputs in the CH1 and CH2 menu and with both probes set to x1 check that the measured magnitudes of CH1 and CH2 are about the same. Set the probe connected to CH1 main input to x10 and set the probe connected to CH2 main input to x1. Press CH1 then TRIG – the scaling factor for channel 1 will be automatically adjusted to a number about 10. Press HOME to exit the menu and observe that the readings for CH1 and CH2 are again about the same.

Set the probe connected to CH1 main input to x1 and set the probe connected to CH2 main input to x10. Press CH2 then TRIG – the scaling factor for channel 2 will be automatically adjusted to a number about 10. Press HOME to exit the menu and observe that the readings for CH1 and CH2 are again about the same.

To adjust for tolerance within the probes connected to the secondary inputs: select secondary voltage inputs in the CH1 and CH2 menu and with both probes set to x1 check that the measured magnitudes of CH1 and CH2 are about the same and are about the same as when using the probes connected to the main inputs. Select differential voltage inputs in the CH1 and CH2 menu and adjust the TRIM potentiometer adjacent to the inverting inputs to obtain the minimum magnitude readings.

10 True RMS Voltmeter

The RMS voltmeter measures the total rms of the signal present at the input terminals to the bandwidth of the instrument (>1MHz). Care must be taken when measuring low signal levels to minimise noise pick on the input leads.

The RMS voltmeter measures the elementary values:

- rms
- dc
- peak
- surge

and derives the values: ac, dBm and crest factor.

The rms value of a periodic waveform, $v(\phi)$, is given by:

$$\text{rms} = \sqrt{\left[\; 1/2\pi \int_{0}^{2\pi} v^2(\phi)\, d\phi \; \right]}$$

For a sampled signal, the formula becomes:

$$\text{rms} = \sqrt{\left[\; 1/n \sum_{i=0}^{i=n-1} v^2[i] \; \right]}$$

where n is the number of samples for an integral number of complete cycles of the input waveform.

These are fundamental definitions that are valid for all waveshapes. For a pure sinewave, the formulae equate to peak/√2, but this cannot be applied to other waveshapes. The PSM1735 computes the true rms value from the fundamental definition for sampled data.

The dc present is given by:

$$dc = 1/2\pi \int_{0}^{2\pi} v(\phi)\, d\phi$$

For a sampled signal, the formula becomes:

$$dc = 1/n \sum_{i=0}^{i=n-1} v[i]$$

where n is the number of samples for an integral number of complete cycles of the input waveform.

Having computed the true rms and the dc component, the ac component can be derived from:

$$rms^2 = ac^2 + dc^2 \quad => \quad ac^2 = rms^2 - dc^2$$

The ac component is also expressed in dB referred to 1mW into 600Ω (dBm):

$$dBm = 20 \log (Vac/Vref)$$

where $Vref = \sqrt{(1mW \times 600\Omega)}$

or $20 \log (Iac/Iref)$

where $Iref = \sqrt{(1mW / 600\Omega)}$

The peak measurement is simply the value with the largest magnitude. Positive and negative peaks are independently filtered then the result with the largest magnitude is taken as the peak value.

In order to measure surge conditions, the maximum instantaneous peak value (unfiltered) is also recorded. It is

important that the PSM1735 does not auto range while measuring surge – either set the range to manual or repeat the test with ranging set to up only. To reset the maximum, press START.

Crest factor is derived from the peak and rms:

cf = peak / rms

The measurements are computed over rectangular windows with no gaps. The processing power of the DSP allows the measurements to be made in real time without missing any samples. In this way, the measured rms is a true value even if the signal is fluctuating. The only occasion when data is missed is when an autozero measurement is requested – this can be disabled in the SYSTEM OPTIONS menu if required.

The ZOOM function can be used to select any combination of up to four parameters from the display.

Note that the wideband nature of true rms measurements prevents the use of heterodyning so the frequency range of the measurement is limited to 1MHz. To minimise noise, there is a 50kHz filter applied by default. To obtain the full bandwidth press ACQU, highlight bandwidth and select "wide".

10.1 RMS voltmeter specification

DVM	
channels	2 differential
display	5 digits
measurement	true rms, ac, dc, dBm, peak, cf, surge
coupling	ac or ac+dc
frequency	dc to 1MHz (heterodyning not available) 20Hz to 1MHz (ac only coupling)
max input	±10V peak
input ranges	10V, 3V, 1V, 300mV, 100mV, 30mV, 10mV, 3mV, 1mV
ranging	full auto, up only, or manual
input impedance	1M // 30pF (exc. leads)
accuracy (ac)	0.05% range + 0.05% reading + 0.1mV <1kHz 0.05% range + 0.05% reading + 0.001%/kHz +0.1mV < 10kHz 0.05% range + 0.05% reading + 0.002%/kHz + 0.1mV < 1MHz
accuracy (dc)	0.1% range + 0.1% reading + 0.5mV
CMRR (typical)	60dB @ 10V 50Hz 50dB @ 10V 1kHz 40dB @ 10V 1MHz
time constant	0.2s, 1.5s or 12s

Conditions:

23ºC +/- 5ºC ambient temperature
instrument allowed to warm up for ≥30 minutes
sinewave
slow speed, normal filtering
ac+dc coupling
autoranging or manual ranging ≥ 1/3 range

11 Frequency response analyser

The PSM1735 measures the gain and phase of channel 2 relative to channel 1 using a discrete Fourier transform (DFT) algorithm at the fundamental frequency.

The DFT technique can measure phase as well as magnitude and is inherently good at rejecting noise – it is much more reliable than measuring the rms at one point relative to another point.

The circuit can be characterised by computing the gain and phase at a number of points over a frequency range. This gives results that show the transfer function of the circuit as a graph on the display.

The DFT analysis yields two components – in-phase and quadrature, or 'a' and 'b' values – from which the magnitude and phase can be derived.

Considering the components at the fundamental frequency:

The fundamental in-phase and quadrature values of a periodic waveform, $v(\phi)$, are given by:

$$a_1 = 1/\pi \int_0^{2\pi} v(\phi).\cos(\phi)\, d\phi$$

$$b_1 = 1/\pi \int_0^{2\pi} v(\phi).\sin(\phi)\, d\phi$$

For a sampled signal, the formulae become:

$$a_1 = 1/n \sum_{i=0}^{i=n-1} v[i].\cos(2\pi ci/n)$$

$$b_1 = 1/n \sum_{i=0}^{i=n-1} v[i].\sin(2\pi ci/n)$$

where n is the number of samples for an integral number of complete cycles of the input waveform, and c is the number of cycles.

Having computed the real and quadrature components, the magnitude and phase of each channel can be derived:

$$mag = \sqrt{(a_1^2 + b_1^2)}$$

$$\theta = \tan^{-1}(b_1/a_1)$$

The relative gain and phase of the circuitry under test at that particular frequency is derived from the real and quadrature components by vector division:

vector gain = (a + jb) {ch2} / (a + jb) {ch1}

gain = magnitude (vector gain)

phase = $\tan^{-1}$(b/a (vector gain))

The gain is usually quoted in dB:

$$dB = 20 \log_{10}(gain)$$

To look at differences in gain from a nominal value, an offset gain can be applied either manually or by pressing ZERO.

offset gain = measured dB – offset dB

The filtering is applied to the real and quadrature components individually, rather than the derived magnitude and phase values. This gives superior results as any noise contribution to the components would have random phase and therefore would be reduced by filtering.

The PSM1735 can operate either in real time mode at a single frequency where the gain and phase are filtered and updated on the display, or it can sweep a range of frequencies and present the results as a table or graphs of gain and phase.

The frequency points to be measured are specified with three parameters:

number of steps
start frequency
end frequency

The PSM1735 computes a multiplying factor that it applies to the start frequency for the specified number of steps. Note that due to compound multiplication it is unlikely that the end frequency will be exactly that programmed. The frequency sweep is initiated by the START key, and when completed the data can be viewed as a table or graphs.

