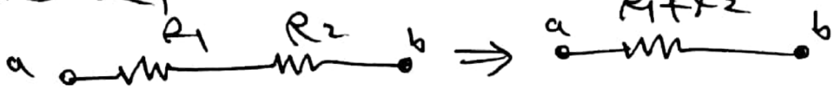
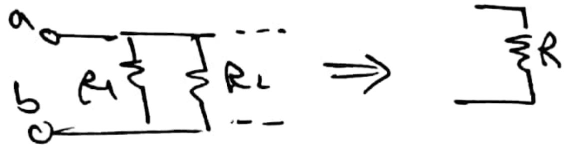
Review

1 series & parallel resistor

series

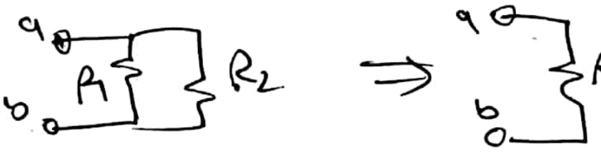


parallel



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

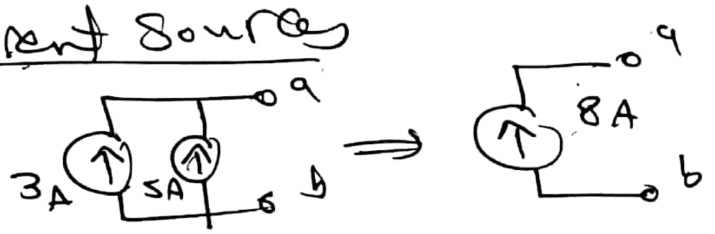
special case

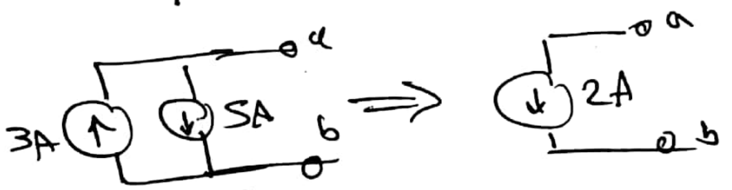


$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

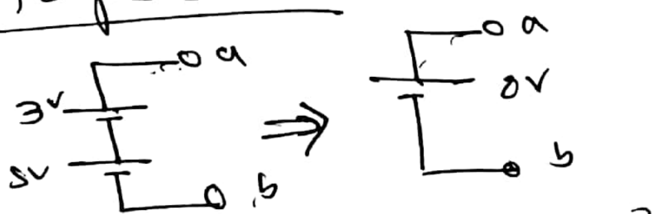
$$R_T = \frac{R R}{R + R} = \frac{R}{2}$$

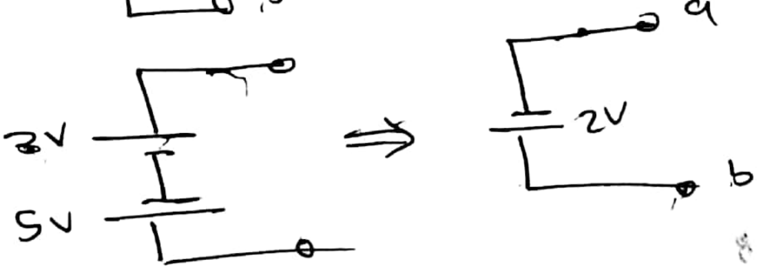
2 current source



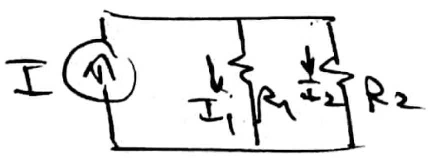


3 voltage source





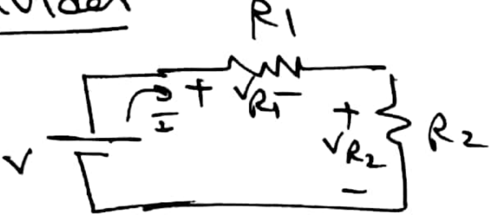
4 current divider



$$I_1 = \frac{I . R_2}{R_1 + R_2}$$

$$I_2 = \frac{I . R_1}{R_1 + R_2}$$

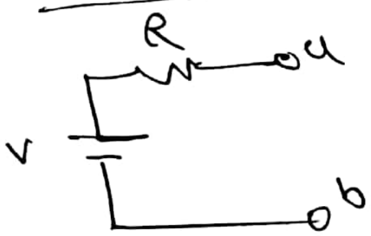
5) voltage divider



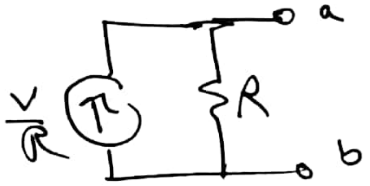
$$V_{R_1} = \frac{V \cdot R_1}{R_1 + R_2}$$

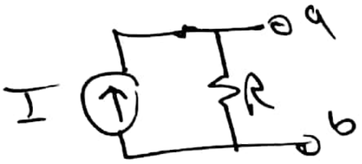
$$V_{R_2} = \frac{V \cdot R_2}{R_1 + R_2}$$

6) voltage source to current source & vice versa

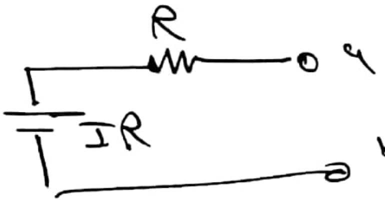


$\Rightarrow$

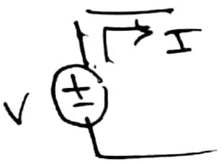




$\Rightarrow$



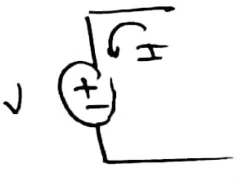
7) Delivered Power



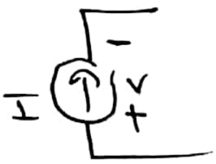
$P = -VI$

$P = -VI$

8) Consumed power (dissipation power)



$P = VI$

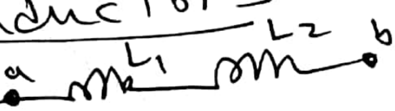


$P = VI$

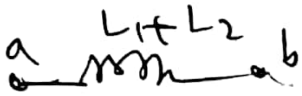
$P = I^2 R$

9) Inductors

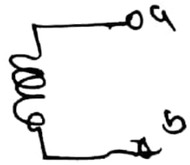
series



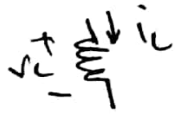
$\Rightarrow$



$\Rightarrow$



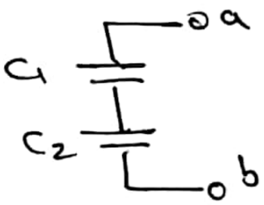
$\frac{L_1 L_2}{L_1 + L_2}$



$V_L = L \frac{di}{dt}$, $i_L = \frac{1}{L} \int v_L \, dt + C$, $W_L = \frac{1}{2} I^2 L$

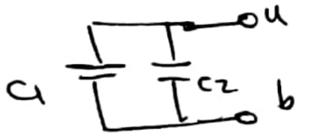
10 Capacitors

series

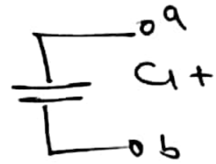


$\Rightarrow$

$\frac{C_1 C_2}{C_1+C_2}$ or $\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\cdots$

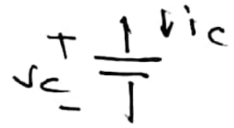


$\Rightarrow$



$C_1 + C_2$

$i_c = C\frac{dv}{dT}$ $\quad V_c = \frac{1}{C}\int i \cdot dT$



$W_c = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

11 material

فائق التوصيل	موصل	شبه موصل	شبه عازل	عازل
superconductor	conductor	semiconductor	dielectric	insulator

