Electronics

(For Sixth Semester General Course)

Lecture 4

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Transistor:

A junction transistor is made up of a semiconductor such as Ge or Si in which a P$-type$ thin layer is sandwiched between two $N-type$ layers. The transistor so formed is called $N-P-N$ transistor. Alternately a transistor can also have an $N-type$ layer between two $P-type$ layers. The transistor is then termed a $P-N-P$ transistor. $P-N-P$ and $N-P-N$ transistor are systematically shown in Fig 1 and Fig2.

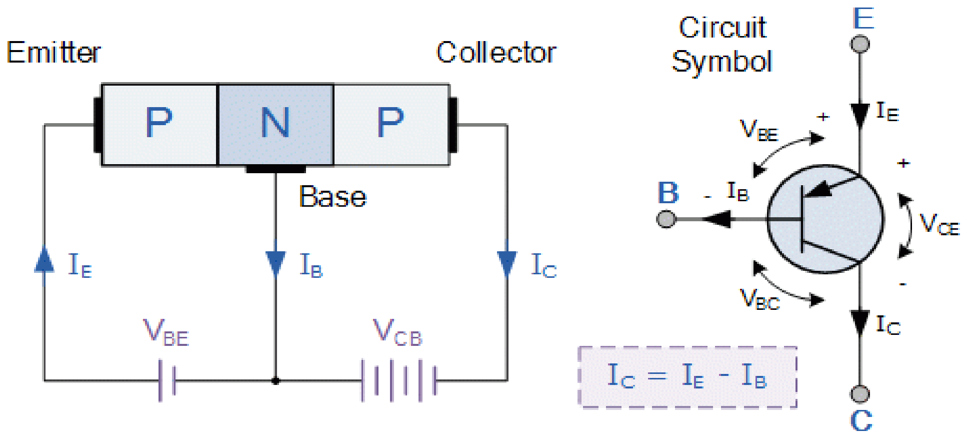


Fig 1

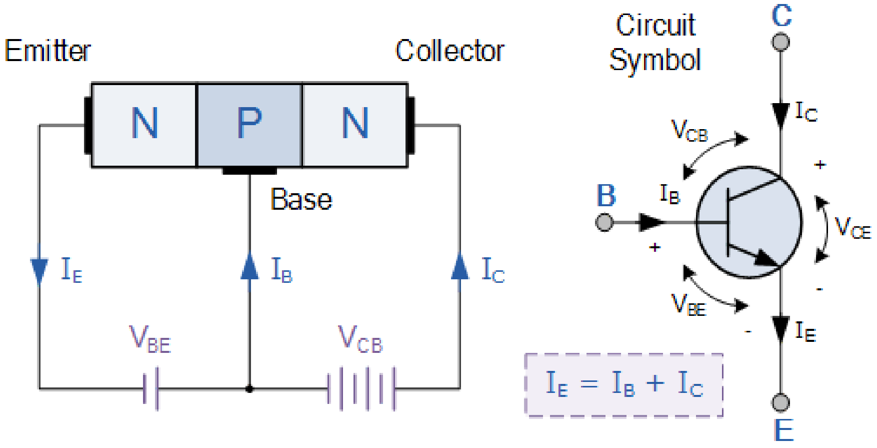


Fig 2

The middle portion of the transistor is called the Base and the two end portions are known as Emitter and Collector. The emitter-base junction is usually referred as emitter junction(J_E) and the collector-base junction as the collector junction(J_C). The size of the transistor is quite small. The structure is sealed inside a metal or plastic case to protect it from moisture. Metal leads $E, B\ and\ C$ come out of the package for connection to the emitter, the base and the collector respectively. Since both the majority and minority carriers are involved in a junction transistor the device is termed as *bipolar junction transistor(BJT) , bipolar transistor or bipolar device*.

In the normal transistor operation emitter-base junction is forward biased and the collector-base junction is reversed biased. The current enters the transistor through the emitter terminal for a $P - N - P$ transistor.

On the other hand current leaves the transistor through the for an $N-P-N$ transistor. In both case the emitter, base and collector currents I_E, I_B and I_C respectively are taken positive when the currents go into the transistor. The symbols V_{EB}, V_{CB} *and* V_{CE} represent respectively the emitter-base, collector-base and collector-emitter voltages.