Following a sweep on a control loop, the gain and phase margins can be computed and displayed on the graph.

The window over which the measurements are computed is adjusted to give an integral number of cycles of the input waveform. In real time mode the results from each window are passed through a digital filter equivalent to a

first order RC low pass filter; in sweep mode, each result comprises a single window without any filtering unless repeat sweep is selected.

The top of the vertical axis for the graph is normally set to be the highest measured value during the sweep. The bottom of the vertical axis is normally either set to the lowest measured value or the result of the highest value less 20dB/decade of frequency. The vertical axis can be fixed to a manual scale using the menus.

The ZOOM function can be used to select up to four parameters from the display when in real time mode. It has no function following a sweep.

Following a sweep, the GRAPH key selects between:

graph of gain v frequency
graph of phase v frequency
graph of gain and phase v frequency.

Pressing HOME or TRIG restarts the real time measurement at the selected frequency.

Although it is most usual to use the PSM1735 generator when performing gain/phase analysis, there may be circumstances where this is impractical, for example measuring across a transformer under load. In this case, turn off the PSM1735 generator (OUT menu) and the frequency reference for the analysis is measured from channel 1. Provided that the signal is clean enough for an accurate frequency measurement (and for DFT analysis the frequency does need to be accurately known), then the gain and phase can be measured reliably.

When using an external frequency reference there can be no sweep function.

11.1 Frequency response analyser specification

Frequency response (gain/phase) analyser	
frequency	10uHz to 35MHz (own generator) 20mHz to 500kHz (external source)
max input	±10V peak
input ranges	10V, 3V, 1V, 300mV, 100mV, 30mV, 10mV, 3mV, 1mV
ranging	full auto, up only, or manual
input impedance	1M // 30pF (exc. leads)
gain accuracy	0.01 dB + 0.0001 dB/kHz < 1MHz 0.1 dB + 0.04 dB/MHz < 35MHz
phase accuracy	0.02° < 10kHz 0.05° + 0.0001°/kHz < 35MHz
sweep step rate	1/20s, 1/3s or 2.5s (approx.)

Conditions:

23ºC +/- 5ºC ambient temperature
instrument allowed to warm up for ≥30 minutes
ac+dc coupling
autoranging or manual ranging ≥ 1/3 range

12 Phase angle voltmeter (vector voltmeter)

A phase angle voltmeter (or vector voltmeter, or phase sensitive voltmeter) measures the signal at one input compared to the phase of the signal at a reference input. The results may be expressed as magnitude and phase, or as separate in-phase and quadrature components.

The PSM1735 measures the in-phase and quadrature components at the fundamental frequency using DFT analysis as described in the section on frequency response analysis. CH2, the measurement input, is phase referred to CH1, the reference input. The individual components are filtered separately to minimise the effects of noise, which would have random phase and would, therefore, be filtered out. The true rms of the input signals is also computed.

CH1 and CH2 may be voltage inputs or may use external shunts.

From the phase referred fundamental components, (a + jb), the following results can be derived:

magnitude	$= \sqrt{(a^2 + b^2)}$
phase	$= \tan^{-1}(b/a)$
tan ϕ	$= b/a$
in-phase ratio	$= a2 / a1$
LVDT (diff)	$= scale * a2 / a1$
LVDT (ratio)	$= scale * (m1-m2) / (m1+m2)$

where a1 and a2 are the in-phase components, and m1 and m2 are the magnitudes, of the signals present at ch1 and ch2 respectively.

The parameter of interest is selected via the PAV or MODE menu. The frequency and phase are always displayed.

A null meter display may be selected via the PAV menu to allow adjustment of a circuit for minimum phase or component. The parameter on the display depends on the selected component:

parameter	display	null meter
in-phase		in-phase
quadrature		quadrature
tanϕ	tanϕ	tanϕ
magnitude	magnitude	magnitude
phase	phase	
rms	rms	rms2
rms2/1	rms2/rms1	rms2/rms1
in-phase ratio	in-phase ratio	in-phase ratio
LVDT diff	LVDT	LVDT
LVDT ratio	LVDT	LVDT

The null meter may be manually ranged or will automatically range as the signal varies. When manually ranging, ZOOM+ and ZOOM- adjust the range by a decade.

There is a phase offset option that applies a vector rotation of a user selectable phase shift to the CH2 input data.

The PSM1735 can operate either in real time mode at a single frequency where the measurements are filtered and updated on the display, or it can sweep a range of frequencies and present the results as a table or graphs. Before performing a sweep, the desired parameter must be selected.

The frequency points to be measured are specified with three parameters:

number of steps
start frequency
end frequency

The PSM1735 computes a multiplying factor that it applies to the start frequency for the specified number of steps. Note that due to compound multiplication it is unlikely that the end frequency will be exactly that programmed. The frequency sweep is initiated by the START key, and when completed the data can be viewed as a table or graphs or printed out.

The window over which the measurements are computed is adjusted to give an integral number of cycles of the input waveform. In real time mode the results from each window are passed through a digital filter equivalent to a first order RC low pass filter; in sweep mode, each result comprises a single window without any filtering.

The ZOOM function can be used to select up to four parameters from the display when in real time mode. It has no function following a sweep.

Although it is most usual to use the PSM1735 generator when making Phase Angle Voltmeter measurements, there may be circumstances where this is impractical, for example measuring LVDT displacement under actual circuit conditions. In this case, turn off the PSM1735 generator (OUT menu) and the frequency reference for the analysis is measured from channel 1. Provided that the signal is clean enough for an accurate frequency measurement (and for DFT analysis the frequency does need to be accurately known), then the measurements can be made reliably.

When using an external frequency reference there can be no sweep function.

12.1 Phase angle voltmeter specification

Phase angle voltmeter (vector voltmeter)	
frequency	10uHz to 35MHz (own generator) 20mHz to 500kHz (external source)
measurement type	DFT analysis, and true rms
measurements	magnitude, phase, in-phase & quadrature components, tanΦ, in-phase ratio, LVDT (diff), LVDT (ratio), rms, rms ratio
max input	±10V peak
input ranges	10V, 3V, 1V, 300mV, 100mV, 30mV, 10mV, 3mV, 1mV
ranging	full auto, up only, or manual
input impedance	1M // 30pF (exc. leads)
basic accuracy	0.05% range + 0.05% reading + 0.05mV <1kHz
	basic + 0.001%/kHz < 10kHz
	basic + 0.002%/kHz < 1MHz
	basic + 1.6% + 0.4%/MHz < 35MHz
phase accuracy	0.01° < 10kHz
	0.05° + 0.0001°/kHz < 35MHz
phase resolution	0.001°
tanΦ resolution	0.0001
CMRR (typical)	60dB @ 10V 50Hz 50dB @ 10V 1kHz 40dB @ 10V 1MHz
sweep step rate	1/20s, 1/3s or 2.5s (approx.)

Conditions:

23ºC +/- 5ºC ambient temperature
instrument allowed to warm up for ≥30 minutes
ac+dc coupling
autoranging or manual ranging ≥ 1/3 range

13 Power meter

The power meter measures the total power and fundamental power of the signal present at the input terminals to the bandwidth of the instrument (>1MHz). Above 1MHz, only the fundamentals are measured.

One of the inputs must be configured as an external shunt input. The external shunt may be a simple resistor or dedicated high frequency precision shunts are available as accessories. Current transformers and clamps may be used if fitted with a suitable burden resistor. For use at mains voltages, a mains power adaptor incorporating voltage and current transformers is available.

The power meter will operate either from its own generator or, more normally, will use the frequency measured on channel 1 (usually voltage).

