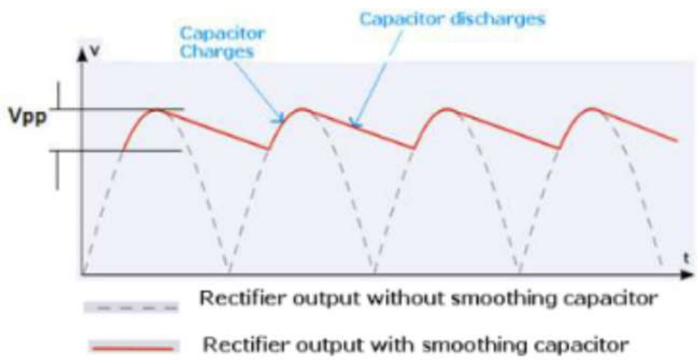


Procedure

Capacitative Rectification for Half Wave Rectifier

1. Take a diode, and Load resistor of 1KOhms and capacitor of 102µF.
2. Connect to AC Voltage Source of 50 Hz, 2 V
3. Click on 'ON' button to make the circuit on.
4. Click on 'Sine Wave' button to observe the input waveform.
5. Click on 'Run Simulation' button to observe the filtered waveform.
6. Observe the corresponding waveform.
7. Channel 1 shows the input wave, Channel 2 shows the output wave and Dual shows both the input and output wave.

Capacitative Rectification for Full Wave Rectifier

1. Take 4 diodes, Load resistor of 1KOhms and capacitor of 102µF.
2. Connect to AC Voltage Source of 50 Hz, 12 V.
3. Click on 'ON' button to make the circuit on.
4. Click on 'Sine Wave' button to observe the input waveform.
5. Click on 'Run Simulation' button to observe the filtered waveform.
6. Vary the amplitude using the controllers.
7. Observe the corresponding waveform.
8. Channel 1 shows the input wave, Channel 2 shows the output wave and Dual shows both the input and output wave.

EXPERIMENT-6

Objective: To verify V-I characteristics of BJT in CE–mode.

Apparatus required

Power supply

Lab trainer kit

Jumper wires

Oscilloscope

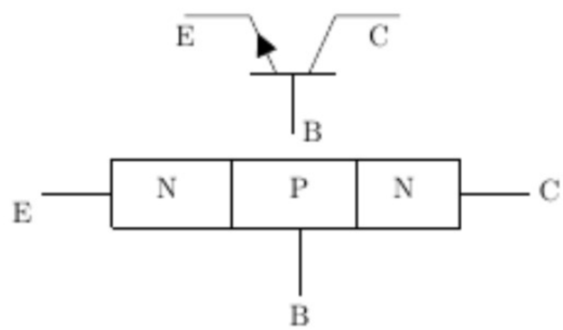
Waveform generator

Multimeter

Theory

Structure of Bipolar Junction Transistor

A bipolar junction transistor, BJT, is a single piece of silicon with two back-to-back P-N junctions.BJTs can be made either as PNP or as NPN. They have three regions and three terminals, emitter, base, and collector represented by E, B, and C respectively. The direction of the arrow indicates the direction of the current in the emitter when the transistor is conducting normally. An easy way to remember this is NPN stands for "Not Pointing iN".



Emitter (E): It is the region to the left end which supply free charge carriers i.e., electrons in n-p-n or holes in p-n-p transistors. These majority carriers are injected to the middle region i.e. electrons in the p region of n-p-n or holes in the n region of p-n-p transistor. Emitter is a heavily doped region to supply a large number of majority carriers into the base. **Base (B):** It is the middle region where either two p-type layers or two n-type layers are sandwiched. The majority carriers from the emitter region are injected into this region. This region is thin and very lightly doped. **Collector (C):** It is the region to right end where charge carriers are collected. The area of this region is largest compared to emitter and base region. The doping level of this region is intermediate between heavily doped emitter region and lightly doped base region.

