9. I-V relationships in active region: (Low to medium freq.)

$$i_E = i_C + i_B = (1+\beta)\, i_B$$

$$i_C = \beta . i_B = \alpha . i_E = \left(\frac{\beta}{1+\beta}\right) . i_E$$

$$\alpha = \frac{\beta}{1+\beta}$$

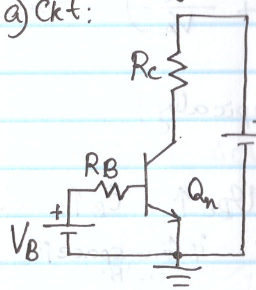
$$\beta = \frac{\alpha}{1-\alpha}$$

npn	pnp
$i_C = I_S . e^{\frac{v_{BE}}{V_T}}$	$i_C = I_S . e^{\frac{v_{EB}}{V_T}}$
$i_E = \frac{i_C}{\alpha} = \frac{I_S . e^{\frac{v_{BE}}{V_T}}}{\alpha}$	$i_E = \frac{i_C}{\alpha} = \frac{I_S . e^{\frac{v_{EB}}{V_T}}}{\alpha}$
$i_B = \frac{i_C}{\beta} = \frac{I_S . e^{\frac{v_{BE}}{V_T}}}{\beta}$	$i_B = \frac{i_C}{\beta} = \frac{I_S . e^{\frac{v_{EB}}{V_T}}}{\beta}$

(without early effect).

10. Active region in common-emitter (CE) configuration:

a) Ckt:

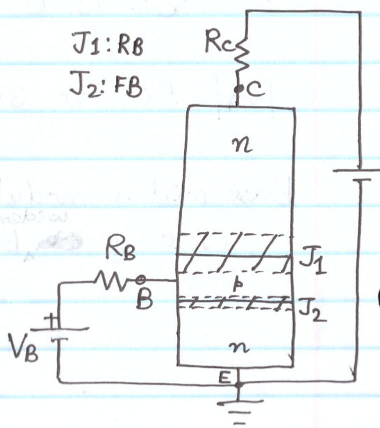


$V_{CC} > V_B$

$J_1 : RB$

$J_2 : FB$

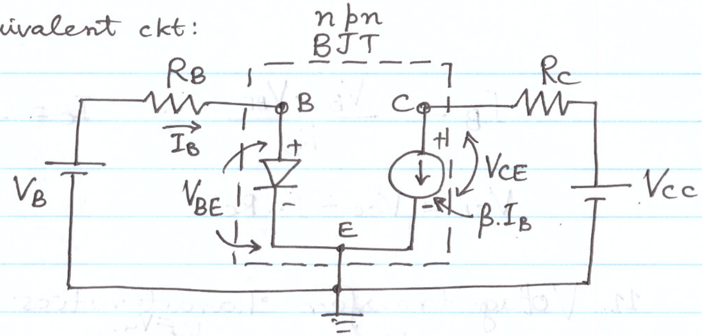
(or)



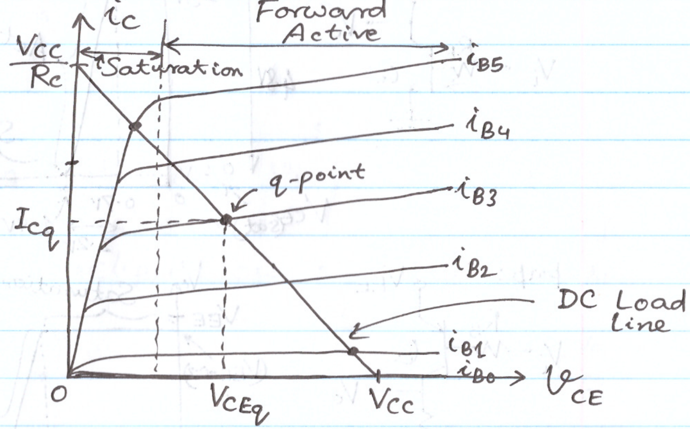
$J_1 \Rightarrow$ Reverse biased junction

