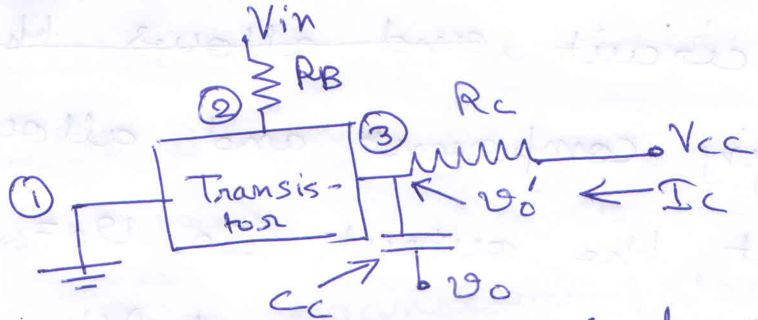
Principle of Amplification.

Amplification is done with the help of transistors. In a transistor, the ~~current~~ voltage between two terminals controls the current through the 3rd terminal.



In the above three terminal structure, the current I_c is independent of V_{cc}. I_c depends on Vin, which is the potential difference between terminals ① and ②. So, I_c is a function of Vin.

$$I_c = f(V_{in})$$

The output voltage $v_o' = V_{cc} - I_c R_c$

$$= \underbrace{V_{cc}}_{\text{dc component}} - \underbrace{R_c f(V_{in})}_{\text{ac component}}.$$

Note that V_{cc} is a constant voltage. Vin on the other hand is a time varying signal. It may be an audio or a video signal. If v_o' is now passed through a capacitor, the capacitor now filters out the dc parts of the voltage (since it acts as an open circuit to dc components). ~~If the~~ Vin is rapidly varying, then $R_c f(V_{in})$ also varies rapidly. Hence the capacitor acts as a short circuit ~~and allows the~~ for the time-varying component and allows it to appear at the output. So, $v_o = -f(V_{in})R_c$

So, v_o is a function of Vin. By increasing R_c, we can increase the ~~value~~ magnitude of v_o, ~~&~~ to a quantity greater than Vin. So, v_o is a function of Vin and the magnitude of v_o can also be greater than Vin if R_c is properly chosen. ~~Hence~~ . This is the principle of amplification. We will study more about it when we do transistor ac analysis.

Bipolar Junction Transistor.

Diodes are not capable of amplifying current or voltage. Hence they are passive element. The element which is capable of amplifying current or voltage is known as transistor. The transistor was first discovered by Bardeen, ~~Bt~~ Brattain and Schockley at Bell Labs in 1940. They discovered the Bipolar junction transistor (also known as BJT). The name "Bipolar" comes from the fact that the action of both the majority and the minority carriers are required for transistor action.

Structure:

p	n	p

pnp transistor.

The n-region is the base while the p regions constitute the emitter and the collector.

n	p	n

npn transistor.

