ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

دفتر لمادة:

الكترونيات (2)

من شرح:

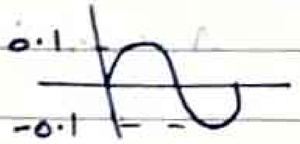
د.هادي العيثاوي

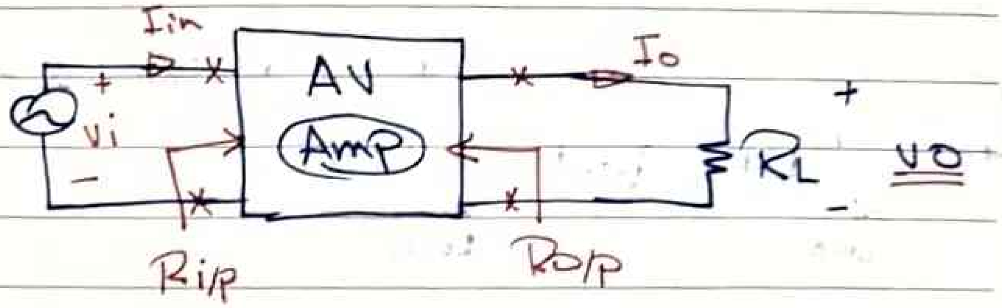
جزيل الشكر للطالب:

محمد صباح

* non-inverting ⇒ Phase shift = 0°

* inverting ⇒ Phase shift = 180°

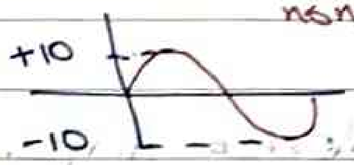




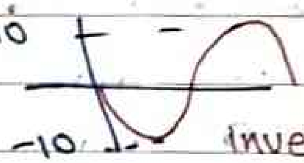
$Vo = AV \cdot Vi$

$AU = \frac{VO}{Vi} = \frac{10}{0.1} = \underline{100}$ ⇒

volt. Gain



$AV = \frac{Vo}{Vi} = \frac{-10}{0.1} = \underline{\underline{-100}}$ ⇒



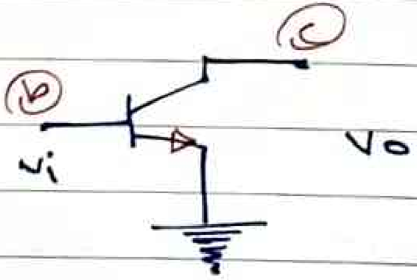
$(AI = \frac{Io}{Iin})$

⇒ يشتغل بال FAM

* BJT Amp :-

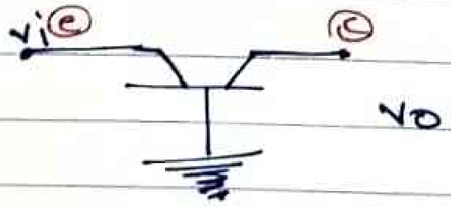
① C.E Amp

المشترك (يعني اللي رايح للارض)



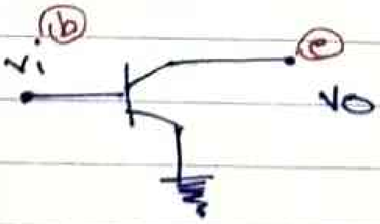
⇒ تكبر التيار والفولتية

② C.B Amp



⇒ تكبر الفولتية ولا تكبر I

③ C.C Amp

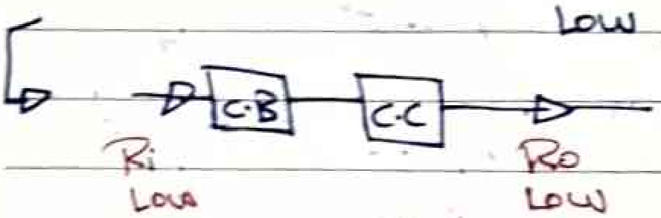


⇒ تكبر I ولا تكبر V

④ Multistage.

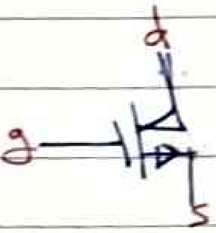
* نعمل dc.AnL وبعدين بنشوف اذا بشتغل بال FAM واذا حقق الشرط بروح Ac.AnL

* اذا بدي اعمل I/P & O/P ⇐ Low



* Mosfet Amp :-

↳ بشتغل على ال sat.



① C.S Amp
② C.G Amp
③ C.D Amp
④ cascade

* بفحص ال Mosfet على dc Analys. وتكون بال on sat بعدين Ac. Analys.

* ∫ / $\frac{d}{d()}$ / Amp & invert / Amp & non-invert. / multip

- - - - - وظائف ال Amp

* $I_{BQ} \xrightarrow{\text{طلع}} I_{CQ} \xrightarrow{\text{يسبب}} V_{CEQ} \Rightarrow$ DC.

* total response = DC Res $\boxed{3}$ + Ac Res.

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ch XI

* The BJT must be biased in F.A.M to be used as an Amp.

* The Amp. is a Linear Net. used to Amplify A.C input signal.

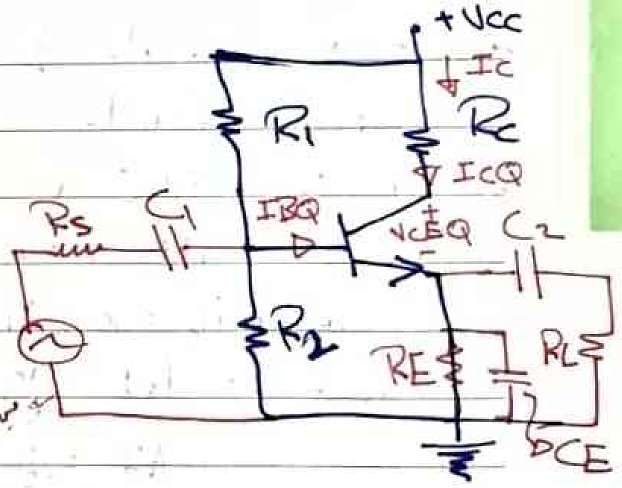
* Any Amp. must contain:-

a)- D.C source(s)
(to biase the Active device in proper mode)

b)- Ac. Source to supply Ac input signal

c)- capacitors (coupling & blocking)
C_1 , C_2

d)- Resistors
biasing (R_1, R_2, R_E)
To control VCE (R_C)
To stab. Q-pt (R_E)
as a Load (R_L)



Dc
$C_1, C_2, C_E \Rightarrow$ open cct

Ac
$C_1, C_2, C_E \Rightarrow$ short cct

* حطينا $\boxed{C_1}$ عشان ما يمر تيار ال Ac
بال source ال بيطلع Pdisp من Rc
بس لما نحط ال cap ال تعطي open cct
وما ال يمر تيار بالاصل

* $R_L \Rightarrow$ Load
* $R_C \Rightarrow V_{CE} = V_{CC} - I_C R_C \Rightarrow$ I_C تحدد ال $\Rightarrow$ to protect I_C
* $R_1, R_2 \Rightarrow$ volt. devid $\Rightarrow$ Biasing Res. $\Rightarrow$ to control I_B & I_C
* $R_E \Rightarrow$ stablized Q-point against β varyation

* حطينا ال CE عشان ال AV تكون قليلة بس حاطط ال cap وبال AC ح تصير short cct ودة غير التيار بالملي وصفر ال AV ح تصير عالية .

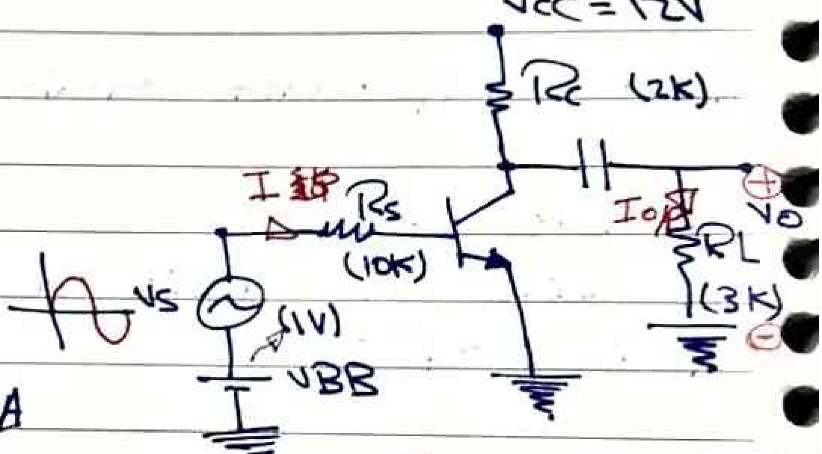
graphical Analysis of basic Amp.

① calculate :-
IBQ , ICQ , VCEQ

② Draw D.C.L.L & Located Q-Pt

③ if Vs drives a base current of the form $i_b = 20 \sin \omega t \ \mu A$
calculate :- $A_V = \frac{V_o}{V_s}$

$A_I = \frac{I_o}{I_s}$



$\beta = 100$, $V_{BE} = 0.7V$

④ write expressions for:-
IB , Ic , VcE

Sol :-

since the Amp is Linear cct so superposition is used.

① D.C source effect ($V_s = 0$)

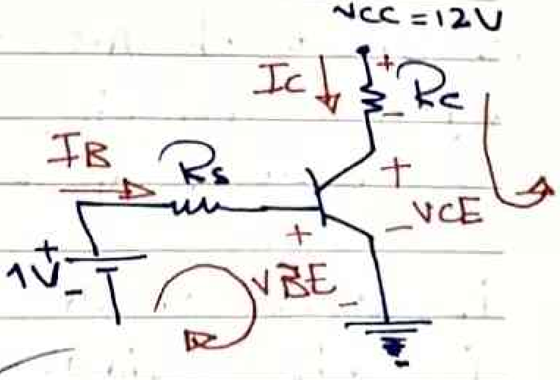
for D.C. Anal. ⟹ A.C → short cct.
cap → O.cct.

⟹

* FAM ⇒ NPN → VC > VB → Reverse
→ Forward.

$\boxed{5}$

* Assume BJT in FAM.



$-1 + I_B R_s + V_{BE} = 0$

$I_B = \frac{(1-0.7)V}{10K} = 0.03mA$

$= \boxed{30\mu A = I_{BQ}}$ ✓

$I_C = \beta I_B = 100 * 0.03 = \boxed{3mA = I_{CQ}}$

$-V_{CC} + I_C R_C + V_{CE} = 0$

$V_{CE} = 12 - 3*2 = \boxed{6V = V_{CEQ}}$ ✓

② D.C.L.L

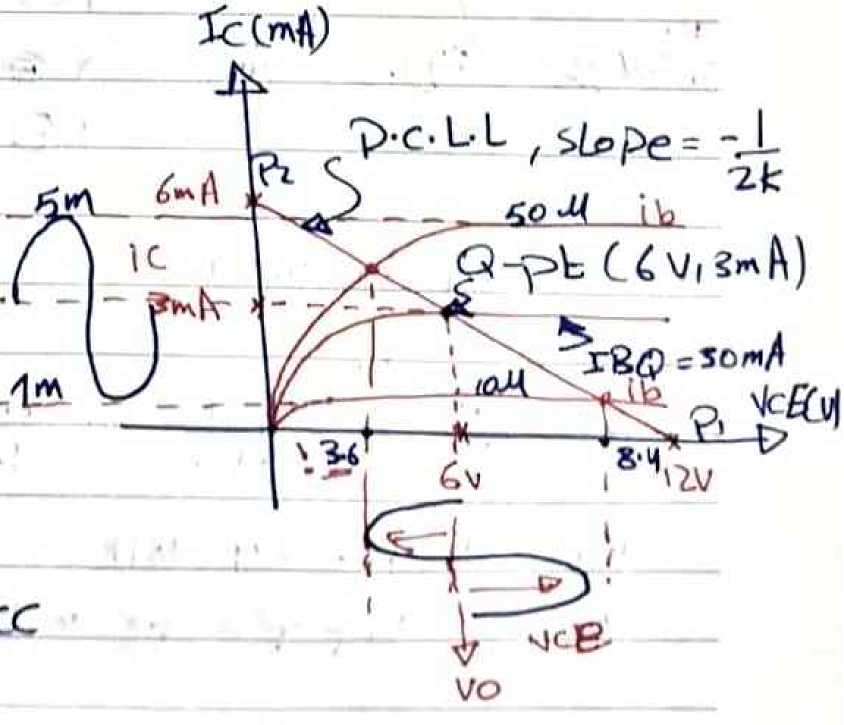
KVL for C-E Loop

⇒ $-V_{CC} + I_C R_C + V_{CE} = 0$

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

D.C.L.L. eq.

slope $= -\frac{1}{R_C}$



VCE(V)

① for $I_C = 0$, $V_{CE} = V_{CC}$

$P_1 (12V, 0)$

② for $V_{CE} = 0$, $I_C = \frac{V_{CC}}{R_C} = 6mA$

$P_2 (0, 6mA)$

2, 10

2+5sin, 10+sin ?

* كيف طلعت قيم 3.6 ,8.4 ؟؟ بطلع معي بالكلي

* اذا مافي RL خلاق ال Rc تعمل عمل ال RL وال $I_{o/p}$ تصبح على Rc

$\boxed{6}$

② Effect of A.C source (DC → S.C)

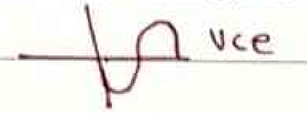
* For AC Analysis

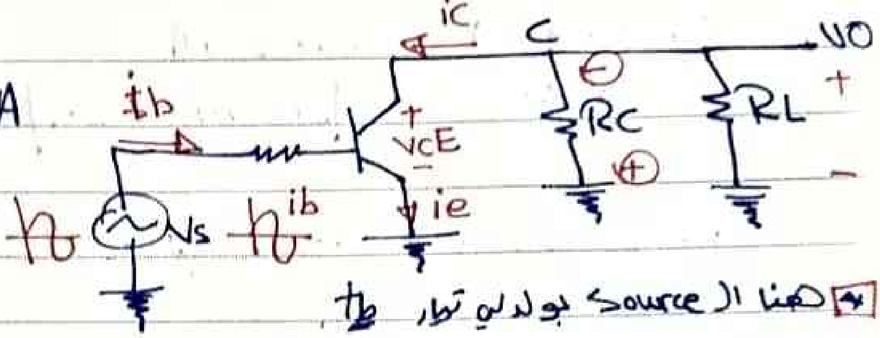
D.C → S.C , cap → S.C

$i_b = 20 \sin \omega t \ \mu A$

$i_c = \beta i_b = 2 \sin \omega t \ mA$

$v_{ce} = -i_c (R_C // R_L)$





* هنا ال Source بولدلي تيار i_b واللي يولد فرق جهد مقداره vcE : واللي ينتج عنه التيار ic

* According to superposition

$i_B = I_{BQ} + i_b \Rightarrow i_B = (30 + 20 \sin \omega t) \mu A$

Total Res → D.C → A.C

$i_C = I_{CQ} + i_c = (3 + 2 \sin \omega t) \ mA$

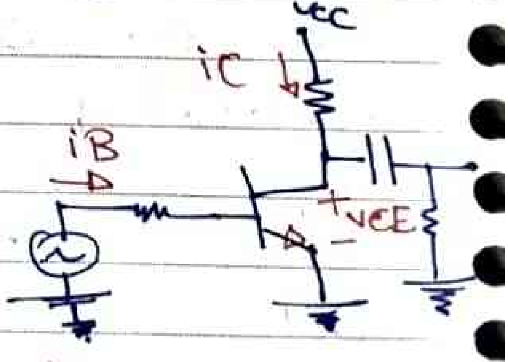
$V_{CE} = V_{CEQ} + v_{ce}$

$v_{ce} = -i_c (R_C // R_L) = -2 \sin \omega t \ (3 // 2)$

$= -2.4 \sin \omega t \ ⓥ$

$v_{ce} = 6 - 2.4 \sin \omega t \ V$

③ $A_V = \frac{v_o}{v_s} = \frac{v_{op-p}}{v_{sp-p}} = \frac{v_{op}}{v_{sp}}$



$v_{op} = v_{cep} = 2.4 \ \underline{Volt}$

$v_{op-p} = v_{cep-p} = \underline{4.8} \ Volt$

for this ccb $I_s = I_B$

$A_I = \frac{I_o}{I_s} = \frac{\frac{v_o}{R_L}}{I_b} = \frac{-0.8 \sin \omega t}{0.02 \sin \omega t} = -40 \ mA$

\# i_c max → V_{ce} min
i_c min → V_{ce} max

* V_{ce} → ?? بعمل Ic ال Projection على D.C.L.L وباخذ نقاط التقاطع دبرا F

BJT in FAM ← open cct ← بين b و e

Reverse biase PN Junc ←

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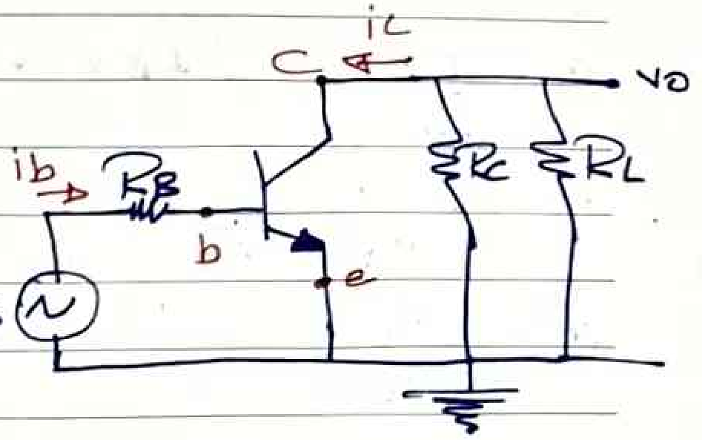
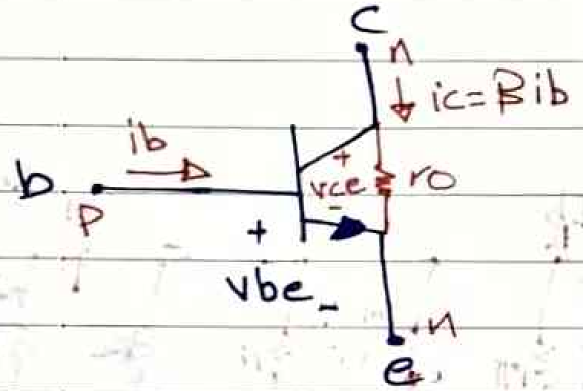
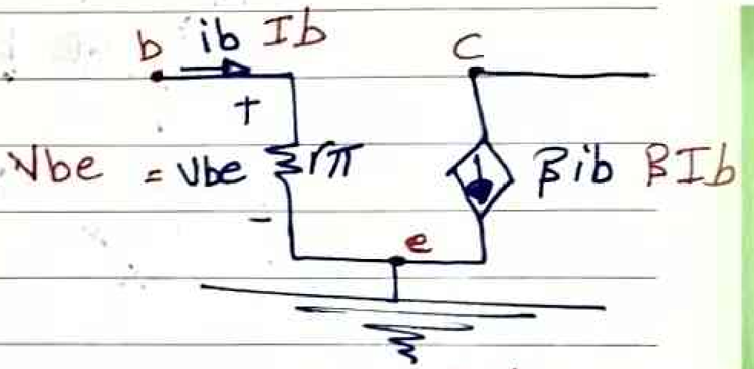
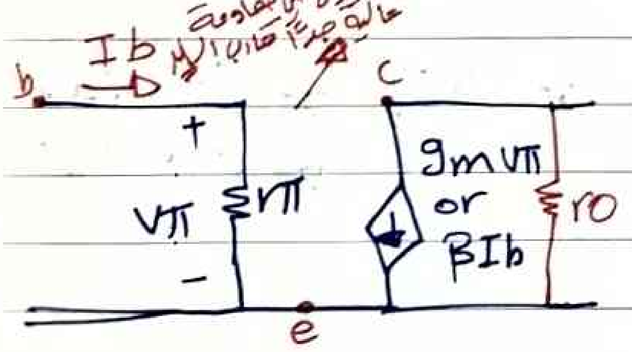
* To perform AC Analysis the BJT is replaced by its **hybrid-π model**







* currents in Red represents phase current.



hybrid-π model

rπ :- Diffusion resistance (B-E resistance)

$$r\pi = \frac{\beta V_T}{I_{CQ}}$$

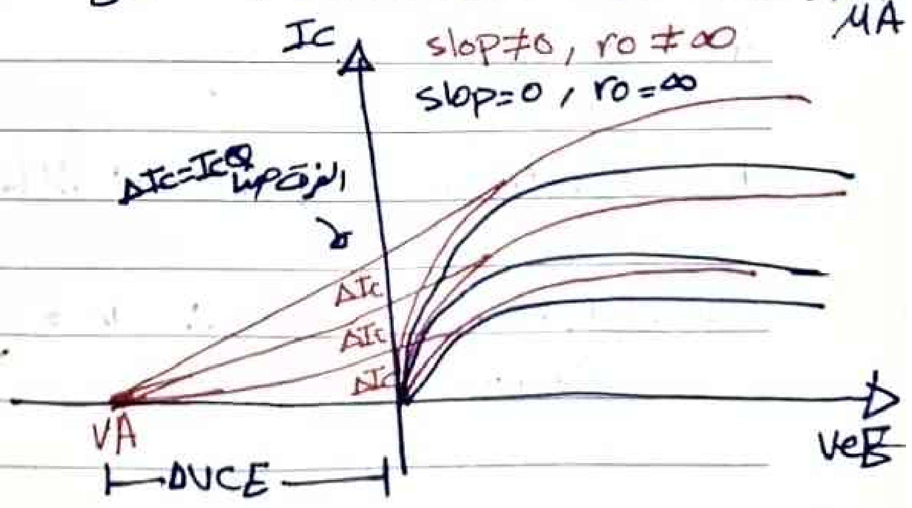
gm :- Transconductance (A/V), mA, μA

- $g_m = \frac{I_{CQ}}{V_T}$ (mA/V)

- $r_o = \frac{V_A}{I_{CQ}}$ Ω ⇝ D.C Anal.

