Transistors

→ Transistor can be used as a switch or amplifier or impedance matching.

→ A signal of small amplitude applied to the base is available in the "magnified form" at the collector of the transistor. This is the "amplification" provided by a transistor. The additional power required for it is obtained from an external source (d.c power supply)

→ Bipolar junction transistor is a basic building block for almost all the electronic circuits right from a simple regulator or oscillator circuit, logic gates to a digital computer.

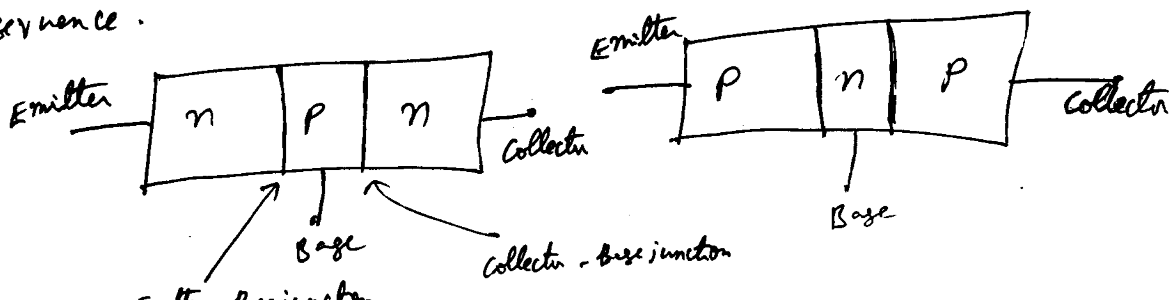
<u>applications</u> :- 1. Amplifiers, 2. oscillators 3. switching circuits, 4. wave shaping circuits 5. logic gates 6. Delay circuits 7. timers and multivibrators.

→ The word transistor ⟶ "Transfer Resistor"

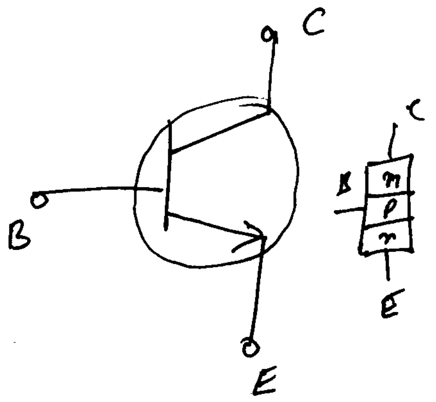
The signal amplification in transistor is achieved by transfering the signal from a region of low resistance to a region of high resistance.

→ BJT has three layers of semiconductor material.

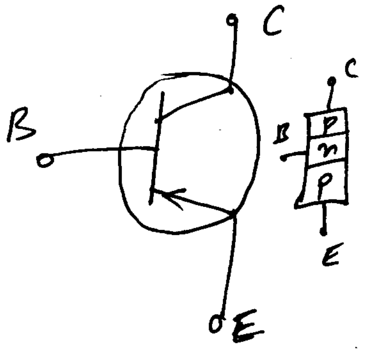
These layers are arranged in either n-p-n sequence or p-n-p sequence.



→ The emitter of a transistor is heavily doped
Base is lightly doped
Collector is less heavily doped than emitter.



NPN



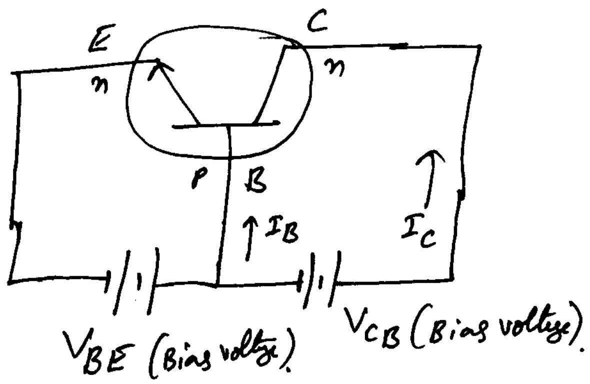
PNP.

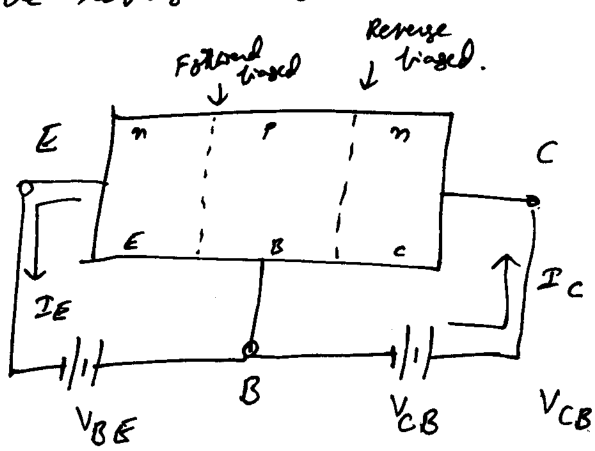
Arrow is directed from P to N between emitter and base.