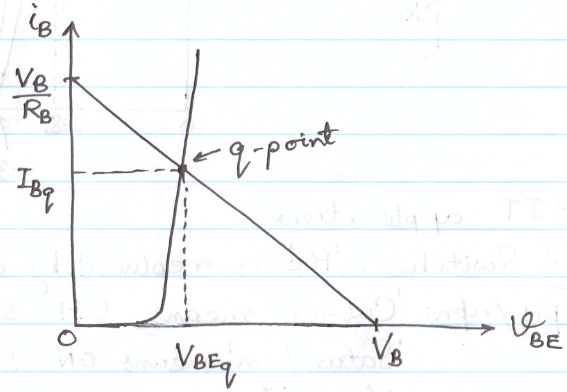
$J_2 \Rightarrow$ Forward biased junction

b. Equivalent ckt: (or)



c. Load lines: DC



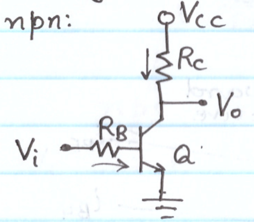


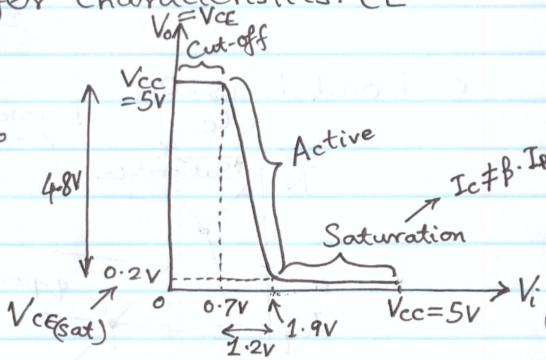
$$I_B = \frac{V_B - V_{BE}}{R_B} \quad ; \quad I_C = \frac{V_{CC} - V_{CE}}{R_C}$$

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

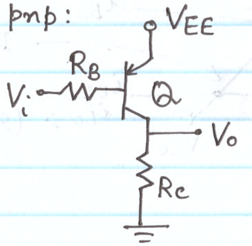
11. Voltage transfer characteristics: CE

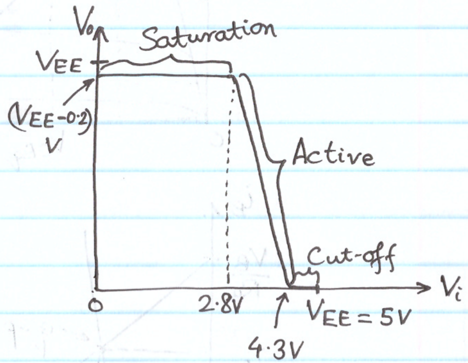
npn:





pnp:





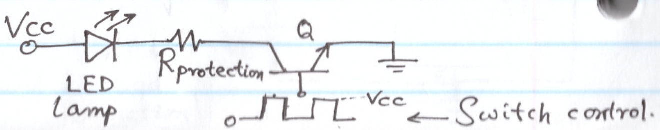
12. BJT applications:

a) Switch : 'Rc' is replaced by a load (e.g. an LED)

pnp/npn: 'Cut-off' means OFF switch 'Q'

'Saturation' means ON switch 'Q'

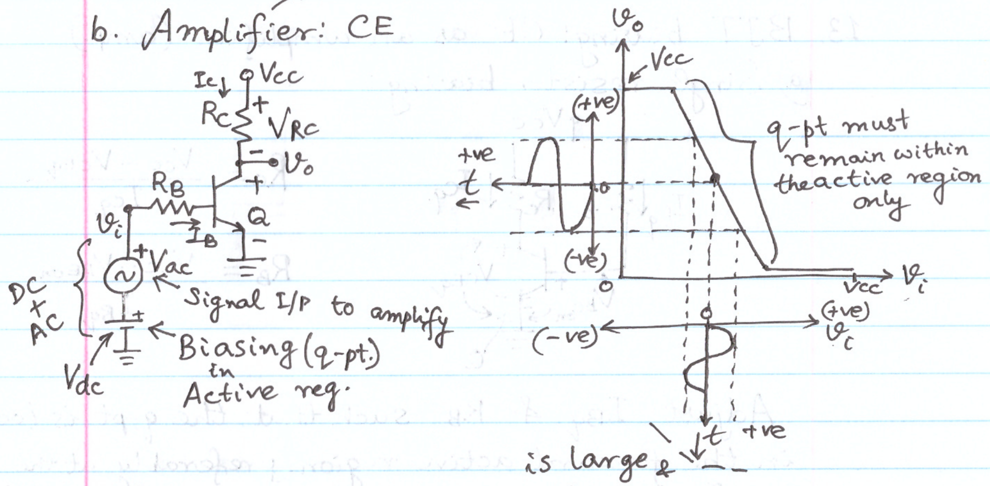
e.g.