- VA :- Early voltage

(50 < VA < 300) V



* اذا اعطاني VA احسب ro ← small

* اذا ما في VA ∞ معناه ro=∞ ← يعني ما في ro

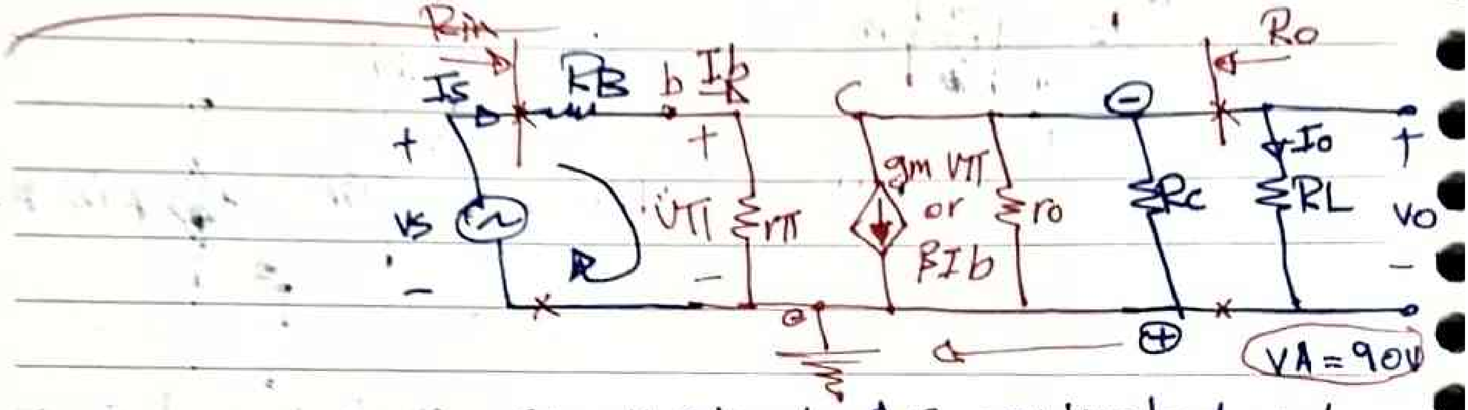
* small signal ⇒ Linear لا تمزج ال linearity
↳ Input signal → small → لا تحركلي ال Q-Pt

\[3\]

$$r_o = \frac{\Delta V_{CE}}{\Delta I_C} \quad (I_B = \text{constant})$$

$$r_o = \frac{1}{\text{slope of } I_C \text{ Lines}}$$

$$r_o = \frac{V_A}{I_{CQ}}$$



small-signal A.C equivalent cct

* Calculate :- AV , AI
Input Res. (Rin)
output Res. (Ro)

* اذا ما في RL فإن ال Io تكون على ال Rc .

Sol:-

$$A_V = \frac{V_o}{V_S}$$

$$V_o = -g_m v_\pi \overline{R_L} \quad , \overline{R_L} = r_o \,//\, R_C \,//\, R_L$$

$$v_\pi = \frac{V_S \cdot r_\pi}{r_\pi + R_S} \qquad \therefore V_o = -g_m \overline{R_L} \, \frac{V_S \cdot r_\pi}{r_\pi + R_B}$$

⇒

* ال Rin ⇐ ننظرلها من ال Input لا and
* ال Ro ⇐ ننظرلها بعند Rc الا اذا اعطاني بالسؤال including RL

* لو اعطاني شكل ال v_s بقدر ارسم ال v_o (in this ex.)

$$\frac{v_o}{v_s} = A_V = -g_m \bar{R}_L \frac{r_\pi}{r_\pi + R_B}$$

$\ominus$ means 180° phase shift between v_o & v_s (only in C.E)

$$A_V = \frac{v_o}{v_s} = \frac{v_o}{v_\pi} \cdot \frac{v_\pi}{v_s}$$

$$\underline{\underline{I_{CQ} = 3mA}}$$

$$= -g_m \bar{R}_L \frac{r_\pi}{r_\pi + R_B}$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{3mA}{26mV}$$ A/V → mA/V بس انا بدي اياه

$$g_m = \frac{3000}{26} \text{ mA/V} \simeq 115 \text{ mA/V}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{100 * 26mV}{3mA} = 860 \Omega$$

$$\Rightarrow \bar{R}_L = r_o // R_C // R_L$$

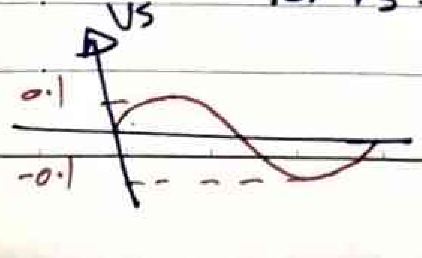
$$r_o = \frac{V_A}{I_{CQ}} = \frac{90V}{3mA} = 30 K\Omega$$

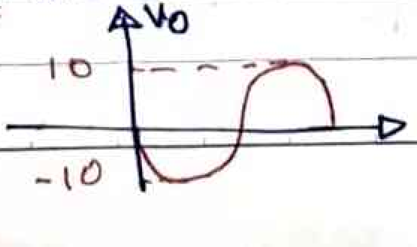
$$\bar{R}_L = 30K // 2 // 3K \Rightarrow \bar{R}_L = 1.1 K\Omega$$

$$A_V = 115 * 1.1 \frac{0.86}{10 + 0.86} = -126 * 0.08 = \underline{\underline{-10}}$$

$$A_V = \frac{v_o}{v_s} = -10 \Rightarrow v_o = -10 v_s$$

for $v_s = 0.1 \sin wt$ V $\Rightarrow v_o = -1 \sin wt$





⇒

$$A_I = \frac{I_o}{I_s} = \frac{I_o}{I_b} \cdot \underbrace{\frac{I_b}{I_s}}_{} \rightarrow 1 \text{ (for this cct)}$$

current.dev.

بسبب انه عكس
حركة التيار

$$I_o = \boxed{-} \beta I_b \cdot \frac{\bar{R_c}}{\bar{R_c} + R_L} \Rightarrow \frac{I_o}{I_b} = \frac{-\beta \bar{R_c}}{\bar{R_c} + R_L}$$

$$\bar{R_c} = r_o // R_c$$

$$\frac{I_b}{I_s} = 1 \Rightarrow \therefore A_I = -\frac{\beta \bar{R_c}}{\bar{R_c} + R_L}$$

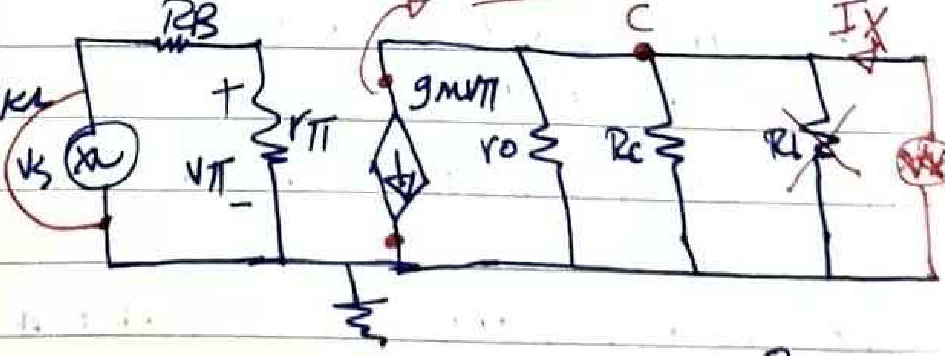
$$\bar{R_c} = 30K // 2K = 1.8K$$

$$\Rightarrow A_I = -\frac{100 * 1.8}{1.8 + 3} = -\frac{180}{4.8} = \underline{-37.5}$$

R_{in} ?? $\Rightarrow R_{in} = R_B + r_\pi$

$R_{in} = 1.0 + 0.86 = 10.86 K\Omega$

open cct



$$\Rightarrow R_o = \frac{V_x}{I_x}\Big|_{V_S = 0}$$

KVL at node C

$\rightarrow$ since $V_S = 0 \Rightarrow V_\pi = \frac{V_S r_\pi}{r_\pi + R_B} \rightarrow 0$

$$\Rightarrow I_x = \frac{V_x}{R_c} + \frac{V_x}{r_o} + g_m V_\pi$$

$\Rightarrow$

$$\frac{I_x}{V_x} = \frac{1}{R_C} + \frac{1}{r_o} = \frac{1}{R_o}$$

$\therefore \boxed{R_o = R_C // r_o}$

when $V_S = 0 \Rightarrow V_\pi = 0 \Rightarrow \therefore g_m V_\pi = 0$

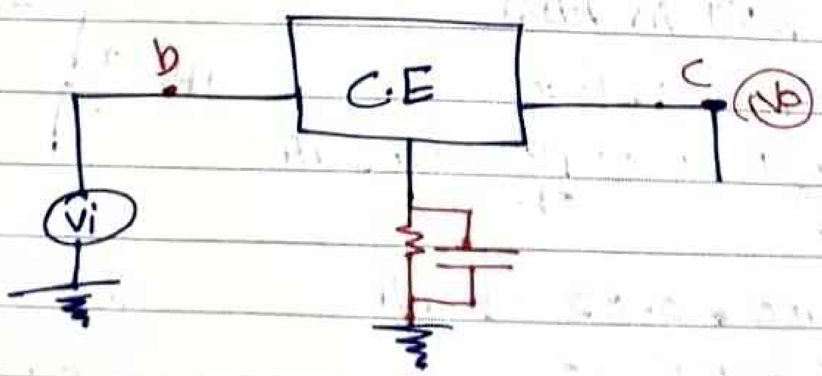
$\therefore$ Dependent C.S is O.C

$\therefore R_o = R_C // r_o = 2 // 30K \Rightarrow R_o = 1.98\ k\Omega$

Single Stage BJT Amp

① common Emitter Amp CE

Vi → base , Vo from C
e → common Terminal



Basic C.E

C.E with RE

C.E with RE & CE

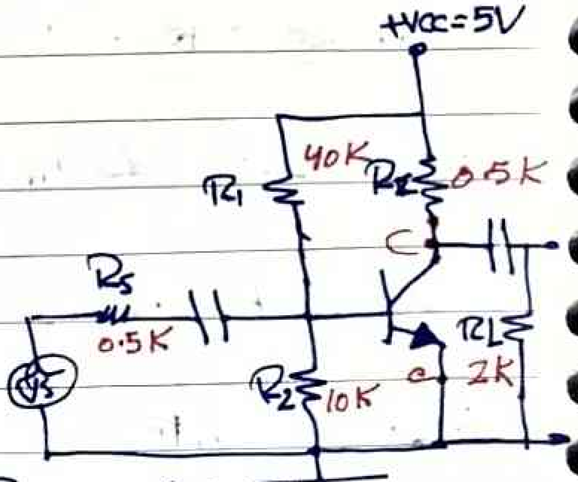
* اذا ماكانت ال BJT بال FAM ← ما بقدر استخدمه ك <u>Amp</u>

$\boxed{12}$

① Basic C.E Amp.

E → is directly connected to ground

<u>Ex:-</u>



β = 100, VBE = 0.6

VA = ∞

① Calculate ICQ, VCEQ

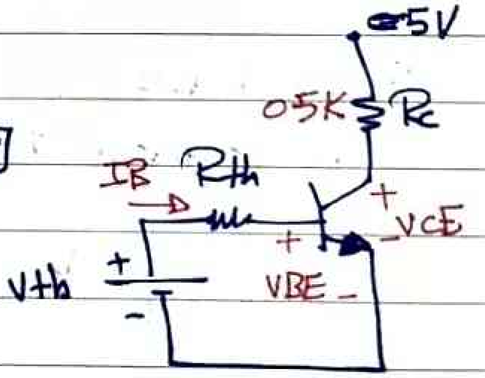
② Draw s.s. AC equivalent cct & find:- AV, AI, Ri, Ro

③ Draw D.C & A.C.L.L & find their slope

<u>SoL:-</u>

① D.C. Analysis.

cap → O.C , AC → S.C



$R_{th} = R_1 // R_2 = 10 // 40 = 8K$

$V_{th} = 5 * \frac{R_2}{R_1+R_2} \Rightarrow V_{th} = \frac{5*10}{40+10} = \boxed{1V}$

Assume the BJT in FAM

$-V_{th} + I_B R_{th} + V_{BE} = 0$

$I_B = \frac{(1-0.6)V}{8K} = \frac{0.4V}{8K} = 0.05mA$

$I_C = \beta I_B = 100 * 0.05 = 5mA$

$-5 + I_C R_C + V_{CE} = 0$

$V_{CE} = 5 - 5 * 0.5 = 2.5 V$

IB = + ✓

VCE > VBE ✓

BJT FAM conditions ⇒

* ال Rin ← ننظرلها من بعد ال Rs لانو ال Rs هي مقاومة ال Vs الا بحالة
طلب Find Rin seen by the volt source ↳Rin=(RL//rπ)

* R_{ib} ⇒ Rinput seen by the base (b)

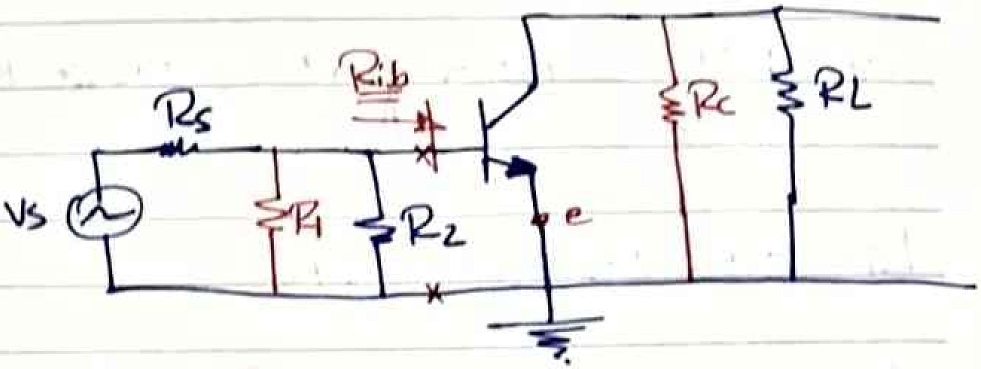
↳ يعني كمستقبلها عند ال b

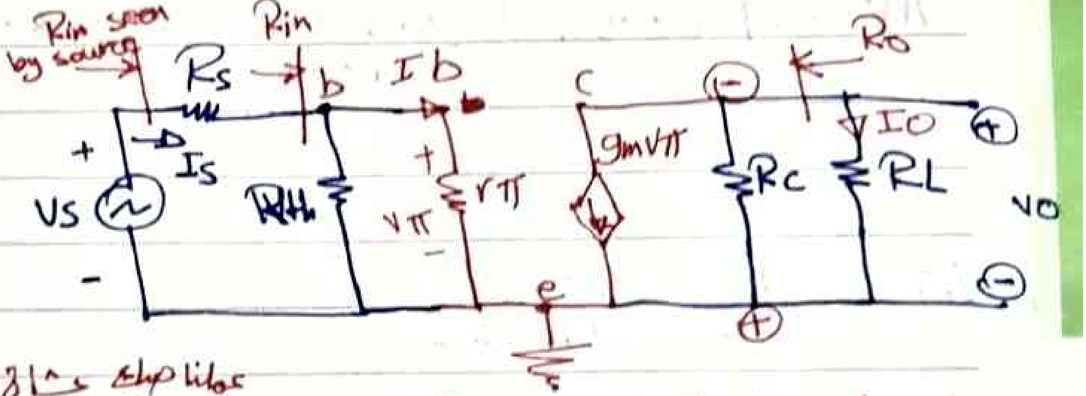
$\boxed{B}$

تعتبرها صفر لأنه Vcc بيصير Zero

بساوي DC Q يعني متصل بال Gnd

② A.C. Analysis





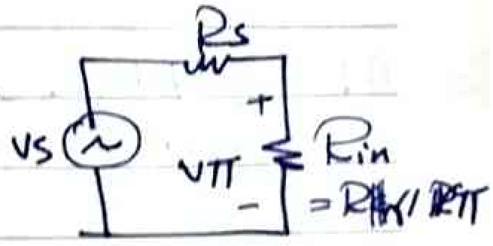
VΠ, rΠ عمل عليها عشان ما نستخدم

S.S. A.C equivalent cct.

$$\Rightarrow VA = \frac{V_o}{V_s} = \frac{V_o}{V_\pi} \cdot \frac{V_\pi}{V_s}$$

$$V_o = -g_m V_\pi (R_c // R_L) \Rightarrow \frac{V_o}{V_\pi} = -g_m (R_c // R_L)$$

$$\frac{V_\pi}{V_s} = \frac{R_{in}}{R_{in} + R_s} \quad (V.D)$$



$$\therefore AV = -g_m (R_c // R_L) \frac{R_{in}}{R_{in} + R_s}$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{5mA}{26mV} = 192\,m\,A/V$$

$R_{in} = R_{th} // R_\pi$

⇒

---

* C.E ⇒ تكبير ال V
و ال I

$R_{in} = R_{th} // r_\pi$

$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{100 * 26mV}{5mA} \simeq 0.520\ K\Omega$

