Bipolar Junction Transistor

Bipolar junction transistor definition

A bipolar junction transistor or BJT is a three terminal electronic device that amplifies the flow of current. It is a current controlled device. In bipolar junction transistor, electric current is conducted by both free electrons and holes.

Unlike a normal pn junction diode, the transistor has two p-n junctions.

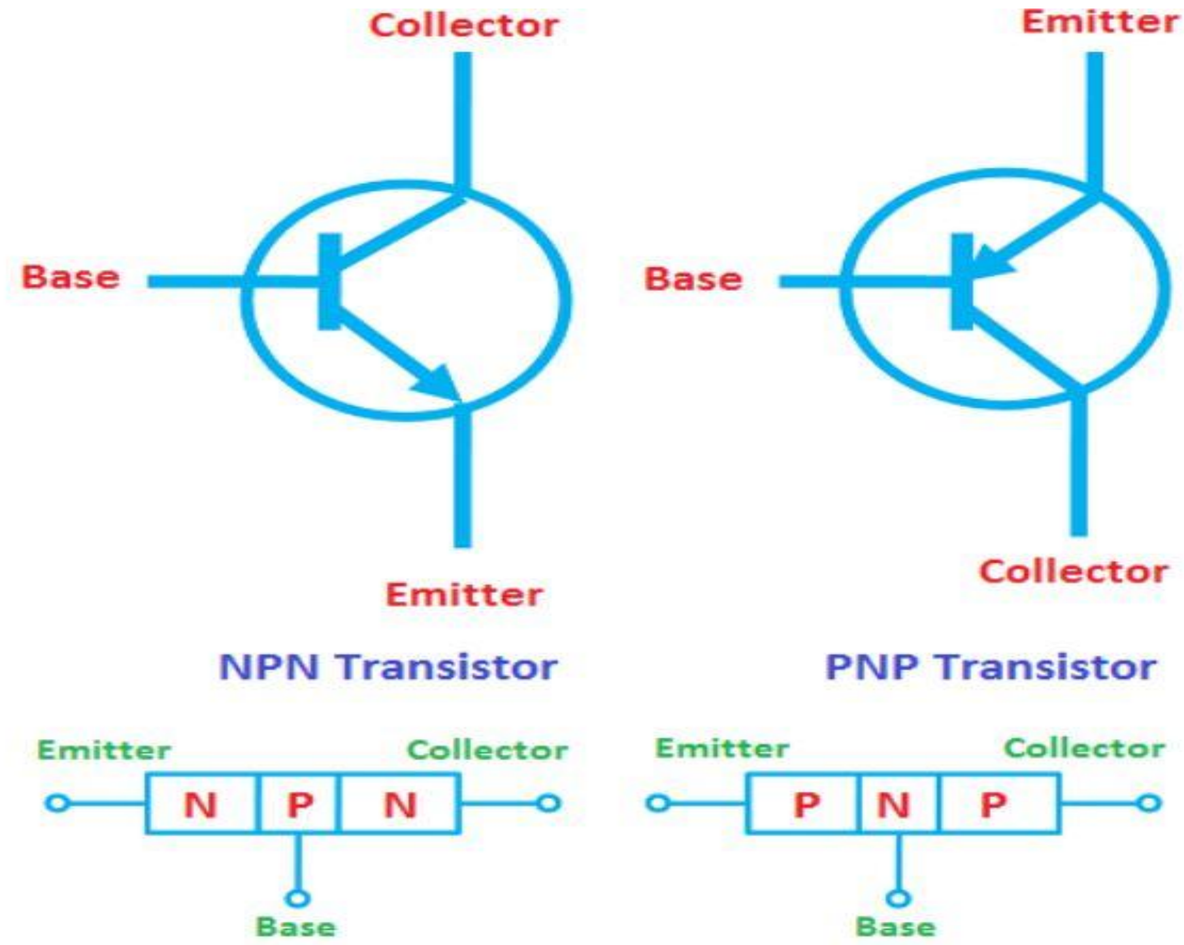
Types of Bipolar Junction Transistors (BJTs)

The bipolar junction transistors are formed by sandwiching either n-type or p-type semiconductor layer between pairs of opposite polarity semiconductor layers.

Bipolar junction transistors are classified into two types based on their construction: They are

1. NPN transistor
2. PNP transistor

Transistor symbol



Terminals of BJT

Emitter:

As the name suggests, the emitter section supplies the charge carriers. The emitter section is heavily doped so that it can inject a large number of charge carriers into the base. The size of the emitter is always greater than the base.

Base:

The middle layer is called base. The base of the transistor is very thin as compared to emitter and collector. It is very lightly doped.

Collector:

The function of the collector is to collect charge carriers. It is moderately doped. That is the doping level of the collector section is in between emitter and base. The size of the collector is always greater than emitter and base. The collector area in the transistor is considerably larger than the emitter area. This is because the collector region has to handle more power than the emitter does and more surface area is required for heat dissipation.

