Lecture - 13
Electronics 1

8/1/18

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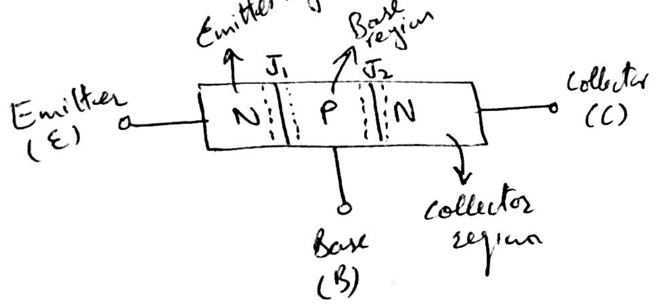
Chapter #4 :- "BIPOLAR JUNCTION TRANSISTORS (BJT)"

⇒ BJT :-

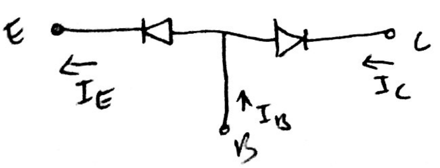
* Transistor was invented in Dec 1947 at bell labs at USA.
* BJT is a three terminal device and it is used in amplification of weak signals and used in switching operation.

→ Physical Structure:

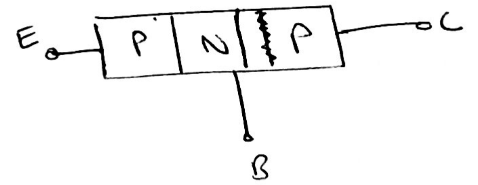
NPN



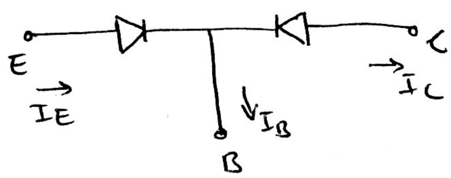
* 2 junctions (N)
* 1 " (P)
* J_1 → emitter-base
* J_2 → collector-base
* There is depletion region at J_1
* There is depletion region at J_2



PNP



width: C > E > B
doping: E > C > B



→ Cross-section View:-

NPN

→ Symbol:

NPN

PNP

* incase of NPN the e' will move from B → E

* incase of PNP the e' will move from E → B.

Why Bipolar Junction Transistor?

* Bipolar: e⁻ and holes.
* Junction: J_1 and J_2
* Transistor: Transfer + resistor.

$J_1 \rightarrow$ F.B : will offer low resistance] active mode.

$J_2 \rightarrow$ R.B : " " high " .

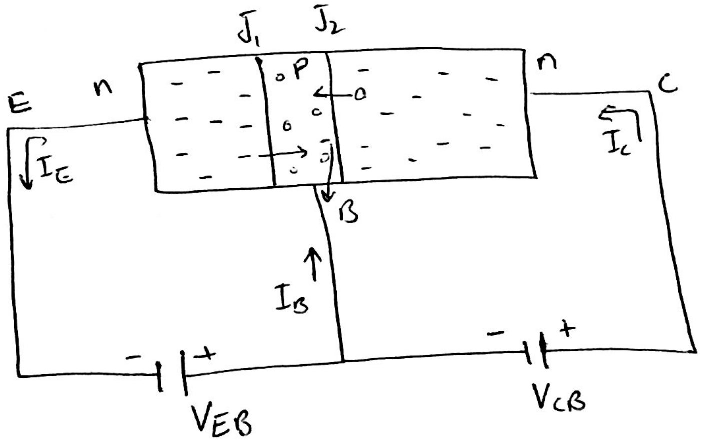
So, BJT transfer a signal from low to high resistance

→ Regions of Operation:

J_1	J_2	Region of operation	
F.B	R.B	Active	Amplifier.
F.B	F.B	Saturation	"ON" switch
R.B	R.B	Cut off	"OFF" / open circuit
R.B	F.B	Inverted	rarely used.

→ Working of BJT:-

* This is an npn transistor.
* We operate it in Active Mode.



* Here in active mode we have J_1 : F.B and J_2 : R.B

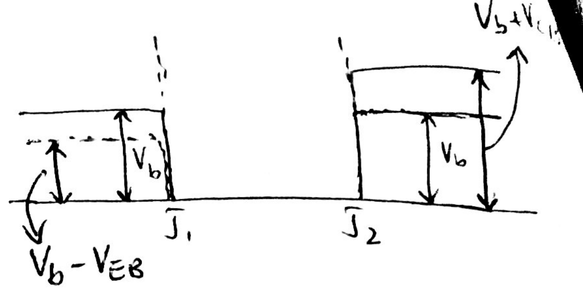
~~Ua~~

→ Analyze Movement of e⁻ :-

* Let's say V_b is barrier potential for J_1 and J_2

$V_b \rightarrow J_1 , J_2$.