$R_{in} = 8 // 0.52 \simeq 0.5 K\Omega$

$A_V = -192(0.5//2)\ \frac{0.5}{0.5+0.5} = -192 * 0.4 * 0.5$

$A_V = -38$

$\Rightarrow A_I = \frac{I_o}{I_s} = \frac{I_o}{I_b} \cdot \frac{I_b}{I_s}$

$I_o = -\beta I_b \frac{R_c}{R_c+R_L} \Rightarrow \frac{I_o}{I_b} = \frac{-\beta R_c}{R_c+R_L}$

(current. Dev)

$I_b = I_s \cdot \frac{R_{th}}{R_{th}+r_\pi} \Rightarrow \frac{I_b}{I_s} = \frac{R_{th}}{R_{th}+r_\pi}$

$A_I = \frac{-\beta R_c}{R_c+R_L} \cdot \frac{R_{th}}{R_{th}+r_\pi}$

$= \frac{-100 * 0.5}{0.5+2} \cdot \frac{8}{8+0.52} = -18$

$R_o = \frac{V_x}{I_x}\Big|_{V_s=0}$

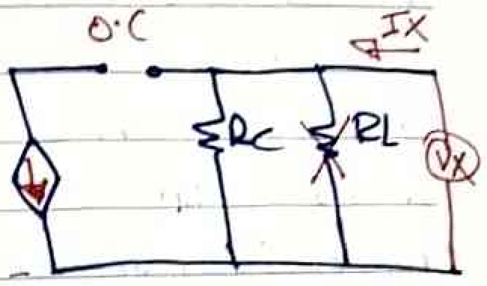
* كما بدينا ارسم ال A.C.L.L برسم ال Ac. cct (مش ال equiv.)
لي بطلع نقطة تقاطع يا على ال V او على I و بوصل من النقطة و بيرزها بال Q-pt

$$\Rightarrow R_o = \frac{V_x}{I_x}\Big|_{V_s=0}$$

when $V_s = 0$, $V_\pi = 0$

$g_m V_\pi = 0 \Rightarrow$ D.C.S is $\boxed{O.C}$

$\therefore R_o = R_C = 0.5\,K$



D.C & Ac.L.L

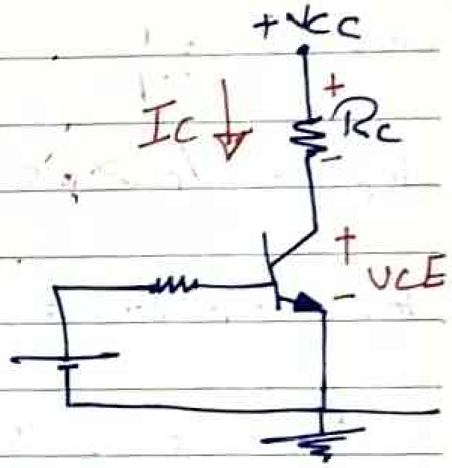
- KUL for C.E Loop:-

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

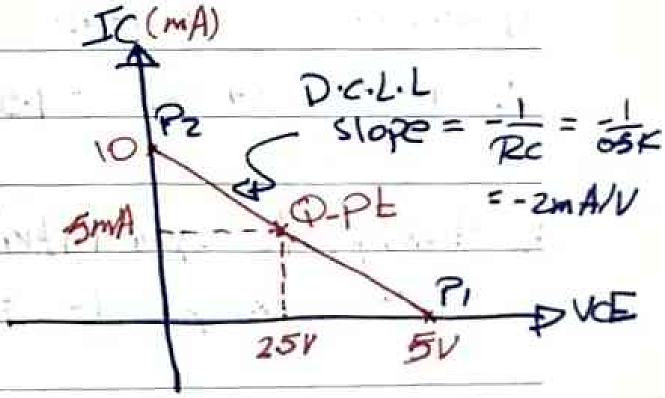
$$\boxed{I_C = \frac{V_{CC}}{R_C} - \frac{V_{CE}}{R_C}} \text{ ... D.C.L.L}$$

$y = b + mX$

slope $= -\frac{1}{R_C}$



Ⅰ for $I_C = 0$, $V_{CE} = V_{CC}$
$P_1 (V_{CC}, 0)$



slope $= -\frac{1}{R_C} = -\frac{1}{0.5K}$
$= -2\,mA/V$

Ⅱ for $V_{CE} = 0$, $I_C = \frac{V_{CC}}{R_C} = \frac{5}{0.5} = 10$
$P_2 (0, 10mA)$

Q-Pt (V_{CEQ} , I_{CQ})
(2.5V , 5mA)

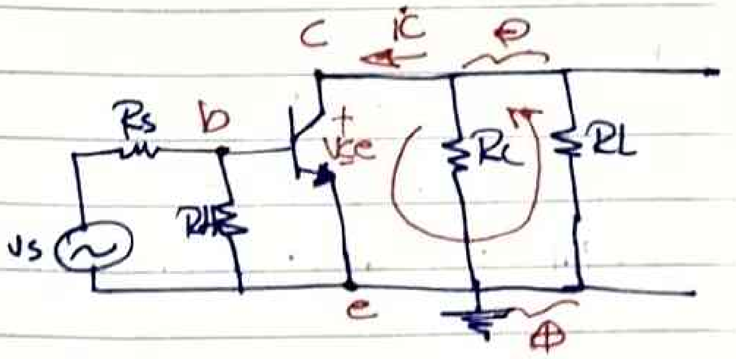
⟹

* ال Q-pt هي نقطة تقاطع خطين ال D.C&A.C.L.L ⇐ عندها ic , vce=0

* the interception between A.c.L.L & x-axis ⇒ the max Peak output signal volt without distortion

$\Delta V_{CE}, V_{CE}$

A.c.L.L



Draw A.C cct

-KVL for c-e Loop

$v_{ce} + i_c (R_c // R_L)$

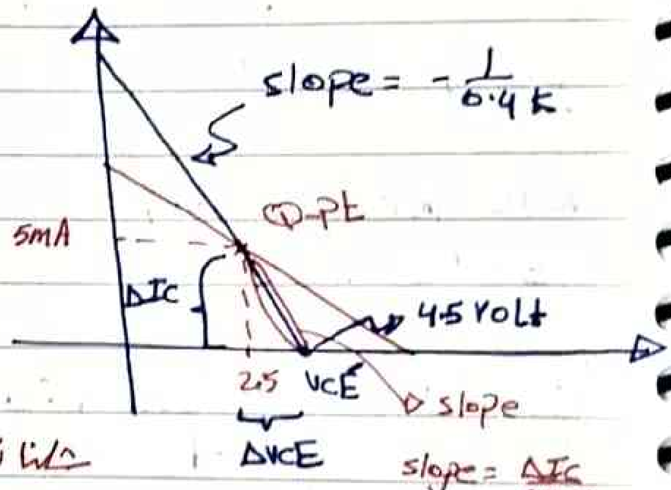
A.c.L.L eqn

$v_{ce} = -i_c (R_c // R_L)$

$slope = \frac{-1}{(R_c // R_L)}$

$slope = \frac{-1}{0.4}$

* slope for Ac > Dc



$slope\ of\ A.c = \frac{\Delta I_c}{\Delta V_{CE}}$

$\frac{1}{(R_c // R_L)} = \frac{5-0}{V_{CE}-2.5}$ → طرفين في وسطين

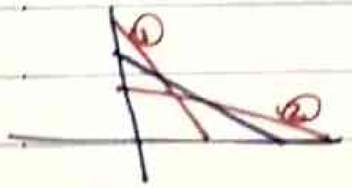
$\therefore V_{CE} = 2 + 2.5 = 4.5$

* Max. Peak symmytrical o/p voltage

$V_o(max)\ Peak = I_{CQ} (R_c // R_L)$

* max peak to peak symmytrical o/p voltage

$v_o (max)_{p.p} = 2 I_{CQ} (R_c // R_L)$



slope① > slope②

* لا يمكن ال slope AC < slopeDC
دائماً ال AC ⇐ أكبر او مساوي .

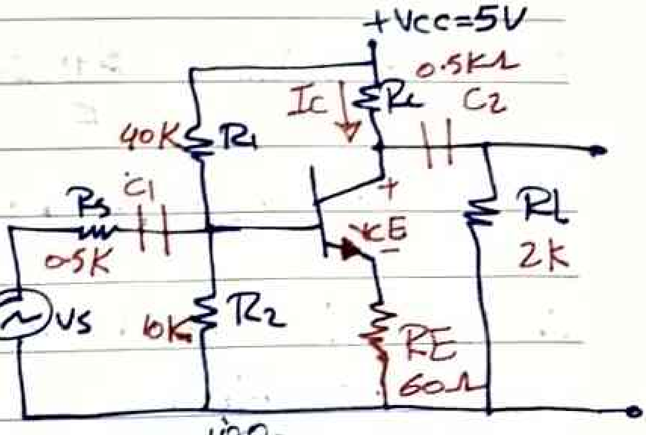
شرط المساواة ⊲ اذا Rc موجودة
⊲ اذا Rc & RL موجودات

* ال IB ما بتغير لانو من ال DC وال Rth ثابتة (من حالة تغير قيمة ال β)

* لما حطينا قيمة $\beta = 200$ ← لما اعمل KVL لل VCE ← ح يطلع فولتية VCEsat سالبة

0.7>0 يعني FAM ← the transistor in sat mode

II CE with RE



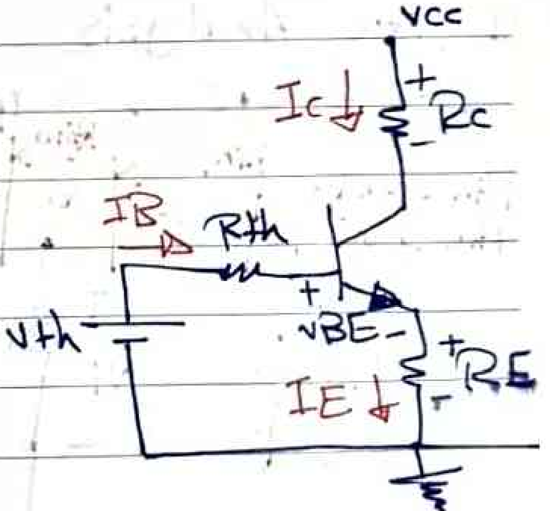
$\overset{100}{\beta = 200}$, $V_{BE} = 0.6V$

* without RE the BJT transistor in sat mode Becuase the Both Junction in ~~FAM~~ forward

* if we add RE ⇒ FAM
  ↳ stablized Q-pt (function) against β variation

① D.C Analysis:-

AC → S.C, cap → O.C



$V_{the} = \frac{5*10}{50} = 1V$

$R_{th} = 10//40 = 8K$ = ~~2.76V~~

$-V_{th} + I_B R_{th} + V_{BE} + \overset{\to (\beta+1)I_B}{I_E} R_E = 0$

$I_B = \frac{V_{th} - V_{BE}}{R_{th} + (\beta+1)R_E} = \frac{(1-0.6)}{[8 + (201)*60]} = \frac{0.4V}{20K}$

$I_B \triangleq 0.02mA$, $I_{CQ} \simeq \beta I_B = 4mA$

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

$IE = (\beta+1) IB = \frac{\beta+1}{B} IC = 4.02 mA$

$VcE = 5 - 4 * 0.5 - 4.0 * 0.06 = 2.76$ volt

∴ RE is used to stablize Q-Pt against β varyation

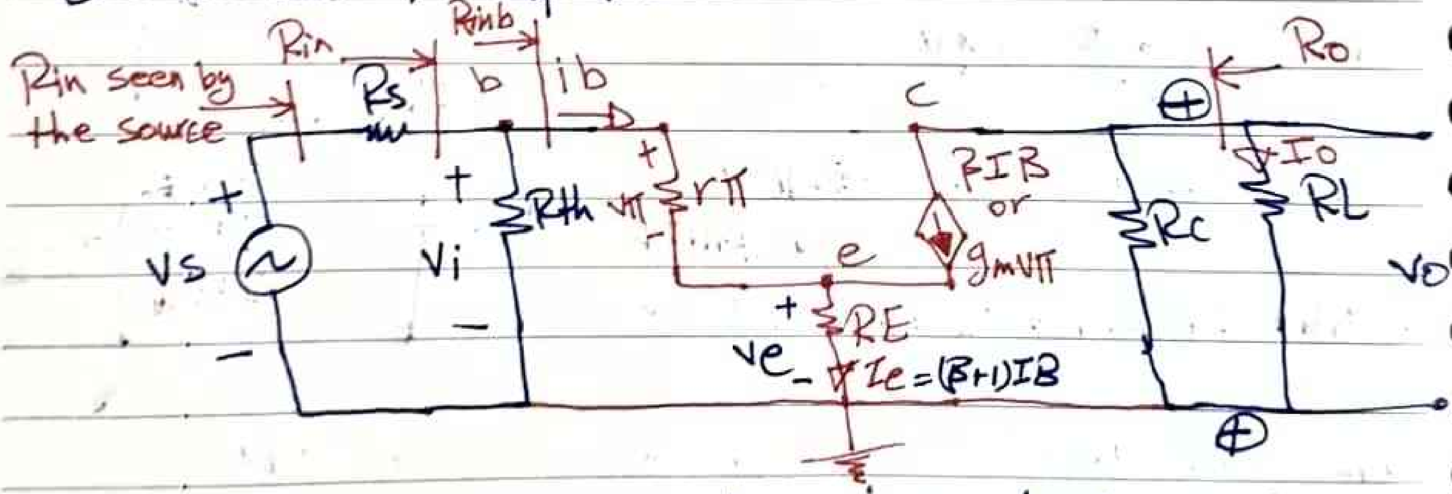
* for bias-stable design ⇒ choose $Rth = 0.1(\beta+1)RE$

* to check bias-stable condition ⇒ $Rth \leq 0.1(\beta+1)RE$

---

② A.C Analysis

D.C → S.C , cap → S.C



s.s. AC equivalent cct.

$AV = \frac{Vo}{VS} = \frac{Vo}{Vi} * \frac{Vi}{VS}$

$Vo = -\beta Ib (Rc \parallel RL)$ ⇒

↳ Advantage.

increase $\underline{R_{in}}$ ⇐ increase R_{ib} ⇐ reduce $\underline{AV}$ ⇐ RE بوجود ال *

*AV ⇒ unitless → because $\boxed{19}$ its a ratio.

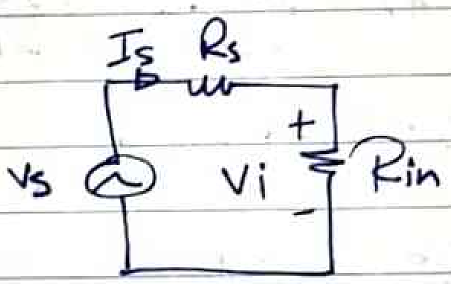
$$-V_i + V_\pi + V_e = 0$$

$$V_i = V_\pi + V_e = I_b r_\pi + (\beta+1) I_b . R_E$$

$$= I_b(r_\pi + (\beta+1)R_E)$$

$$\frac{V_o}{V_i} = \frac{-\beta(R_C // R_L)}{r_\pi + (\beta+1)R_E}$$

$$-R_{in} = R_{th} // R_{ib}$$



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

$$= r_\pi + (\beta+1)R_E$$

$$\frac{V_i}{V_s} = \frac{R_{in}}{R_{in}+R_s}$$

$$\therefore AV = \frac{-\beta(R_C // R_L)}{r_\pi + (\beta+1)R_E} \cdot \frac{R_{in}}{R_{in}+R_s}$$ ∴ R_E reduces A_V.

$I_{CQ} = 4mA$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{200 * 26mV}{4mA} = 1.3K\Omega$$

$$R_{ib} = 1.3K + (201) * 60 = 13K\Omega$$

⇒

* Resistance Refliction Rule * important *

* RE stablized the gain AV against β varyation
(Independent)

$R_{in} = 8K // 13 = 4.9\,K\Omega$ ∴ RE increases Rin

$$AV = \frac{-200(0.5 // 2)}{(1.3+12)\,K} \cdot \frac{4.9}{49+0.5}$$

$$AV = \frac{-80}{13} \cdot \frac{4.9}{5.4} \Rightarrow \underline{\underline{AV = -5.9}}$$

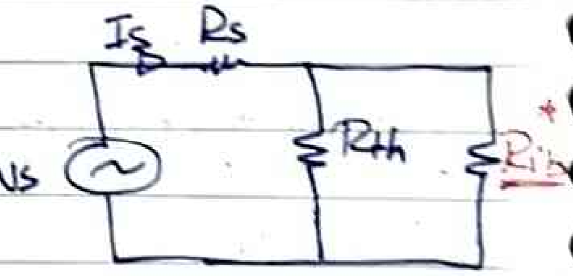
$$-\; AI = \frac{I_o}{I_s} \Rightarrow = \frac{I_o}{I_b} \cdot \frac{I_b}{I_s}$$

$$I_o = -\beta I_b \frac{R_c}{R_c+R_L}$$ (curr. dev. Rule)

$$\frac{I_o}{I_b} = \frac{-\beta R_c}{R_c+R_L}$$

$$I_b = I_s \cdot \frac{R_{th}}{R_{th}+R_{ib}}$$

$$\frac{I_b}{I_s} = \frac{R_{th}}{R_{th}+R_{ib}}$$



$R_{ib} = r\pi + (\beta+1)R_E$

$$\therefore AI = \frac{-\beta R_c}{R_c+R_L} \cdot \frac{R_{th}}{R_{th}+R_{ib}} = -\frac{200 * 0.5}{2.5} \cdot \frac{8}{8+13} = \boxed{-16}$$

∴ RE reduces AI

$$\Rightarrow R_o = \left.\frac{V_x}{I_x}\right|_{V_s=0}$$

When $V_s = 0$, $V_\pi = 0$, $I_b = 0$

βI_b or $g_m V_\pi = 0 \Rightarrow$ O.C

$\underline{\underline{R_o = R_c = 0.5k}}$

⇒

$$\therefore\ AV = \frac{-\beta\,(Rc\,//RL)}{r\pi + (\beta+1)RE} \cdot \frac{Rin}{Rin + Rs}$$

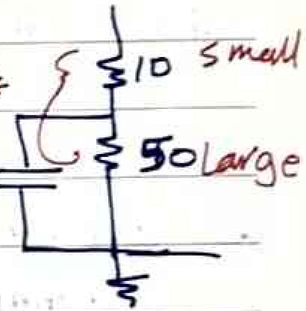
If $(\beta+1) >> r\pi$ & $\beta >> 1$, $Rin >> Rs$

$$\Rightarrow AV \simeq \frac{(Rc//RL)}{RE}$$

Ac

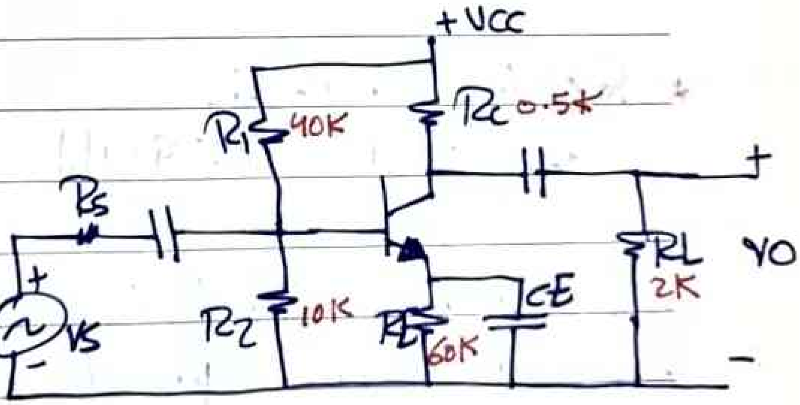
من (disadvantages) [illegible] كل ← RE

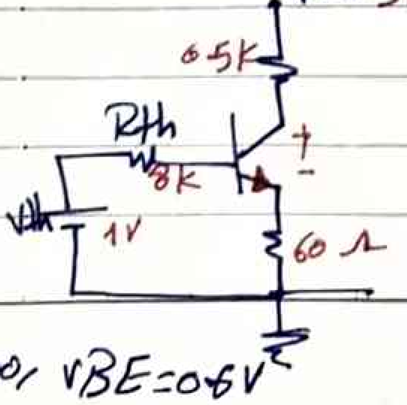
عشان يصير جيد كده ·-



III CE with bypass cap. CE:-

① for D.c Analysis
CE is O.c & the cct is
analyzed as CE with RE





$\beta = 200$, $VBE = 0.6V$

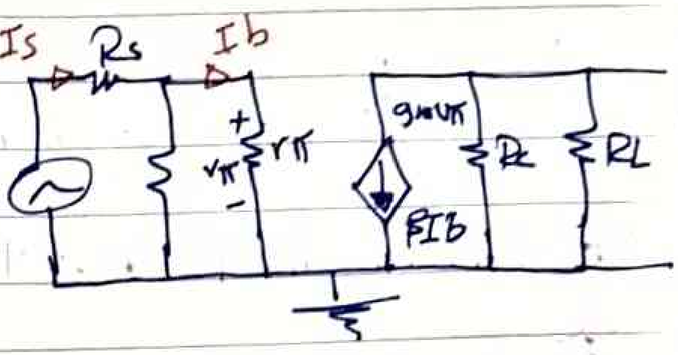
$ICQ = 4mA$
$VcEQ = 2.76\ V$.