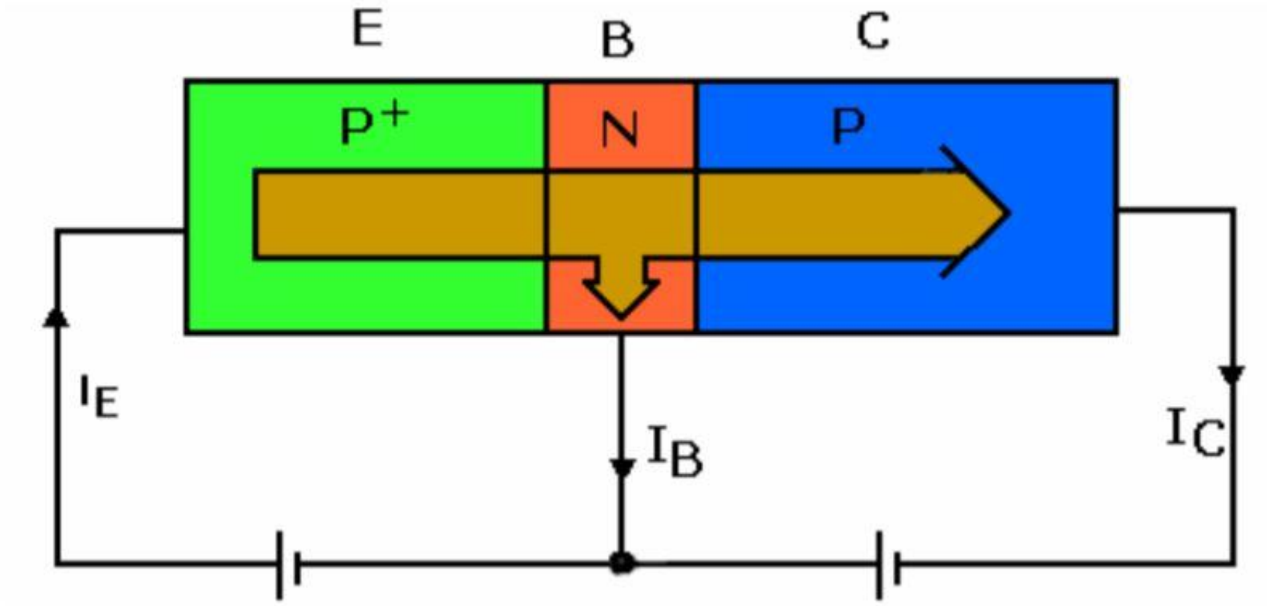
Applications of bipolar junction transistor

The various applications of bipolar junction transistors include:

- Televisions
- Mobile phones
- Computers
- Radio transmitters
- Audio amplifiers

Transistor current equation

$$I_E = I_C + I_B$$

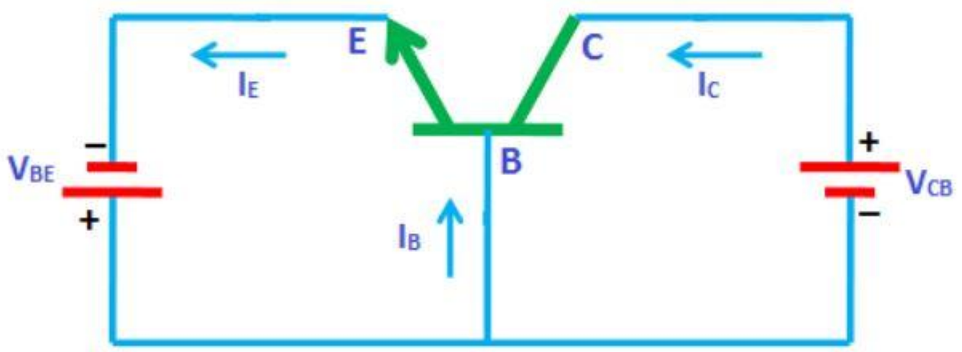


Transistor terminal voltages

The supply voltage polarities for **NPN** transistor is shown in the below figure.

The supply voltage between the base and the emitter is denoted by V_{BE}. The base is biased positive with respect to the emitter and the arrowhead points from the positive base to the negative emitter. The arrowhead direction represents the direction of current flow.

The supply voltage between the collector and the base is denoted by V_{CB}. The collector is biased to a higher positive level than the base to keep the collector-base junction reverse biased.



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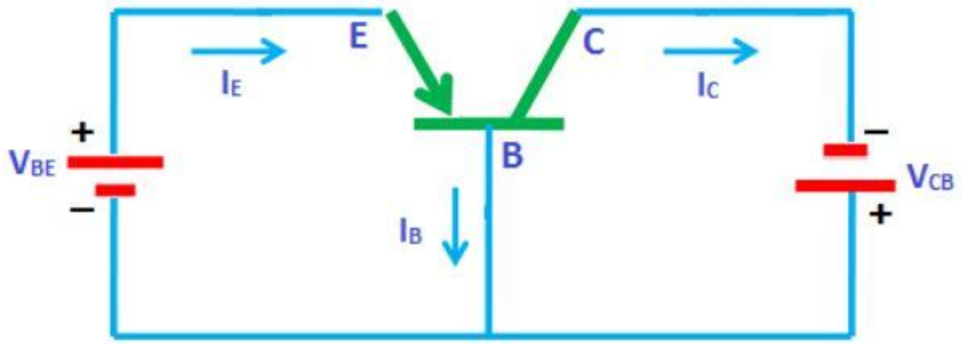
The supply voltage polarities for **PNP** transistor is shown in the below figure.