The power meter measures the elementary values:

- W
- V rms
- A rms
- V fundamental (in-phase and quadrature)
- A fundamental (in-phase and quadrature)
- V dc
- A dc
- V harmonic (in-phase and quadrature)
- A harmonic (in-phase and quadrature)
- frequency

and derives the following values:

- V & A fundamental magnitude
- VA (true and fundamental)
- power factor (true and fundamental)
- fundamental W
- harmonic W
- phase shift

When the integrator function is activated, the following values are available:

Elapsed time (in hours, minutes and seconds)
Watt-hours (true and fundamental)
VA hours (true and fundamental)
average power factor (true and fundamental)
Ampere hours (true and fundamental)

The power dissipated in a load subjected to a periodic voltage, $v(\phi)$, with a current flowing $a(\phi)$, is given by:

$$w = 1/2\pi \int_0^{2\pi} v(\phi).a(\phi)\, d\phi$$

For a sampled signal, the formula becomes:

$$w = 1/n \sum_{i=0}^{i=n-1} v[i].a[i]$$

where n is the number of samples for an integral number of complete cycles of the input waveform.

These are elementary definitions that are valid for all waveshapes. The PSM1735 computes the true watts value from the elementary definition for sampled data. Formulae for the components at the fundamental frequency are given in the section on frequency response analysis; formulae for the harmonic components are given in the section on harmonic analysis.

The formulae for the derived results are:

VA = $V_{rms} \times A_{rms}$
power factor = Watts/VA
fundamental Watts = $V_{real} \times A_{real} + V_{quad} \times A_{quad}$

harmonic Watts = VH_{real} x AH_{real} + VH_{quad} x AH_{quad}
fundamental VA = V_{fund} x A_{fund}
fund power factor = W_{fund} / VA_{fund}

In power meter mode, the UP and DOWN key do not adjust the amplitude but step the harmonic number.

The measurements are computed over rectangular windows with no gaps. The processing power of the DSP allows the measurements to be made in real time without missing any samples. In this way, the measured power is a true value even if the signal is fluctuating. The only occasion when data is missed is when an autozero measurement is requested – this can be disabled in the SYSTEM OPTIONS menu.

The high linearity of the PSM1735 allows real-time measurements be made on waveforms with periodic bursts such as low standby power PSUs. Use "autorange up" to find the range.

The PSM1735 blanks the results when either of the measured rms signals are low compared to the full scale range. This function can be disabled if desired in the SYSTEM menu.

The ZOOM function can be used to select any combination of up to four parameters from the display.

The integrator is started, or reset, by pressing the START key. The Watt hour integration and the Ampere hour integration can be selected to be signed or magnitude. To integrate the total power in terms of heating effect, choose magnitude. If signed integration is selected then the rms current is given the sign of the power before integration. The Ampere hours and Watt hours then reflect the power taken by the load, less any power generated by the load, such as during regenerative braking in battery systems.

13.1 Power meter specification

Power meter	
current input	external shunt
display	5 digits
measurement	W, VA, PF, fundamental, rms, phase
coupling	ac or ac+dc
frequency	dc to 1MHz 1MHz to 35MHz (fundamentals only) 20Hz to 35MHz (AC only coupling)
max input	±10V peak
input ranges	10V, 3V, 1V, 300mV, 100mV, 30mV, 10mV, 3mV, 1mV
ranging	full auto, up only, or manual
input impedance	1M // 30pF (exc. leads)
accuracy (ac)	0.15% range + 0.15% reading < 1kHz 1.5% range + 1.5% reading < 50kHz 2% range + 8% reading < 1MHz
accuracy (dc)	0.2% range + 0.3% reading
CMRR (typical)	60dB @ 10V 50Hz 50dB @ 10V 1kHz 40dB @ 10V 1MHz
time constant	0.2s, 1.5s or 12s

Conditions:

23ºC +/- 5ºC ambient temperature
instrument allowed to warm up for ≥30 minutes
sinewave, power factor > 0.7
slow speed, normal filtering
ac+dc coupling
autoranging or manual ranging ≥ 1/3 range
0.1% current shunt selected to give 100mV rms

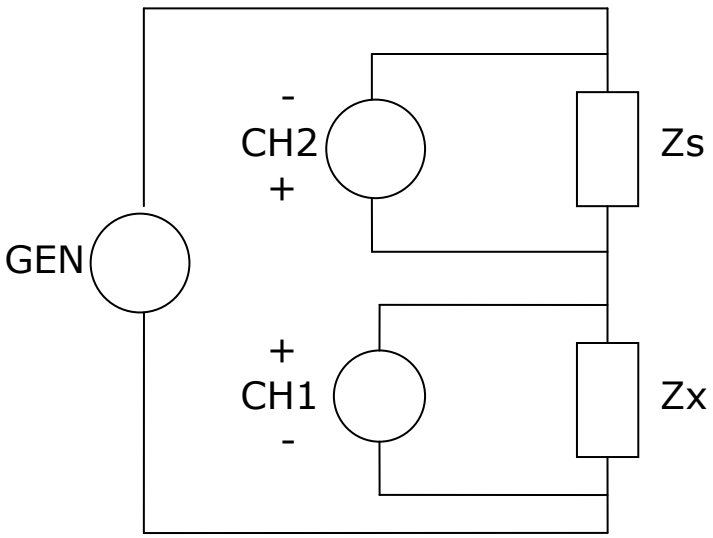
14 LCR meter

In LCR meter mode, channel 1 measures the voltage across the component under test, and channel 2 measures the current through it. To measure the current, channel 2 must be connected across an appropriate external shunt.

The easiest way to use the LCR meter is with the 'LCR active head' (see accessories) that fits onto the front of the PSM1735 and provides 4 wire Kelvin clip connections to the component under test. The active head provides a choice of shunts, selectable from the front panel, and buffers the signals to minimise the effects of stray capacitance and inductance.

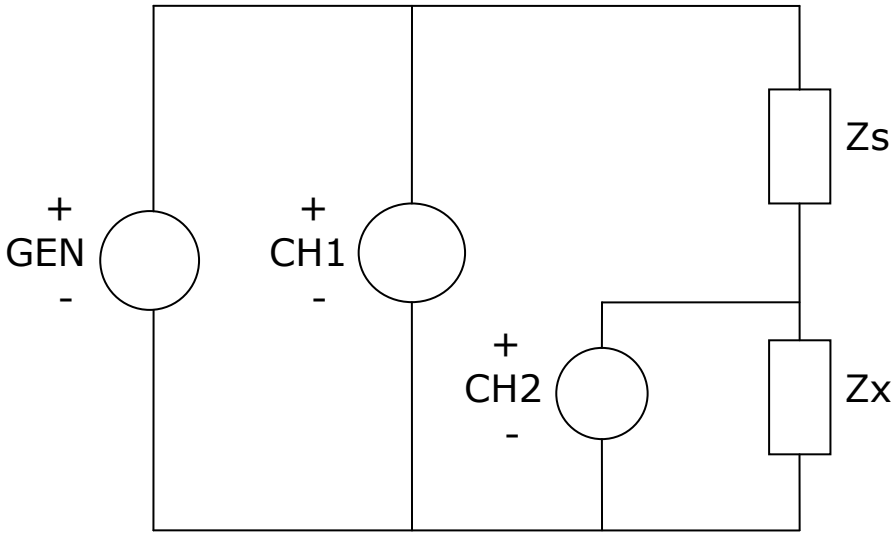
Measurements can be made without the active head by simply connecting a series shunt (set the LCR head option in the SETUP menu to 'none'). The shunt chosen must be appropriate for the voltage, the current and the frequency of operation.

There are three manual connection options, "shunt", "divider Zx low", "divider Zx high".



For “shunt” connection, shown above, the current is measured directly across the shunt using CH2 while the voltage across the Zx is measured by CH1. Notice that the positive inputs to both CH1 and CH2 are connected to the midpoint to minimise common mode loading effects.