* After application of V_{BE}, the junction J_1 is F.B, so the barrier potential will now reduce and new barrier potential will be $V_b - V_{BE}$



* After application of V_{CB}, the J_2 is R.B, so the B.P will increase and new B.P will be $V_b + V_{CB}$

* Because of reduce B.P at J_1 the e⁻ will move into P-region and recombine with holes at Base. We know that base is very small and lightly ~~to~~ dopped. So the recombination of e⁻ and holes is very small and most of e⁻ pass over into n-region at 'C'. (95% — 98%).

* very few e⁻ combine with hole and will move into Base (V_{EB}). (2% → 5%)

* J_2 is R.B so there must be a reverse saturation current (I_{CO}) or leakage current due to minority carriers in N and P regions.

I_{CO} : C: collector
O: open circuit. we measure it when V_{EB} is open circuit.

* If we find I_C.

$$\boxed{I_C = \alpha I_E + I_{CO}}$$

* Next we find relationship b/w I_E, I_B and I_C. first we see direction of current i.e.

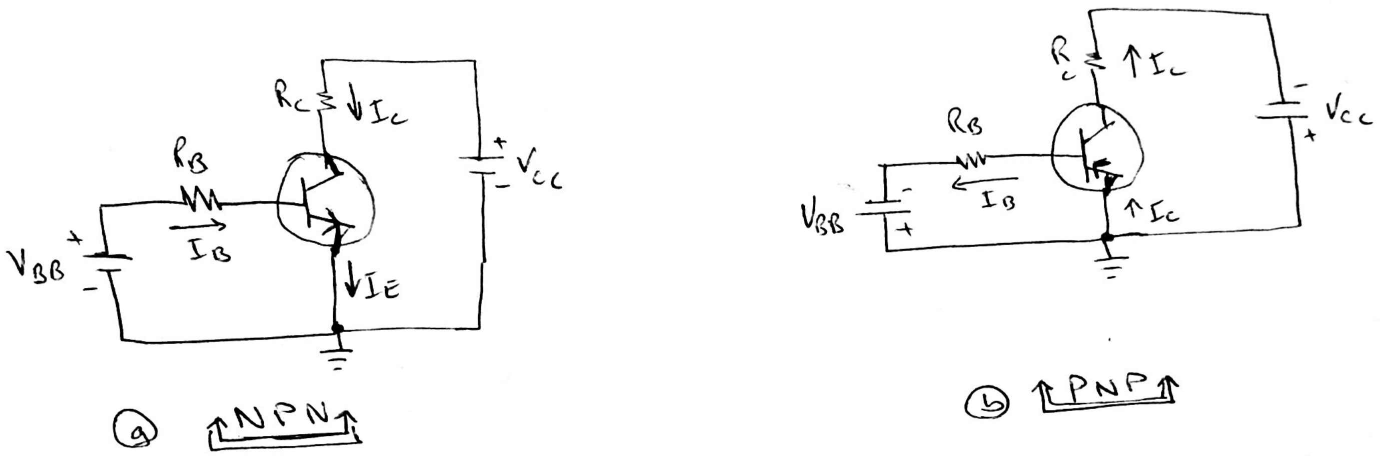
Use KCL :
Sum of current entering = Sum of current leaving.

$$I_C + I_B = I_E$$

Transistor Characteristics & Curves:-

* when a transistor is connected to dc bias voltages, for both npn and pnp types.

* V_{BB} F.B the base-emitter junction.
* V_{CC} R.B " " - collector "



* From above ⓐ and ⓑ we can see that current I_E is sum of I_C and I_B.

⇒ DC beta and DC alpha: β_{DC}, α_{DC}:-

** The DC current gain of a transistor is the ratio of the DC collector current (I_C) to the DC base current (I_B) and is designated as DC beta current.

$$\beta_{DC} = \frac{I_C}{I_B}$$

* β_{DC} ranges from 20 — 200 or higher. Sometimes the β_{DC} is called equivalent hybrid (h) parameter h_{FE} i.e.

$$h_{FE} = \beta_{DC}$$

** The ratio of the DC collector current (I_C) to the DC emitter current (I_E) is the alpha DC (α_{DC}):

$$\alpha_{DC} = \frac{I_C}{I_E}$$

* α_{DC} is less used as compared to β_{DC}
* α_{DC} ranges from 0.95 to 0.99 or higher. but is always less than 1.