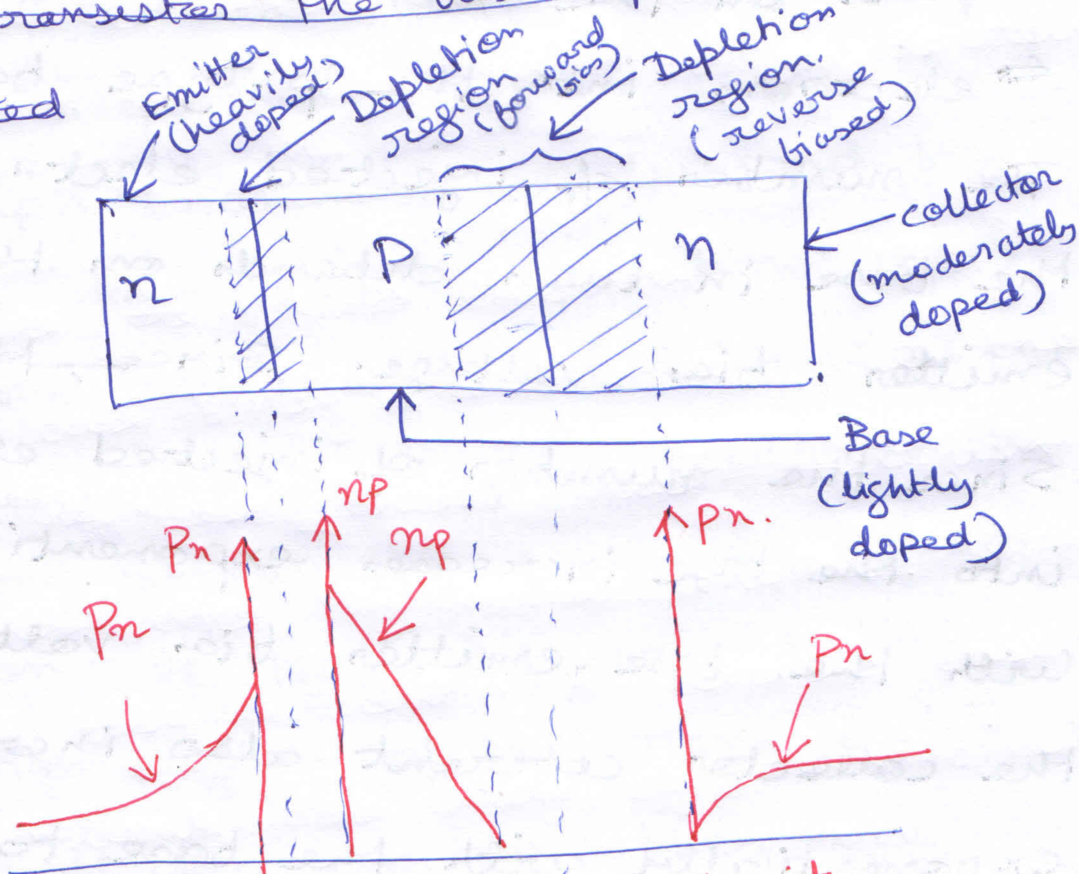
The p region is the base while the n regions are the emitter and the collector.

There are two junctions on the transistor. The most common configuration, ~~also~~ is known as the Forward active Mode where the base emitter junction is forward biased while the collector base junction is reverse biased.

<u>Working principle</u>: The forward bias in the base emitter junction injects ~~electron~~ minority carriers in the base and emitter respectively. Let us consider an npn transistor. A forward bias in the base-emitter junction inject electrons into the base (which is p-type). This electrons ~~to~~ diffuse towards the collector. Some also undergo recombination. If they diffuse at the depletion region of the reverse-biased base-collector junction, they are swept by the electric field in the depletion region. The electric field in the reverse biased base-collector junction typically sweeps the electrons injected into the base towards the collector. This gives rise to the collector current despite of the reverse biased

junction. Since the reverse bias current is limited by the supply of carriers, the collector current is typically independent of the base-collector bias voltage. The collector current depends on the number of injected electrons into the p-type base. The number of injected electrons in the base in turn depends on the base-emitter bias voltage. ~~Since, the So,~~ Since the number of injected electrons into the base increases exponentially with the base-emitter bias voltage, the collector current also increases exponentially with the base to ~~and~~ emitter bias voltage. So the collector current is typically independent of the collector voltage but depends on the base to emitter voltage. We can thus control the current at a third terminal (collector) by controlling the voltage between the other two terminals (base and emitter). This is the principle of transistor action. The collector ~~is~~ thus acts as a constant current source (independent of the collector voltage).

~~In a transistor the base input is generally provided~~



Graph of excess minority carrier conc.

~~In the forward biased p-n junc.~~

Since the ~~electro~~ excess carriers injected into the base by the emitter must flow toward the reverse biased. base - collector junction by diffusion, the length of the base must be less than the minority carrier diffusion length. Minority carrier diffusion length is the average length a minority carrier diffuses before recombination.

Component of collector current:

The ~~electr~~ excess carriers (electrons for npn transistors) injected from the emitter into the base ~~are~~ is the source of collector current.

Component of base current:

① Base current has several components:-

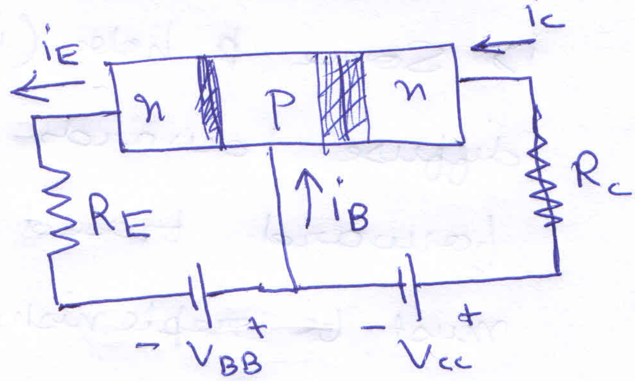
i) Some ~~h~~ holes (in npn transistor) can diffuse towards the emitter in the forward biased junction. These holes must be replenished through the base ~~current~~ contact and constitutes one component of the base current. Since the number of holes flowing towards the emitter ~~do~~ is directly proportional to the doping concentration in the base, this component of the base current is directly proportional to the base doping. Since we want to reduce the base current as far as possible, the base region is moderately doped