⇒

* هنا ال Rin ⇐ Z1 تقل

* هنا ال AV Z2 يصير يعتمد على β يعني Dependent (الكل انو الجزء ال RE

② for Ac Analysis
CE → S.C → Cancells RE effect. the cct behaves as Basic C.E Amp.



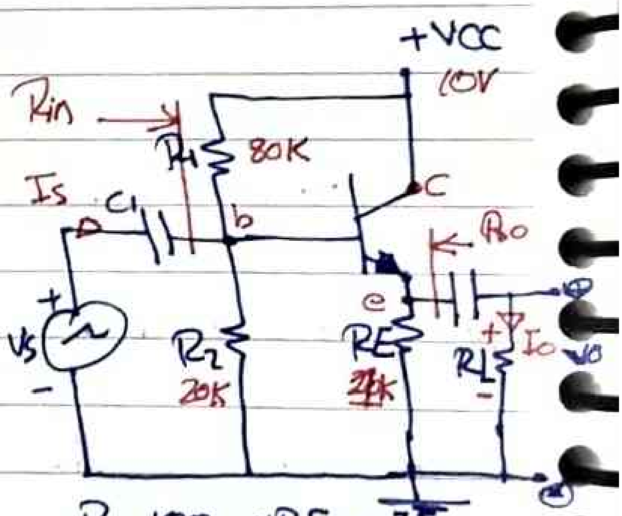
$$\Rightarrow A_V = -\frac{\beta(R_C // R_L)}{r_\pi} \cdot \frac{R_{in}}{R_{in}+R_S} \simeq \boxed{-45}$$

$$R_{in} = r_\pi // R_{th}$$

② common-collector Amp

c.c. Amp Emitter follower.

Vi → to base
Vo from Emitter
common Terminal is Ⓒ



β = 100, VBE = 0.7
VA = 100V

* For A.C Analysis
C → ground (C-Terminal)

① Determine ICQ, VCEQ
② Draw S.S.A.C eq. cct & Find AV, AI, Rin, Ro

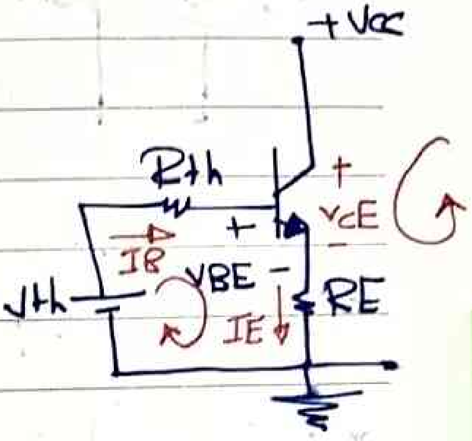
⇒

* اتجاه ال current في dependent source من ال c ← e

Sol:-

① D.c Analysis

C → O.C , AC → S.C



$Rth = 80 // 20 = 16k$

$Vth = \frac{10 * 20}{100} = 2V$

$-Vth + IB\,Rth + VBE + (\beta+1) IB\,RE = 0$

$IB = \frac{(2-0.7)V}{16+101*1} = \frac{1.3V}{117k\Omega} = 0.011\ mA$ ✓ ④

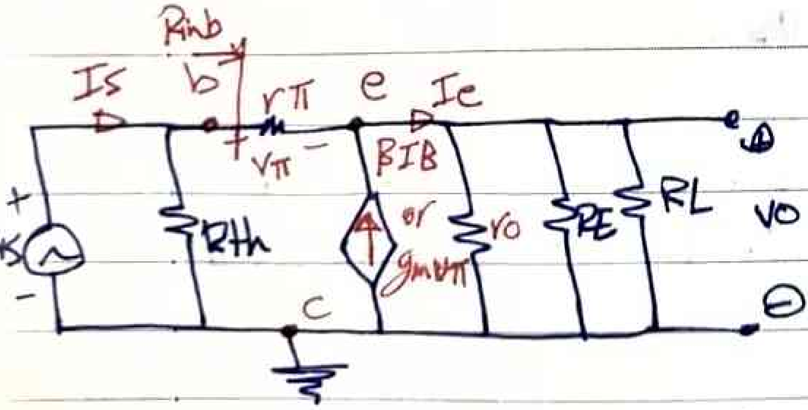
$Ic = \beta IB = 1.1mA \ , \ IE = \frac{\beta+1}{\beta} IC$

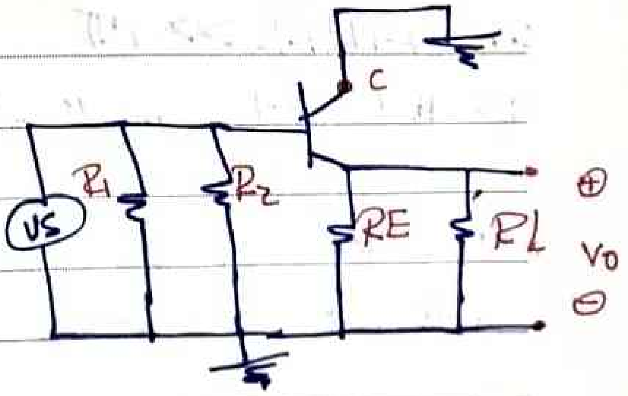
$VCE = Vcc - IERE = 10 - 1.11*1 = 8.9\ Volt$ ✓ $> VBE$

∴ BJT in FAM

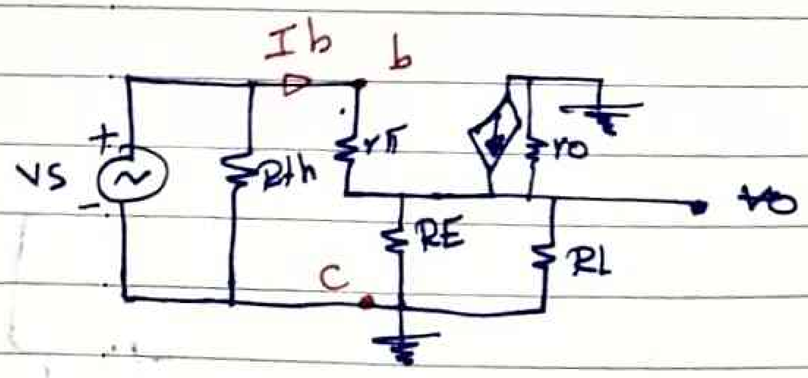
② A.c. Analysis

D.c → S.C , cap → S.C





small signal A.c. eq. cct. ⟹



$$AV = \frac{vo}{vs} = \frac{vo}{vi}$$

$$vo = Ie \cdot \overline{RL} = (\beta+1) Ib \overline{RL}$$

$$\overline{RL} = ro // RE // RL$$

$$-vi + v\pi + vo = 0$$

$$vi = v\pi + vo$$

$$= Ib r\pi + (\beta+1) Ib \overline{RL}$$

$$\frac{vo}{vi} = \frac{(\beta+1)\overline{RL}}{(r\pi + (\beta+1)\overline{RL})}$$

⇒ ① AV < 1 → لا تكبر الفولتية
② $\phi = 0°$, no phase

If $(\beta+1)\overline{RL} \gg r\pi$

⇒ AV ≃ 1 ⇒ vo ≃ vs

* vo follows vs in mag. & sign and it is taken from emitter so it is called Emitter follower

⇒

* Power Amp = AV · AI

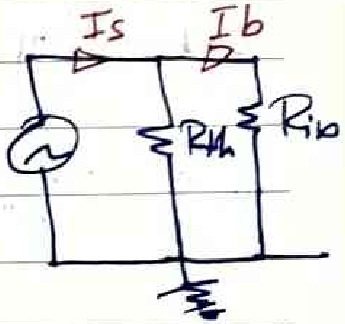
?⇒ this cct is conseder as a power Amp.

$$A_I = \frac{I_o}{I_s} = \frac{I_o}{I_b} * \frac{I_b}{I_s}$$

$$I_o = \frac{I_e \cdot \bar{R}_E}{\bar{R}_E + R_L} = \frac{(\beta+1)\, I_b\, \bar{R}_E}{\bar{R}_E + R_L}$$

* $\bar{R}_E$ اخذتها eq. بين ⟶
ro & RE وما اخذت الـ RL لانو طالبها
Io اللي بره الطلعه بالـ (C.D)

$$\therefore \frac{I_o}{I_b} = \frac{(\beta+1)\,\bar{R}_E}{\bar{R}_E + R_L}$$, where $\bar{R}_E = r_o \,//\, R_E$



$$R_{ib} = \frac{V_i}{I_b} = \frac{\cancel{I_b}\,(r_\pi + (\beta+1)\bar{R}_L)}{\cancel{I_b}}$$

$$R_{ib} = r_\pi + (\beta+1)\,\bar{R}_L$$

$$I_b = \frac{I_s\, R_{th}}{R_{th} + R_{ib}}$$

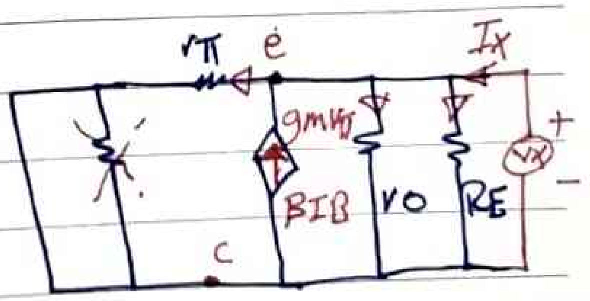
$$\frac{I_b}{I_s} = \frac{R_{th}}{R_{th} + R_{ib}}$$

$$A_I = \frac{(\beta+1)\,\bar{R}_E}{\bar{R}_E + R_L} \cdot \frac{R_{th}}{R_{th} + R_{ib}}$$ ⟹ *③ $A_I > 1$ (current Amp)

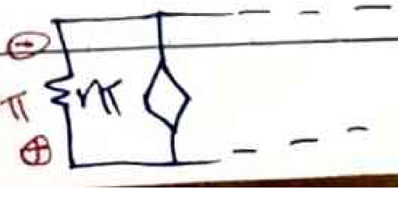
* $R_{in} = R_{th} \,//\, R_{ib}$ ⟹ *④ high Rin

* $R_o = \left.\frac{V_x}{I_x}\right|_{V_s=0}$

kcl at node ⓔ



$$I_x + g_m V_\pi = \frac{V_x}{r_o} + \frac{V_x}{R_E} + \frac{V_x}{r_\pi}$$



⟹

but when $vs = 0$

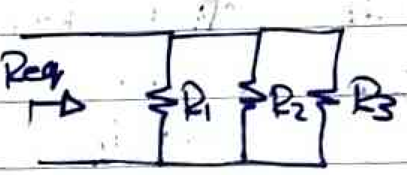
$v\pi = -vx$

$$Ix = vx\left(gm + \frac{1}{ro} + \frac{1}{RE} + \frac{1}{r\pi}\right)$$

$$= vx\left(\frac{gm\,r\pi + 1}{r\pi} + \frac{1}{ro} + \frac{1}{RE}\right)$$

but $gm\,r\pi = \frac{IC\cancel{Q}}{\cancel{V}T} \; \frac{\beta\,\cancel{VT}}{ICQ} = \beta$

$$\frac{Ix}{vx} = \frac{1}{Ro} = \frac{\beta+1}{r\pi} + \frac{1}{ro} + \frac{1}{RE}$$



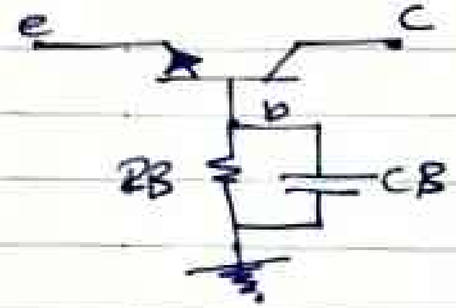
$Req = R_1 // R_2 // R_3$

$\therefore Ro = \frac{r\pi}{\beta+1} // ro // RE$

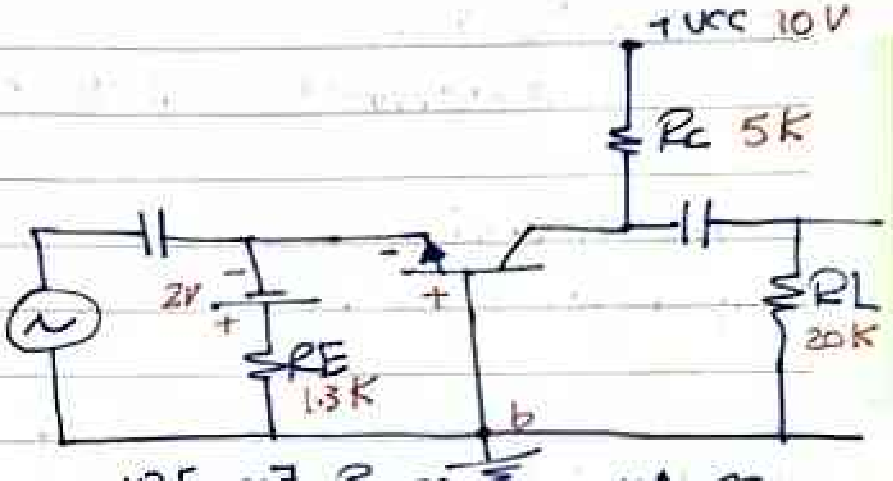
⇒ * ⑤ Low $\underline{\underline{Ro}}$

ال $\underline{D=0}$ ف لازم ال e يكون سالب .

⑤ common-Base Amp. C.BAmp



vi to emitter
vo taken from collector
base is common terminal



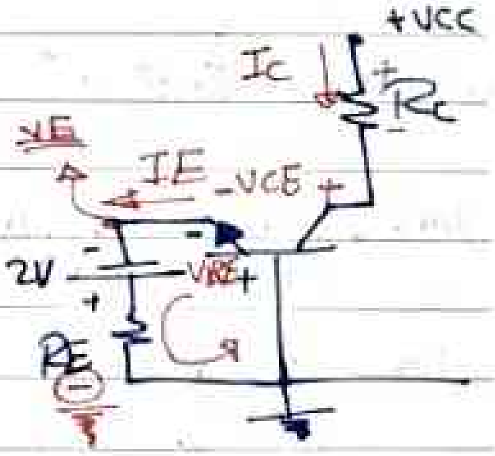
$V_{BE}=0.7$, $\beta=100$ $V_A=\infty$

① Find I_{CQ}, V_{CEQ}, V_E

② Draw S.S.A.c eq. cct & Find AV, AI, Rin, Ro

sol :-

① D.c Analysis
C-D.O.C, A.C-D.S.C



$V_{BE}-2+I_ER_E=0$

$I_E=\frac{(2-0.7)V}{1.3K}=\frac{1.3V}{1.3K}=\underline{1mA}$

$I_c=\alpha I_E=\frac{100}{100+1}\cdot 1=\underline{0.99\,mA}$

$-V_{cc}+I_cR_c+V_{CE}-2+I_ER_E=0$

$V_{CE}=10+2-(0.99*5)-(1.3*1) \Rightarrow V_{CE}=5.8$ ✓

$\therefore$ Trans in FAM

$V_E = ??$

$\Rightarrow V_E = -V_{BE} = -0.7$

OR $V_E \Rightarrow -V_E - 2V + I_E R_E = 0 \ldots$

$V_C = ??$

$\Rightarrow V_C = V_{CC} - I_C R_C$

$= (10 - 0.99 * 5) \Rightarrow V_C \simeq \underline{5.1 V}.$

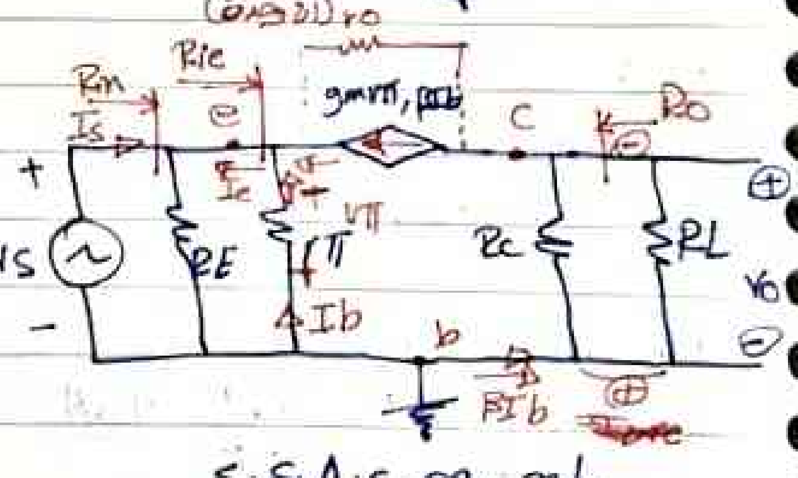
② A.C. Analysis

cap → S.C , D.C → S.C

$A_V = \frac{v_o}{v_s} = \frac{-g_m v_\pi (R_C // R_L)}{-v_\pi}$

$A_V = g_m (R_C // R_L)$

① $A_V > 1$ ② $\phi = 0°$



S.S.A.C. eq. cct

$g_m = \frac{I_{CQ}}{V_T} = \frac{0.99 mA}{26 mV}$

$g_m = 38 \underline{mA}$

$A_V = 38 (5 // 20) = 152$

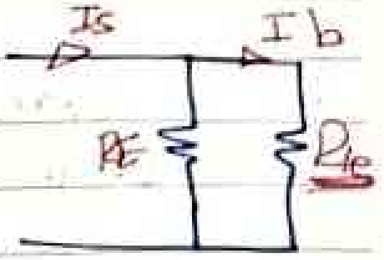
R_{ic}

* ~~Rπ~~ ~~Rie~~ ⟹ Vπ اذا لا نراها من e وليس الـ b نتطلع لها * ⟹

عشان ما في اصلا RRR او لو انقطعها

من الـ b ، اوصولها $\underline{r_\pi}$.