Working of n-p-n transistor :-

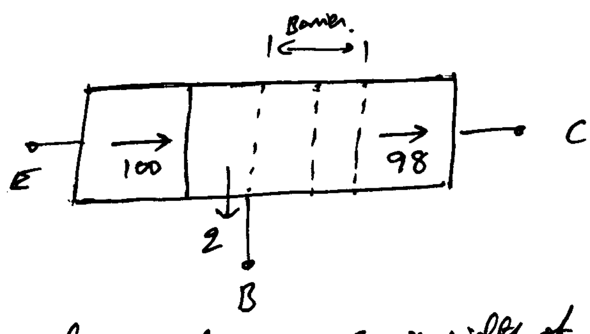
→ For a transistor to work, it has to be biased by applying external voltage supply with proper polarity.

→ For operation in active region, E-B junction should be forward biased and C-B junction should be reverse biased.





$V_{CB} >> V_{BE}$



→ Barrier width of E-B Junction = nill & Barrier width of B-C junction will be more. As Base is lightly doped, barrier width is more towards base region.

→ Since EB junction is FB (Forward Biased), electrons form the majority carriers and would flow from the emitter to the base region.

→ Since the base is lightly doped, there will be a smaller number of holes present there. only a small percentage of electrons flow from the emitter will recombine with holes in the base region. only around 2 % of electrons from the emitter recombine with the holes present in base region.

→ Due to large CB bias voltage, electrons will be pulled across the CB depletion region by the positive terminal of the collector.

→ The collector thus collects 98 % of electrons emitted by emitter.

→ The quantity of charge carriers crossing the emitter to the base is controlled by the base emitter bias voltage.

→ Thus it can be said that emitter and collector current levels can be controlled by the base-emitter bias voltage.

→ for silicon transistor, substantial current will start flowing when the bias voltage V_{BE} is about 0.7 V and for germanium it is 0.3 V. Beyond this voltage, small variation in V_{BE} will control I_E & I_C.

Let $I_C = \alpha_{dc} I_E$

$\alpha_{dc} \simeq 0.95$ to 0.99

$\beta_{dc} \simeq 25$ to 200.

$$I_E = I_C + I_B.$$

$$I_B = (1-\alpha_{dc}) I_E$$

Let $I_C = \beta_{dc} I_B \Rightarrow \beta_{dc} = \dfrac{\alpha_{dc}}{1-\alpha_{dc}}.$

$$I_C = \frac{\alpha_{dc}}{1-\alpha_{dc}} I_B.$$

α_{dc} = emitter to collector current gain. $= \dfrac{I_C}{I_E}$

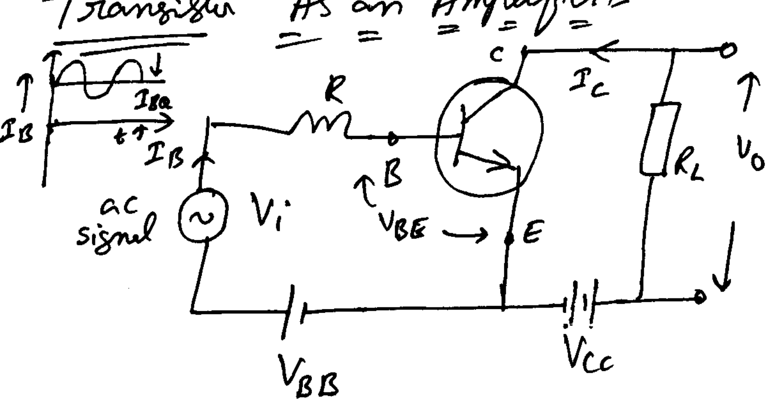
β_{dc} = base to collector current gain $= \dfrac{I_C}{I_B}$

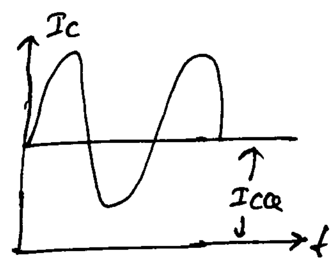
Transistor configurations:

→ For the connections of input & output, one of the transistor terminals are made common.

Characteristics	common base	Common Emitter	Common Collector
1. Input Impedence	Low in ohms	Low in ohms	high in Kilo-ohms
2. output Impedence	very high in KΩ	High in KΩ	Low in ohms.
3. current gain	Less than unity	High	High
4. voltage gain	High	High	Less than unity
5. Applications	For high freq applications	For audio freq applications	For impedence matching

Transistor As an Amplifier:





→ The ac signal which is to be amplified is connected to the base circuit and output is taken across R_L in collector circuit.

→ V_{BB} is such that base emitter junction is always forward biased irrespective of magnitude of input signal. ie $V_{BB} \pm V_i \geq V_{BE}$ reversed

→ collector is reverse biased using V_{CC}.