Kind of semiconductor

1. Single element semiconductor
   silicon, Germanium
   Si, Ge
2. Compound semiconductor
   Gallium Arsenide (GaAs)

12 Atom construction

(a) Bohr Theorem

\# of electrons in each orbit $= 2N^2$

$Si = 14 \Rightarrow 2, 8, 4$

$Ge \Rightarrow 32 \Rightarrow 2, 8, 18, 4$

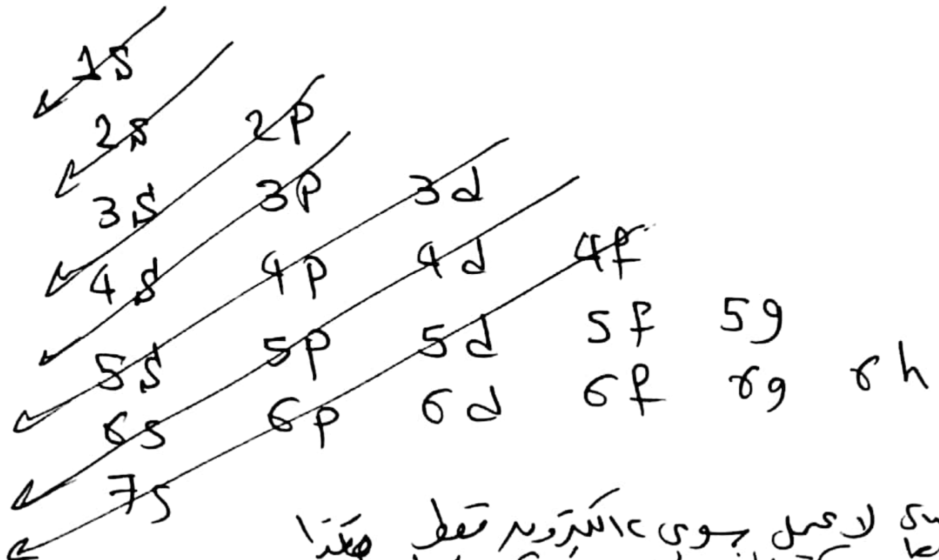
(b) Quantum Mechanics Theorem

atom $\Rightarrow$ orbits K, L, M, N, O — each orbit have s p d f g h i j sublevel

\# of electron in sublevel $= 2N$ odd

s	p	d	f	g	h	i	j
2	6	10	14	18	22	26	30

Aufbau principle



في الواقع ان sub level طبقة لا تحمل سوى ١٤ الكترون فقط جدلا
ونعلم بأن p به ١٦ الكترونات موزعة على ثلاث مستويات

Silicon Si = 14

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

$1s^2 \quad 2s^2 2p^6 \quad 3s^2 3p^2$

2   8   4   Bohr

K   L   M

Germanium Ge = 32

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^2$

$1s^2 \quad 2s^2 2p^6 \quad 3s^2 3p^6 3d^{10} \quad 4s^2 4p^2$ Bohr

2   8   18   4

Distrubition of electrons

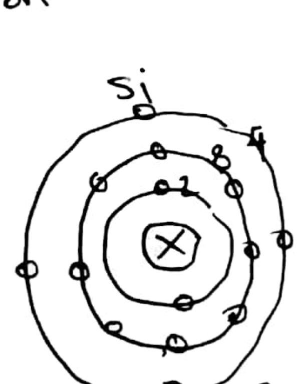
Si = 14

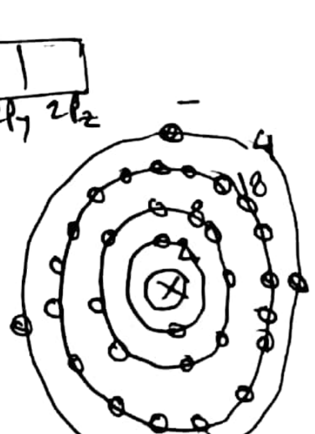
1s	2s	2p	3s	3p
↓↑	↓↑	↓↑ ↓↑ ↓↑	↑↓	↓↑
2	2	6	2	2

Boron B = 5

1s	2s	2p
↓↑	↓↑	↑
		$2p_x$ $2p_y$ $2p_z$

Si





من النافع سيلكون لان مدار الاضعف النواة من Ge اقل يعتبره Si
لذا لا نستخدم Ge بكثره

Dopping of Semiconductor

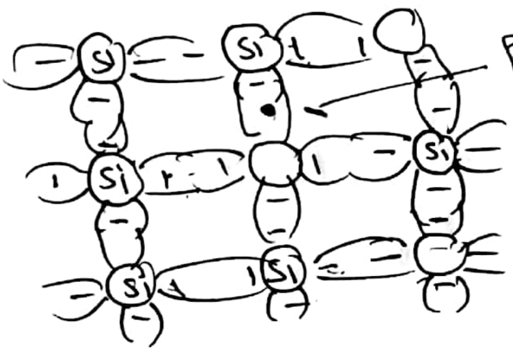
Type of dopping material

[a] pentavalent atoms
That have 5 electrons in valence band
such as phosphorous, antimoney, arsenic, etc...
all called (Donners)

[b] Trivalent atoms
That have 3 electrons in valence band
Such as Aluminium, boron, gallium, etc...

negative material (N-Type)

Si + ph = 4+5 = 8+1 — free electrons

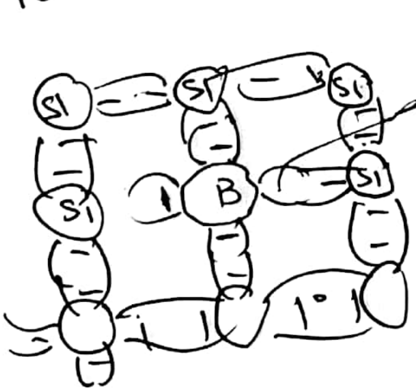


as # of phosphorous impurities increase as material be more negative

N ⇒ n+

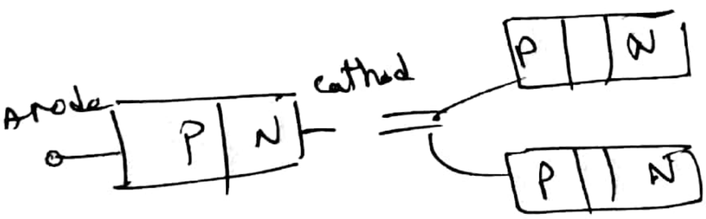
Positive material (P-Type)