* هنا ال $AI < 1$ حالة المداخل بال BJT هو Ic والخارج Ic فتأكيد
راح تكون أقل من 1



$$AI = \frac{I_o}{I_s} = \frac{I_o}{I_b} \times \frac{I_b}{I_s}$$

$$I_o = \frac{-\beta I_b R_c}{R_c + R_L}$$

$$\frac{I_o}{I_b} = \frac{-\beta R_c}{R_c + R_L}$$

$$I_b = -\frac{I_s R_E}{R_E + R_{ie}} \Rightarrow \frac{I_b}{I_s} = \frac{-R_E}{R_E + R_{ie}}$$

$$AI = \frac{\beta R_c}{R_c + R_L} \cdot \frac{R_E}{R_E + R_{ie}} \Rightarrow R_{ie} = \frac{V_T}{I_e}$$

عكس الموالية →
عكس ال Ic
تكون →

$$R_{ic} = \frac{r_\pi}{\beta + 1} \Rightarrow R_{in} = R_E \parallel R_{ie}$$

③ $AI \lesssim 1$

$\Rightarrow I_o \simeq I_i \Rightarrow$ current follower

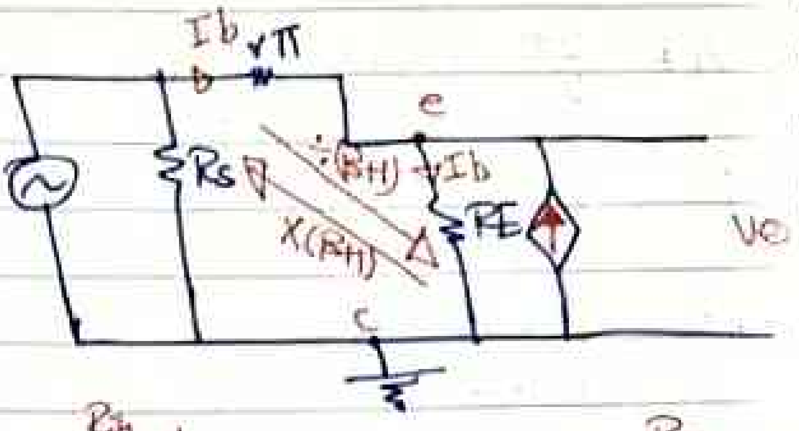
* $R_o = R_c$

* Resistance Refliction Rule & it inverse *
(R.R.R) & (I.R.R)

⇒

* Common.C ⇒ Voltage follower / common.b ⇒ current follower

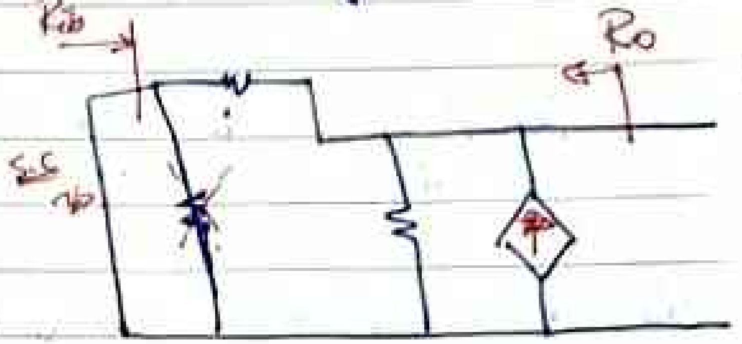
* High current Level ⇒ low Resistance Level (b)
* Low current Level → high " " (c)



$V_e = I_b(\beta+1)R_E$

$V_\pi = I_b \cdot r_\pi$

$R_o = \frac{r_\pi}{\beta+1} \parallel R_E$



E → Base → R.R.R
× (β+1) multiply

B → E → I.R.R.R

$\frac{1}{\beta+1}$ devide

$R_{ib} = r_\pi + (\beta+1)R_E$

summary of Single Stage BJT Amp.

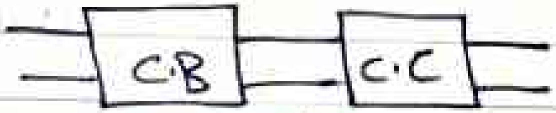
Amp	Av	A.I	ϕ	Rin	Ro
C.E	>1	>1	180°	moderate	moderate to high
C.B	>1	<1	0	Low < $\frac{r_\pi}{\beta+1}$	moderate to high
C.C	≲1	>1 (β+1)	0	high	Low ≤ $\frac{r_\pi}{\beta+1}$

لـ التكبير

* بالنسبة لل Rin & Ro في ال③ حالات ⇐ Rth لهم متساوية
* اذا بدي مواصفات خارج حالات المواصفات (يعني Mix) ⇐ استخدم Multistage

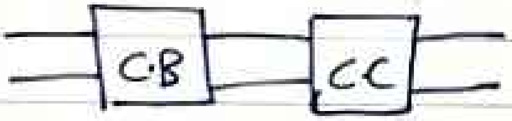
⇒

* Low Ri & Ro ⇒



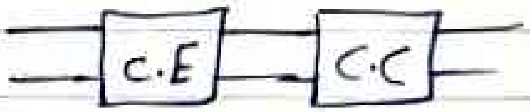
⇒ cascade

* AV>1, Low Ro, $\phi = 0^\circ$ ⇒

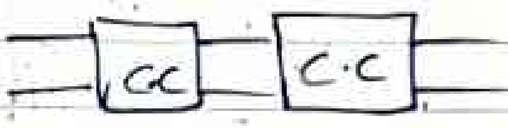


[*] ال Rin لل stage الاولى اما ال Ro لل stage الاخيرة ⇒ cascade

* 〃 〃 〃, $\phi = 180^\circ$ ⇒

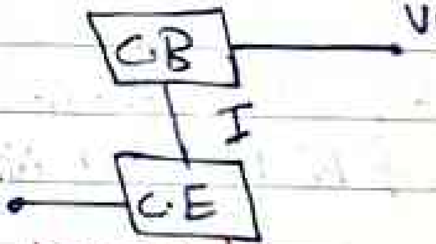


* $AI = (\beta+1)^2$ ده كبير جداً ⇒



[*] ال Rin لل stage ال ② يدخل Load لل stage ال ①

* تستخدم لتكبير الموجات !



⇒ cascade

* Multistage BJT Amps *

Amps. contain more than ONE Transistor (At Least two). They are used to achiev certain combined specifications which can't be achieved using single stage such as :-
- very high Av or AI
- Low Ro & AV>1
- Low Ro & Low Ri

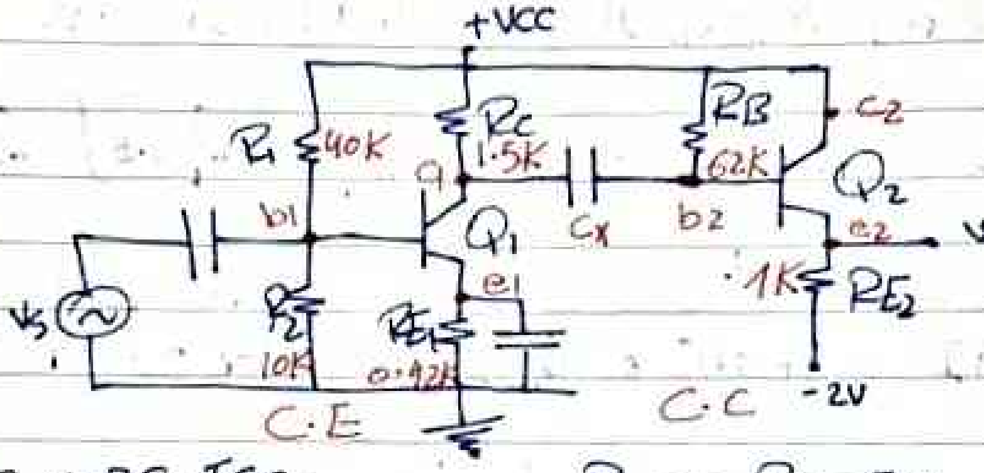
* $v_{b2} = V_{C1}$ ⇒ في حالة انو شيل الـ Cx فهو توصيل مباشر

Z_o تجميع EA

Multistage

cascode connection | cascade connection

① cascade Multistage



① Find $I_{CQ}, V_{CEQ}, I_{CQ_1}$
I_{CQ_2}, V_{CEQ_2}

$\beta = 100, \beta_2 = 50$
$V_{BE_1} = V_{BE_2} = 0.7V$
$V_{A1} = V_{A2} = 100V$

② Draw s.s.A.C eq.ccb
& Find A_V, A_I, R_{in}, R_o

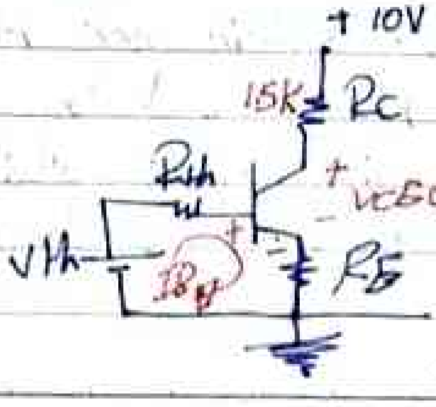
Sol:

① D.C Analysis

* Q_1 (C.E)

$R_{th} = 40//10 = 8K$

$V_{th} = \frac{10 * 10}{50} = 2V$



Qpt1
Qpt2

⇒

* بما انو في Cx يعني التوصيل غير مباشر وفيه ال D.C ≠ O.C ف ما الهم دخل ببعض

$-V_{th} = I_B R_{th} + V_{BE} + (\beta+1) I_{B_1} R_{E_1} = 0$

$I_{B_1} = \frac{(2-0.7)V}{3+100*0.42} \simeq \frac{1.3V}{50K} \simeq 0.026\ mA$

$I_{CQ_1} = \beta_1 I_{B_1} = 2.6 mA$

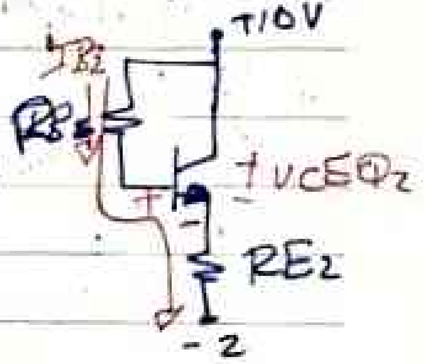
$V_{CEQ_1} = 10 - I_{CQ_1} R_C - I_{E_1} R_{E_1}$

$I_{E_1} = \frac{\beta+1}{\beta} I_C = 2.626\ mA$

$V_{CEQ_1} = 10 \cdot 2.6 * 1.5 - 2.625 * 0.4$

$V_{CEQ_1} = \underline{5V}$

* $Q_2 (C.C)$



$-10 + I_{B_2} R_B + V_{BE_2} + (\beta_2+1) I_{B_2} R_{E_2} - 2 = 0$

$I_{B_2} = \frac{(10+2-0.7)V}{R_B + (\beta_2+1) R_{E_2}}$

$I_{B_2} = \frac{11.3V}{113K} = 0.1\ mA$

$I_{CQ_2} = \beta_2 I_{B_2} \Rightarrow = 50 * 0.1 = 5 mA$

$I_{E_2} = \frac{\beta_2+1}{\beta_2} I_{CQ_2} = 5.1\ mA$

$\Rightarrow$

* اذا كانت ال cct الاولى off ⟸ كل ال cct off
〃 〃 〃 الثانية 〃 ⟸ ال بيشتغل على الاولى والثانية ⟸ O.C

$-10 + V_{CE2} + I_{E2}R_{E2} - 2 = 0$

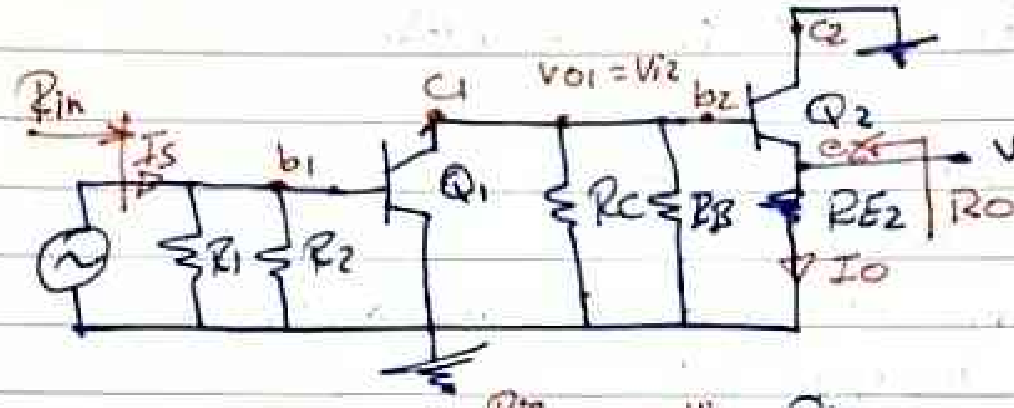
$V_{CE2} = 12 - 5.1 * 1$

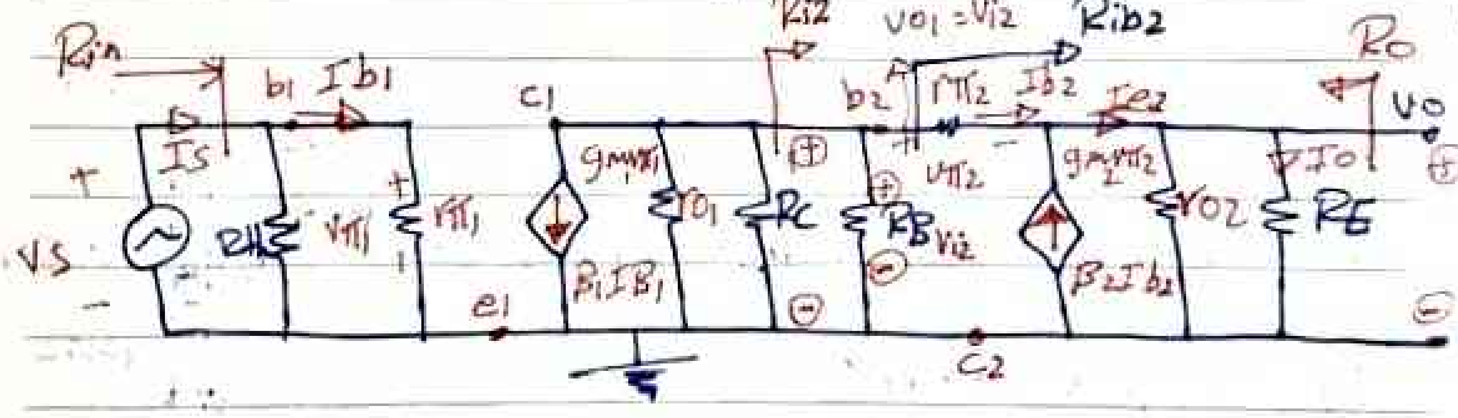
$V_{CE2} = 6.9V$

---

② Ac. Analysis

Cap → S.C, D.C → O.C





S.S.A.C eq. cct

$$* A_V = \frac{V_o}{V_S} = \frac{V_o}{V_{O1}} * \frac{V_{O1}}{V_S}$$

$$V_o = I_{e2} \cdot r_{o2} // R_E = (\beta_2 + 1) I_{b2} (R_{E2} // r_{o2})$$

$$-V_{i2} + V_{\pi 2} + V_o = 0$$

$$V_{i2} = I_{b2} r_{\pi 2} + (\beta_2 + 1) I_{b2} (R_E // r_{o2})$$

⇒

$$\frac{V_o}{V_{i2}} = \frac{V_o}{V_{o1}} = \frac{(\beta_2+1)(R_E // r_{o2})}{r_{\pi 2}+(\beta_2+1)(R_{E2} // r_{o2})}$$

$A_{V2} < 1$ (C.C)

$\Rightarrow V_{o1} = -g_{m1} V_{\pi 1} (r_{o1} // R_C // R_{ie})$

$R_{i2} = R_B // R_{ib2}$

$R_{ib2} = (R_{E2} // r_{o2})(\beta_2+1) + r_{\pi 2}$

$V_s = V_{\pi 1}$

$A_{V1} = \frac{V_{o1}}{V_s} = -g_{m1} \bar{R}_L$

$\bar{R}_L = R_C // r_{o1} // R_{in2}$

$$\Rightarrow V_A = \frac{V_o}{V_s} = \underbrace{\overset{A_{V1}}{-g_{m1} \bar{R}_L}} \; \underbrace{\overset{A_{V2}}{\frac{(\beta_2+1)(R_{E2} // r_{o2})}{r_{\pi 2}+(\beta_2+1)(R_E // r_{o2})}}}$$

$\therefore A_{V1} > 1 \Rightarrow A_V > 1 \; , \; \varnothing = 180^\circ$

$\simeq -150$

$* \; A_I = \frac{I_o}{I_s}$

$$A_I = \frac{\frac{V_o}{R_E}}{\frac{V_s}{R_{in}}} \Rightarrow A_I = \overset{A_V}{\frac{V_o}{\underset{\sim}{V_I}}} \cdot \frac{R_{in}}{R_E}$$

$\Rightarrow$

$* \; A_I = \frac{I_o}{I_s} = \frac{I_o}{I_{b2}} \cdot \frac{I_{b2}}{I_{b1}} \cdot \frac{I_{b1}}{I_s} \rightsquigarrow X$ طويلة و صعبة

$AI = AV \frac{Rin}{RE}$, $Rin = r\pi_1 // Rth = 1//18 = 0.9k$

$AI = -150 \cdot \frac{0.9}{1K} = -135$

* AV & AI Relations.

① AI interms of AV

$$AI = \frac{Io}{Is} = \frac{\frac{Vo}{RL}}{\frac{Vs}{Rin}} = AV \cdot \frac{Rin}{RL}$$

Rs ⇐ source اذا في مع ال ← Rin

راح يصير $\frac{Vs}{Rin + Rs}$

② AV interms

$AV = \frac{Vo}{Vs} = \frac{Io}{Is} \cdot \frac{RL}{Rin + RS}$ ← * انتبه انو RL مش RS لنفسها مطلقة ابداً

← * اذا كان مع السورس في مقاومة

$* \; Ro = \frac{Vx}{Ix}\Big|_{Vs=0}$

$Ro = \underbrace{(ro_1 // Rc // RB) + r\pi_2}_{} // ro_2 // RE_2$

$\beta_2 + 1$

لو قسمت حسب قاعدة

INV. R.R

لا منو بتطلع من ال e_2 ال b_2

* بنفصل هو ال Vs و بتصير short ⇐ $gm_1 v\pi_1 = 0$

$V\pi_1 = 0$

o.c

ما بنشتغل باقي الدارة

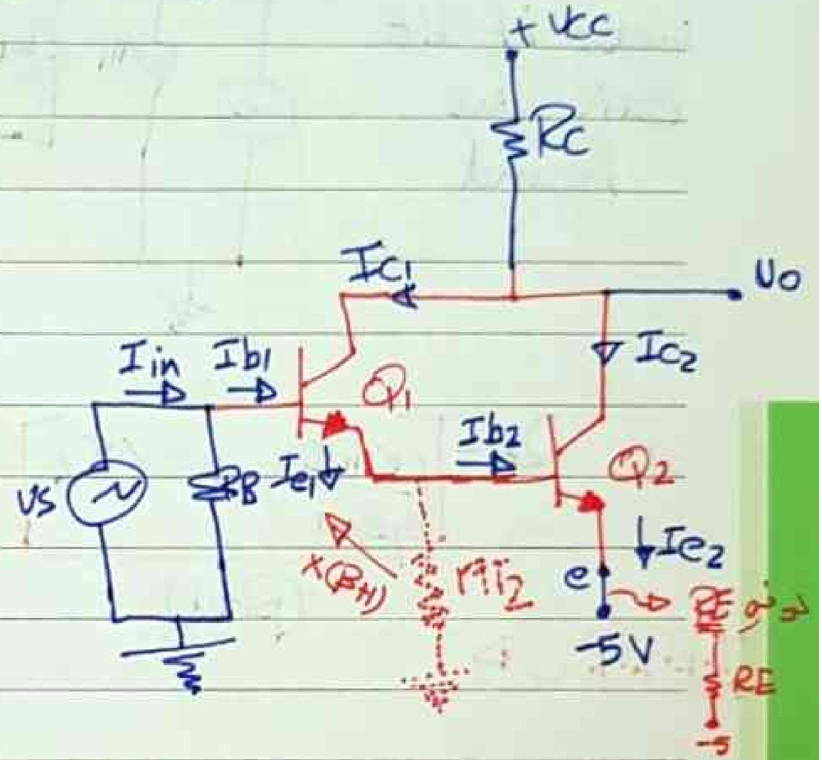
* very high current Gain cct.