Then: Zx = Zs x CH1 / CH2



For “divider Zx low” connection, shown above, the total voltage is measured by CH1 and the voltage arising from the potential divider effect of Zs and Zx is measured by CH2. Notice that all the negative terminals are connected together.

Then: Zx = Zs / ((CH1 / CH2) – 1)

The connections for “divider Zx high” are the same as above but with Zx in the high arm of the potential divider and the shunt in the low arm.

Then: Zx = Zs x ((CH1 / CH2) – 1)

The PSM1735 measures the real and imaginary components at the fundamental frequency using DFT analysis as described in the section on gain/phase analysis. The frequency may be taken from its own generator or from the circuitry under test.

From the fundamental components of voltage, (a + jb), and those of the current, (c + jd), the PSM1735 computes the complex impedance given by:

$$\mathbf{z} = \mathbf{v} / \mathbf{i}$$
$$= (a + jb) / (c + jd)$$

The components of the complex impedance are filtered independently to minimise the effects of noise, which would have random phase and would therefore be filtered out.

The magnitude of the voltage and current are also computed.

From the complex impedance the following parameters can be derived:

- ac resistance
- inductance,
- capacitance
- impedance
- phase
- tanδ (= real/imaginary)
- Q factor (= imaginary/real)

Values are displayed for both series and parallel configurations.

Optionally, the values can be expressed as admittance, conductance, and susceptance instead of impedance, resistance and reactance.

If the parameter option in LCR menu is set to ‘auto’, the PSM1735 will display capacitance or inductance according to the phase of the measurement. Alternatively, the display can be forced to capacitance, inductance or impedance.

Capacitance is displayed with tanδ, inductance is displayed with Q factor, and impedance is displayed in its resistive + reactive form and as magnitude. The phase of the impedance is displayed with all options.

The operating conditions for the component under test may be selected manually or the PSM1735 will automatically try to find appropriate conditions.

When measuring large electrolytic capacitors, it may be necessary to add an appropriate bias voltage to polarise the electrodes. In this case it may be necessary to select ac coupling in the CH1 menu in order to reliably measure the small ac voltage present.

The PSM1735 can operate either in real time mode at a single frequency where the measurements are filtered and updated on the display; or it can sweep a range of frequencies and present the results as a table or graphs. Before performing a sweep, either series circuit or parallel circuit must be selected.

The frequency points to be measured are specified with three parameters:

number of steps
start frequency
end frequency

The PSM1735 computes a multiplying factor that it applies to the start frequency for the specified number of steps. Note that due to compound multiplication it is unlikely that the end frequency will be exactly that programmed. The

frequency sweep is initiated by the START key, and when completed the data can be viewed as a table or graphs or printed out.

The window over which the measurements are computed is adjusted to give an integral number of cycles of the input waveform. In real time mode the results from each window are passed through a digital filter equivalent to a first order RC low pass filter; in sweep mode each result comprises a single window without any filtering unless repeat sweep is selected.

Very good results can be obtained in a reasonable time using the medium speed setting (e.g. 50 points x ~1/3s ≅ 17s); for the very best results, use the slow setting (50 points x ~2.5s ≅ 125s or 2 minutes, 5 seconds).

The ZOOM function can be used to select up to four parameters from the display when in real time mode. It has no function following a sweep.

Although it is most usual to use the PSM1735 generator when performing LCR measurements, there may be circumstances where this is impractical, for example measuring the inductance of a transformer primary winding under load. In this case, turn off the PSM1735 generator (OUT menu) and the frequency reference for the analysis is measured from channel 1. Provided that the signal is clean enough for an accurate frequency measurement (and for DFT analysis the frequency does need to be accurately known), then the measurements can be made reliably.

When using an external frequency reference there can be no sweep function.

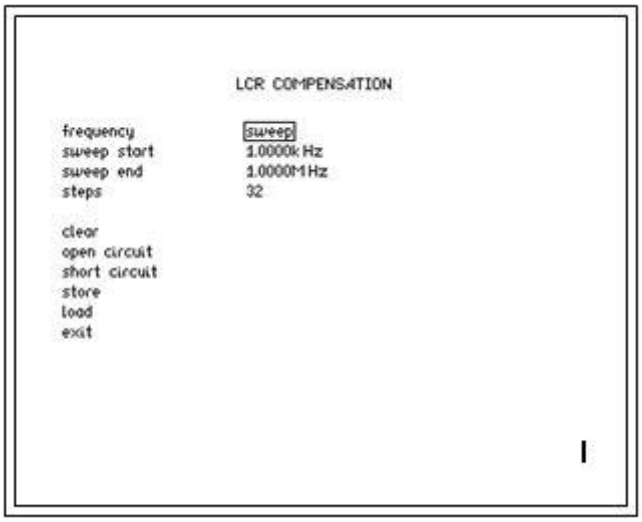
14.1 Applying Compensation

When measuring small inductance or capacitance, it may be necessary to zero out the stray effects from the test connections. Press ZERO to access the compensation menu. For inductance connect together the test leads to a good short and select "short circuit" – the message 'SHORT CIRCUIT ZERO SET' will be displayed; for capacitance disconnect the test leads and press ZERO – the message 'OPEN CIRCUIT ZERO SET' will be displayed. To remove the zero, press ZERO then press DELETE within 1.5s – the message 'ZERO CLEARED' will be displayed.

For repeated measurements under the same test conditions (eg. production testing of a batch of capacitors) it is possible to compensate for the inherent phase shift of the connection jig. Connect a known reference component to the system, enter the known phase shift of the component as the "phase reference" in the ZERO menu and select "phase adjust". The PSM1735 then applies a compensating vector rotation to all subsequent measurements.

14.1.1 Applying sweep compensation

As the PSM17xx range provide the benefit of frequency sweep functions for all measurement modes, it is common to use the instruments to test components over a range of frequencies. In this case, the issues discussed above in relation single frequency compensation now apply to the complete frequency range over which measurements will be made.



Here, the ZERO key has been pressed on the PSM front panel to present the LCR Compensation screen and then by using the navigation keys, the frequency option has been changed form ‘single’ to ‘sweep’.

Here it can be seen that ‘sweep start’, ‘sweep end’ and ‘step’ options are presented. As would be expected, sweep compensation cover a frequency range that is at least equal to the range of measurement frequencies that will be required.

The default number of steps is 32 and the maximum number is 100 steps. By selecting the number of steps, a user has control over the total time required for compensation and the accuracy of compensation throughout a sweep. While interpolation between frequency steps is applied so that the frequency steps within compensation do not have to correlate with the number of steps in a measurement sweep, superior compensation over a frequency sweep range will be achieved when using more steps, especially if a very wide frequency range is being used.

Saved Compensation

Single

When using single frequency compensation, there is no store function since the compensation of a single frequency is fast. The Compensation will be lost when the instrument is switched off.

However, when the instrument settings are saved to a program file in the internal flash memory of the PSM17xx (refer to section 4.2), any single point compensation that has been undertaken will be included in that file. When the program file is recalled any compensation settings will also be recalled and will then be applicable. Each program memory location can include its own saved Single point compensation settings, these settings will be applied when that program is recalled including after the power cycling of the instrument.

Note:
When recalling programs with saved Compensation settings it is important to consider any repositioning or replacement of cables or fixtures etc used to interface the DUT to the instrument since the compensation was originally performed. It may be necessary to repeat the Compensation procedure before performing the tests.

Sweep

However, sweep compensation can be quite consuming, especially when many steps are selected and for this reason, a **STORE** function is provided. The store function should be selected only when the complete compensation has been completed, i.e. if both short circuit and open circuit compensation are applied, the ‘store’ function should

be used when both processes have been completed. A new sweep compensation can be made at any time without affecting the stored compensation but only one sweep store is provided, therefore pressing ‘store’ after a new compensation has been made will overwrite the previous compensation.