Si + B. = 4+3 = 8 (-1) — +ve



as # of Boron impurities increase as material be +ve

P ⇒ P+



$V_D = 0.5 - 0.7$ Si

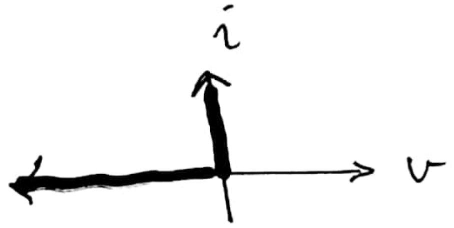
$V_D = 0.2 - 0.3$ Ge

Di-electrode = diode

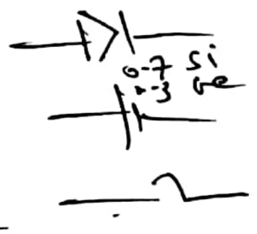
S/

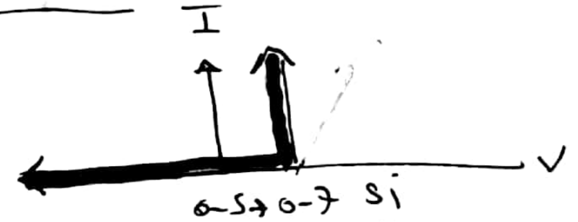
voltage current relation in diodes

(a) ideal diode



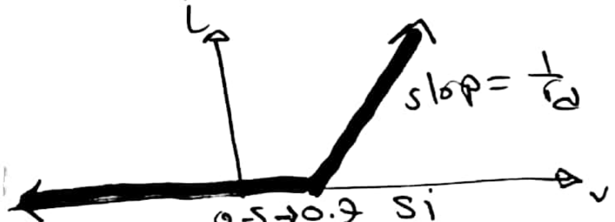
(b) Constant voltage drop diodes





0.5 → 0.7 Si
0.2 → 0.3 Ge

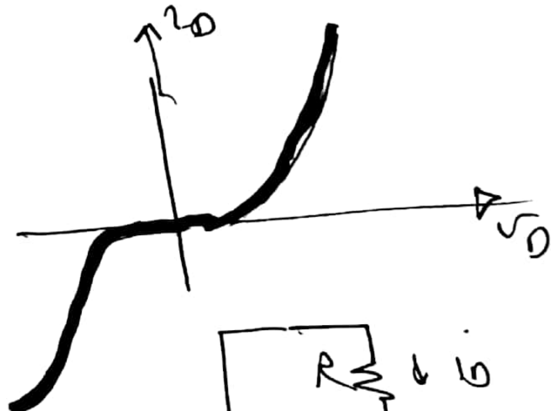
(c) Constant voltage drop + Resistance



0.5 → 0.7 Si
0.2 → 0.3 Ge

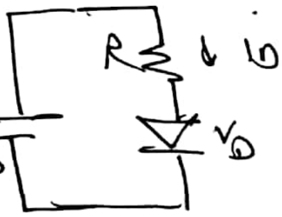
(d) practical relation

$$I_D = I_S\left(e^{\frac{V_D}{nV_T}} - 1\right)$$



$$\text{or} \quad I_D = \frac{V_{DD} - 0.7}{R} \quad (1)$$

$$V_D = nV_T \ln \frac{I_D}{I_S} \quad (2)$$



يعطيني معطى فيه R و VDD
ونحل

$V_D = 0.7$ at 1mA

نعوض من المعادلة رقم ① بجيب I_D

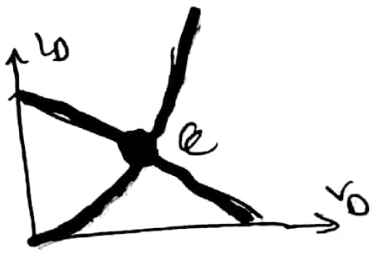
نعوض به في المعادلة رقم ② بجيب V_D

نعوض به في المعادلة رقم ① بجيب I_D

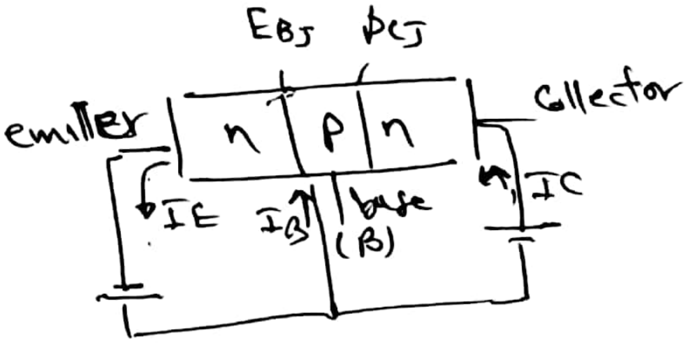
V_D ~ ~ ② ~ ~

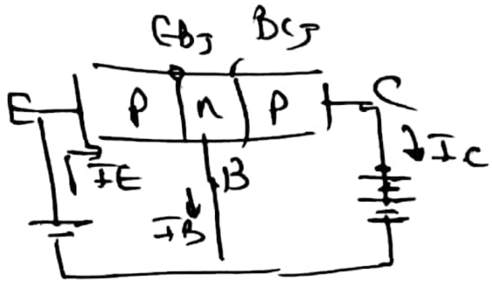
وبنظل في عملية تكرار حتى تثبت قيم I_D و V_D تقريبا هي ما هي

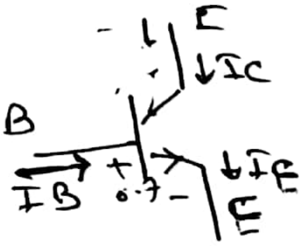
والموضح أمامنا تقدر تعتبر Q



Bipolar Junction Transistor (BJT)



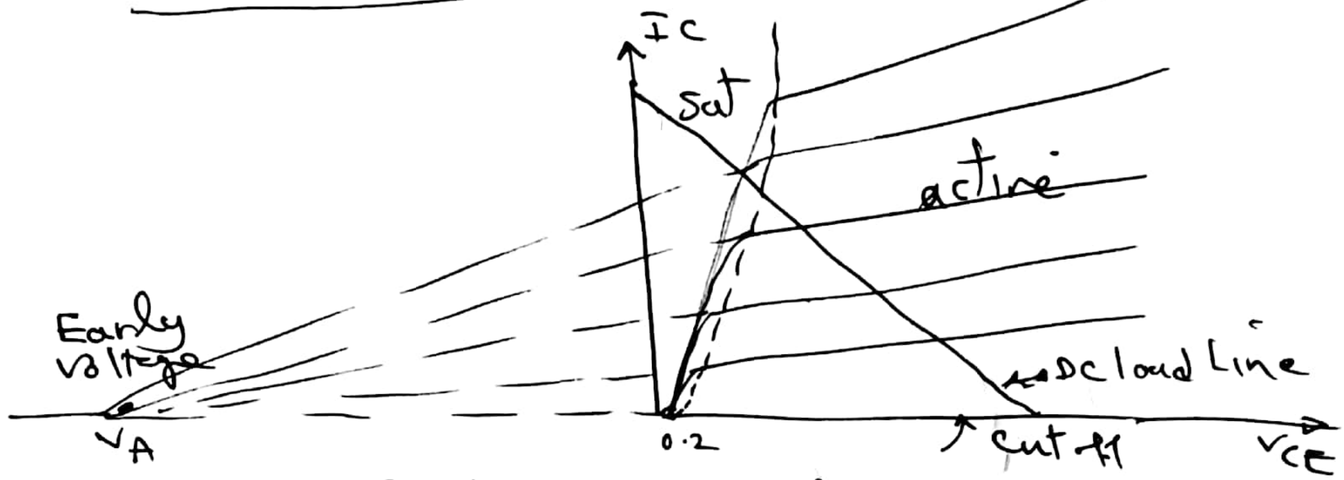




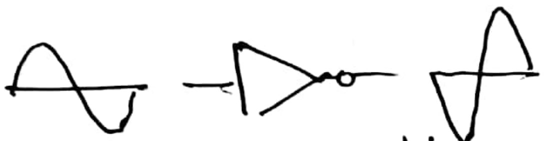
Transistor region

region	EBJ	BCJ	Laws	applications
Active region	forward Bias	Reverse Bias	$I_E = I_B + I_C = (1+\beta) I_B$ $I_C = \beta I_B$ $I_C = \alpha I_E$ $\alpha = \frac{\beta}{1+\beta}$, $\beta = \frac{\alpha}{1-\alpha}$ $\beta >> 1$, $\alpha << 1$ $V_{BE} = 0.7 \rightarrow npn$ $V_{EB} = 0.7 \rightarrow pnp$	Amplifier
Saturation region	Forward Bias	Forward Bias	$V_{CE} = 0.2V \rightarrow pnp$ $V_{BE} = 0.7V \rightarrow pnp$ $V_{EC} = 0.2V \rightarrow npn$ $V_{EB} = 0.7V \rightarrow npn$ $I_E = I_C + I_B$	Switch on
Cut-off region	Reverse bias	Reverse Bias	$I_E = 0$ $I_B = 0$ $I_C = 0$	off