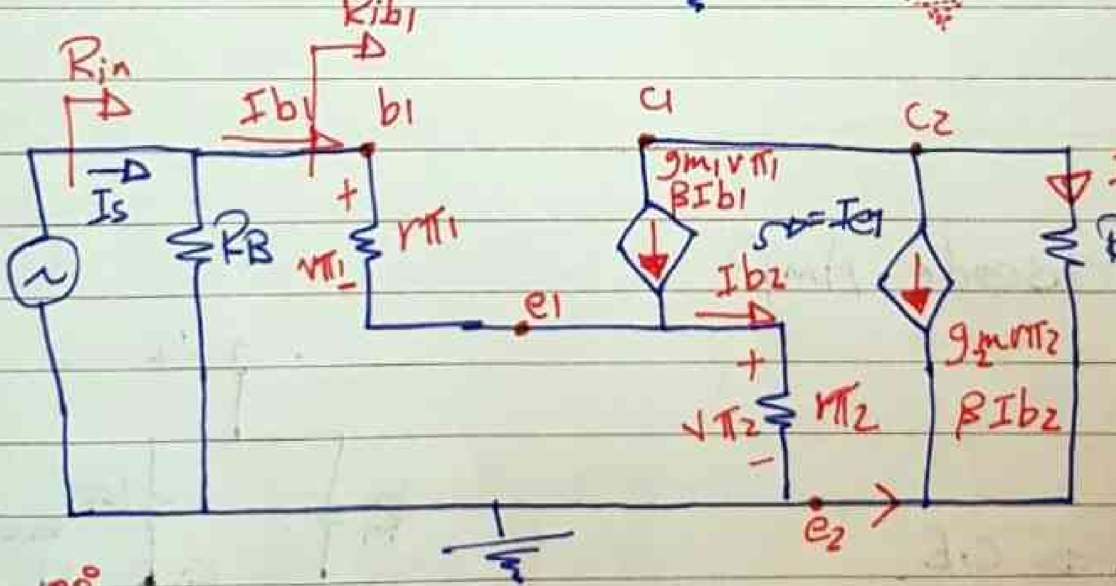
Cascade:- Darlingtor Pair configuration.

$I_{b1} \simeq I_{in}$

$R_B \Rightarrow$ very big.

$$A_I = \frac{I_o}{I_i} \simeq \frac{I_o}{I_{b1}}$$





-180°

$$\Rightarrow I_o = -\beta I_{b2} = \beta I_{e1} = \beta(\beta+1) I_b = (\beta^2+\beta) I_{b1}$$

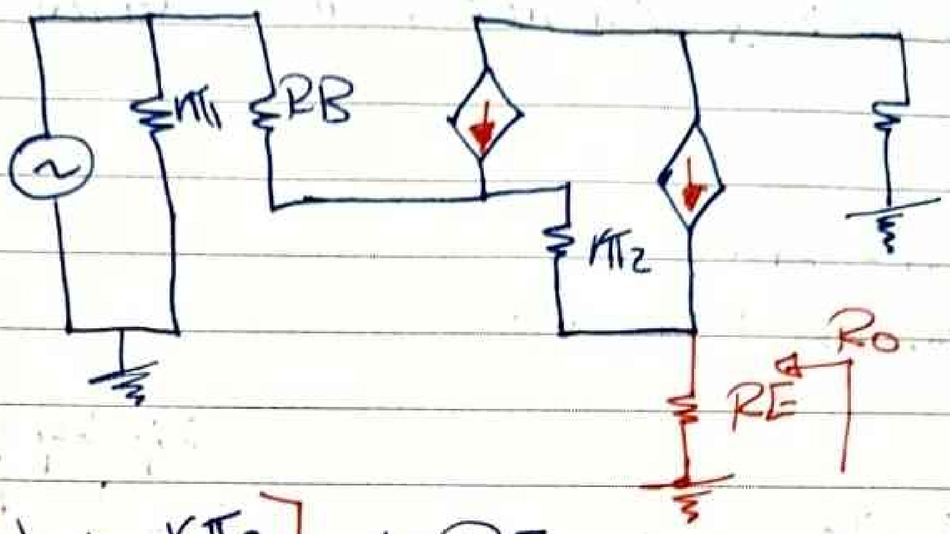
$$\therefore A_I \simeq \frac{I_o}{I_{b1}} \simeq \beta^2+\beta \simeq -\beta^2$$

$\Rightarrow R_{in} = R_B \,//\, R_{ib1}$

$R_{ib1} = r_{\pi 2}(\beta+1) + r_{\pi 1}$ → بليش من اشكال

* $R_o = ??$ ⇒ $R_o = R_C$

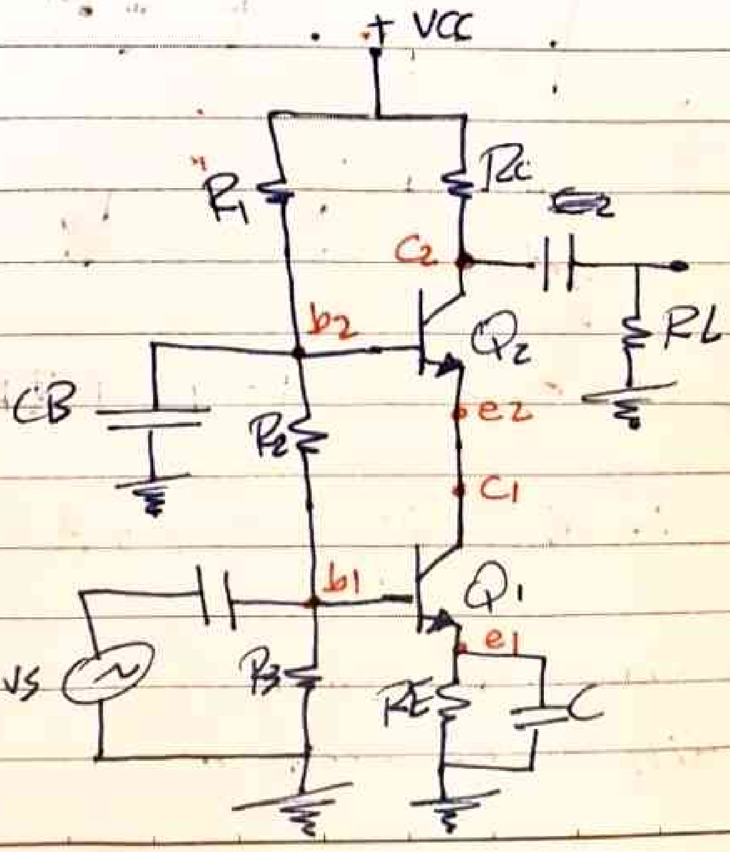
incase if RE ~~ext~~ was found



$$\Rightarrow R_o = \frac{\left[\left(\frac{r\pi_1}{\beta+1}\right) + r\pi_2\right]}{(\beta+1)} // RE$$

I.R.R.R ⇒

② Cascode Amp

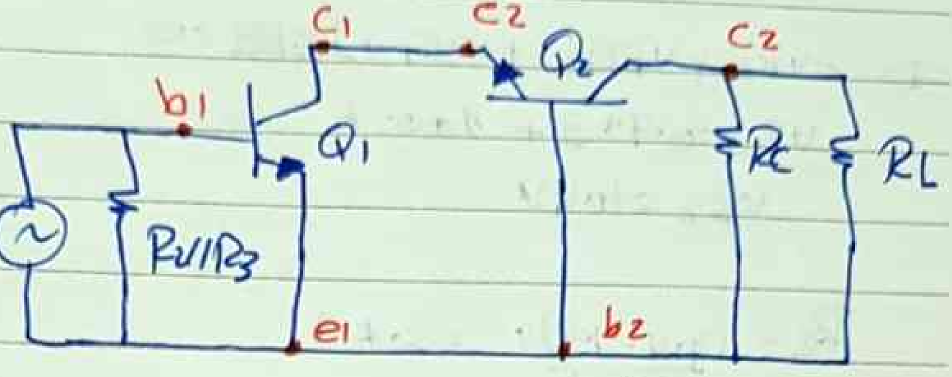


Q_1 ⇒ C.E

Q_2 ⇒ C.B

* R_1 ⇒ S.C in A.C

⇒



Ex: ① Design the cascode cct shown in Fig :- to have $I_{CQ} = 1\,mA$, $V_{CE1} = V_{CE2} = 3V$

* Assume $I_C \approx I_E$ ⟶ * ما بقدر اعمل design ا Analysis الا بهاد الشرط واذا ما اعطاني اياه لازم افرضه

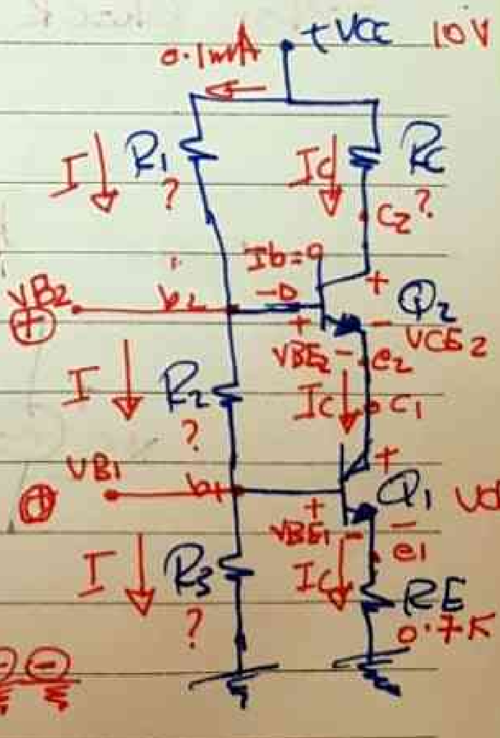
2⟶ $I_b = 0$

Choose the biasing current

$I = 10\%$ of I_C

The BJT has $V_{BE} = 0.7V$

② Draw s.s.A.C eq.t cct & Find AV, AI, Rin, Ro.



Sol:-

Rc ?

$-10 + I_C R_C + V_{CE2} + V_{CE1} + I_C R_E = 0$

$I_C R_C = 10 - 3 - 3 - 1 * 0.7 = 3.3V$

$R_C = \frac{3.3V}{1mA} = 3.3K\Omega$ ✓

R1, R2, R3 ?

$R_3 = \frac{V_{B1}}{I}$, $R_2 = \frac{V_{B2} - V_{B1}}{I}$, $R_1 = \frac{V_{CC} - V_{B2}}{I}$

$-V_{B1} + V_{BE1} + I_E R_E = 0$

$V_{B1} = 0.7 + 1 * 0.7 = 1.4V$

$R_3 = \frac{1.4V}{0.1mA} = 14K\Omega$

⟹

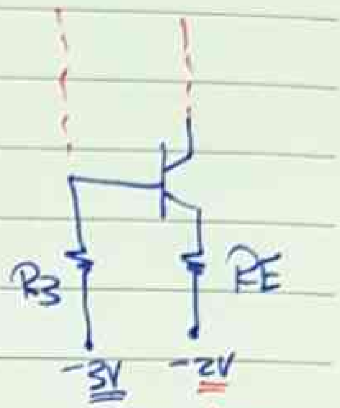
* ممكن يعطيك ال $RT = ...$ صورة بطلع قيمة التيار المار في المقاومات R_1, R_2, R_3 و بعدين تكمل حل (يعني ما بنربط اصل الا اذا طلعت التيار او اذا معطيني اياه مسبقًا)

40

$\Rightarrow -V_{B2} + V_{BE2} + V_{CE1} + I_E R_E = 0$

$V_{B2} = 0.7 + 3 + 1 * 0.7$

$V_{B2} = 4.4V$



$R_2 = \frac{(4.4 - 1.4)v}{0.1mA} = 30k\Omega$

$R_1 = \frac{10 - 4.4}{0.1} = 56k\Omega$

لو صار ع2 تغيير لقيمة ال VB1

و ع2 تغيير ال Rc

$RT = 14 + 30 + 56 = 100k$

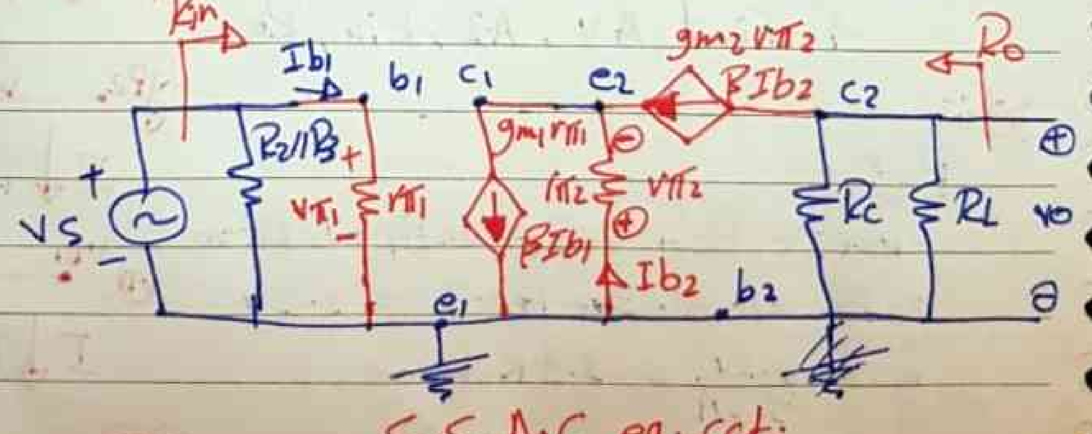
$RT = \frac{V_{cc}}{I} = \frac{10V}{0.1} = 100K$

for Check

لو صار ع1 تغيير لقيمة التيار، ع2 بصير يساوي

$I = \frac{V_{CC} + 2}{RT}$

و ع2 تغيير لقيمة ال R's



S.S.A.C eq. cct.

$AV = \frac{V_o}{V_S} = \frac{V_o}{V_{\pi 2}} \cdot \frac{V_{\pi 2}}{V_{\pi 1}} \cdot \frac{V_{\pi 1}}{V_S}$

$V_o = -g_{m2} V_{\pi 2} (R_C // R_L)$

$\frac{V_o}{V_{\pi 2}} = -g_{m2} (R_C // R_L)$

$\Rightarrow$

* KCL at node c1

$$g_{m2} v_{\pi2} + \frac{v_{\pi2}}{r_{\pi2}} = g_{m1} v_{\pi1}$$

$$v_{\pi2}\left(g_{m2} + \frac{1}{r_{\pi2}}\right) = g_{m1} v_{\pi1}$$

$$v_{\pi2}\left(\frac{\beta_2 + 1}{v_{\pi2}}\right) = g_{m1} v_{\pi1}$$

$$\frac{v_{\pi2}}{v_{\pi1}} = \frac{r_{\pi2}}{\beta_2 + 1} g_{m1} \qquad \Rightarrow \frac{v_{\pi1}}{v_s} = 1$$

$$\therefore A_V = -g_{m2}\left(R_C // R_L\right)\left(\frac{r_{\pi2}}{\beta_2 + 1}\right) g_{m1}$$

$$= -g_{m1}\left(R_C // R_L\right)\frac{\beta_2}{\beta_2 + 1} = \boxed{-g_{m1}\left(R_C // R_L\right)}$$

* AV of cascode $\simeq$ AV for C.E Amp because Q2 is C.B which Does Not Amplify the current.

$$* \; A_I = \frac{I_o}{I_s} = \frac{\frac{V_o}{R_L}}{\frac{V_s}{R_{in}}} = A_V \frac{R_{in}}{R_L}$$

* $R_{in} = r_{\pi 1} // R_2 // R_3$

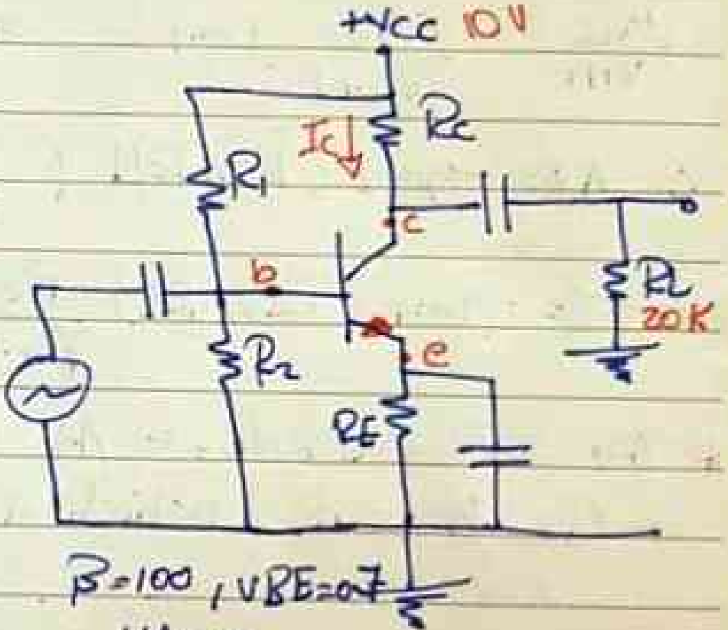
* $R_o = R_C$

$\rightarrow V_S = 0 \rightarrow V_{\pi 1} = 0 \rightarrow V_{\pi 2} = 0 \rightarrow g_{m2} = 0$

Ex:- Design the cct shown to have $I_{CQ} = 1mA$, $V_{CEQ} = 4V$, $A_V = -155$ & its biase-stable

Determine:-

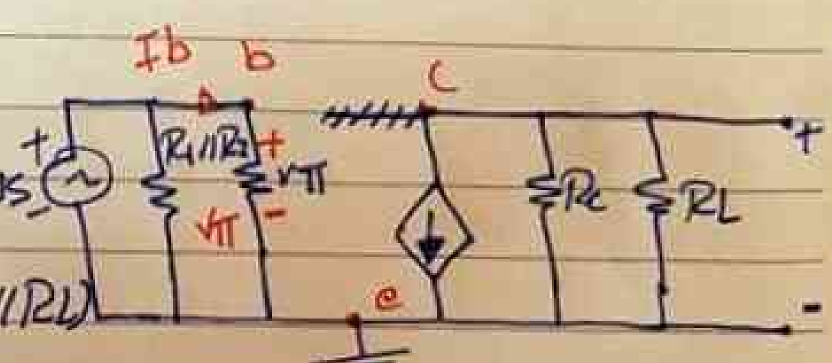
1. R_C, R_E, R_1, R_2
2. Draw S.S.A.C eq. ccb & find A_I, R_{in}, R_o
3. write D.C & A.C.L.L & find their slopes.