The **LOAD** function will re-load the stored Sweep compensation. As the sweep compensation memory is non-volatile, the stored compensation can be loaded at any time. In order to ensure that users do not switch on the instrument and inadvertently make a measurement with inappropriate compensation, the default power on condition is with no compensation applied. If therefore a user wishes to apply the stored sweep compensation, they should enter the sweep compensation menu and ‘load’ the compensation. The applied compensation will remain active while the unit remains powered on or until the clear function is selected.

Note: Sweep compensation can’t be stored in a Program file and then recalled with the other settings.

14.2 LCR meter specification

LCR meter	
frequency	10uHz to 35MHz (own generator)
measurement type	DFT analysis
measurements	L, C, R (ac), Q, tanδ, impedance, phase, admittance series or parallel circuit
conditions	auto, or manual
display	numeric values table of sweep results graph of any measurement
ranges (with external shunt)	100pF to 100uF 1μH to 100H 1Ω to 1MΩ
ranges (with active head)	10pF to 1000uF 100nH to 10kH 10mΩ to 100MΩ
basic accuracy	0.1% + Tolerance of Shunt
sweep step rate	1/20s, 1/3s or 2.5s (approx.)

Conditions:

23ºC +/- 5ºC ambient temperature
instrument allowed to warm up for ≥30 minutes
ac+dc coupling
autoranging or manual ranging ≥ 1/3 range
using impedance interface adaptor

15 Harmonic analyser

The PSM1735 harmonic analyser computes multiple DFTs on the input waveforms in real time (refer to the chapter on frequency response analysis for the formulae for DFT analysis).

There are three modes of operation: single harmonic, difference thd, and series thd. In single harmonic mode, the specified harmonic is displayed both in Volts and as a ratio to the fundamental; in either thd mode, the computed thd and a specified harmonic are displayed as a ratio to the fundamental.

In difference thd mode, the thd is computed from the rms and fundamental:

$$thd = 1/h_1 \sqrt{(rms^2 - h_1^2)}$$

In series thd mode, the thd is computed from a series of up to 64 harmonics.

$$thd = 1/h_1 \sqrt{\sum_{i=2}^{i=n} h_i^2}$$ where h_i is the i^{th} harmonic

In series mode the magnitude and phase of all the harmonics can be seen as a table or the magnitudes can be displayed as a bargraph which changes in real time with the measurements. When viewing the bargraph, ZOOM+ and ZOOM- change the vertical axis by a factor of 10.

In all cases the harmonics are phase referred to CH1 fundamental so that their in-phase and quadrature components may be separately filtered to minimise noise.

The single harmonic and the thd are expressed relative to the fundamental either as a percentage or in dB, as selected via the HARM menu.

The PSM1735 can operate either in real time mode at a single frequency where the measurements are filtered and updated on the display; or it can sweep a range of frequencies and present the results as a table or graphs.

The frequency points to be measured are specified with three parameters:

number of steps
start frequency
end frequency

The PSM1735 computes a multiplying factor that it applies to the start frequency for the specified number of steps. Note that due to compound multiplication it is unlikely that the end frequency will be exactly that programmed. The frequency sweep is initiated by the START key, and when completed the data can be viewed as a table or graphs or printed out.

The window over which the measurements are computed is adjusted to give an integral number of cycles of the input waveform. In real time mode the results from each window are passed through a digital filter equivalent to a first order RC low pass filter; in sweep mode each result comprises a single window without any filtering.

Very good results can be obtained in a reasonable time using the medium speed setting (e.g. 50 points x ~1/3s $\cong$ 17s); for the very best results, use the slow setting (50 points x ~2.5s $\cong$ 125s or 2 minutes, 5 seconds).

The ZOOM function can be used to select up to four parameters from the display when in real time mode. It has no function following a sweep.

Although it is most usual to use the PSM1735 generator when making harmonic measurements, there may be circumstances where this is impractical, for example measuring harmonic currents drawn from the mains. In this case, turn off the PSM1735 generator (OUT menu) and the frequency reference for the analysis is measured from channel 1. Provided that the signal is clean enough for an accurate frequency measurement (and for DFT analysis the frequency does need to be accurately known), then the measurements can be made reliably.

When using an external frequency reference there can be no sweep function.

15.1 Harmonic analyser specification

Harmonic analyser	
fundamental frequency	10uHz to 500kHz (own generator) 20mHz to 500kHz (external source)
harmonic frequency	10uHz to 1MHz
measurement type	multiple DFT analysis
measurements	single harmonic, differential thd, thd by series of harmonics
max harmonic	64
max input	±10V peak
input ranges	10V, 3V, 1V, 300mV, 100mV, 30mV, 10mV, 3mV, 1mV
ranging	full auto, up only, or manual
input impedance	1M // 30pF (exc. leads)
magnitude accuracy	0.1% of fundamental + 0.01mV + accuracy of fundamental
sweep step rate	1/20s, 1/3s or 2.5s (approx.)

Conditions:

23ºC +/- 5ºC ambient temperature
instrument allowed to warm up for ≥30 minutes
ac+dc coupling
autoranging or manual ranging ≥ 1/3 range

16 Transformer analyser

The transformer analyser mode allows a comprehensive set of measurements to be performed on a transformer at a single frequency or automatically swept over a range of frequencies.

The tests available are:

- turns ratio
- inductance
- leakage inductance
- ac resistance and Q factor
- dc resistance
- interwinding capacitance
- magnetising current
- insertion loss
- return loss
- single harmonic distortion
- total harmonic distortion
- longitudinal balance

The transformer analyser function is invoked, and the test selected, by the MODE key.

The easiest way to connect to the transformer in the various configurations for the different test is to use the transformer analyser fixture (see accessories) that connects to the PSM1735 BNC connectors via the BNC splitters and also to the PSM1735 extension port. Using the fixture, with appropriate source and load resistors, the test configuration and winding selection is selectable from the front panel. Active buffers within the fixture minimise the effects of stray capacitance and inductance.

For higher frequency operation, or if the automatic fixture is not available, make the connections manually with x10 oscilloscope probes (set the fixture option in the AUX menu to ‘none’).

The operating conditions for the component under test may be selected manually or for some tests (such as turns ratio). The PSM1735 will automatically try to find appropriate conditions.

The PSM1735 can operate either in real time mode at a single frequency where the measurements are filtered and updated on the display; or it can sweep a range of frequencies and present the results as a table or graphs. Before performing a sweep, the required test must be selected.

The ZOOM function can be used to select up to four parameters from the display when in real time mode. It has no function following a sweep.

Although it is most usual to use the PSM1735 generator when performing transformer analysis, there may be circumstances where this is impractical, for example measuring the turns ratio of a transformer under load. In this case, turn off the PSM1735 generator (OUT menu) and the frequency reference for the analysis is measured from channel 1. Provided that the signal is clean enough for an accurate frequency measurement (and for DFT analysis the frequency does need to be accurately known), then the measurements can be made reliably.

When using an external frequency reference there can be no sweep function.

16.1 Turns ratio

Turns ratio is computed from the real part of the complex ratio of CH2 divided by CH1 using DFT analysis at the fundamental frequency (refer to the chapter on gain/phase analysis for the formulae for DFT analysis). This technique gives good results even on 'lossy' transformers.

The polarity of the windings is indicated by a positive turns ratio for in phase windings and negative ratio for inverted windings.

A nominal number of turns may be entered using the SETUP menu if known and the PSM1735 will then also display the computed number of turns.

As the inputs are independent of the output it is possible to energise a third winding when measuring turns ratio, or only two windings may be used.

To manually connect a transformer for turns ratio, connect the PSM1735 output to the winding to be energised, and the inputs to the two windings for the ratio.