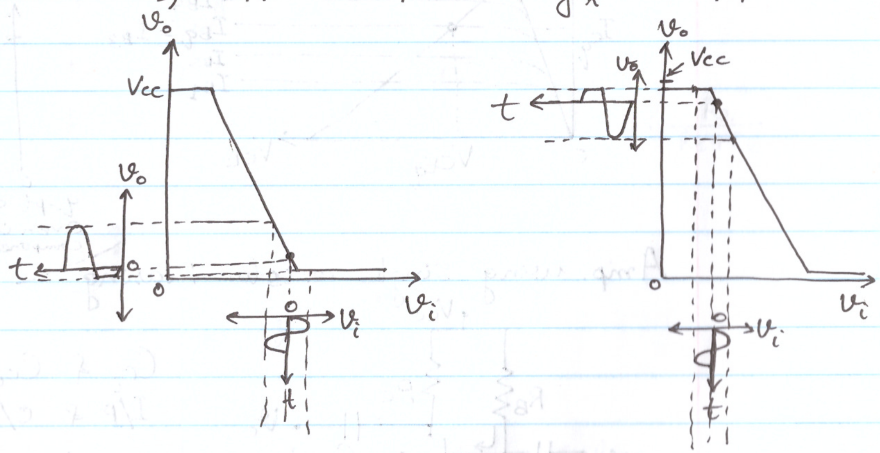
Normalized '0'

V-amplifier → Low/med. freq

b. Amplifier: CE



For any instance, if v_i forces the transistor Q to operate outside the active region (to either cut-off or Saturation), a clipped output voltage (v_o) will appear.

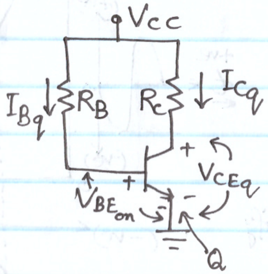


$$\text{Gain (voltage)} : A_V = \frac{\Delta V_o}{\Delta V_i}$$

$$a_v = \frac{\Delta v_o}{\Delta v_i}$$

13. BJT biasing: CE as an amplifier (amp.)

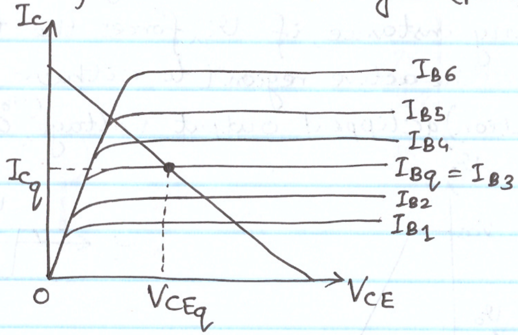
a) Single resistor biasing:

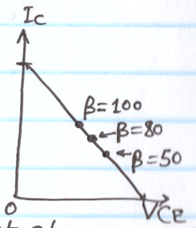


$R_C = \dfrac{V_{CC} - V_{CEq}}{I_{Cq}}$

$R_B = \dfrac{V_{CC} - V_{BEon}}{I_{Bq}}$

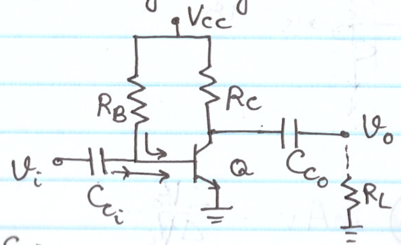
Adjust I_{Bq} & R_B such that the q-pt is located in the forward active region (preferably at the middle)



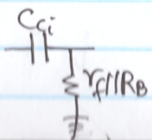


q-pt changes with β even if all other components are same.