$\beta = 100$, $V_{BE} = 0.7$

$V_A = \infty$

Sol:-



$v_o = -g_m v_\pi (R_C // R_L)$

$v_\pi = v_S \rightarrow \frac{v_o}{v_S} = -g_m (R_C // R_L)$

$g_m = \frac{I_{CQ}}{V_T} = \frac{1}{26mV} = 38.5 \frac{mA}{V}$

$-155 = -38.5 (R_C // R_L)$

$\Rightarrow$

RL Given

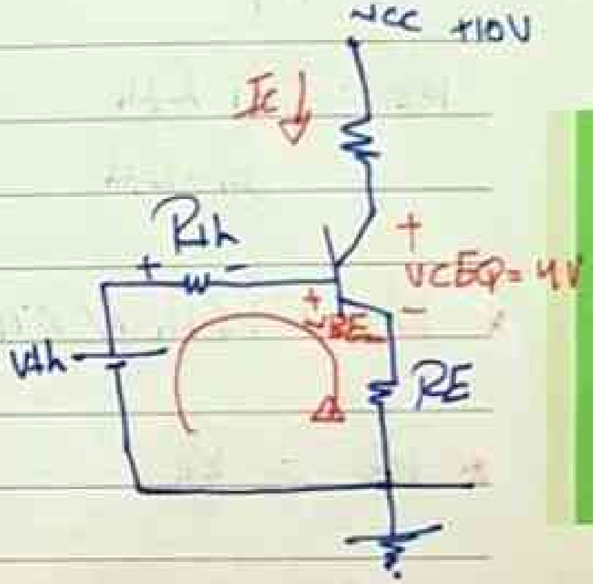
* من ال Ac بجيب ال Rc
* من ال Dc بجيب ال RE

$(R_C // R_L) = \frac{155}{38.5} = 4K\Omega$

$4K = R_C // 20K$

$R_C = 5K\Omega$

* From Dc *



$-10 + I_C R_C + V_{CE} + I_E R_E = 0$

$R_E = \frac{10 - 5*1 - 4}{I_E} = \frac{1}{I_E} \simeq 1K\Omega$

(for $I_E \simeq I_C$)

* for biase-stable design

$R_{th} = 0.1\,(\beta+1)R_E$

$= 0.1 * 101 * 1 = 10.1K\Omega$

$R_{th} = R_1 // R_2$

$R_1 V_{th} = V_{cc} \frac{R_2}{R_1 + R_2} . R_1$ (multiply both sides by R_1)

$R_1 V_{th} = V_{cc} . R_{th}$

$R_1 = \frac{V_{cc}}{V_{th}} . R_{th}$

$\Rightarrow -V_{th} + I_B R_{th} + V_{BE} + I_E R_E = 0$

$\Rightarrow$

$$V_{th} = \frac{I_{CQ}}{\beta}(10.1) + 0.7 + \frac{\beta+1}{\beta} I_{CQ} * 1$$

$$= 0.01 * 10.1 + 0.7 + 1.1 = 1.9V$$

$$R_1 = \frac{10}{1.9} * 10.1 = 52 k\Omega$$

$$R_2 = \frac{R_1 R_{th}}{R_1 - R_{th}} = \frac{52 * 10.1}{52 - 10.1} = \frac{520k}{42} = 125 k\Omega$$

* $R_{in} = R_{th} // r_\pi$

* $R_o = R_c$

* $A_I = A_V \cdot \frac{R_{in}}{R_L}$

* D.C.L.L

$$-V_{CC} + I_C R_C + V_{CE} + \underbrace{I_E R_E}_{\frac{\beta+1}{\beta} I_c} = 0$$

$$V_{CE} = V_{CC} - I_C \left(R_C + \frac{\beta R_E}{\beta+1}\right)$$

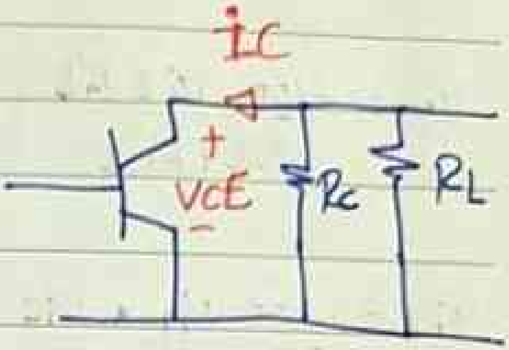
[illegible] $\Rightarrow I_C \simeq I_E$

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

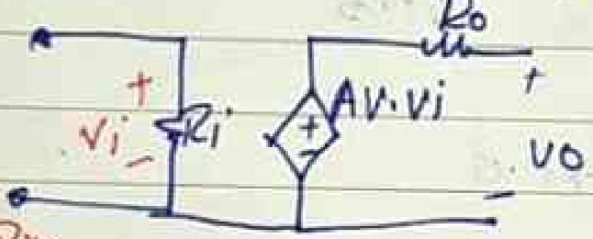
* Ac.L.L

$v_{ce} + i_c (R_C // R_L) = 0$

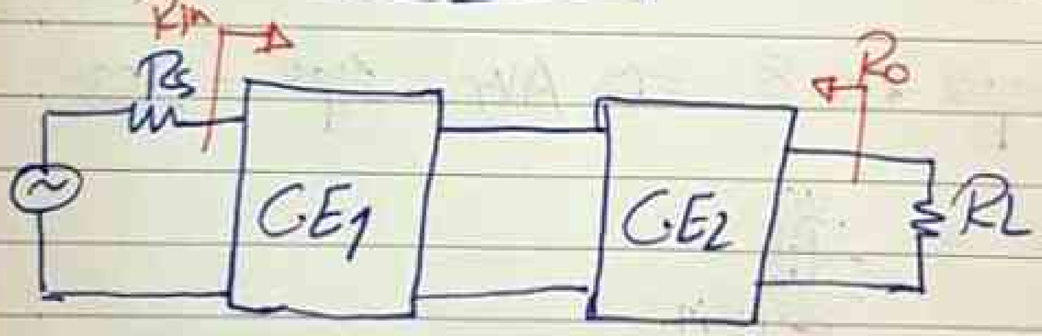
$v_{ce} = -i_c (R_C // R_L)$



* Any voltage Amp can be represented by

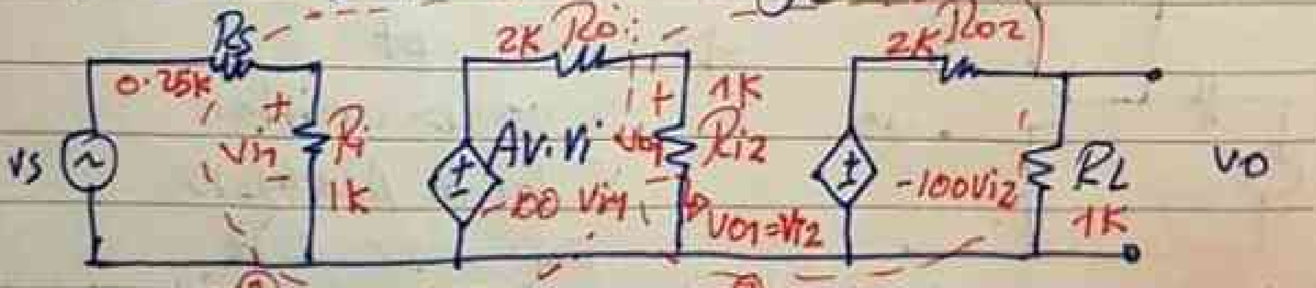


*



* Find overall AV, over ALL AI, over all Ri
overall Ro

overall Rin ⇒ Rin for 1st stage
〃 〃 Ro ⇒ Ro for 2nd stage



Ri = 1K Ω, Ro = 2K, AV = -100

⇒

اذا ما في Rs (قيمه مش) بنشيلها و بتصير Ideal

Ri↑ , Ro↓ ⇒ بتقرب ال Trans من كونها Ideal $\boxed{46}$ { Ideal ?? ↳ $AV_T = AV_1 \cdot AV_2$ Direct

* $AV_T = \frac{V_o}{V_S} = \frac{V_o}{V_{i2}} * \frac{V_{i2}}{V_{i1}} * \frac{V_{i1}}{V_S}$

$V_o = \frac{-100\, V_{i2} R_L}{R_L + R_{o2}} \Rightarrow \frac{V_o}{V_{i2}} = \frac{-100*1}{1+2} = \frac{-100}{3}$ ✓

$V_{i2} = \frac{100\, V_{i1} * R_{i2}}{R_{i2} + R_{o1}} \Rightarrow \frac{V_{i2}}{V_{i1}} = \frac{-100 \times 1}{2+1} = \frac{100}{3}$ ✓

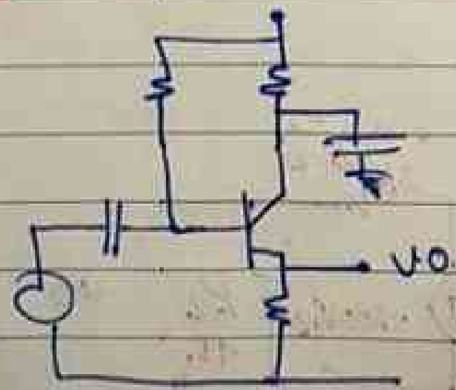
$V_{i1} = \frac{V_S * R_{in1}}{R_{in1} + R_S} = \frac{V_{i1}}{V_S} = \frac{1}{1+0.25} = 0.8$

$AV_T = (\frac{-100}{3}) \cdot (\frac{-100}{3}) * 0.8$

$= \frac{10000}{9} * 0.8 \Rightarrow AV_T = \frac{8000}{9} = 900$

* $AI = \frac{I_o}{I_S} = \frac{\frac{V_o}{R_L}}{\frac{V_S}{R_S + R_{i1}}}$

$= AV \cdot \frac{R_S + R_{i1}}{R_L} = 1125$

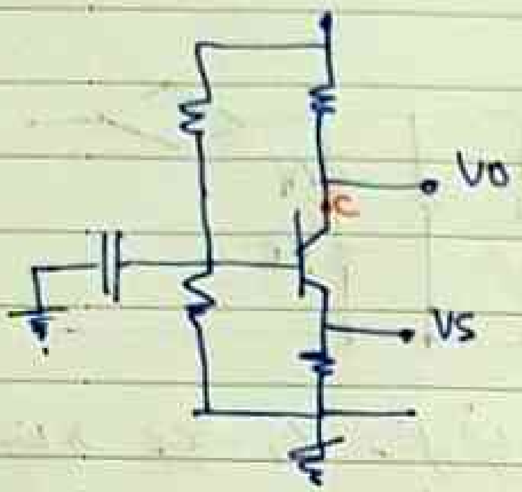


⇒ C.C cct

① vo ⇒ emitter

② for Ac Analysis

cap ⇒ S.C ⇒ $\cancel{R_E}$

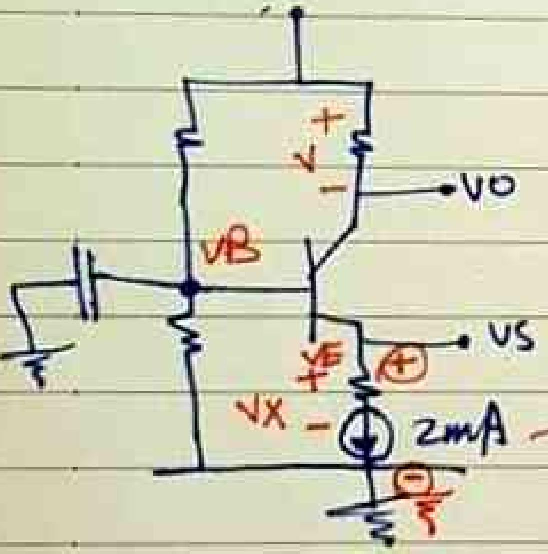


=D C.B cct

① vo =D collector

② for Ac Analysis

cap =D S.C =D B =D Gnd

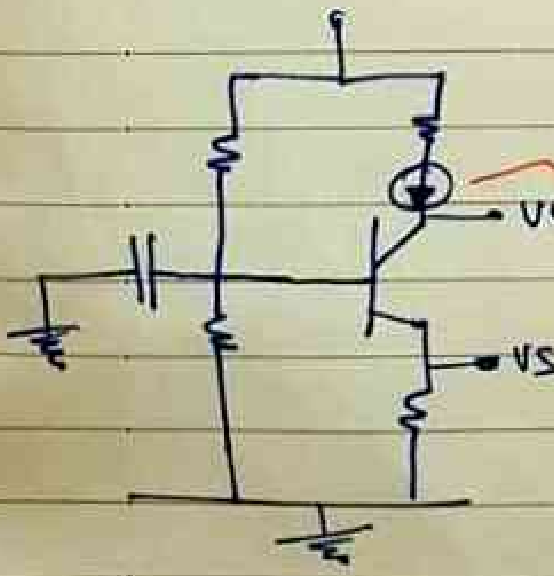


~~VX~~ ═ C.B

* $VE = VB - VBE$

for VX =D $\underbrace{-VCC + ICRC + VCE + VX - 5 =}$

~D IE = 2mA



~D Ic

C.B

Q1 =D design for single stage

Q2 =D myltistage

Q3 =D multiple Choice

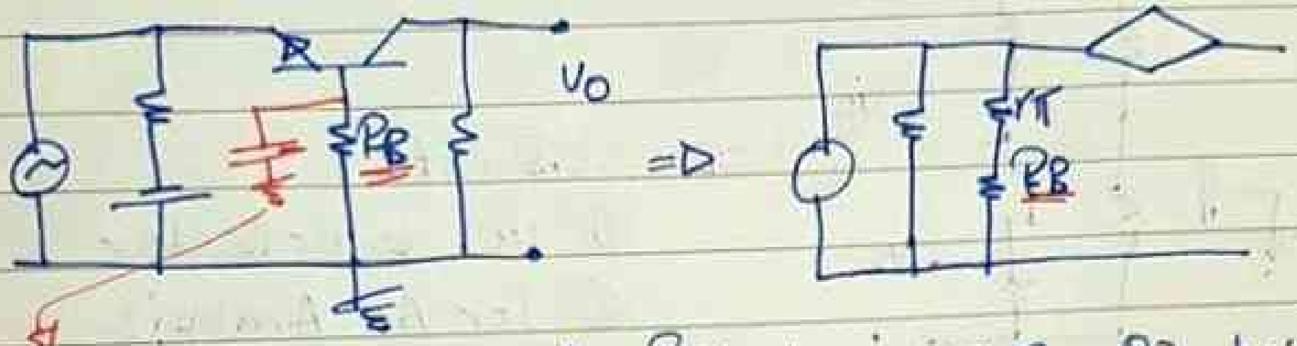
5 concept 15 calculation

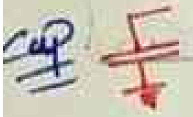
$\boxed{48}$

* write Dc & Ac & their slopes

لو هون اشي انو ما ارسم

بس اكتب الكلام الو.





* هون ال RB ، رح تدخل في ال Dc & Ac بس اذا وصلت

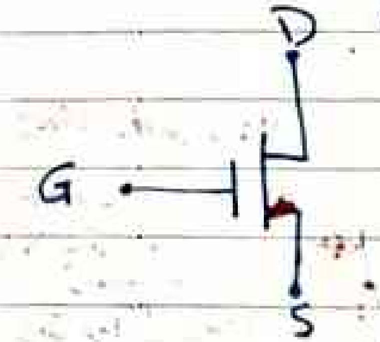
رح تدخل بس بال Ac.

+ أصغر من ال BJT بالحجم

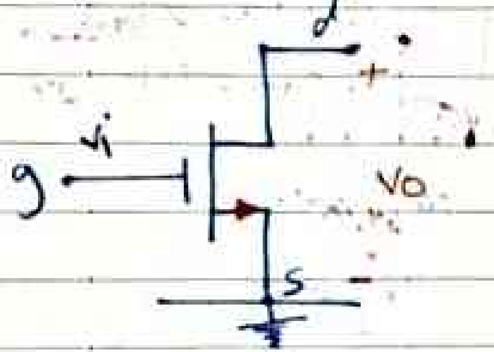
★ ال noise اللي فيه أقل من ال noise اللي بال BJT (ال G مفصول عن ال ch)

Ch XII

Mosfet Amplifires.

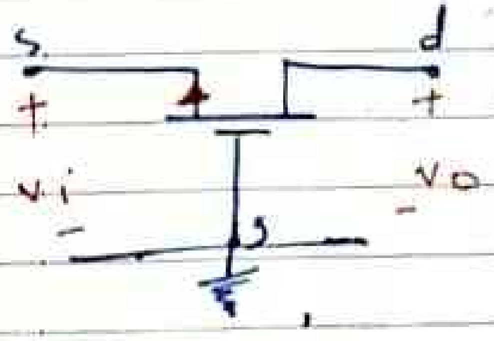


N-channle



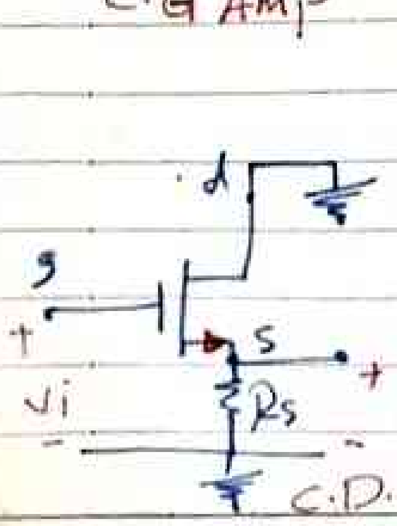
$\Rightarrow$ C.E

C.S. Amp



$\Rightarrow$ C.B

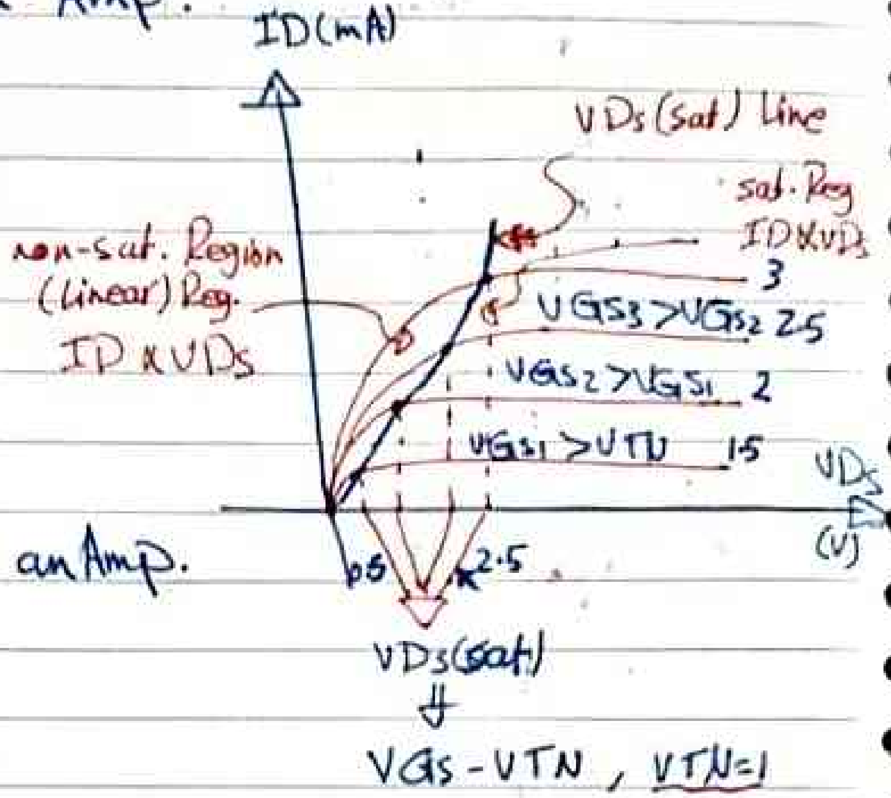
C.G Amp



$\Rightarrow$ C.C

C.D. Amp

* Mosfet must be biased in saturation Region to be used as an Amp.



+ saturation Region

$ID = Kn(VGs - VTN)^2$

VTN → Given

Kn → Given

Mosfet is used as an Amp.

+ Non-Sat. Region.