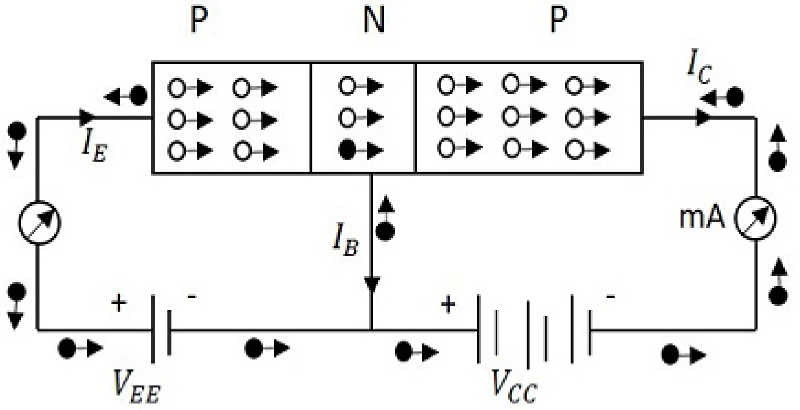


Fig 3

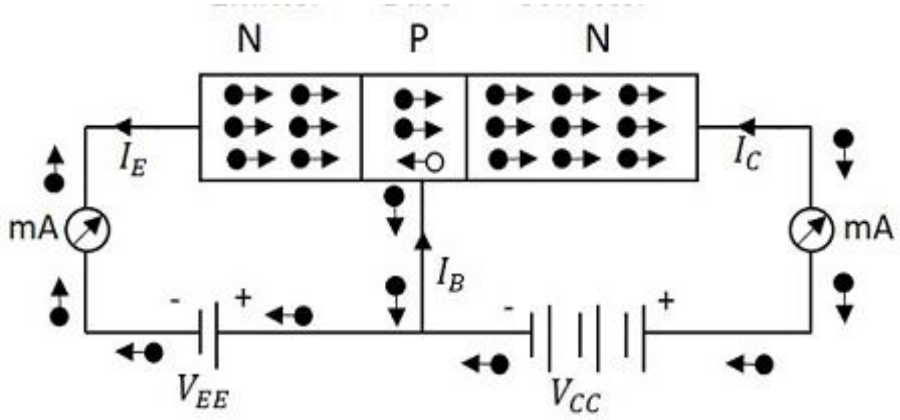


Fig 4

The operation of $P-N-P$ transistor can be explained by $Fig\ 3$. Here emitter-base junction is forward biased and collector-base is in reversed biased. Hence voltage V_{EE} provides positive potential at the emitter which repel the holes in the $P-type$ material and these holes cross the emitter-base junction to reach the base region. There a very low percent of holes recombine with free electrons of *N-region*. These provide a very low current which constitute the base current I_B. The remaining holes cross the collector-base junction to constitute the collector current I_C which is the hole current. As a hole reaches the collector terminal an electron from the battery negative terminal fills the space in collector. The flow slowly increases and the electron minority current flows through the emitter where each electron entering the positive terminal of V_{EE} is replaced by a hole by moving towards the emitter junction. This constitute emitter current I_E.

Three points are important for $P-N-P$ transistor

a)The conduction in $P-N-P$ transistor takes place through holes.

b)The collector current is slightly less than the emitter current

c)The increase or decrease in emitter current affects the collector current.

Similarly the operation of $N-P-N$ transistor can be explained by $Fig\ 4$, in which emitter-base junction forward biased and collector-base junction is revered biased. The V_{EE} provides negative potential at the emitter which repels the electrons in the $N-type$ material and these electrons cross the emitter-base junction to reach the base region. This flow slowly increases and the electron current flows through the transistor.

The points are important for $N-P-N$ transistor

The conduction in a $N-P-N$ transistor takes place through electrons.

The collector current is higher than the emitter current.

The increase or decrease in the emitter current affects the collector current.

The amplification factor $\alpha\ and\ \beta$ may be defined as

$$\alpha = \left(\frac{\partial I_C}{\partial I_E}\right) \rightarrow (i), when\ V_{CB}\ is\ constant$$

$$\beta = \left(\frac{\partial I_C}{\partial I_B}\right) \rightarrow (ii), when\ V_{CE}\ is\ constant$$

By definition $\Delta I_C = \alpha.\Delta I_E$

The magnitude of emitter current is equal to sum of collector and base current. Thus

$$|\Delta I_E| = |\Delta I_C| + |\Delta I_B| = |\alpha I_E| + |\Delta I_B|$$

$$\Longrightarrow \Delta I_B = \Delta I_E(1-\alpha)$$

$$\Longrightarrow \frac{\Delta I_B}{\Delta I_C} = \frac{\Delta I_E}{\Delta I_C}(1-\alpha)$$

$$\Longrightarrow \frac{1}{\beta} = \frac{1}{\alpha}(1-\alpha)$$

$$\Longrightarrow \beta = \frac{\alpha}{1-\alpha} \rightarrow (iii)$$

The emitter current I_E consist of two component. One is hole component of emitter current I_{PE} and other is electron component of emitter current I_{NE}. The emitter efficiency (γ) is defined as ratio of change in injected component of hole current I_{PE} to the total emitter current I_E.