Note that when using the transformer analyser fixture, the transformer is always energised through the source resistance.

Pressing ZERO makes the turns ratio read 1:1, and the computed number of turns equal to the value entered via SETUP. This allows accurate testing of transformers or chokes against a known good reference. Press ZERO followed by DELETE to restore true turns ratio measurement.

16.2 Inductance & leakage inductance

The inductance of a winding is computed from the complex ratio of CH1 (voltage across the winding) divided by CH2 (current through the winding) using DFT analysis at the fundamental frequency (refer to the chapter on gain/phase analysis for the formulae for DFT analysis).

CH2 is forced to be external shunt input – enter the value of the external shunt as the source resistance via the SETUP menu.

To manually connect a transformer for inductance measurement, connect an appropriate source resistance in series with the winding and connect the PSM1735 output across the series combination of the source resistance and winding. Connect the CH1 input across the winding to measure the voltage, and CH2 across the series resistance (note that the polarity of external shunt input is the opposite of that for voltage). Leave all other windings open.

To manually measure leakage inductance, use the same set up as for inductance but short the other windings.

When using the transformer analyser fixture, the connections for inductance or leakage inductance are made automatically by relays.

When measuring small inductance it may be necessary to zero out stray effects by replacing the winding with a good short and pressing ZERO. The message ‘ZERO SET’ will be displayed. To remove the effect of the zero press ‘ZERO’ followed ‘DELETE’ within 1.5s and the message ‘ZERO CLEARED’ will be displayed.

16.3 AC resistance and Q factor

AC resistance is measured the same way as inductance with CH1 monitoring the voltage across the winding, and CH2 monitoring the current through it via the external shunt (source resistance).

The Q factor measurement is an effective way of detecting a shorted turn – either on a transformer, or on a choke. When using suitable conditions (often very different from the normal operating conditions of the device under test) the Q factor changes dramatically when a shorted turn is present.

16.4 DC resistance

DC resistance is measured with the same circuit arrangement as inductance and ac resistance, but dc signals are used (refer to the chapter on the rms voltmeter for the formulae for dc analysis).

16.5 Interwinding capacitance

The interwinding capacitance of a transformer is computed from the complex ratio of CH1 (voltage across the transformer) divided by CH2 (current through the transformer) using DFT analysis at the fundamental frequency (refer to the chapter on gain/phase analysis for the formulae for DFT analysis).

CH2 is forced to be external shunt input – enter the value of the external shunt as the source resistance via the SETUP menu.

To manually connect a transformer for interwinding capacitance measurement, connect an appropriate source resistance in series with one winding and connect the PSM1735 output across the transformer from the series resistance to another winding. Connect the CH1 input across the transformer from one winding to the other to measure the voltage across the windings, and CH2 across the series resistance (note that the polarity of external shunt input is the opposite of that for voltage).

When using the transformer analyser fixture, the connections for interwinding capacitance are made automatically by relays.

When measuring small capacitance it may be necessary to zero out stray effects by disconnecting the transformer and pressing ZERO – the message 'ZERO SET' will be displayed. The transformer analyser fixture TAF01, has a stray capacitance of around 60pF that can be zeroed out this way. To remove the effect of the zero press 'ZERO' followed 'DELETE' within 1.5s and the message 'ZERO CLEARED' will be displayed.

16.6 Magnetising current

The magnetising current is the current drawn by the primary, energised under normal operating conditions but without any secondary load. It is typically measured on power transformers rather than signal transformers so although the transformer analyser fixture, TAF01, will select appropriate relays to make the measurement it is more common that a manual connection or a custom fixture would be used.

The magnetising current is measured as the true rms value (refer to the chapter on the rms voltmeter for the formulae for rms analysis) so it will include all distortion components.

To manually connect a transformer for magnetising current measurement, connect an appropriate shunt in series with the primary. When selecting the shunt, bear in mind the current that it must pass, the resulting voltage drop across it, and the power that will be dissipated in it. Connect CH1 directly across the primary winding using a pair of appropriate probes, and CH2 across the series resistance with a second pair of probes(note that the polarity of external shunt input is the opposite of that for voltage). Ensure that all probes and the series resistance are appropriate for the voltage, the current and the frequency of operation.

Energise the primary so that the voltage seen at the primary after the series resistance, is the normal operating voltage.

16.7 Return loss

Return loss is a measure of impedance mismatch in signal transformers that are terminated with the design load resistance.

The secondary winding is terminated with the appropriate load resistance and the primary is energised via a source resistance that is equal to the resistance that should be reflected back from the secondary (load resistance * (turns ratio)^2). The impedance looking into the primary is measured.

If **z** is the complex impedance measured at the primary, and R is the source resistance then the return loss is given by:

$$\text{return loss} = | \mathbf{z} + R | / | \mathbf{z} - R |$$

Return loss is usually expressed in dB:

$$= 20 \log (| \mathbf{z} + R | / | \mathbf{z} - R |) \text{ dB}$$

As a figure of merit, a higher value of return loss indicates a better transformer.

The circuit arrangement for return loss is the same as that for inductance measurement except that the secondary is terminated with the appropriate load resistance.

As the value of the load source resistance, R, is used in the computation, it is important that this value be entered via the MODE menu.

16.8 Insertion loss

Insertion loss is a measure of power loss due to impedance mismatch in signal transformers that are terminated with the design load resistance.

The secondary winding is terminated with the appropriate load resistance and the primary is energised via a source resistance that is equal to the resistance that should be reflected back from the secondary (load resistance * (turns ratio)²). The voltage energising the series resistance and primary winding is measured and the voltage on the secondary is measured.

If Rs is the source resistance, the power into the transformer is computed as:

$$Win = Vin^2 / 4\,Rs$$

If Rl is the load resistance, the power out is computed as:

$$Wout = Vout^2 / Rl$$

Insertion loss then is given by:

$$\text{Insertion loss} = Win / Wout$$
$$= (Vin / Vout)^2 \,.\, Rl / 4\,Rs$$

Insertion loss is usually expressed in dB:

$$= 10 \log ((Vin / Vout)^2 \,.\, Rl / 4\,Rs)\ dB$$

As a figure of merit, a lower value of insertion loss indicates a better transformer.

To manually connect a transformer for insertion loss measurement, fit the appropriate source resistance in series with the primary winding then connect the PSM1735

output and CH1 differential input across the series combination of the source resistance and the primary winding. Connect the appropriate load resistance and CH2 differential input across the secondary.

When using the transformer analyser fixture, the connections for insertion loss are made automatically by relays.

As the values of the load resistance, Rl, and the source resistance, Rs, are used in the computation, it is important that both values are entered via the MODE menu.

16.9 Harmonics and distortion

Harmonic distortion introduced by a signal transformer may be measured either at a single spot harmonic or as the thd computed from a series of harmonics.

The primary of the transformer is energised either by the output of the PSM1735 or by external means and CH2 is connected across the secondary. It is usual to measure harmonic distortion with the secondary loaded.

Specify the single harmonic, or the maximum series harmonic via the SETUP menu.

The PSM1735 analyses for up to 50 harmonics in real time, using multiple DFTs (refer to the chapter on gain/phase analysis for the formulae for DFT analysis). Each harmonic is individually phase referenced to the fundamental so that the in-phase and quadrature components can be separately filtered. As the harmonics are usually very small, this technique is important to give adequate noise rejection.

The series harmonic data is combined to give the thd (refer to the chapter on harmonic analysis for the thd formula).

The single harmonic and the thd are expressed as dB relative to the fundamental.

16.10 Longitudinal balance

Longitudinal balance is a measure of the common mode rejection ratio, CMRR, of the transformer.

Longitudinal balance requires external circuitry to give the required accuracy – a plug in module is available for the transformer analyser fixture, TAF01, with precision resistors and active buffers adjacent to the transformer pins to minimise stray effects.