The supply voltage between the base and the emitter is denoted by V_{BE}. The base is biased negative with respect to the emitter and the arrowhead points from the positive emitter to the negative base. The arrowhead direction represents the direction of current flow.

The supply voltage between the collector and the base is denoted by V_{CB}. The collector is biased to a higher negative level than the base to keep the collector-base junction reverse biased



Typical voltages for a transistor

Base-emitter voltages (V_{BE}) for NPN and PNP transistors

The transistor is normally operated in the active region for amplifying the electric current. In active region, the emitter junction (J_E) is forward biased and the collector junction (J_C) is reverse biased.

The typical base-emitter voltages (V_{BE}) for both **NPN** and **PNP** transistors are as follows:

If the transistor is made up of a silicon material, the base-emitter voltage (V_{BE}) will be 0.7 V.

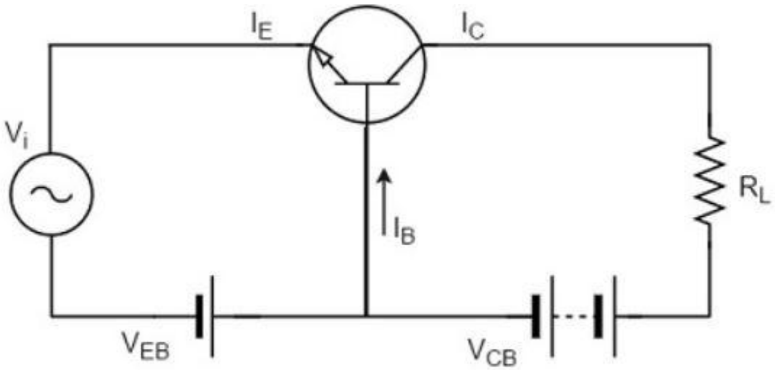
If the transistor is made up of a germanium material, the base-emitter voltage (V_{BE}) will be 0.3 V.

Collector-base voltages (V_{CB}) for NPN and PNP transistors

The typical collector-base voltages (V_{CB}) for both **NPN** and **PNP** transistors will be anywhere between 3 V to 20 V.

Transistor Amplifier

A transistor acts as an amplifier by raising the strength of a weak signal. The DC bias voltage applied to the emitter base junction, makes it remain in forward biased condition. This forward bias is maintained regardless of the polarity of the signal. The below figure shows how a transistor looks like when connected as an amplifier.



The low resistance in input circuit, lets any small change in input signal to result in an appreciable change in the output. The emitter current caused by the input signal contributes the collector current, which when flows through the load resistor R_L, results in a large voltage drop across it. Thus a small input voltage results in a large output voltage, which shows that the transistor works as an amplifier.

Example

Let there be a change of 0.1v in the input voltage being applied, which further produces a change of 1mA in the emitter current. This emitter current will obviously produce a change in collector current, which would also be 1mA.

A load resistance of 5kΩ placed in the collector would produce a voltage of

$5\ k\Omega \times 1\ mA = 5V$

Hence it is observed that a change of 0.1v in the input gives a change of 5v in the output, which means the voltage level of the signal is amplified.

Types of Transistor Configuration

Transistor is an electronic device which is primarily used to amplify the electric current.

We know that transistor has three terminals namely emitter (E), base (B), and collector (C). But to connect a transistor in the circuit, we need four terminals: two terminals for input and other two terminals for output.

But the transistor does not have four terminals, then how do we connect transistor in a circuit. It is not as difficult as you think. One of the three terminals is used as common to both input and output.

When a transistor is to be connected in a circuit, one terminal is used as the input terminal, the other terminal is used as the output terminal and the third terminal is common to the input and output.

That means here input is applied between the input terminal and common terminal, and the corresponding output is taken between the output terminal and common terminal.

Depending upon the terminal which is used as a common terminal to the input and output terminals, the transistor can be connected in the following three configurations. They are:

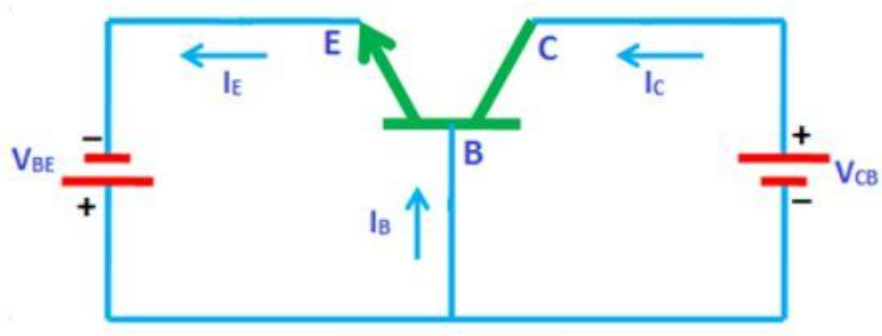
Common base (CB) configuration

Common emitter (CE) configuration

Common collector (CC) configuration

Common base (CB) configuration

In common base configuration, emitter is the input terminal, collector is the output terminal, and base is the common terminal. The base terminal is grounded in the common base configuration. So the common base configuration is also known as grounded base configuration.