Note

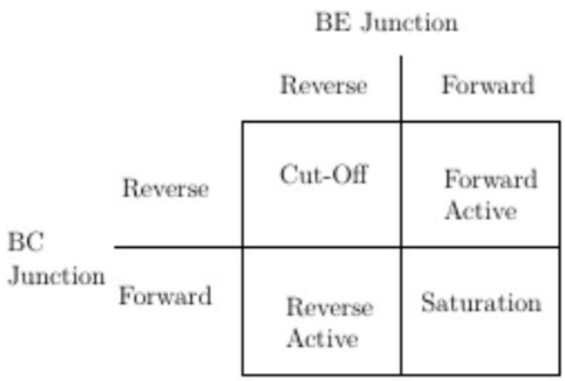
1. In digital electronics applications,the transistors are used as a switch.
2. Most bipolar switching circuits use NPN transistors.

Operation of Bipolar Junction Transistor

Cutoff Region: Base-emitter junction is reverse biased. No current flow. **Saturation Region:** Base-emitter junction is forward biased and Collector-base junction is forward biased. **Active Region:** Base-emitter is junction forward biased and Collector-base junction is reverse biased. **Breakdown Region:** IC and VCE exceed specifications and can cause damage to the transistor.

Cut-Off Region

In Cut-Off region both junctions are reverse biased, Base-emitter junction is reverse biased (VBE<0)and also Collector-Base junction is reverse biased(VCB>0).With reverse biasing, all currents are zero.There are some leakage currents associated with reverse biased junctions,but these currents are small and therefore can be neglected. Application: Open switch



Forward Active Region

In Forward Active region Base-emitter junction is forward biased (VBE<0) and Collector-Base junction is reverse biased(VCB<0). In this case, the forward bias of the BE junction will cause the injection of both holes and electrons across the junction. The holes are of little consequence because the doping levels are adjusted to minimize the hole current. The electrons are the carriers of interest. The electrons are injected into the base region where they are called the minority carrier even though they greatly outnumber the holes. Application: Amplifier in analog circuits

$$I_C = -\alpha_F \times I_E + I_{CO}$$

where, α_F is the forward current transfer ratio ICO is Collector reverse saturation current

Saturation Region

In Saturation region both junctions are Forward biased,Base-emitter junction is forward biased(VBE>0) and also Collector-Base junction is forward biased(VCB<0). Maximum currents flows through the transistor with only a small voltage drop across the collector junction.The transistor also does not respond to any change in emitter current or base-emitter voltage. Application: Closed switch

Reverse Active Region

In Reverse Active region Base-emitter junction is reverse biased(VBE<0) and Collector-Base junction is forward biased(VCB<0).The operation is just the same as the forward active region, except all voltage sources, and hence collector and emitter currents, are the reverse of the forward bias case. The current gain in this mode is smaller than that of forward active mode for which this mode in general unsuitable for amplification. Application: In digital circuits and analog switching circuits.

$$I_E = -\alpha_R * I_C + I_{EO}$$

where, α_R is the reverse current transfer ratio\newline IEO is the Emitter reverse saturation current

This configuration is rarely used because most transistors are doped selectively to give forward current transfer ratios very near unity, which automatically causes the reverse current transfer ratio to be very low.

BJT -Common Emitter Circuit

The DC behavior of the BJT can be described by the Ebers-Moll Model. The equations for the model are:

$$I_F = I_{ES}(exp^{\frac{V_{BE}}{V_T}} - 1)$$

$$I_R = I_{CS}(exp^{\frac{V_{CB}}{V_T}} - 1)$$

where I_{ES} is base-emitter saturation currents, I_{CS} is base-collector saturation currents

$$V_T = \frac{kT}{q}$$

where, k is the Boltzmann’s constant (k = 1.381 e-23 V.C/ K), T is the absolute temperature in degrees Kelvin, and q is the charge of an electron (q = 1.602 e-19 C).