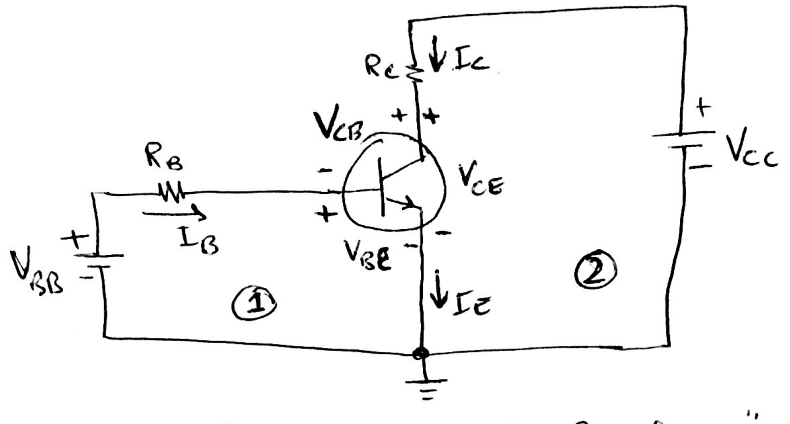
Exp 4.1:- Find $\beta_{DC} = ?$, $I_E = ?$, $I_B = 50\,\mu A$, I_C =

Soln.
$$\beta_{DC} = I_C / I_B = \frac{3.65\,mA}{50\,\mu A} = 73.$$

and $I_E = I_B + I_C = 50\,\mu A + 3.65\,mA = 3.75\,mA.$

=> BJT Circuit Analysis:-

* Consider the basic transistor bias circuit configuration in figure below
* Three transistor DC currents and three DC voltages can be identified:
  - I_B: DC base current
  - I_E: DC emitter "
  - I_C: " collector "
  - V_{BE}: DC volt. at base w.r.t emitter
  - V_{CB}: DC volt. at collector w.r.t base
  - V_{CE}: DC volt. at collector w.r.t emitter.



" Transistor currents & voltages"

* V_{BB}, forward biases the base-emitter junction, and the V_{CC} reverse " " " -collector " .
* When base-emitter junction is F.B, it is like a F.B diode and has a nominal forward voltage drop of:
$$V_{BE} = 0.7V.$$
* Since emitter is at ground (0V), apply KVL(1) to solve for V_{RB}:
$$V_{RB} = V_{BB} - V_{BE}$$
using ohm's law: $V_{RB} = I_B R_B$.
$$I_B R_B = V_{BB} - V_{BE}$$
$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

* Now the voltage at the collector w.r.t ground emitter is given by KVL at (2):

$$V_{CE} = V_{CC} - V_{R_C}$$

also, $V_{R_C} = I_C R_C$

$$\boxed{V_{CE} = V_{CC} - I_C R_C}$$

where, $I_C = I_B \beta_{DC}$

* To solve for volt. across the reverse biased collector-base junction is.

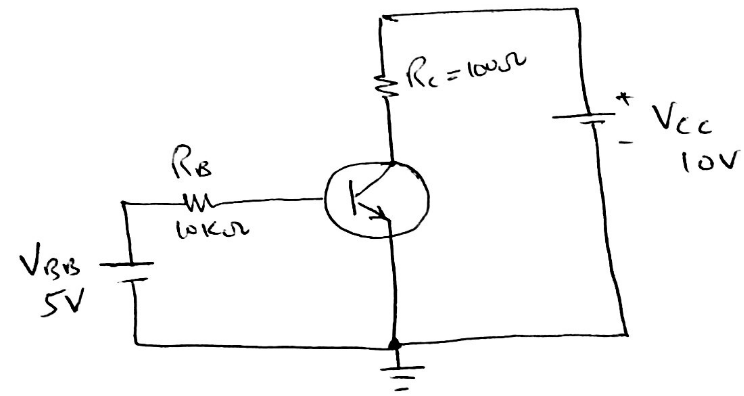
$$V_{CE} = V_{CB} + V_{BE}$$

$$\boxed{V_{CB} = V_{CE} - V_{BE}}$$

Exp: 4.2:- Find $I_C, I_B, I_E, V_{BC}, V_{CE}, V_{CB}$. $\beta_{DC} = 150$.

Sol:

$V_{BE} \simeq 0.7V$



$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5V - 0.7V}{10k\Omega} = 430\mu A$$

$I_C = \beta_{DC} I_B = (150)(430\mu A) = 64.5mA$

$I_E = I_C + I_B = 64.5mA + 430\mu A = 64.9mA$

Now we solve for V_{CE} and V_{CB}.

$$V_{CE} = V_{CC} - I_C R_C = 10V - (64.5mA)(100\Omega)$$
$$= 10V - 6.45V = 3.55V$$

$$V_{CB} = V_{CE} - V_{BE} = 3.55V - 0.7V = 2.85V.$$