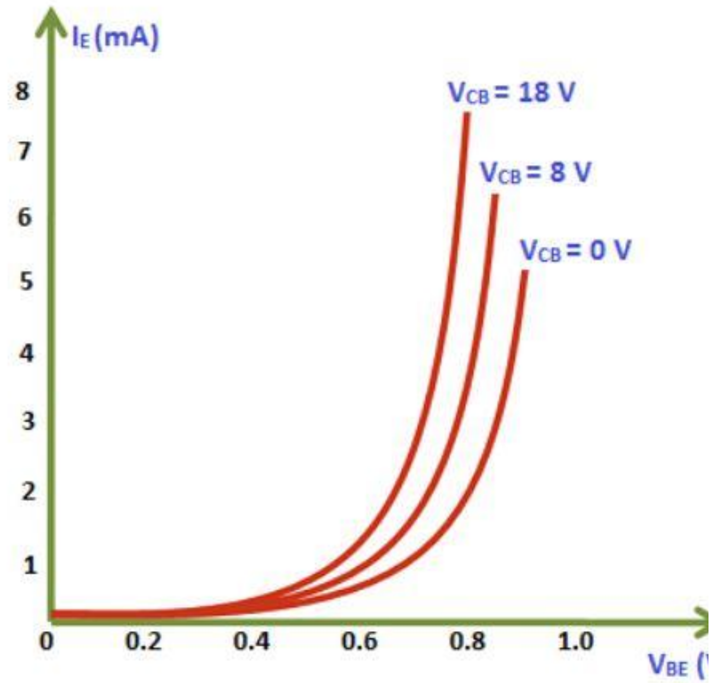


Current gain (α)

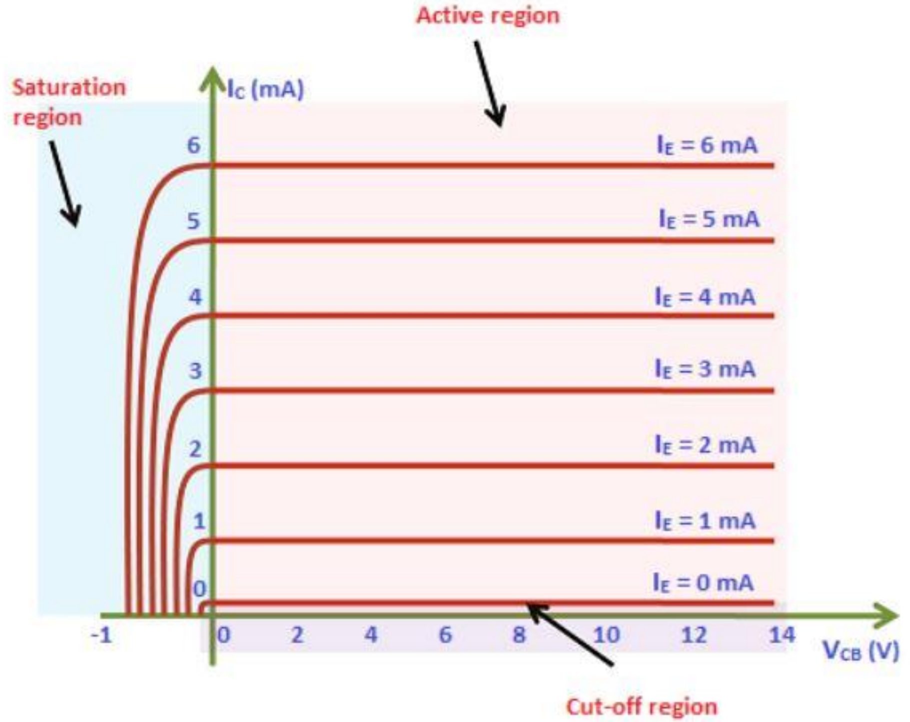
The current gain of a transistor in CB configuration is defined as the ratio of output current or collector current (I_C) to the input current or emitter current (I_E).

$$\alpha = \frac{I_C}{I_E}$$

I/P and O/P Characteristics



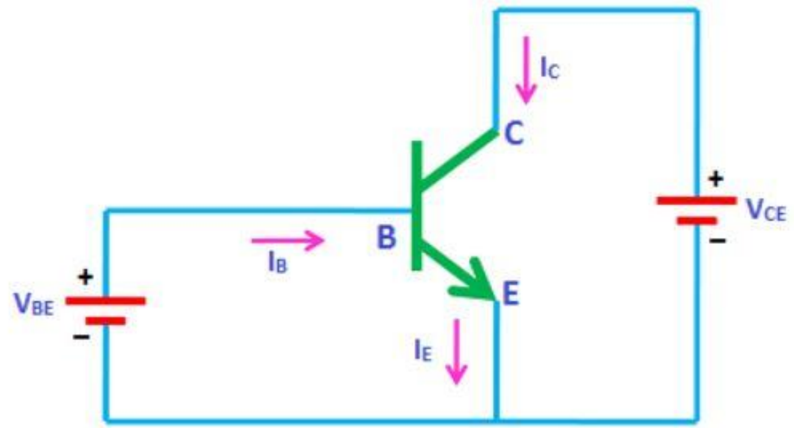
I/p characteristics CB configuration



O/P characteristics CB configuration

Common emitter (CE) configuration

In common emitter configuration, base is the input terminal, collector is the output terminal, and emitter is the common terminal. The emitter terminal is grounded in the common emitter configuration. So the common emitter configuration is also known as grounded emitter configuration.