$$\beta_F = \frac{\alpha_F}{1-\alpha_F}$$

$$\beta_R = \frac{\alpha_R}{1-\alpha_R}$$

where, β_F is large signal forward current gain of common-emitter configuration, β_R is the large signal reverse current gain of the common-emitter configuration

$$\alpha_F = \frac{\beta_F}{1+\beta_F}$$

$$\alpha_R = \frac{\beta_R}{1+\beta_R}$$

where, α_R is large signal reverse current gain of a common-base configuration, α_F is large signal forward current gain of the common-base configuration.

$$I_C = \alpha_F \times I_F - I_R$$

$$I_E = -I_F + \alpha_R * I_R$$

$$I_B = (1-\alpha_F) \times I_F + (1-\alpha_R) \times I_R$$

The forward and reverse current gains are related by the expression

$$\alpha_R \times I_{CS} = \alpha_F \times I_{ES} = I_S$$

where, $I_S$is the BJT transport saturation current. The parameters α_R and α_F are influenced by impurity concentrations and junction depths. The saturation current, I_S, can be expressed as

$$I_S = J_S \times A$$

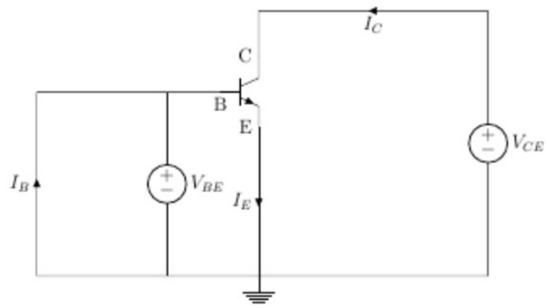
where, A is the area of the emitter and J_S is the transport saturation current density.

Input Characteristics

The most important characteristic of the BJT is the plot of the base current, I_B, versus the base-emitter voltage, V_{BE}, for various values of the collector-emitter voltage,V_{CE}

$$I_B = \phi(V_{BE}, V_{CE})$$

for constant V_{CE}

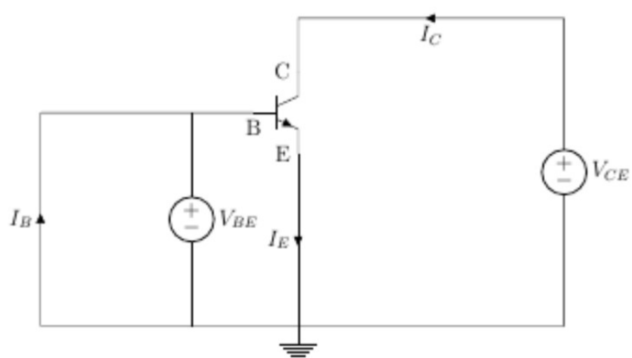


Output Characteristics

The most important characteristic of the BJT is the plot of the collector current, I_C, versus the collector-emitter voltage, V_{CE}, for various values of the base current, I_B as shown on the circuit on the right.

$$I_C = \phi(V_{CE}, I_B)$$

for constant I_B



Procedure

BJT Common Emitter - Input Characteristics

1. Initially set rheostat R_{h1} = 1 Ω and rheostat R_{h2} = 1 Ω
2. Set the Collector-Emitter Voltage(V_{CE}) to 1 V by adjusting the rheostat Rh2
3. Base Emitter Voltage(V_{BE}) is varied by adjusting the rheostat Rh1.
4. Note the reading of Base current(I_B)in micro Ampere.
5. Click on 'Plot' to plot the I-V characteristics of Common-Emitter configuration. A graph is drawn with V_{BE} along X-axis and I_B along Y-axis.
6. Click on 'Clear' button to take another sets of readings
7. Now set the Collector-Emitter Voltage(V_{CE}) to 2 V, 3 V, 4 V