Thus Emitter Efficiency

$$\gamma = \frac{\Delta I_{PE}}{\Delta I_E} = \frac{\Delta I_{PE}}{\Delta I_{PE} + \Delta I_{NE}} \rightarrow (iv)$$

The transport factor

$$\beta^* = \frac{\Delta I_C}{\Delta I_{PE}} \approx \frac{\Delta I_{PC}}{\Delta I_{PE}} \rightarrow (v)$$

β^* will be high if highest possible amount of hole current reaches the collector junction, this will be available as collector current. The relation between α, β^{*} and γ are

$$\alpha = \frac{\Delta I_C}{\Delta I_E} = \left(\frac{\Delta I_C}{\Delta I_{PE}}\right).\left(\frac{\Delta I_{PE}}{\Delta I_E}\right) = \beta *.\gamma \rightarrow (vi)$$

The collector efficiency δ is defined as the ratio of current leaving the collector region to the hole current entering the collector region from base.

Transistor Biasing:

In transistor biasing amplifier, it is essential that the emitter-base junction should be forward biased and collector-base junction should be reversed biased. The circuit providing the desired biasing is known as biasing circuit.

The transistor biasing is defined as proper flow of zero signal of collector current and the maintenance of CE voltage during the passage of the signal. If transistor is not properly biased it works inefficiently and it gives distorted output signal. In addition amount of biased required is important for establishing $Q-point$. It is also important that $Q-point$ should be stable. It means that $Q-point$ should not shift due to rise of temperature.

Base Bias or Fixed Current Bias:

A high resistance R_B is connected as shown in Fig 5 The required zero signal base current is provided by V_{CC} which passes through R_B. By proper selection of R_B the required base current I_B can be made to flow.

Let I_C be required zero signal collector current.

$$V_{CC} = I_B R_B + V_{BE} \rightarrow (vii)$$

$$\Longrightarrow R_B = \frac{V_{CC} - V_{BE}}{I_B} = \frac{V_{CC}}{I_B} \rightarrow (viii)$$

Here V_{BE} is very small so can be negligible.

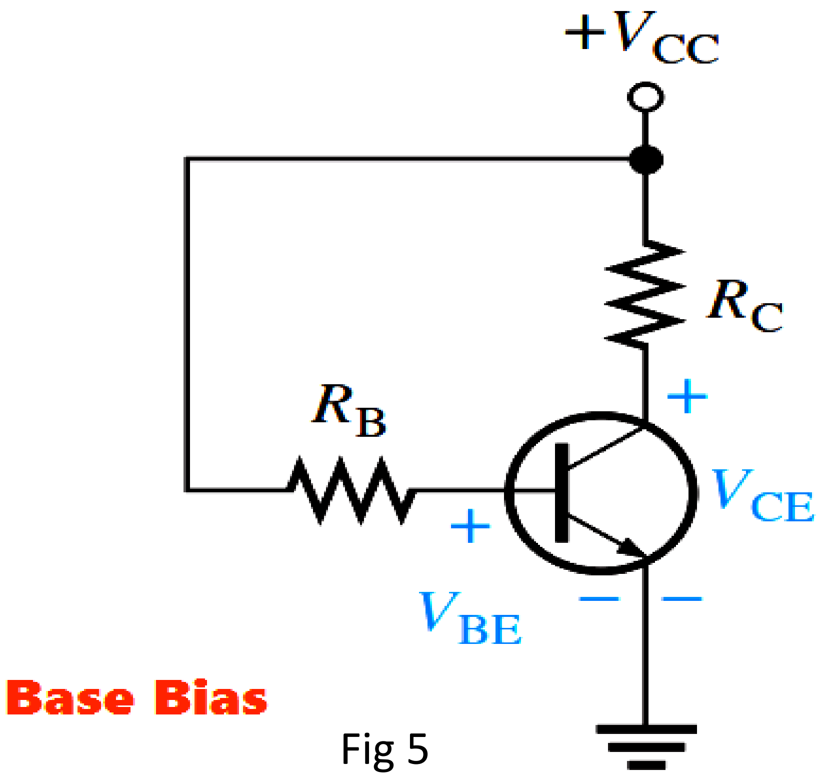
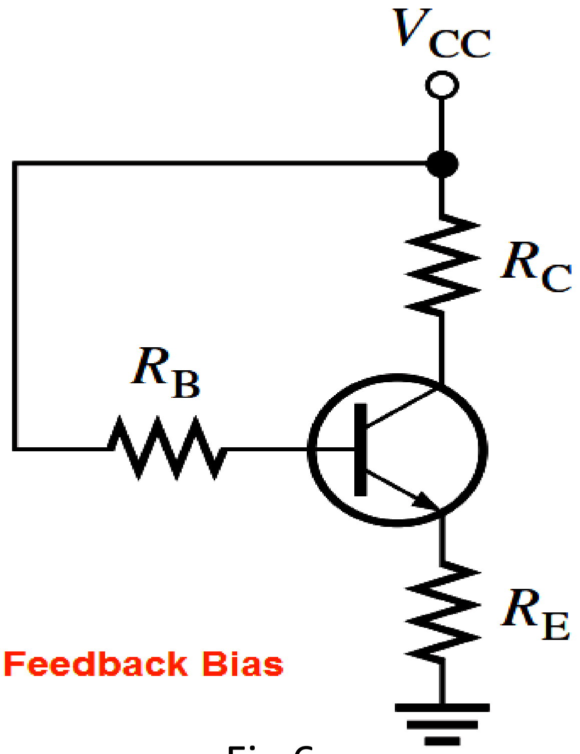