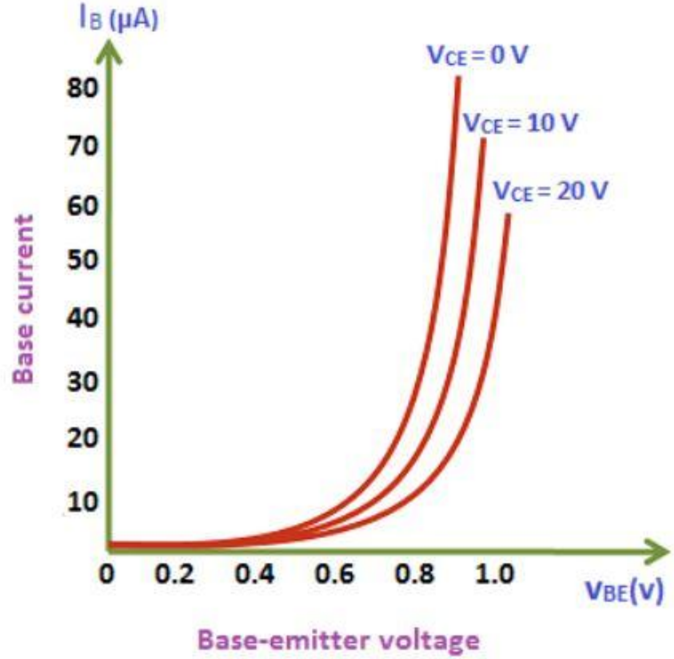


Current gain (β)

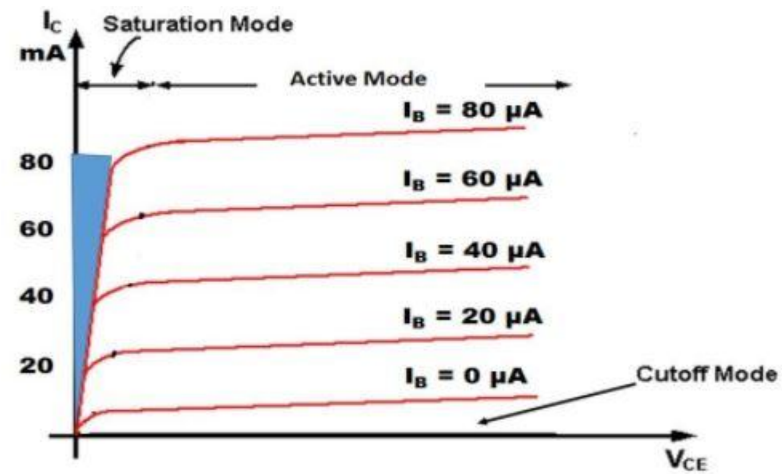
The current gain of a transistor in CE configuration is defined as the ratio of output current or collector current (I_C) to the input current or base current (I_B).

$$\beta = \frac{I_C}{I_B}$$

I/P and O/P Characteristics

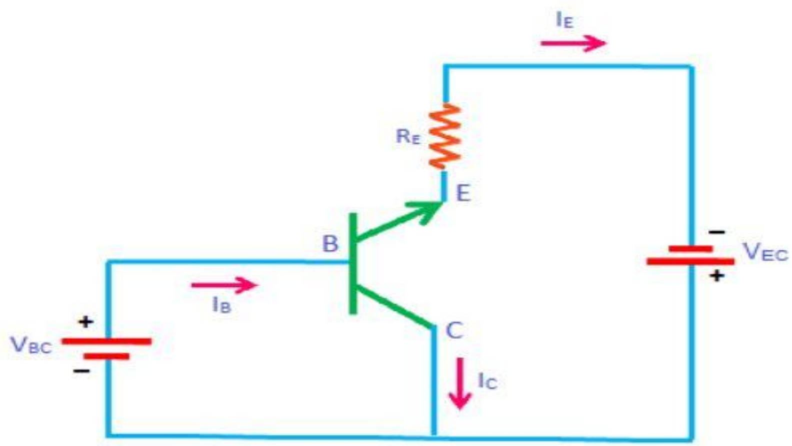


I/P characteristics CE configuration



Common collector (CC) configuration

In common collector configuration, base is the input terminal, emitter is the output terminal, and collector is the common terminal. The collector terminal is grounded in the common collector configuration. So the common collector configuration is also known as grounded collector configuration.