BJT Common Emitter - Output Characteristics

1. Initially set rheostat R_{h1} = 1 Ω and rheostat R_{h2} = 1 Ω
2. Set the Base current(I_B)15 uA by adjusting the rheostat R_{h1}
3. Vary the Collector-Emitter Voltage(V_{CE})is varied by adjusting the rheostat R_{h2}.
4. Note the reading of Collector current(I_C).
5. Click on 'Plot' to plot the I-V characteristics of Common-Emitter configuration. A graph is drawn with V_{CE} along X-axis and I_C along Y-axis.
6. Click on 'Clear' button to take another sets of readings
7. Now set the Base Current(I_B) to 20 uA

BJT Common Emitter Amplifier

The common emitter configuration is widely used as a basic amplifier as it has both voltage and current amplification. Resistors R_{B1} and R_{B2} form a voltage divider across the base of the transistor. The function of this network is to provide necessary bias condition and ensure that emitter-base junction is operating in the proper region.

In order to operate transistor as an amplifier, biasing is done in such a way that the operating point is in the active region. For an amplifier the Q-point is placed so that the load line is bisected. Therefore, in practical design V_{CE} is always set to $V_{CC}/2$. This will confirm that the Q-point always swings within the active region. This limitation can be explained by maximum signal handling capacity. For the maximum input signal, output is produced without any distortion and clipping.

The Bypass Capacitor

The emitter resistor RE is required to obtain the DC quiescent point stability. However the inclusion of RE in the circuit causes a decrease in amplification at higher frequencies. In order to avoid such a condition, it is bypassed by a capacitor so that it acts as a short circuit for AC and contributes stability for DC quiescent condition. Hence capacitor is connected in parallel with emitter resistance.

$$X_{CE} << R_E$$

$$\frac{1}{2\pi f C_E} << R_E$$

$$C_E >> \frac{1}{2\pi f R_E}$$

The Input/ Output Coupling (or Blocking) Capacitor

An amplifier amplifies the given AC signal. In order to have noiseless transmission of a signal (without DC), it is necessary to block DC i.e. the direct current should not enter the amplifier or load. This is usually accomplished by inserting a coupling capacitor between two stages.

$$X_{CC} << R_i h_{ie}$$

$$\frac{1}{2\pi f C_C} << R_i h_{ie}$$

$$C_C >> \frac{1}{2\pi f (R_i h_{ie})}$$

C_C - Output Coupling Capacitor, C_B - Input Coupling Capacitor

Frequency response of Common Emitter Amplifier

Emitter bypass capacitors are used to short circuit the emitter resistor and thus increases the gain at high frequency. The coupling and bypass capacitors cause the fall of the signal in the low frequency response of the amplifier because their impedance becomes large at low frequencies. The stray capacitances are effectively open circuits. In the mid frequency range large capacitors are effectively short circuits and the stray capacitors are open circuits, so that no capacitance appears in the mid frequency range. Hence the mid band frequency gain is maximum. At the high frequencies, the bypass and coupling capacitors are replaced by short circuits. The stray capacitors and the transistor determine the response.

The input resistance is medium and is essentially independent of the load resistance R_L . The output resistance is relatively high and is essentially independent of the source resistance.

The coupling capacitor, C_{C1} , couples the source voltage V_S to the biasing network. Coupling capacitor C_{C2} connects the collector resistance R_C to the load R_L . The bypass capacitance C_E is used to increase the midband gain, since it effectively short circuits the emitter resistance R_E at midband frequencies. The resistance R_E is needed for bias stability. The external capacitors C_{C1}, C_{C2}, C_E will influence the low frequency response of the common emitter amplifier. The internal capacitances of the transistor will influence the high frequency cut-off.

$$A(s) = \frac{A_m S^2 (S + w_Z)}{(S + w_{L1})(S + w_{L2})(S + w_{L3})(1 + \frac{S}{w_H})}$$

where, A_M is the midband gain, ω_H is the frequency of the dominant high frequency pole,

ω_{L1}, ω_{L2}, ω_{L3} are low frequency poles introduced by the coupling and bypass capacitors,

w_Z is the zero introduced by the bypass capacitor. The midband gain is obtained by short circuiting all the external capacitors and open circuiting the internal capacitors.