Transistor Dc Bias

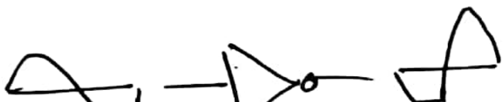


فانسطاعي Bias هو تكوين ابيه عمل الترانسستور

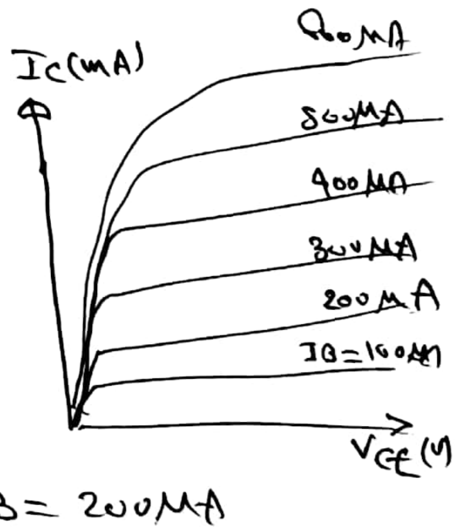


Linear operation
o/p Like I/p with 180° shift

non linear output
o/p is Limited by cutoff

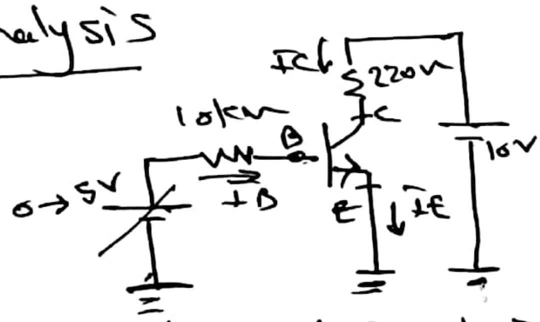


non linear operation
o/p is Limited by Saturation



Graphical analysis

$\beta = 100$

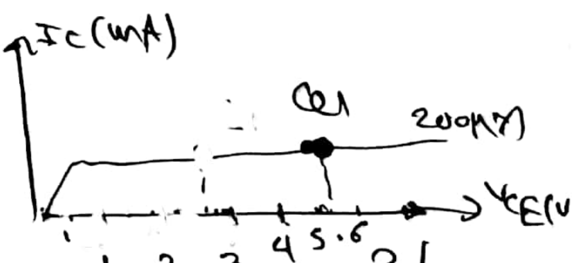


ⓐ assume VBB adjust such That $I_B = 200 \mu A$

or $\frac{V_{BB} - 0.7}{10 k\Omega} = 200 \mu A \quad \therefore V_{BB} = 2.7 V$

$V_{CE} = V_{CC} - I_C R_C = 10 - \beta I_B R_C = 10 - 100 * 0.2 mA * 0.22 \Omega$

$= 5.6 V$



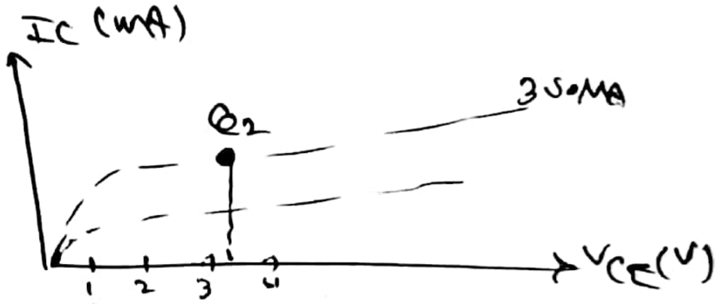
(b) when V_{BB} adjust such that $I_B = 300\mu A$

or $\frac{V_{BB} - 0.7}{10K\Omega} = 300\mu A$ $\therefore V_{BB} = 3.7V$

$V_{CE} = V_{CC} - I_C R_C = V_{CC} - \beta I_B R_C = 10 - 100 * 0.3mA * 0.220$

$= 3.4V$

نلاحظ ان Q_2 تحرك إلى sat
او إلى اليسار، مقارنة مع Q_1



(c) when V_{BB} adjust such that $I_B = 400\mu A$

or $\frac{V_{BB} - 0.7}{10K\Omega} = 400\mu A$ $\therefore V_{BB} = 4.7$

$V_{CE} = V_{CC} - \beta I_B R_C = 10 - 100 * 0.4mA * 0.220 = 1.2V$

DC load Line

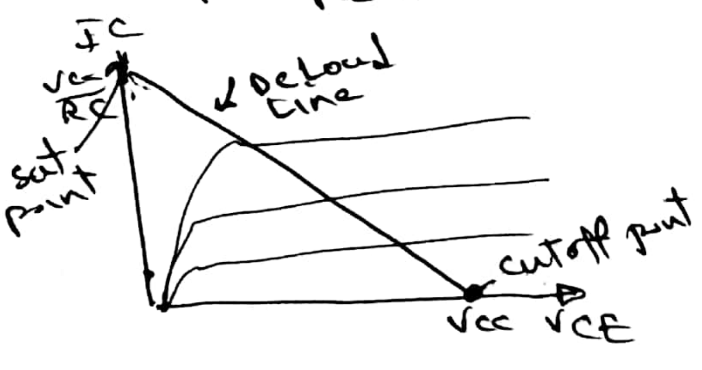
$V_{CC} = I_C R_C + V_{CE}$

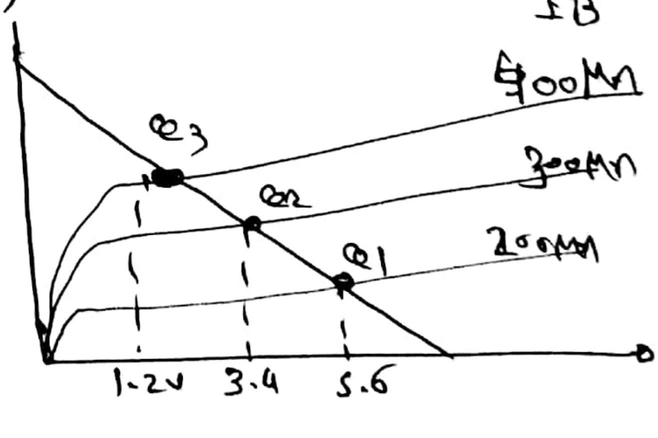
when $V_{CE} = 0$ $\therefore I_C = \frac{V_{CC}}{R_C}$ } represent Two point on DC Load Line (edges)

when $I_C = 0$ $\therefore V_{CE} = V_{CC}$

$\therefore I_C = \frac{V_{CC} - V_{CE}}{R_C} = -\frac{V_{CE}}{R_C} + \frac{V_{CC}}{R_C}$

which represent straight line eq with slop $(-\frac{1}{R_C})$, and intercept with V_{CE} axis at V_{CC} & with I_C axis at $\frac{V_{CC}}{R_C}$ (which is $I_{C\,sat}$)



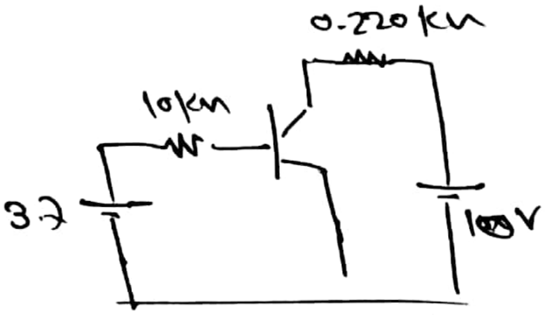


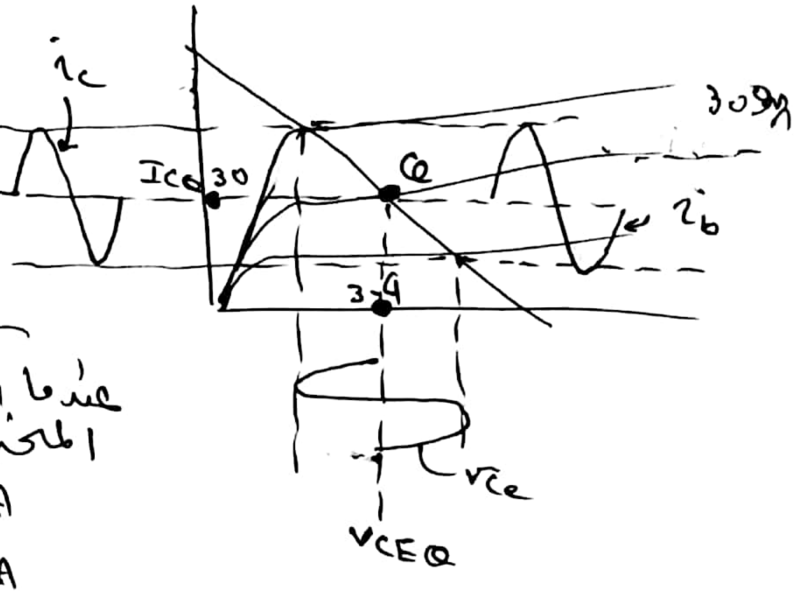
تقع تقاطع DC Load Line مع منحنى لتيار IB تكون فيه Q point