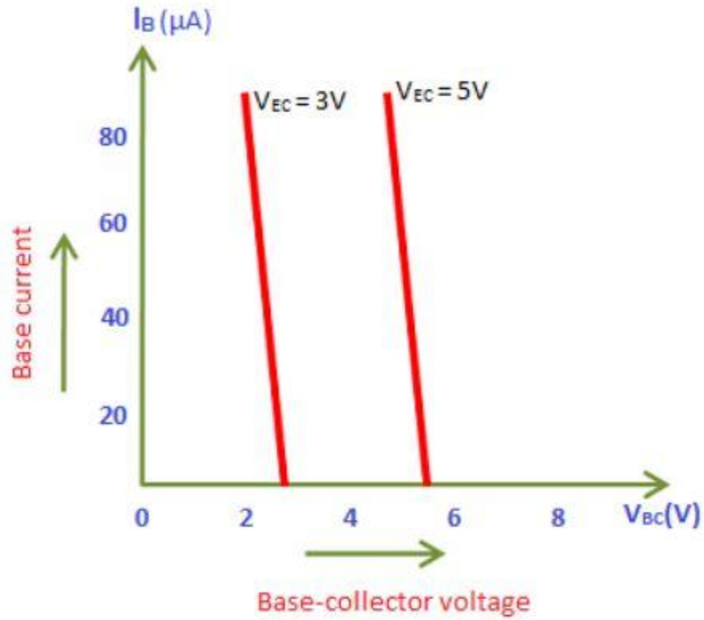


Current amplification factor (γ)

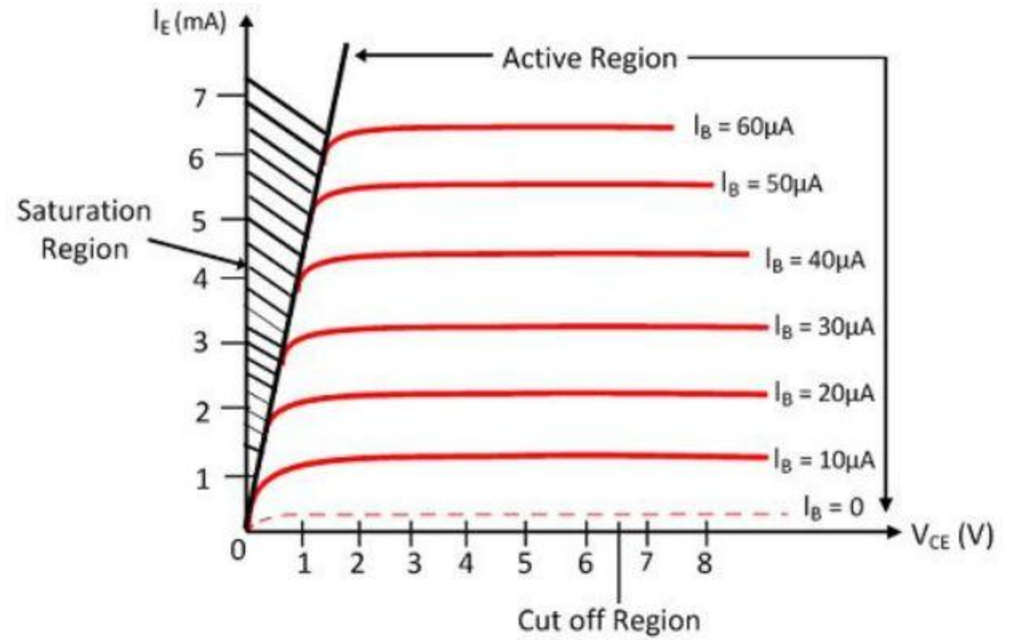
The current amplification factor is defined as the ratio of change in output current or emitter current I_E to the change in input current or base current I_B. It is expressed by **γ.**