Fig 5

Base biased with Emitter Feedback:

Here only an emitter resistor is connected to the base circuit. At saturation V_{CC} is essentially zero.

The saturated collector current is



Emitter Feedback Bias

Fig 6

This increase in base voltage reduce the voltage across R_B, thus reducing the base current and keeping the collector current from increasing. A similar action occurs if the collector current tris to decrease. While this is better for linear circuit than base bias, it is still dependent on β and is not predictable as voltage divider bias.

Base Bias with Collector Feedback:

Here one end of R_B is connected to base while other end is connected to collector. Here zero signal base current is determined by V_{CB} and it is forward bias the base-emitter junction and I_B flows R_B. This causes zero signal collector current to flow in the circuit.

Here voltage for R_B is derived from the collector, there exist a negative feed back effect which stabilized I_C against changes in β. Here R_B is connected to the collector rather than V_{CC}. The collector voltage provides bias for base-emitter junction. The negative feedback creates an offsetting effect that tends to keep the $Q - point$ stable.

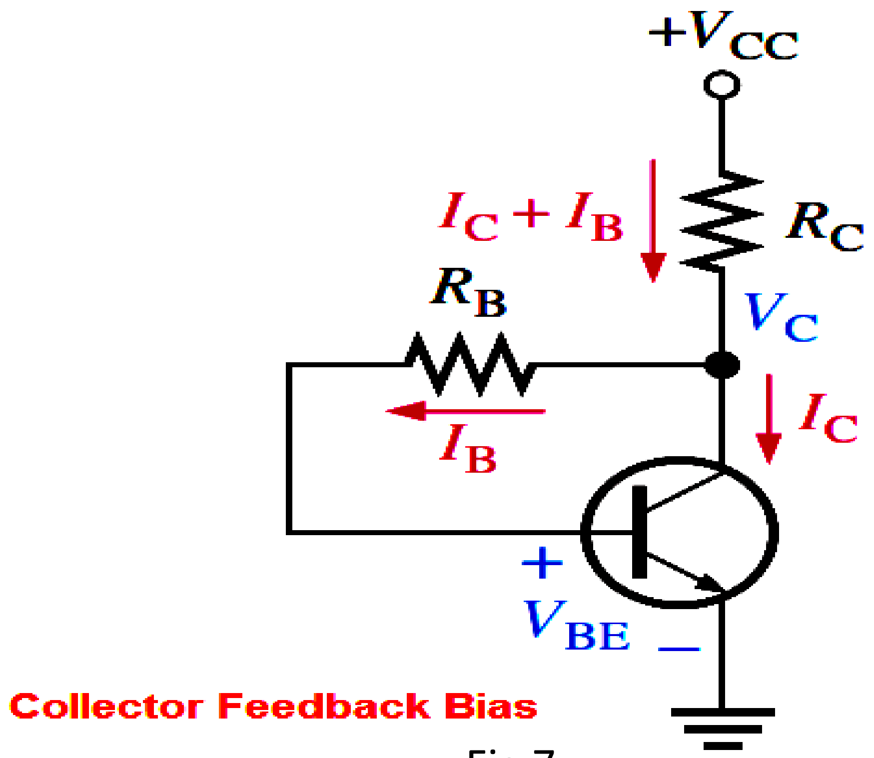


Fig 7

If I_C tends to increase it drops more voltage across R_C thereby causing V_C to decrease. When V_C decreases there is decrease in voltage across R_B, which decreases I_B. The decrease in I_B produces less I_C which in turn drops less voltage across R_C and thus offsets the decrease in V_C.