Amp. using single resistor biasing



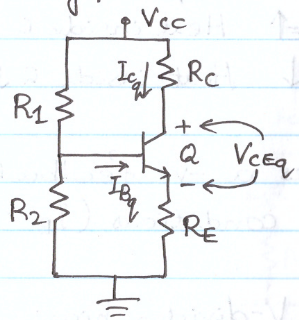
C_{C_i} & C_{C_o} are I/P & O/P coupling capacitors. (eliminates DC offsets at I/P & O/P)



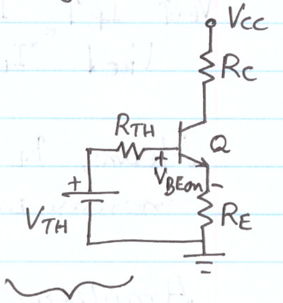
To maintain I_{Bq} when no AC signal is present

Drawback: Bias instability due to temperature change

b) Voltage/resistor divider biasing:



≈



Thevenin's equivalent base driving ckt.

Advantage: Improved bias stability due to temp. change. Ratiometric connection of R_1 & R_2 reduces the change in V_{TH} & R_{TH}, which helps in improving bias stability with temp. variation.

$\because \beta \gg 1$

$R_{TH} = R_1 // R_2 \approx 0.1(1+\beta) R_E$

$V_{TH} = I_{Bq} . R_{TH} + V_{BEon} + I_{Eq} . R_E \approx \dfrac{R_2}{R_1+R_2} . V_{CC}$

$I_{Eq} = (1+\beta) I_{Bq}$

$I_{Bq} = \dfrac{V_{TH} - V_{BEon}}{R_{TH} + (1+\beta) R_E}$

$I_{Cq} = \beta . I_{Bq} \approx \dfrac{V_{TH} - V_{BEon}}{R_E}$

$V_{CEq} = V_{CC} - I_{Cq} . R_C - I_{Eq} . R_E$

Adjust R_1 & R_2 & Vcc such that the q-pt lies at the middle of forward active region.

Purpose of R_E: 1. V-drop additional to V_{BEon} in base ckt.
2. Prevent thermal runaway.

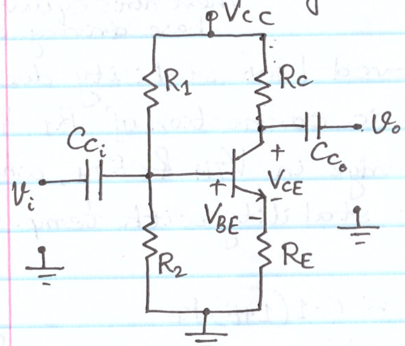
Thermal runaway: & its prevention: $-ve\ f/b$

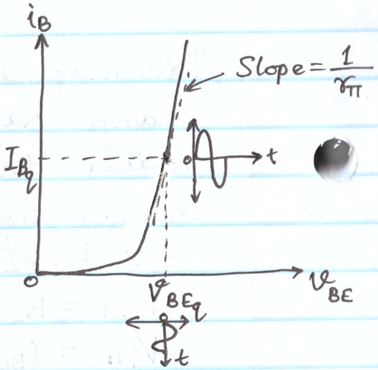
$V_{BE}\uparrow$ $I_B\uparrow$ $I_C\uparrow$ $I_E\uparrow$ Heat inside Q $\uparrow$ $V_{RE}\uparrow$