Q → point ⇒ quiescent point (operating point)

process point (nominal point)

1 Linear operation





عندما تكون نقطة Q في منتصف
المنحنى الثاني بـ IB أيضا ،

$$I_{BQ} = \frac{3.7 - 0.7}{10} = 300\,\mu A$$

$$I_{CQ} = \beta I_{BQ} = 30\,mA$$

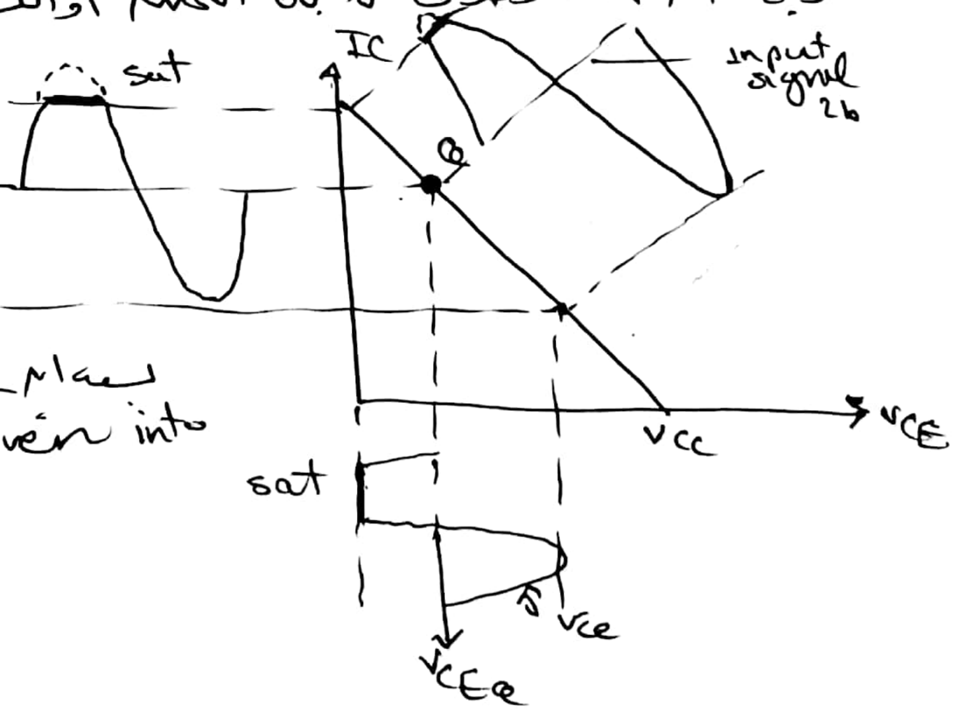
$$V_{CEQ} = V_{CC} - I_{CQ} R_{C}$$

$$= 10 - 30 * 0.220 = 3.4\,V$$

2 waveform Distortion

بسبب وضع Q تكون الموجه تشوه جزئي او كلي حسبا
قربها من احد الاطراف خط المحمل او التيار بعيدا عن الوسط

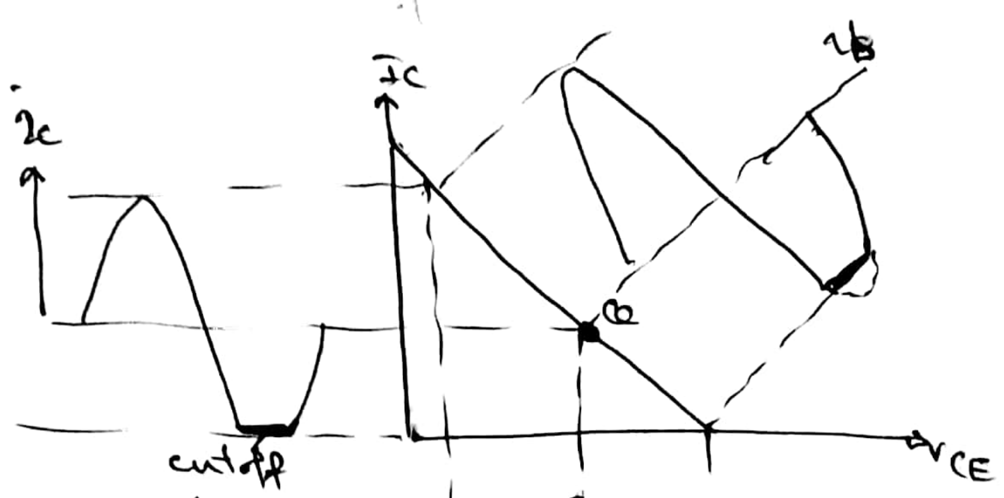
(a)



sat بسبب Q قريبة من

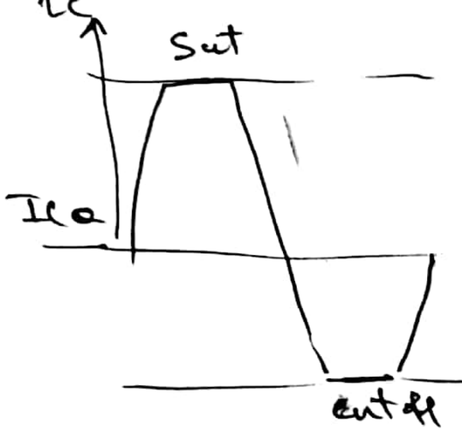
Transistor driven into sat

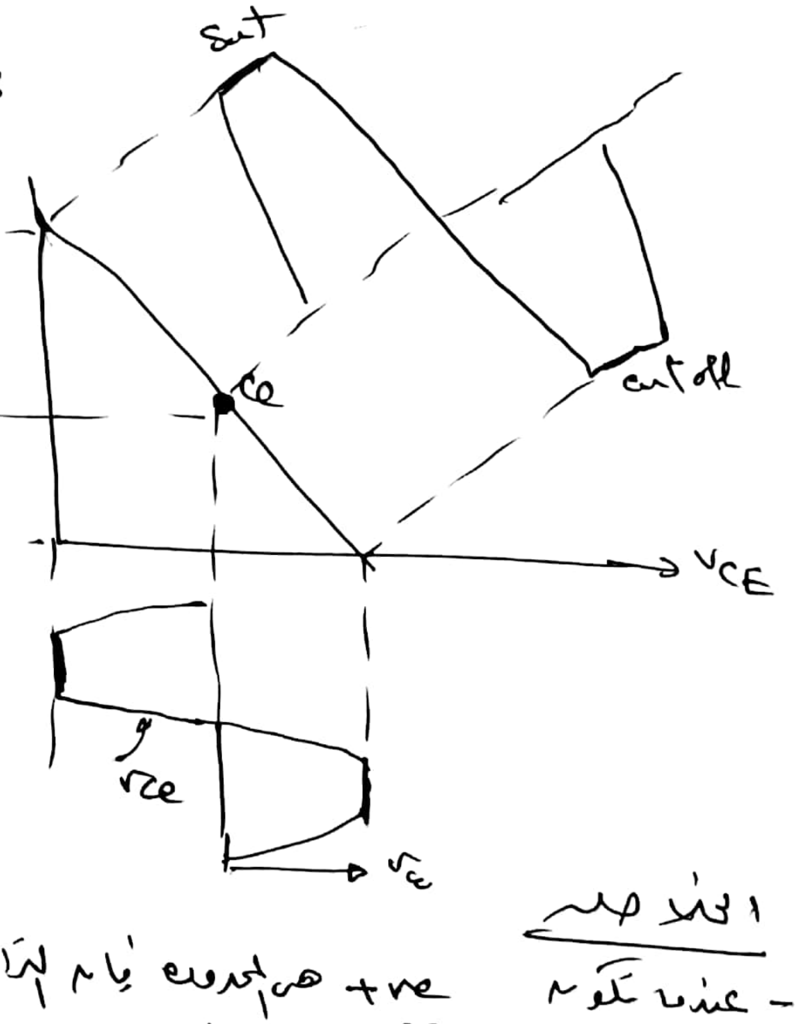
(b)