Here, since the emitter is grounded $V_{CE} = V_C$

$$V_{CE} = V_{CC} - I_C R_C \ \rightarrow (ix)$$

This does not provide good stabilization.

Base Bias with Collector and Emitter feedback:

Better stabilization of $Q - point$ may be achieved by base bias with emitter and collector feed back as shown in Fig 8. Here when β increases emitter voltage increases but collector voltage decrease. So that voltage across R_B reduces which causes I_B to decrease.

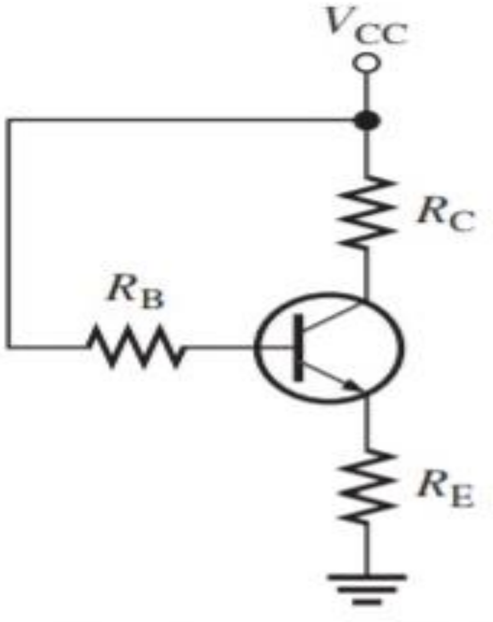


Fig 8

$$(I_C)_{saturated} = \frac{V_{CC}}{R_C + R_E}$$

Here $I_B \approx small$. Therefore we have

$$I_C = \frac{V_{CC} - V_{BE}}{R_C + R_E + \frac{R_B}{\beta}} \rightarrow (x)$$

Voltage Divider or Self Bias:

Here two resistance R_1 and R_2 are connected across the supply voltage V_{CC}. The emitter resistance R_E provides the stabilization. The voltage divider is derived from the fact that resistance R_1 and R_2 form a potential divider across the V_{CC}.

The voltage drop across R_2 forward biased the base-emitter junction while V_{CC} supply reverse biased the base-collector junction. The forward bias on base-emitter junction causes the base current and hence collector current flows in zero signal condition

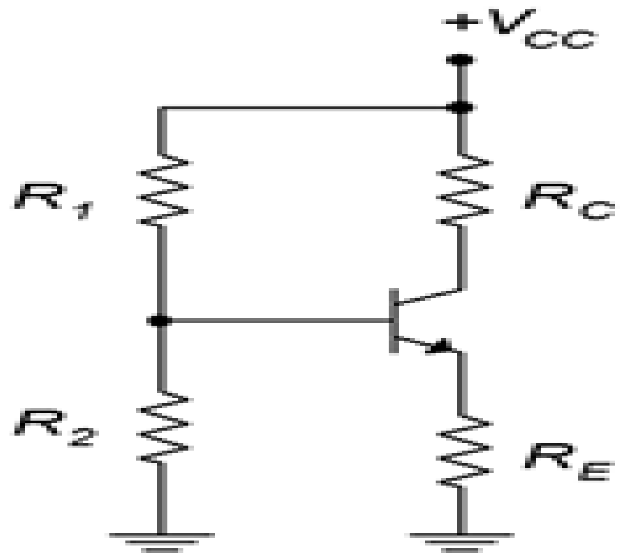


Fig 9

Voltage divider bias is the most popular and used may to bias a transistor. It uses few resistors to make sure that a voltage is divided and distributed into the transistor at correct levels. One resistor, the emitter resistor also helps to provide stability against variation in β may exist from transistor to transistor. Here stability is good. In this case I_C tend to increase due to increase $in\ ICO$ (leakage current) because of temperature rise. This increase current I_C cases an increase DC voltage drop across R_E. This reduces net emitter to base forward bias. As a result the base current I_B is reduced. The reduction in the base current causes a reduction in collector current. Thus the self biasing resistor R_E reduces the increase in I_C and improves the operating point stability.