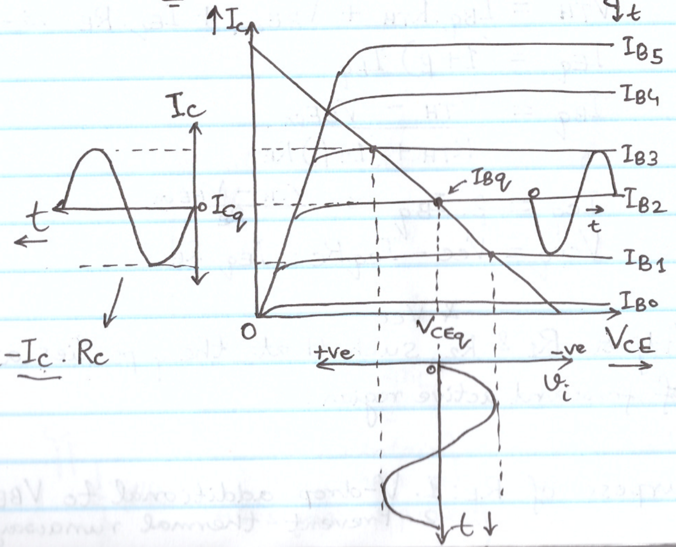
$V_{BE}\downarrow$ $I_B\downarrow$ $I_C\downarrow$ Heat inside Q $\downarrow$

Means, R_E provides a $-ve$ feedback with increase in input conditions (I_B & V_{BE})

Amplifier using V-divider bias:



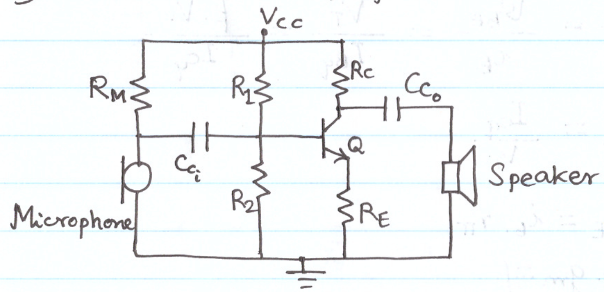




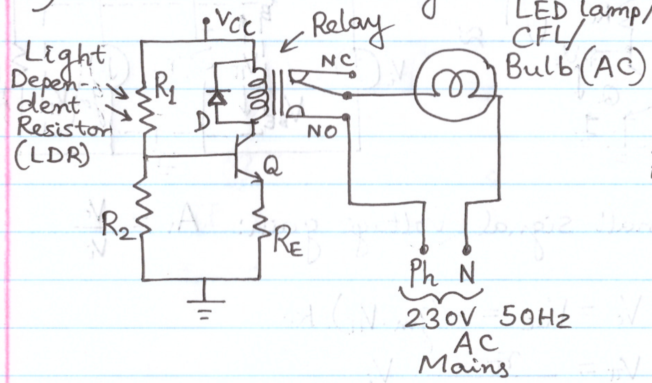
$V_o = V_{CC} - I_C \cdot R_C$

14. Applications of V-divider bias based CE amplifier:

1) Microphone amplifier:



2) Automatic street light controller:



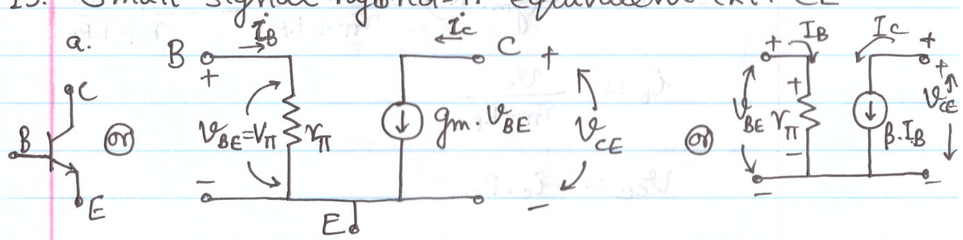
NC : Normally Closed

NO : Normally Open

D : Free-wheeling Diode

15. Small signal hybrid-π equivalent ckt: CE (→ Forward active reg.)

a.



r_π = Diffusion res. (B-E I/P res.)

g_m = Transconductance.

$$i_B = \frac{I_S}{\beta} \cdot e^{\frac{v_{BE}}{V_T}} \quad ; \quad i_C = I_S \cdot e^{\frac{v_{BE}}{V_T}}$$