لسه أنَّه Q point أقرب إلى الـ cutoff
فالم الترانزستور سوف يعمل في جزء من
إلى الـ cutoff

(c) when both peaks are limited





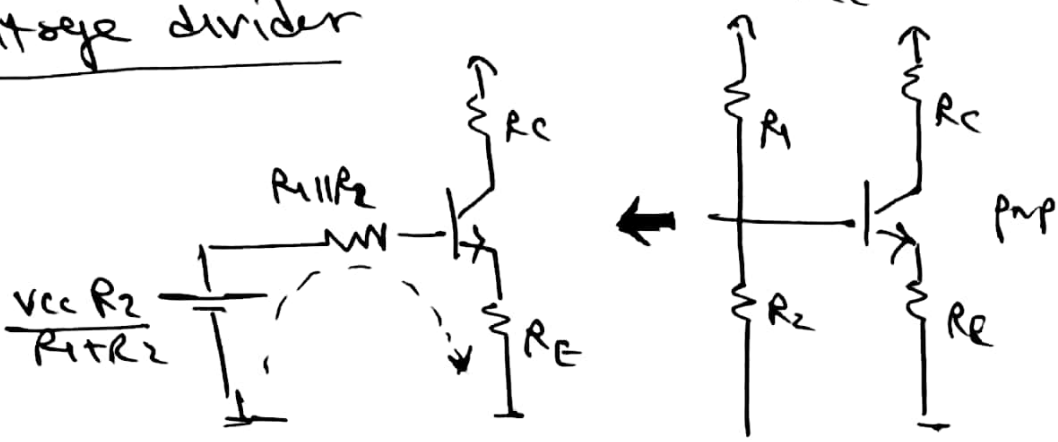
Transistor is driven into both saturation and cutoff due to Large I/P signal

الخلاصة

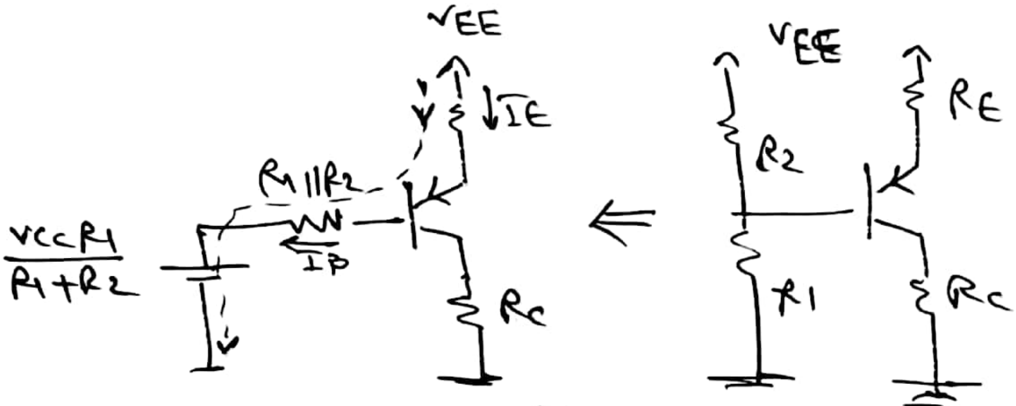
- عندما تقطع +ve هذا يحدث فإن الترانزستور يصل cutoff (b)
- " " -ve " " " " " " sat (a)
- عندما تقطع كلاهما +ve / -ve يحدث فإن الترانزستور يعمل في كلا region (c)

Biasing circuits

(a) voltage divider



$$\frac{V_{cc}R_2}{R_1+R_2} = \frac{I_E}{1+\beta}(R_1 \| R_2) + V_{BE} + I_E R_E \longrightarrow I_E \checkmark$$

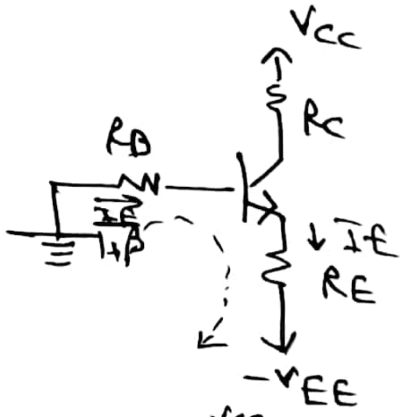


$$V_{EE} - \frac{V_{cc}R_1}{R_1+R_2} = I_E R_E + \frac{I_E}{1+\beta}(R_1 \| R_2)$$

(b) Emitter bias

$$0 = \frac{I_E}{1+\beta}R_B + V_{BE} + I_E R_E - V_{EE}$$

$$I_E = \frac{V_{EE} - V_{BE}}{\frac{R_B}{1+\beta} + R_E} \checkmark$$



(c) Base Bias

$$V_{cc} = \frac{I_E}{1+\beta}R_B + V_{BE}$$

$$\frac{I_E}{1+\beta} = \frac{V_{cc} - V_{BE}}{R_B}$$

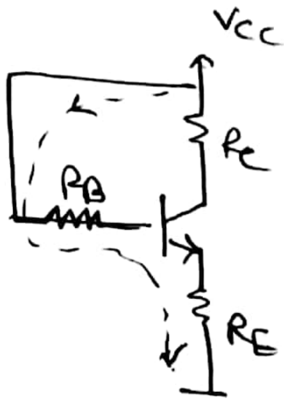
$$V_{CE} = V_{cc} - I_c R_c$$

(d) Emitter feed back bias

$$V_{CC} = \frac{I_E}{1+\beta} R_B + V_{BE} + I_E R_E$$

$$I_E = \frac{V_{CC} - V_{BE}}{\frac{R_B}{1+\beta} + R_E}$$

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

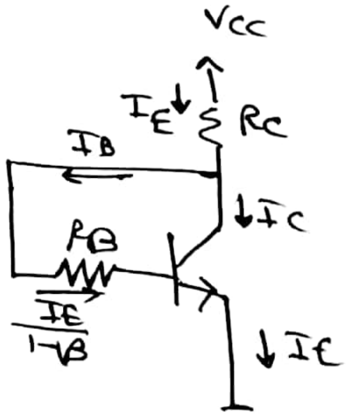


(e) Collector feed back bias

$$V_{CC} = I_E R_C + \frac{I_E}{1+\beta} R_B + V_{BE}$$

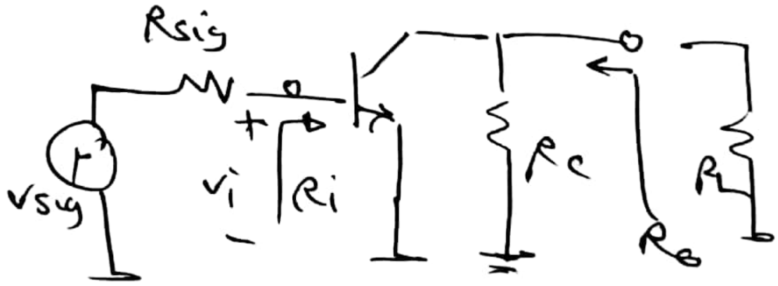
$$I_E = \frac{V_{CC} - V_{BE}}{R_C + \frac{R_B}{1+\beta}}$$