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

I/P and O/P Characteristics



Input characteristics



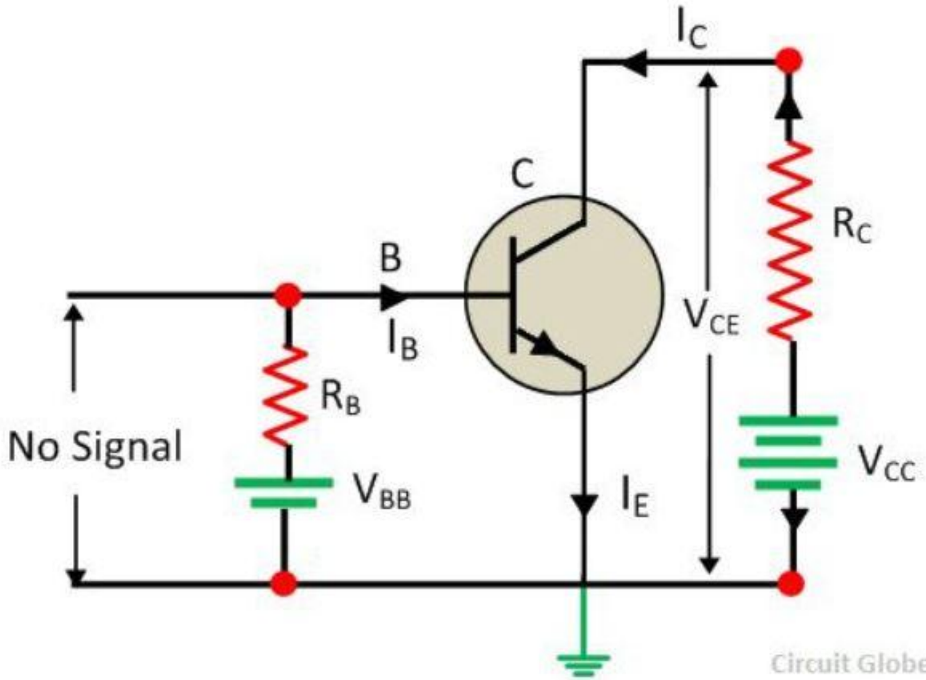
Output Characteristic Curve

Transistor Load Line Analysis

- **Definition:** The load line analysis of transistor means for the given value of collector-emitter voltage we find the value of collector current. This can be done by plotting the output characteristic and then determine the collector current I_C with respect to collector-emitter voltage V_{CE}. The load line analysis can easily be obtained by determining the output characteristics of the load line analysis methods.

DC Load Line

- The DC load represents the desirable combinations of the collector current and the collector-emitter voltage. It is drawn when no signal is given to the input, and the transistor becomes bias.
- Consider a CE NPN transistor circuit shown in the figure below where no signal is applied to the input side. For this circuit, DC condition will obtain, and the output characteristic of such a circuit is shown in the figure below.



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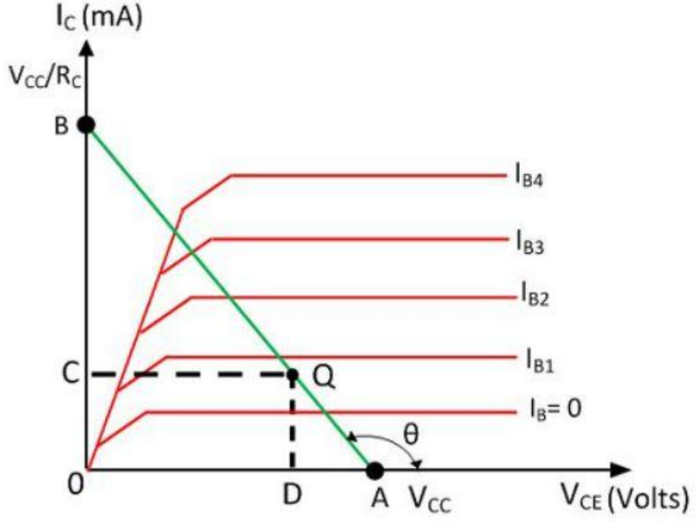
- The DC load line curve of the above circuit is shown in the figure below.



Transistor biasing.

- Transistors are one of the largely used semiconductor devices which are used for wide variety of applications including amplification and switching. However to achieve these functions satisfactorily, transistor has to be supplied with certain amount of current and/or voltage. The process of setting these conditions for a transistor circuit is referred to as **Transistor Biasing**. This goal can be accomplished by variety of techniques which give rise to different kinds of biasing circuits. However, all of these circuits are based on the principle of providing right-amount of base current, I_B and inturn the collector current, I_C from the supply voltage, V_{CC} when no signal is present at the input. Moreover the collector resistor R_C has to be chosen so that the collector-emitter voltage, V_{CE} remains greater than 0.5V for transistors made of germanium and greater than 1V for the transistors made of silicon. A few biasing circuits are
- Fixed bias
- Collector-to-base bias
- Fixed bias with emitter resistor
- Voltage divider bias or potential divider
- Emitter bias

Fixed Base Bias or Fixed Resistance Bias

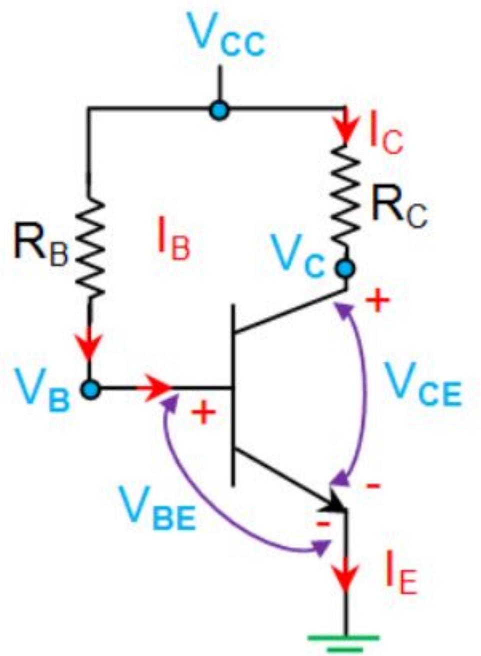


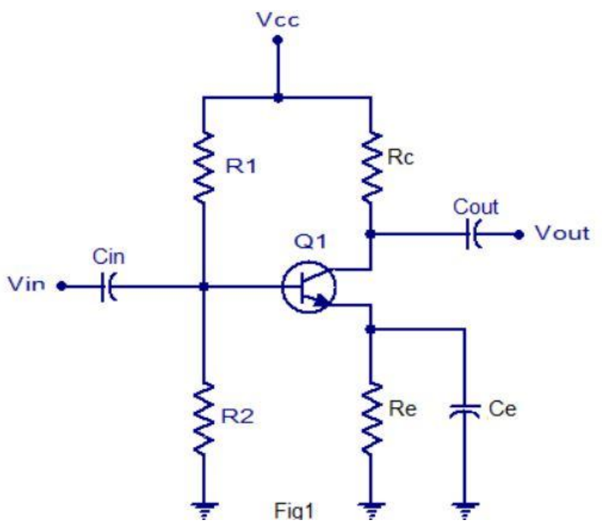
Figure 1 Fixed Base Bias Circuit

Transistor Amplifier

Amplification is a process of increasing the signal strength by increasing the amplitude of a given signal without changing its characteristics. An RC coupled amplifier is a part of a multistage amplifier wherein different stages of amplifiers are connected using a combination of a resistor and a capacitor. An amplifier circuit is one of the basic circuits in electronics.