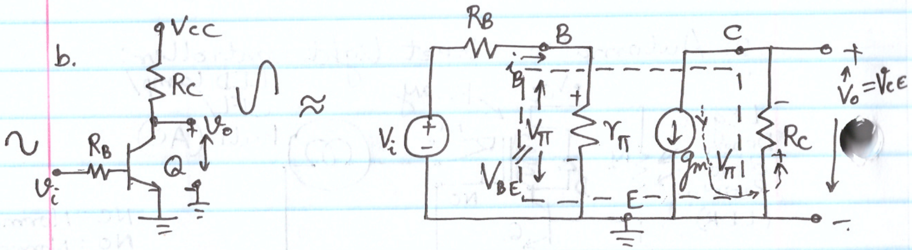
$$r_\pi = \frac{v_{BE}}{i_B} = \frac{V_T}{I_{Bq}} = \frac{\beta \cdot V_T}{I_{cq}}$$

$$g_m = \frac{I_{cq}}{V_T}$$

$$v_{BE} = i_B \cdot r_\pi$$

$$r_\pi \cdot g_m = \beta$$

b.



Small signal voltage gain: $A_v = \frac{V_o}{V_i}$

$$V_o = V_{CE} = -(g_m \cdot V_\pi) \cdot R_C$$

$$V_\pi = \frac{r_\pi}{r_\pi + R_B} \cdot V_i$$

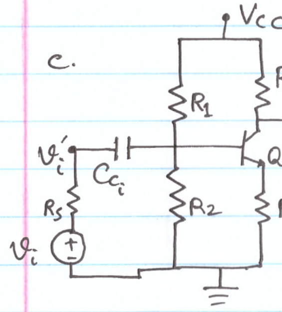
$$\therefore A_v = -(g_m \cdot R_C) \cdot \frac{r_\pi}{r_\pi + R_B} = \frac{-\beta \cdot R_C}{r_\pi + R_B}$$

$$i_B = \frac{v_i}{r_\pi + R_B}$$

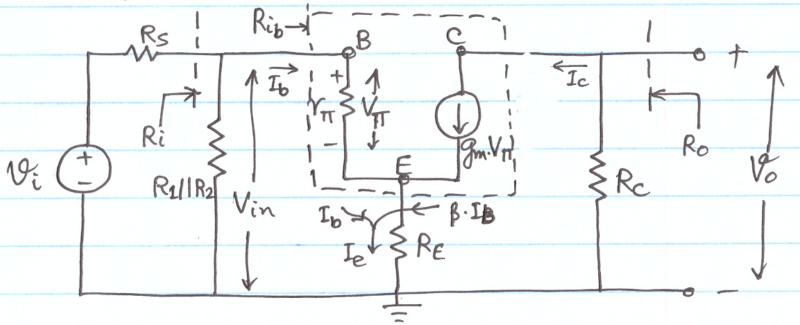
$$v_{CE} = -i_C \cdot R_C$$

Note: Consider '$r_o // R_C$' if r_o is connected in parallel to '$g_m V_\pi$' I-source.

c.



AC small signal hybrid-π model



$$V_o = -(\beta \cdot I_b) R_C = -I_c \cdot R_C$$

$$V_{in} = I_b \cdot r_\pi + (I_b + \beta \cdot I_b) R_E$$

$$R_{ib} = \frac{V_{in}}{I_b} = r_\pi + (1+\beta) R_E$$

(Resistance Reflection Rule)

$$R_i = R_1 // R_2 // R_{ib}$$

$$V_{in} = \frac{R_i}{R_i + R_S} \cdot v_i$$

$$A_v = \frac{v_o}{v_i} = \frac{-(\beta \cdot I_b) R_C}{v_i} = -\beta \cdot R_C \cdot \frac{v_{in}}{R_{ib}} \cdot \frac{1}{v_i}$$

$$= \frac{-\beta \cdot R_C}{r_\pi + (1+\beta) R_E} \left(\frac{R_i}{R_i + R_S} \right)$$

$$\cong \frac{-\beta \cdot R_C}{(1+\beta) R_E} \cong -\frac{R_C}{R_E} \quad \left[\because \beta \gg 1 \ \& \ R_i \gg R_S \right]$$