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

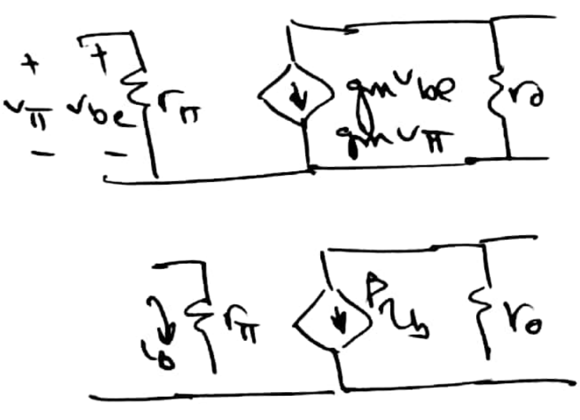


Transistor Amplifier

(a) Common emitter



ac model



$$r_\pi = \frac{V_T}{I_B}$$

$$g_m = \frac{I_C}{V_T}$$

$$r_o = \frac{V_A}{I_C}$$

} from DC analysis

ac analysis

$\because V_o = -g_m v_\pi (r_o \| R_c) \rightarrow ①$, $A_{v_o} = \frac{v_{oo}}{v_\pi} = -g_m (R_c \| r_o) \rightarrow ②$

$v_o = -g_m v_\pi (R_c \| R_L \| r_o)$, $A_v = \frac{v_o}{v_\pi} = -g_m (R_c \| R_L \| r_o)$

$\because v_\pi = \frac{v_{sig}\, r_\pi}{R_{sig} + r_\pi}$

$\frac{v_\pi}{v_{sig}} = \frac{r_\pi}{R_{sig} + r_\pi} \rightarrow ③$

from eq 2 & 3

$G_v = \frac{v_o}{v_{sig}} = \frac{v_o}{v_\pi} \cdot \frac{v_\pi}{v_{sig}} = -g_m (R_c \| r_o) \cdot \frac{r_\pi}{R_{sig} + r_\pi}$ ④ ✓

$G_{v_o} = \frac{v_{oo}}{v_{sig}} = \frac{v_{oo}}{v_\pi} \cdot \frac{v_\pi}{v_{sig}} = -g_m (r_o \| R_c \| R_L) \frac{r_\pi}{R_{sig} + r_\pi}$

$R_{in} = \frac{v_\pi}{i_b} = r_\pi$ ④ ✓

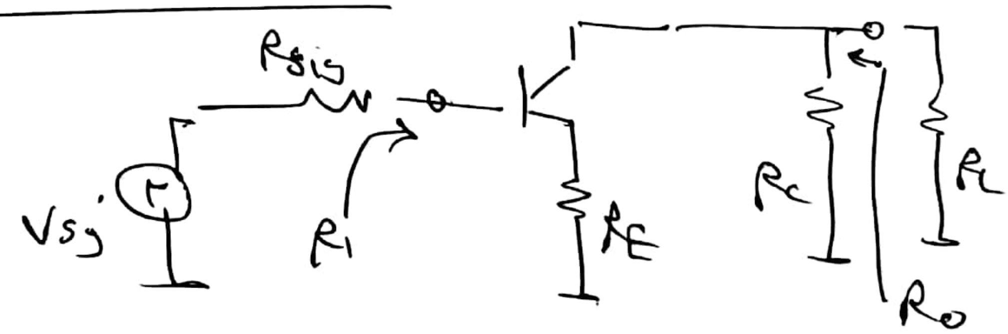
R_o, s.c on I/P so $v_\pi = 0$ $\therefore g_m v_\pi$ is equal to zero $\Rightarrow$ open circuit

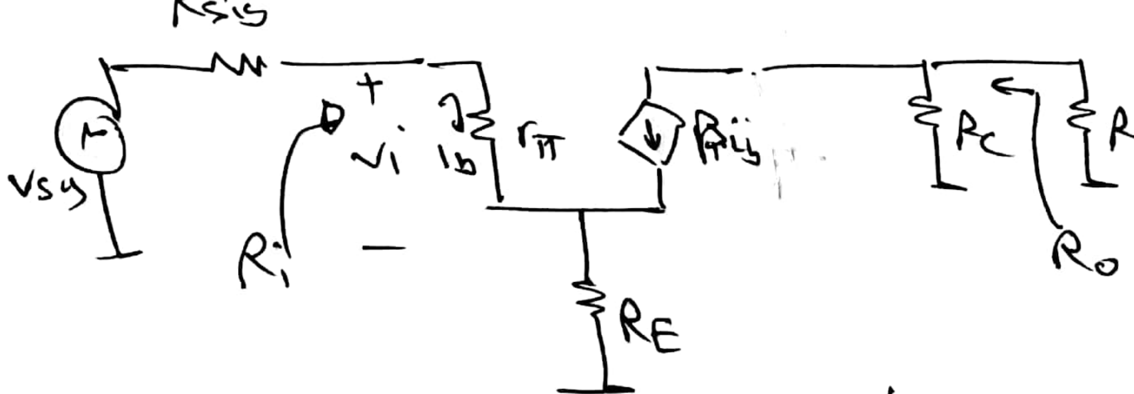
$\therefore R_o = r_o \| R_c$

إذا بنحسب Ro قبل load، وكذلك Ri بعد Source

ⓑ Common emitter with R_E

neglect ro





$\because v_i = i_b r_\pi + (1+\beta) i_b R_E$

$v_i = i_b [r_\pi + (1+\beta) R_E)$

$\therefore R_{in} = \dfrac{v_i}{i_i} = \dfrac{v_i}{i_b} = r_\pi + (1+\beta) R_E \Rightarrow (A)$ ✓

$V_{oo} = -\beta i_b R_C \longrightarrow (1)$

$V_o = -\beta i_b (R_C \| R_L) \rightarrow (2)$

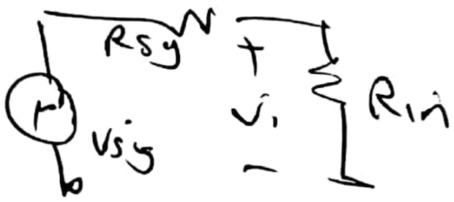
$\because v_i = i_b (r_\pi + (1+\beta) R_E) - (3)$

$\therefore A_v = \dfrac{V_o}{V_i} = \dfrac{eq(2)}{eq(3)} = -\dfrac{\beta (R_C \| R_L)}{r_\pi + (1+\beta) R_E} \text{ — } (4)$

$A_{vo} = \dfrac{V_{oo}}{V_i} = \dfrac{eq(1)}{eq(3)} = -\dfrac{\beta R_C}{r_\pi + (1+\beta) R_E} \text{ — } (5)$

$\because v_i = \dfrac{V_{sig} R_{in}}{R_{in} + R_{sig}}$

$\dfrac{v_i}{V_{sig}} = \dfrac{R_{in}}{R_{in} + R_{sig}} \text{ — } (6)$



$\therefore G_v = \dfrac{V_o}{V_{sig}} = \dfrac{V_o}{V_i} \cdot \dfrac{V_i}{V_{sig}} = A_v \cdot \dfrac{V_i}{V_{sig}} = eq(4) * eq(6)$

$= -\dfrac{\beta (R_C \| R_L)}{\cancel{r_\pi + (1+\beta) R_E}} \cdot \dfrac{\cancel{R_{in}}}{R_{in} + R_{sig}}$