As a figure of merit, a higher value of longitudinal balance indicates a better transformer.

Transformer analyser specification

Transformer analyser	
frequency	10uHz to 35MHz (own generator) 20mHz to 500kHz (external source)
measurement type	DFT analysis, true rms as appropriate
measurements	turns ratio turns inductance leakage inductance ac resistance dc resistance interwinding capacitance insertion loss return loss harmonics thd longitudinal balance
conditions	auto, or manual
display	numeric values table of sweep results graph of any measurement
accuracy	refer to other functions
sweep capability	all ac functions
sweep step rate	1/20s, 1/3s or 2.5s (approx.)

Appendix A – Accessories

ACCESSORIES

Power meter adaptors

The power meter adaptors allow easy and safe connection of the PSM1735 to a mains appliance under test to measure the power or harmonics.

The appliance under test plugs into an IEC mains outlet on the adaptor, which contains an isolating voltage transformer and current transformer with precision low resistance shunt.

The adaptor is fitted with an IEC mains inlet for use with an appropriate mains lead.

When the adaptor is plugged into the mains and the mains switched on, the appliance is energised and the PSM1735 can be used to measure the power or harmonics.

Leave the PSM1735 generator off (OUT menu) so that it will synchronise to the mains frequency.

Part numbers

500-058 IEC 10A power meter adaptor

75Ω / 600Ω output adapter

The generator output from the PSM1735 has a series impedance of 50Ω. The output adapter fits directly onto the front of the instrument and provides 2 outputs:

75Ω via a BNC connector
600Ω via 4mm sockets.

There are two versions of the adapter that have different spacing between the 4mm sockets:

½" (12.5mm) as commonly used for communications.
¾" (19mm) as standard on instruments.

In both cases, the red connector carries the output signal, the green or black connector is 0V (connected to earth via the PSM1735 chassis).

The impedance conversion is resistive and does not limit the frequencies available from the generator (dc coupled). When driving into the characteristic impedance (75Ω or 600Ω as appropriate) the voltage delivered to the load will be half that delivered into open circuit.

Matching the source to the load impedance minimises reflections at higher frequencies and improves transient response, especially when driving long lengths of cable or transformers.

Part numbers

500-005	75/600Ω adaptor with ½" spacing
500-026	75/600Ω adaptor with ¾" spacing

LCR active head

The PSM1735 LCR active head fits onto the front of the instrument, making connection to the output and the two inputs, to provide four BNC connections for use with Kelvin leads to connect to the component under test.

A cable from the active head connects to the AUX port on the front of the PSM1735 to allow selection of one of the three internal shunts:

shunt	value	purpose
normal	100Ω	general purpose, all frequencies
high	10kΩ	higher impedance, low to medium frequency
very high	1MΩ	impedance > 100kΩ, low frequency only

*Ensure the LCR Active Head option is enabled in the AUX menu.

The active head contains high impedance buffer amplifiers that help to reduce the effect of stray capacitance and inductance.

The active head is usually supplied with Kelvin clip leads but Kelvin test probes are also available for in-circuit testing.

Part numbers

500-056	LCR active head
510-013	Kelvin clip lead set
510-014	Kelvin test probe set

Transformer analyser fixture, TAF01

The transformer analyser fixture TAF01 consists of a relay switching base unit that accepts plug in module to interface to transformers.

It connects to the BNC connectors on the front of the PSM1735 and is controlled by the PSM1735 via the extension port.

It supports transformers with 2 single windings, or with 1 single winding and one split winding. The winding(s) to be used for a measurement may be controlled by the front panel or by communications.

The connections to the transformer may be made either by a plug in pcb with suitable ZIF socket and resistors, or by flying leads with cable clips. To use the latter, plug in a resistance carrier board with appropriate source and load resistors.

NB it is essential that a source resistor be fitted for all tests.

The fixture contains high impedance buffer amplifiers that help to reduce the effect of stray capacitance and inductance.

Part numbers

500-017	TAF01 transformer analyser fixture
500-019	plug in module for modem transformers
500-020	plug in module for longitudinal balance
500-021	plug in resistance carrier
500-044	plug-in terminal block module
510-015	TAF01 Kelvin lead set
509-004	UK mains PSU

Injection transformer

When testing the stability of control loops it is necessary to inject a small disturbance signal into the loop. The PSM1735 output is ground referenced so it is necessary to isolate the output before it can be connected to the loop.

The standard injection transformer provides an isolated output at a reduced signal level of about 1/6 of the direct output level over a frequency range of about 10Hz to 200kHz. The high frequency injection transformer operates over a frequency range from 1kHz to 25MHz.

Connections are via BNC connectors – one is grounded to the case the other is isolated. The grounded connector should be connected to the OUTPUT connector of the PSM1735 – the isolated connector should be wired to the circuit under test.

Part numbers

500-042	standard injection transformer
500-047	High frequency injection transformer
500-048	High Voltage injection transformer
500-070	Low frequency injection module

CommView2 PC software

CommView2 is a self contained software program for a PC, which facilitates communication with the PSM1735 over RS232.

CommView2 allows strings to be sent and received between a PC and the PSM1735. The strings can be viewed in a window and optionally stored in a file. Data received from the PSM1735 may be displayed in normal scientific notation with an identifying label.

Strings to be sent to the PSM1735 can be stored in a "script file" and executed automatically. The script file is created with any text editor and includes three types of lines (interpreted by the first character on each line):

lines beginning with " are sent to the PSM1735
lines beginning with # are commands for CommView2
any other line is a comment.

The # commands that are recognised:

#beep	*sound the beeper on the PC*
#label,i,string	*apply a label to data value[i]*
#pause,t	*wait for time t*
#reply,t	*wait time t for a reply*

For an example script file, look at example.scr on the CommView2 release disc.

Other functions in CommView2:

save results	*results menu*
set COM port parameters	*configure menu*
firmware upgrade	*instrument menu*
read/store user programs	*instrument menu*

Appendix B – Serial command summary

command format	reply format
*CLS	
*ESE,value	
*ESE?	single integer data value
*ESR?	single integer data value
*IDN?	company,product,serial no,version
*OPC?	0 or 1
*RST	
*SRE,value	single integer data value
*SRE?	
*STB?	single integer data value
*TRG	
*TST?	single integer data value
*WAI	
ABORT	
ACTRIM,channel,level,tol	
ALARM,latch,sounder	
ALARM?	single integer data value
ALARME,value	
ALARME?	single integer data value
ALARM1,type,data,high,low	
ALARM2,type,data,high,low	
AMPLIT,amplitude	
ANALOG,type,value1,value2	
BANDWI,type	
BEEP	
BLANKI,on/off,threshold	
CALSTR?	
CALVER?	
CONFIG,parameter,data	
CONFIG,parameter?	single integer or real data value
COUPLI,channel,coupling	
COUPLI,channel?	single integer data value
CYCLES,value	
DATALO,function,interval	
DATALO,start,records?	index,time,data… one record per line
DAV?	single integer data value
DAVER,value	
DAVER?	single integer data value
DELAY,value	