→ During +ve half cycle of input signal, the dc and ac voltages are added up and base current is highly positive.

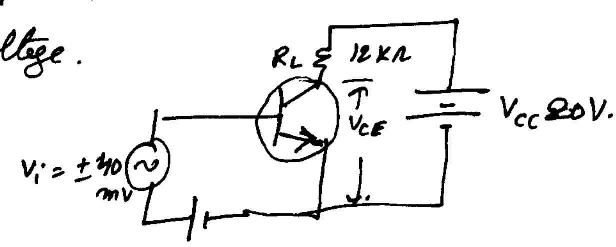
→ During -ve half cycle, ac voltage is subtracted from the dc voltage. The net voltage is low but +ve. The base current will be low positive.

→ ∵ $I_C = \beta I_B$.

due to large variation in base current there will be large variation in the collector current, which will flow through the load resistance.

→ output voltage $= I_C R_L$ which will be very high.

ex:- In an n-p-n transistor in the common emitter configuration, an ac input signal of $\pm 40\,mV$ is applied as shown in fig. The dc current gain, β_{dc} and ac current gain β_{ac} are given as 80 and 100, respectively. Calculate the voltage amplification, A_V of the amplifier. The I_B versus V_{BE} characteristic is such that for $V_B = 0.7\,V$, $I_B = 12\,\mu A$ and for $V_i = \pm 40\,mV$, $I_b = \pm 4\,\mu A$. Also calculate the dc collector voltage.



Sol:-

$I_B = 12\,\mu A$, $V_{BB} = 0.7\,V$, $\beta_{dc} = 80 \Rightarrow I_C = \beta_{dc} I_B = 0.9\,mA$

The collector voltage $V_{CE} = V_{CC} - I_C R_L$

$$= 20 - 0.96 \times 10^{-3} \times 12 \times 10^{3} = \underline{8.48\,V}$$

A.C base current $I_b = \pm 4\,\mu A$ for $V_i = \pm 40\,mV$, $\beta_{ac} = 100$

$I_C = \beta_{ac} I_b = 100 \times (\pm 4\,\mu A) = \pm 400\,\mu A$

ac ouput voltage across load resistor $= I_C R_L = \pm 400 \times 10^{-6} \times 12 \times 10^{3}$

$= \pm 4.8\,V$.

A.C voltage amplification factor, $A_V = \dfrac{v_o}{v_i} = \dfrac{\pm 4.8}{\pm 40 \times 10^{-3}} = \underline{60}$.

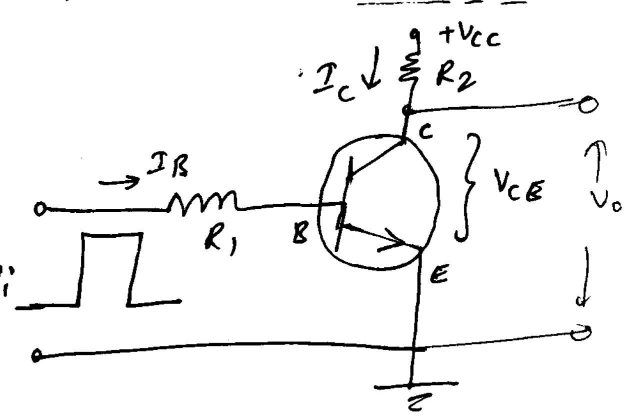
Transistor as a switch :-

- → A switch either closes a circuit or opens a circuit.
- → There are 2 states of a switch. ie. either there is no current flow (cut off) or the switch is closed, ie. current flows through it with the minimum of resistance offered.
- → In case of switching operation, a pulse voltage of appropriate level has to be applied.
- → The base voltage level is either zero or at an appropriate +ve level.
- → when $V_i = 0 \Rightarrow I_B = 0 \Rightarrow I_C = 0 \Rightarrow$ open circuit.

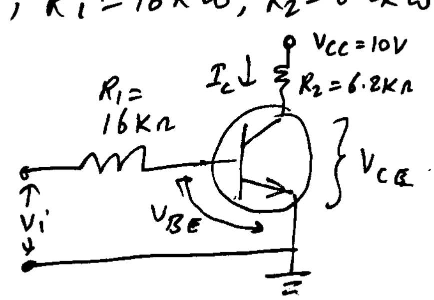
$$V_{CE} = V_{CC} - I_C R_2 = V_{CE}.$$

- → when $V_i = +ve \Rightarrow I_B \neq 0 \Rightarrow I_C \neq 0 \Rightarrow V_{CE} = V_{CC} - I_C R_C = 0$

The transistor will act as a closed switch.



ex:- What minimum input voltage level is required to switch a BJT into saturation (on state) when $V_{CC} = 10V$, $R_1 = 16K\Omega$, $R_2 = 6.2K\Omega$, $\beta_{dc} = 20$ in n-p-n CE configuration BJT as shown in fig.



Ans:- taking $V_{BE} = 0.7V$.

$$V_i = \underline{1.99V}$$