$= -\dfrac{\beta (R_C \| R_L)}{R_{in} + R_{sig}}$ (#) ✓

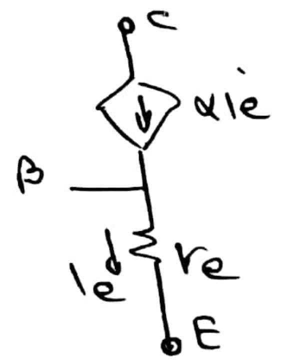
$G_{vo} = \dfrac{V_{oo}}{V_{sig}} = eq(5) * eq(6) = \dfrac{-\beta R_C}{\cancel{r_\pi + (1+\beta) R_E}} \cdot \dfrac{\cancel{R_{in}}}{R_{in} + R_{sig}}$

$= -\dfrac{\beta R_C}{R_{in} + R_{sig}}$ (#) ✓

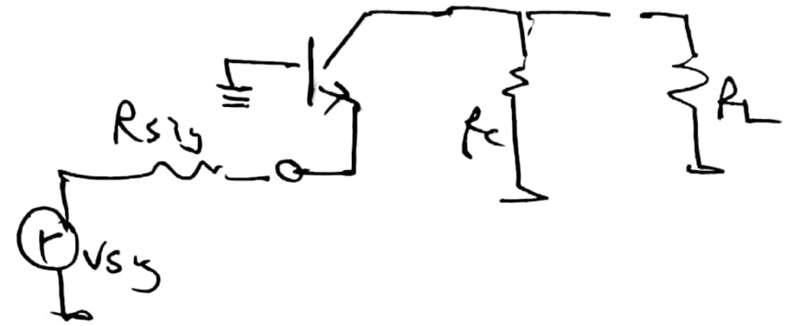
$R_o \downarrow_{\text{s.c on I/P}} = R_C$

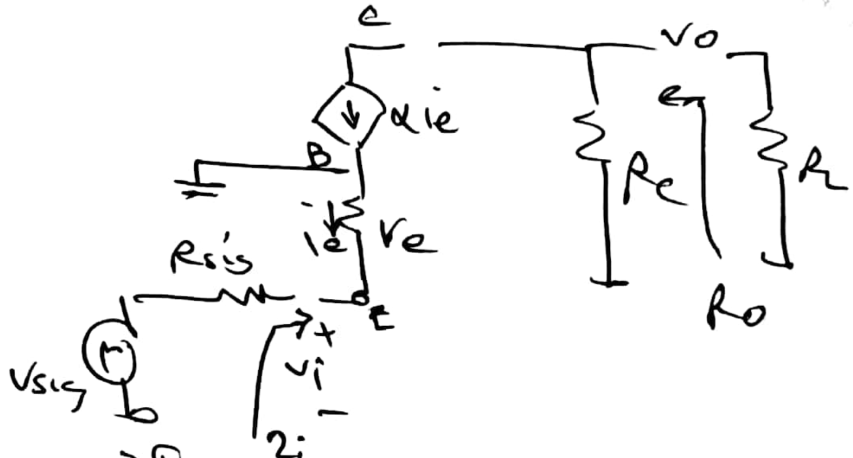
Common Base

ac model



$r_e = \frac{V_T}{I_E}$





$v_{o_0} = -\alpha i_e R_c$ → ①

$v_o = -\alpha i_e (R_c \| R_L)$ → ②

∵ $i_e r_e + v_i = 0$

$v_i = -i_e r_e$ → ③

∴ $A_{v_0} = \frac{v_{o_0}}{v_i} = \frac{eq①}{eq③} = \frac{-\alpha R_c}{-r_e} = \frac{\alpha R_c}{r_e}$ # ✓

$A_v = \frac{v_o}{v_i} = \frac{eq②}{eq③} = \frac{-\alpha (R_c \| R_L)}{-r_e} = \frac{\alpha (R_c \| R_L)}{r_e}$ # ✓

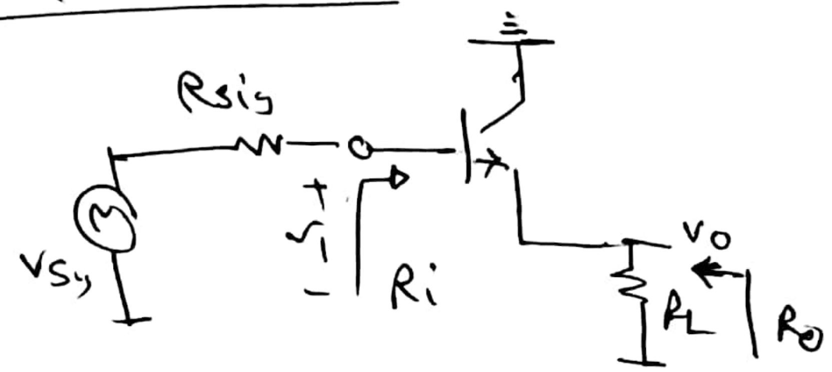
From eq ③ ∵ $R_{in} = \frac{v_i}{i_i} = \frac{v_i}{-i_e} = r_e$ # ✓

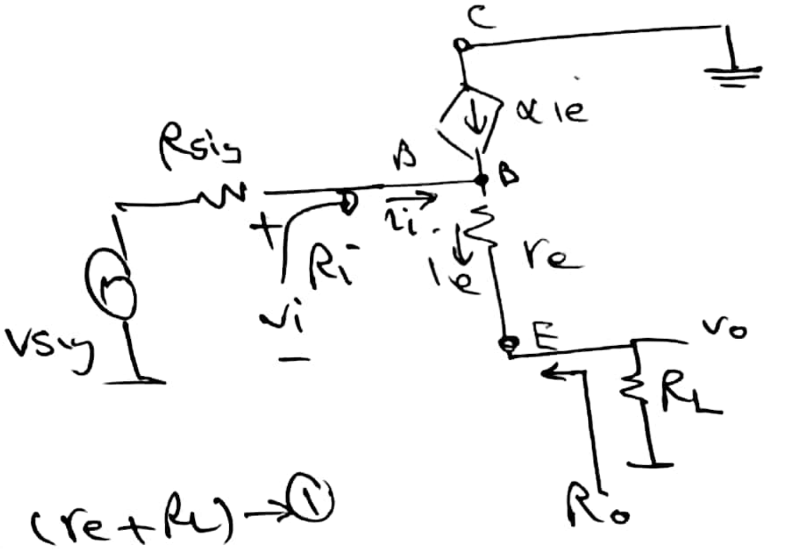
Ro↓ s-c on vi ∴ $i_e = 0$, so $\alpha i_e = 0$ (open circuit)

$R_o = R_C$ # ✓

10/

Common Collector (emitter follower)





$v_i = i_e (r_e + R_L) \rightarrow (1)$

$v_o = i_e R_L$

$\therefore \frac{v_o}{v_i} = \frac{R_L}{r_e + R_L}$ (#) ✓ since $r_e << R_L$)

$\therefore \frac{v_o}{v_i} \cong 1$

هذا معناه ان ا/ر بيعرفني I/P
تم ملاحظة بالتعرف في E
ولذا يسمى بـ emitter follower

at node B

$i_i + \alpha i_e = i_e$

$i_i = (1-\alpha) i_e \rightarrow (2)$

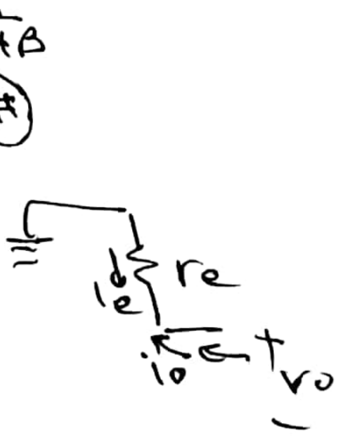
from eq (1), (2)

$R_{in} = \frac{v_i}{i_i} = \frac{i_e (r_e + R_L)}{(1-\alpha) i_e} = \frac{r_e + R_L}{1-\alpha}$

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

$\therefore R_{in} = (1+\beta)(r_e + R_L)$ ✓ (#)

Ro calculation



$\therefore i_e r_e + v_o = 0$

$-i_o r_e + v_o = 0$

$v_o = i_o r_e$

$R_{out} = \frac{v_o}{i_o} = r_e$ (#) ✓