FILTER,type,dynamics	
FRA	
FRA?	freq,mag1,mag2,dB,phase
FRA,SWEEP?	n lines of GAINPH? data
FREQUE,frequency	
FSWEEP,steps,start,end	
GAINPH	
GAINPH?	freq,mag1,mag2,dB,phase
GAINPH,SWEEP?	n lines of GAINPH? data
HARMON,scan,para,h,hmax	
HARMON?	freq,mag1,mag2,hmag1,hmag2,h1,h2
or	freq,mag1,mag2,thd1,thd2,h1,h2
HARMON,SWEEP?	n lines of HARMON? data
HARMON,SERIES?	mag1,%1,ϕ1,mag2,%2,ϕ2 1 line for each harmonic
HOLD,on/off	
INPUT,channel,type	
INPUT,channel?	single integer data value
INTYPE,channel,type	
KEYBOA,value	
LCR,conditions,param,head	
LCR?	freq, mag1, mag2, impedance, phase, R, L, C (series), R, L, C (parallel), tanδ, Q, reactance
or	freq, mag1, mag2, impedance, phase, resistance, reactance, admittance, phase, conductance, susceptance
LCR,SWEEP?	n lines of data: freq,QF,tanδ,impedance,phase,L,C,R
or	freq,QF,tanδ,admittance,phase,L,C,R
LOWFRE,on/off	
MARKER,on/off,frequency	
MODE,type	
OFFSET,offset	
OUTPUT,type,sweep	
PAV,parameter,scaling	
PAV?	freq,mag1,mag2,parameter,phase,a,b
PAV,SWEEP?	n lines of VECTOR? data
PHASE	
PHASE?	freq,phase
PHASE,STREAM,window	phase,phase,phase,phase,phase,…….
PHCONV,convention	
PHREF,channel	

POWER,integration type	
POWER,WATTS?	W,W.f,VA,VA.f,pf,pf.f,Wdc,W.h,freq
POWER,RMS?	rms1,rms2,dc1,dc2,fnd1,fnd2,ϕ1,ϕ2
POWER,INTEGR?	Wh,Wh.f,VAh,VAh.f,pf,pf.f,Ah,Ah.f,t
PPORT,value	
PPORT?	single integer data value
PROGRAM,function,number	
PROGRAM?	CR terminated text string
RANGE,ch,ranging,range	
RESOLU.format	
REZERO	
RUN?	data
SCALE,channel,factor	
SCALE,channel?	single real data value
SHUNT,channel,resistance	
SHUNT,channel?	single real data value
SINGLE,on/off	
SPEED,speed[,window]	
SSWEEP,function,number	
START	
STATUS,channel?	range number,range text,over/low/ok
STOP	
STREAM,enable,window	
STREAM,disable	
STREAM?	data, data, data, data, data, …..
SUSPEND,on/off	
TFA	
TFA?	freq,mag1,mag2,dB,phase
TFA,SWEEP?	n lines of GAINPH? data
TXA,test,fixture,load,source	
TXA?	freq,mag1,mag2,parameter
TXA,SWEEP?	n lines of TXA? data
TXTEST,test,wind1,wind2	
USER?	3 CR terminated text strings
VECTOR,parameter,scaling	
VECTOR?	freq,mag1,mag2,parameter,phase,a,b
VECTOR,SWEEP?	n lines of VECTOR? data
VERSION?	datecode,cpu,dsp,fpga,boot
VRMS	
VRMS?	RMS? data followed by SURGE?
VRMS,RMS?	rms1,rms2,dc1,dc2,ac1,ac2,db1,db2
VRMS,SURGE?	pk1,pk2,cf1,cf2,surge1,surge2
WAVEFO,type	

ZERO
ZERO,DELETE
ZOOM,level,d1,d2,d3,d4
ZOOM? level,d1,d2,d3,d4

Appendix C – Available character set

The following characters can be selected in text entry mode.
The table is to be read across then down (eg, starting at space and repeatedly pressing NEXT gives ! " # $ % & ` ( ) * etc.)

	!	"	#	$	%	&	`
(	)	*	+	,	-	.	/
0	1	2	3	4	5	6	7
8	9	:	;	<	=	>	?
@	A	B	C	D	E	F	G
H	I	J	K	L	M	N	O
P	Q	R	S	T	U	V	W
X	Y	Z	[	\	]	^	_
`	a	b	c	d	e	f	g
h	i	j	k	l	m	n	o
p	q	r	s	t	u	v	w
x	y	z	{	|	}		

Appendix D – Configurable parameters

All parameters can be accessed using the CONFIG command:

CONFIG,*parameter*?
CONFIG,*parameter,data*

Number	Function
	System parameters
1	operating mode
3	bandwidth auto or wide
4	autozero manual or auto
5	blanking disable
6	phase convention
7	main output on/off
8	line drawing on/off
9	keyboard beep on/off
11	low frequency mode
12	user window size
13	measurement speed
14	filter type
15	filter dynamics
16	baud rate
18	sweep steps
19	sweep start frequency
20	sweep stop frequency
21	single sweep / continuous sweep
22	auto conditions
23	auto shunt
	Input parameters
24	enable channel 1
25	enable channel 2
26	input range channel 1
27	input range channel 2
28	input ranging channel 1
29	input ranging channel 2
30	coupling channel 1

31	coupling channel 2
32	scale factor channel 1
33	scale factor channel 2
34	external shunt channel 1
35	external shunt channel 2
36	input connection channel 1
37	input connection channel 2
	General parameters
38	5/6 digit resolution
39	phase reference
	Display parameters
42	zoom level
43	function zoomed on 1
44	function zoomed on 2
45	function zoomed on 3
46	function zoomed on 4
47	display type
	Signal generator parameters
48	generator frequency
49	generator amplitude
50	generator offset
51	generator waveform
52	delta frequency
53	delta amplitude
54	generator amplitude in dBm
55	generator action at end of sweep
57	generator ceiling
	Datalog parameters
58	datalog memory type
59	datalog interval
	General parameters
64	frequency marker enable
65	marker frequency
66	program jump enable
67	PLC interface enable

Power meter parameters

83 integration type

Streaming parameters

95 data streaming
96 data streaming window size

Harmonic analyser parameters

99 mode
100 selected harmonic
101 maximum harmonic
102 computation
103 Bargraph scale

LCR sweep zero parameters

106 sweep compensation
107 compensation start frequency
108 compensation stop frequency
109 compensation steps

System parameters

116 dBm level control
117 step message enable
118 display sequence
119 length units

Transformer analyser parameters

121 test
122 fixture
123 winding 1
124 winding 2
125 source impedance
126 load impedance
127 nominal number of turns

TAF control parameters

130 source winding
131 load
132 measure 1
133 measure 2

LCR meter parameters

137 computation
138 series/parallel sweep
139 graph option
140 active head control
141 impedance lin/log
142 phase adjust value
143 reference impedance
144 reference type
145 connection

gain/phase analyser parameters

147 phase or delay time selection
148 dB offset
149 gain/phase margin enable
150 ratio selection

System parameters

151 minimum number of cycles
152 delay time
153 IEEE address
154 LAN enable

Alarm functions

156 alarm data
157 type
158 high threshold
159 low threshold
160 latching type
161 sounder enable
162 analogue scale

Analogue output parameters

164 analogue zero
165 analogue scale

Alarm functions

167 alarm 2 data
168 alarm 2 type

169 alarm 2 high threshold
170 alarm 2 low threshold

Graph functions

173 graph 2 manual/auto
174 graph 2 maximum
175 graph 2 minimum

Phase angle voltmeter parameters

177 computation
178 LVDT scaling
179 manual null meter ranging
180 null maximum
181 phase offset

Trim parameters

186 ac trim enable
188 ac trim level
190 trim tolerance

Other parameters

192 log/linear sweep
193 graph scaling manual/auto
194 manual graph scaling maximum
195 manual graph scaling minimum

Appendix E – Contact details

Please direct all queries or comments regarding the PSM1735 instrument or manual to:

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At Newtons4th Ltd. we have a policy of continuous product improvement and are always keen to hear comments, whether favourable or unfavourable, from users of our products.

An example comment form can be found at the end of this manual – if you have any comments or observations on the product please fill a copy of this form with as much detail as possible then fax or post it to us.

Alternatively send an e-mail with your comments.

PSM1735 comments

serial number:	main release: dsp release: fpga release: boot release: (press SYS then LEFT)	date:

your contact details:

comments:

detailed description of application or circumstances:

Please post or fax to Newtons4th Ltd.