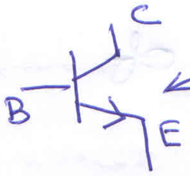
(2) Some ~~etc~~ excess electrons (in npn) in the base may recombine with the holes. The base contact must replenish these holes and this forms another component of the base current. A narrow base region limits the rate of recombination in the base.

(3) Some minority carriers can also escape from the base contact.

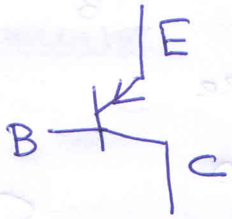
~~3~~ The total current through the emitter is the sum of the base and collector currents.

$$i_E = i_C + i_B$$



npn → 

arrow denotes the direction of current flow. Arrow is put at the emitters.

pnp 

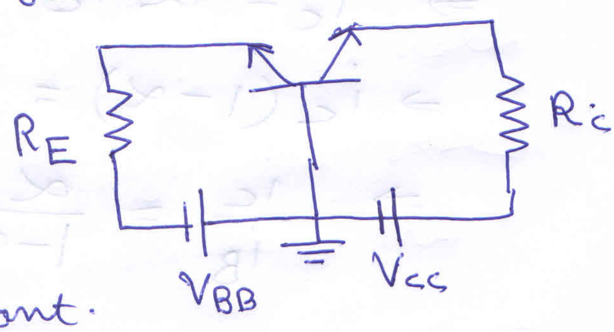
The goal is to make the base current as low as possible, so that $i_C \cong i_E$.

The parameter $\frac{i_C}{i_E}$ is called the common base current gain and denoted by the parameter α.

$\alpha = \frac{i_C}{i_E}$. The maximum value of α is 1. The objective of modern technology is to make α as close as 1 as possible

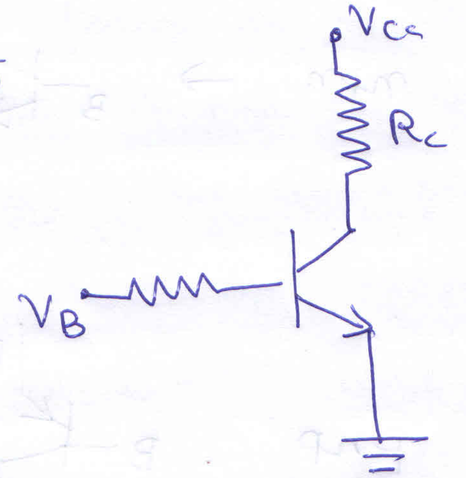
This parameter is often used in the common-base configuration, where the emitter and collector are voltage biased with respect to the base.

The output current is i_C and the input current is i_E.



Hence $\alpha = \frac{i_C}{i_E}$ is important.

The parameter $\frac{i_c}{i_B}$ is of importance in the Common emitter config where i_B ~~and~~ the base and collector are biased with respect to the emitter. This is designated by the parameter β. Here i_B is the input current and i_c is the output current.



Common emitter config.

$$\beta = \frac{i_c}{i_B}.$$

Since, $i_B << i_E \cong i_c$, $\beta >> 1$ in the desirable case. β is called the common emitter current gain.

Relation between α and β:-

$$i_E = i_c + i_B$$

$$\cancel{= \alpha i_c + i_B}$$

$$\frac{i_c}{\alpha} = i_c + i_B$$

$$\Rightarrow i_c = \alpha i_c + \alpha i_B$$

$$\Rightarrow i_c(1-\alpha) = \alpha i_B$$

$$\Rightarrow \frac{i_c}{i_B} = \frac{\alpha}{1-\alpha} \Rightarrow \beta = \frac{\alpha}{1-\alpha}.$$

Study current-voltage characteristics of the ~~np~~ ~~bra~~ common base and common emitter transistor yourself.

<u>Study the following:-</u>

* Saturation region
* Base width modulation or Early voltage.

~~With increases in base to collector reverse bias the def~~