An amplifier that is completely based on the transistor is basically known as a transistor amplifier. The input signal may be a current signal, voltage signal, or a power signal. An amplifier will amplify the signal without changing its characteristics and the output will be a modified version of the input signal. Applications of amplifiers are of a wide range. They are mainly used in audio and video instruments, communications, controllers, etc.

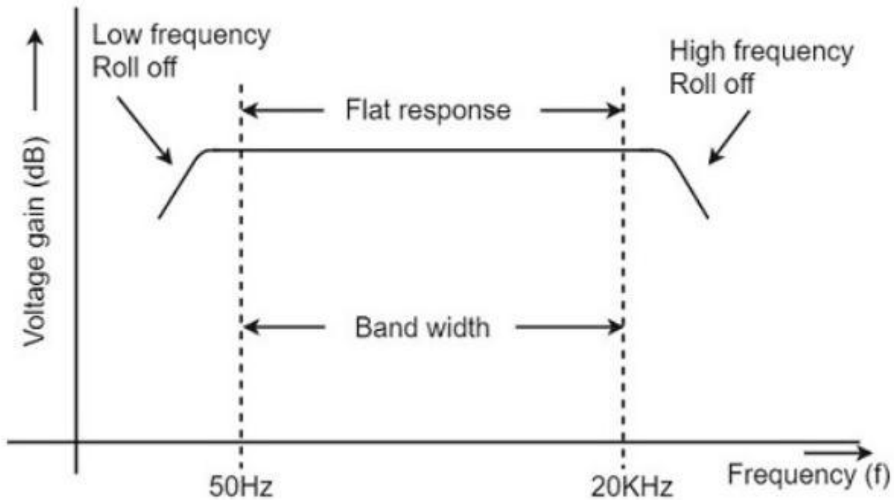
Single Stage Common Emitter Amplifier



A single-stage common emitter RC coupled amplifier is a simple and elementary amplifier circuit. The main purpose of this circuit is pre-amplification that is to make weak signals to be stronger enough for further amplification. If designed properly, this RC coupled amplifier can provide excellent signal characteristics.
The capacitor Cin at the input acts as a filter which is used to block the DC voltage and allow only AC voltage to the transistor. If any external DC voltage reaches the base of the transistor, it will alter the biasing conditions and affects the performance of the amplifier.
R1 and R2 resistors are used for providing proper biasing to the bipolar transistor. R1 and R2 form a biasing network that provides necessary base voltage to drive the transistor in active region.
Resistors Rc and Re are used to drop the voltage of Vcc. Resistor Rc is a collector resistor and Re is emitter resistor. Both are selected in such a way that both should drop Vcc voltage by 50% in the above circuit. The emitter capacitor Ce and emitter resistor Remakes negative feedback for making the circuit operation more stable.

Frequency response of the amplifier

Frequency response curve is a graph that indicates the relationship between voltage gain and function of frequency. The frequency response of a RC coupled amplifier is as shown in the following graph.



From the above graph, it is understood that the frequency rolls off or decreases for the frequencies below 50Hz and for the frequencies above 20 KHz. whereas the voltage gain for the range of frequencies between 50Hz and 20 KHz is constant.

We know that,

X_C=1/2πfc

It means that the capacitive reactance is inversely proportional to the frequency.

At Low frequencies (i.e. below 50 Hz)

The capacitive reactance is inversely proportional to the frequency. At low frequencies, the reactance is quite high. The reactance of input capacitor Cin and the coupling capacitor CC are so high that only small part of the input signal is allowed. The reactance of the emitter by pass capacitor CE is also very high during low frequencies. Hence it cannot shunt the emitter resistance effectively. With all these factors, the voltage gain rolls off at low frequencies.

At High frequencies (i.e. above 20 KHz)

Again considering the same point, we know that the capacitive reactance is low at high frequencies. So, a capacitor behaves as a short circuit, at high frequencies. As a result of this, the loading effect of the next stage increases, which reduces the voltage gain. Along with this, as the capacitance of emitter diode decreases, it increases the base current of the transistor due to which the current gain (β) reduces. Hence the voltage gain rolls off at high frequencies.

At Mid-frequencies (i.e. 50 Hz to 20 KHz)

The voltage gain of the capacitors is maintained constant in this range of frequencies, as shown in figure. If the frequency increases, the reactance of the capacitor CC decreases which tends to increase the gain. But this lower capacitance reactive increases the loading effect of the next stage by which there is a reduction in gain.

Due to these two factors, the gain is maintained constant.v