(Linear- Region)

$ID = Kn\left[2(VGs-VTN)VDs + VDs^2\right]$

for small VDs → VDs → Negligible

$ID \simeq 2Kn(VGs - VTN)VDs$

$$\frac{VDs}{ID} = \frac{1}{2Kn(VGs-VTN)}$$

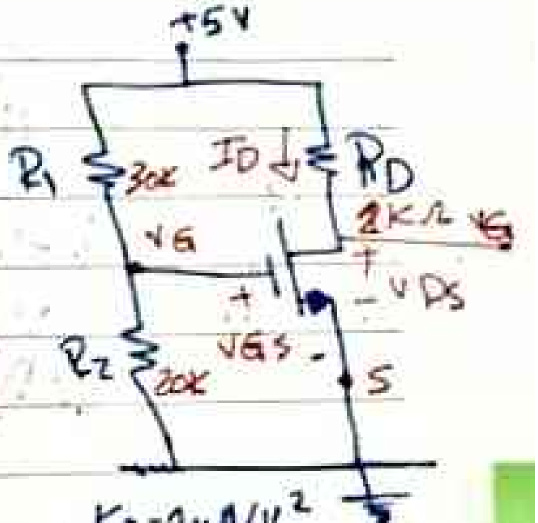
$$\overset{\uparrow}{R}_{mos} = \frac{1}{2Kn(\overset{\uparrow}{VGs}-VTN)}$$

⇒

* In Linear Region I can use Mosfet as a Voltage Variable Resistance

*

* Assume Mosfet In sat



$K_n = 1mA/V^2$

$V_{TN} = 1V$

$I_D = K_n(V_{GS} - V_{TN})^2$

$V_{GS} = V_G - V_S = \frac{5 \times 20}{50} - 0 = 2V$

$I_D = 1(2-1)^2 = 1mA$ ←

$-5 + I_D R_D + V_{DS} = 0$

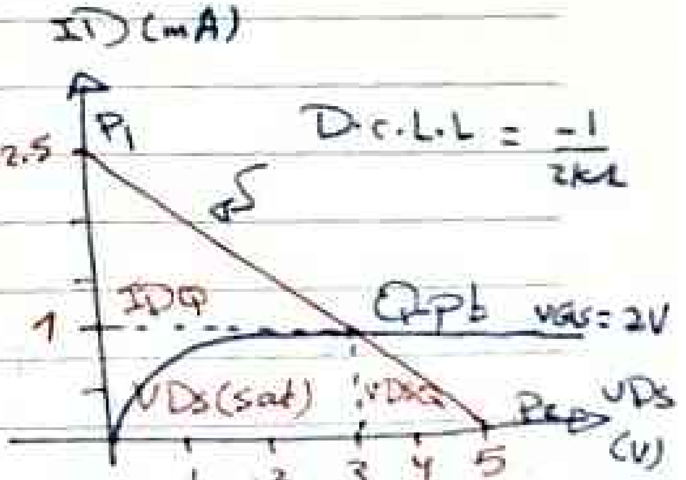
$V_{DS} = 5 - 2 \times 1 = 3V$

$V_{DS(sat)} = V_{GS} - V_{TN} = 2 - 1 = \underline{1V}$

since $V_{DS} > V_{DS(sat)}$

∴ Mosfet in sat

* D.C.L.L



$-5 + I_D R_D + V_{DS} = 0$

$V_{DS} = 5 - I_D R_D$

slope $= \frac{-1}{R_D}$

Ⓘ for $I_D = 0$, $V_{DS} = 5V$

P1 (5V, 0mA)

Ⓘ for $V_{DS} = 0$, $I_D = \frac{5}{2} = 2.5 mA$

P2 (0V, 2.5mA)

Q-pt, $I_{DQ} = 1mA$, $V_{DSQ} = 3V$

$V_{GSQ} = 2V$

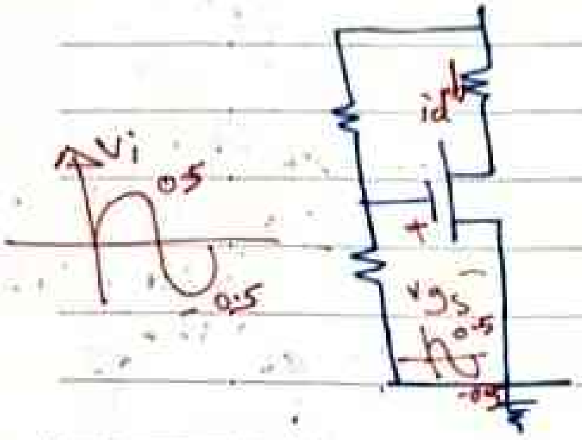
$V_{DS(sat)} = 1$

⇒

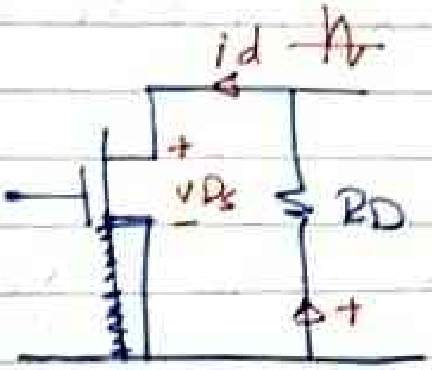
$v_i \Rightarrow v_{gs} \Rightarrow I_d \Rightarrow v_{ds}$ (AC) ⇒ voltage controlled device (Mosfet)

↳ $I_G=0$

$I_G=0$



⇒



$v_{ds} = i_d R_D$ ⇒

$A_V = \frac{v_{ds}}{v_i}$

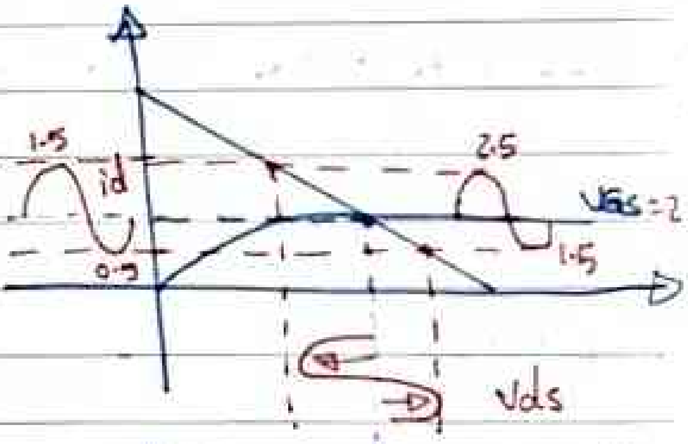
* According to superposition

$i_D = I_{DQ} + i_d$

$V_{GS} = V_{GSQ} + v_{gs}$

total Res. DC AC

$v_{DS} = V_{DSQ} + v_{ds}$

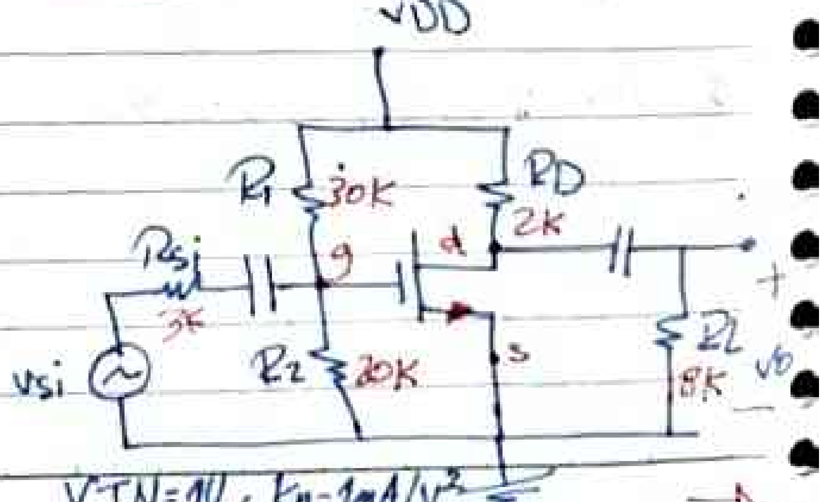


$\uparrow I_D = k_n (\uparrow V_{GS} - V_{TN})^2$
$+ v_{gs}$

① common-Source Amp

Ⓘ Basic . C.S

vi → gate
vo from drain
s → common terminal

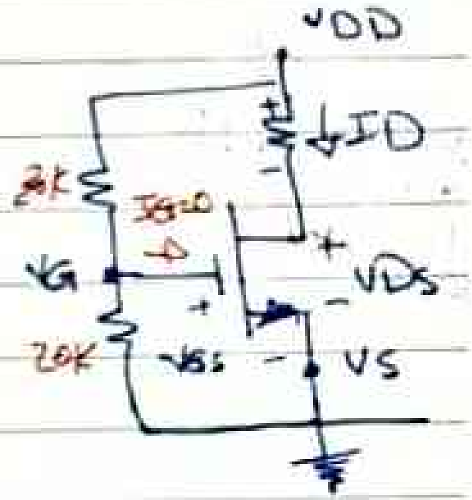


$V_{TN}=1V$, $K_n=1mA/V^2$ ⇒

Common Source = common Emitter

1)- Determine IDQ
VDSQ

2)- Draw s.s A.c eq cct
& Find AV, Rin & Ro



sol:-

① D.c Analysis
Assume the Mosfet in sat Region

$ID = kn(VGs - VTN)^2$

$VGs = VG - Vs$

$= \frac{VDD \cdot R_2}{R_1+R_2} - 0 = \frac{5 * 20}{50} = 2V$

$ID = 1(2-1)^2 = 1mA$

$-VDD + ID\,RD + VDs = 0$

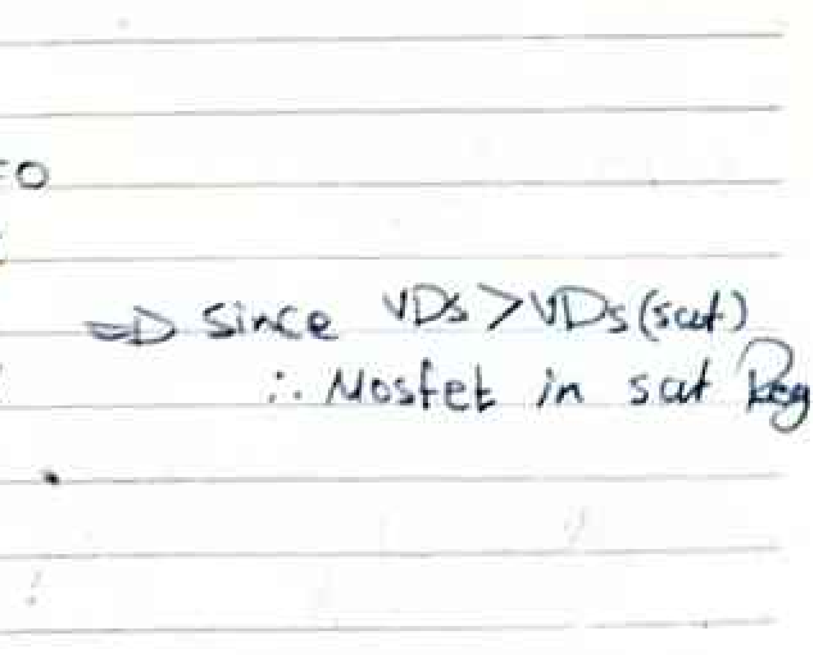
$VDs = 5 - 1*2 = \underline{3V}$

$VDs(sat) = VGs - VTN$

$= 2 - 1 = \underline{1V}$.

⇒ Since VDs > VDs(sat)
∴ Mosfet in sat Reg.

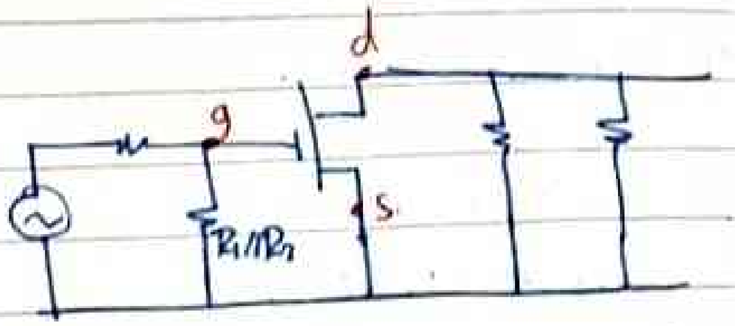
② A.c Analysis
C→DS.C , D.C→DS.C

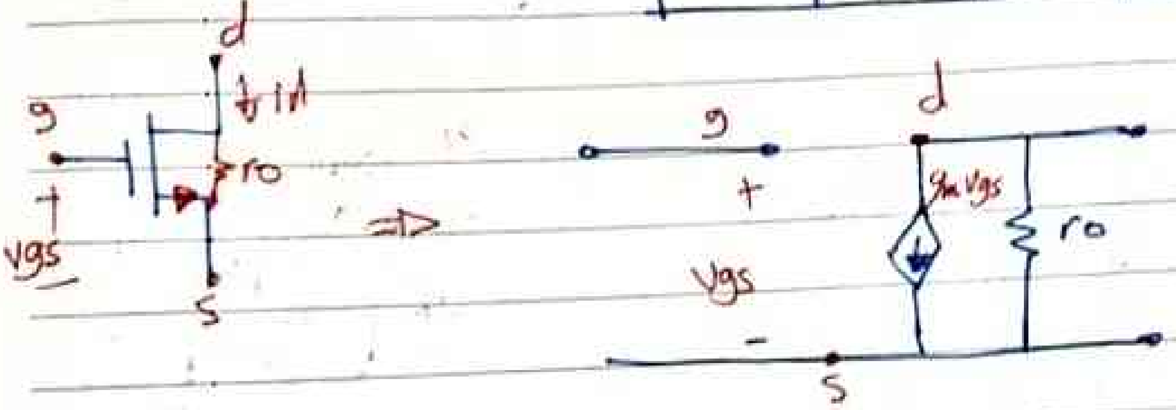


AC . cct .

⇒

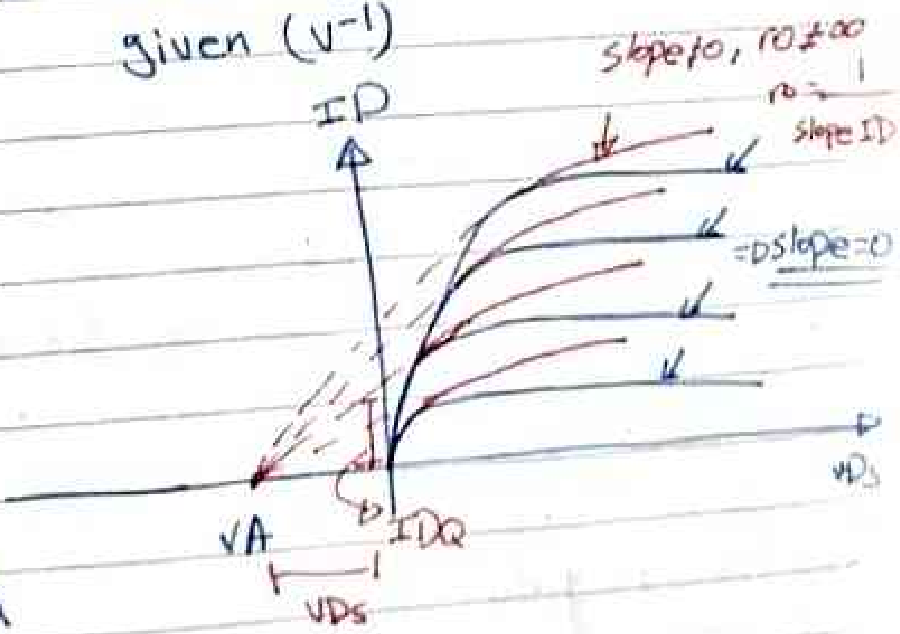
- $\lambda = 0 \Rightarrow r_o = \infty$
- $\lambda = \text{value} \Rightarrow r_o = \text{value}$





$$r_o = \frac{1}{\lambda I_{DQ}}$$ (Mosfet drain-source Resistance)

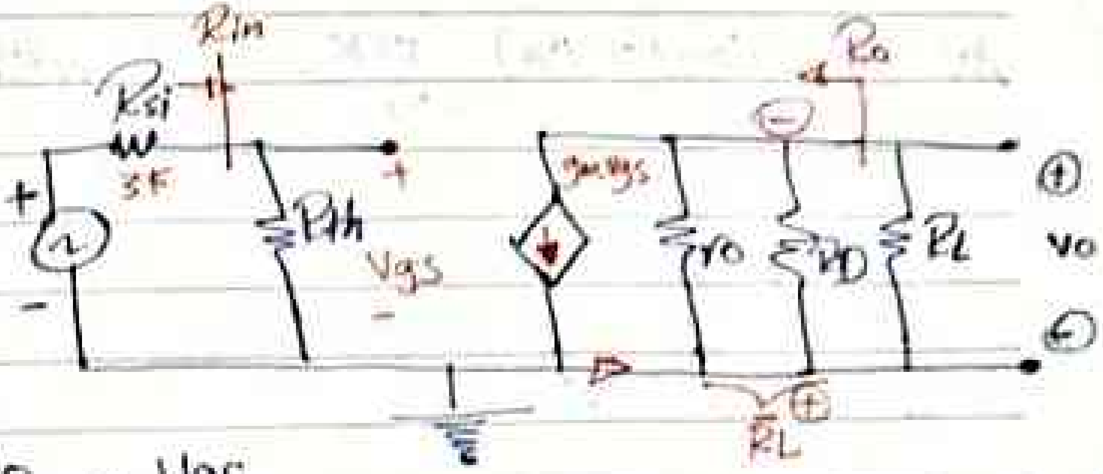
λ:- channle length modulation parameter given (V^{-1})



$$\text{slope} = \frac{\Delta I_D}{\Delta V_{DS}}$$

$$\text{slope} = \frac{I_{DQ}}{V_A}$$

$$r_o = \frac{V_A}{I_D} = \frac{1}{I_D \lambda}$$



$$A_V = \frac{v_o}{v_{si}} = \frac{v_o}{v_{gs}} * \frac{v_{gs}}{v_{si}}$$

$K_n = 1 mA/V^2$

$V_{TN} = 1V, \lambda = 0.02V^{-1}$

$$v_o = -g_m v_{gs} \bar{R}_L$$

$$\bar{R}_L = V_O // R_D // R_L$$

$$\frac{v_o}{v_{gs}} = -g_m \bar{R}_L \quad , v_{gs} = \frac{v_{si} * R_{th}}{R_{th} + R_{si}}$$

$$\frac{v_{gs}}{v_{si}} = \frac{R_{th}}{R_{th} + R_{si}}$$

$$A_V = \ominus g_m \bar{R}_L \frac{R_{th}}{R_{th} + R_{si}}$$

⊖ means 180° phase-shift between v_{si} & v_o (only in CS)

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = \frac{\partial (K_n (V_{GS} - V_{TN})^2)}{\partial V_{GS}}$$

$$g_m = 2K_n (V_{GS} - V_{TN}) \checkmark$$

OR $g_m = 2\sqrt{K_n \cdot I_D} \checkmark$

$= 2\sqrt{1*1} \Rightarrow g_m = \frac{2mA}{V}$

$$r_o = \frac{1}{\lambda I_{DQ}} = \frac{1}{0.02 * 1 * 10^{-3}} = \underline{50 k\Omega} \Rightarrow$$

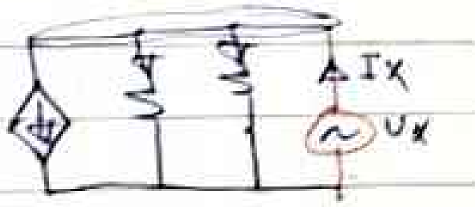
$AV = -2\,(50 // 2 // 8)\, \frac{12K}{12+3} = -2 \times 1.5 \times 0.8$

$\Rightarrow AV = -2.4.$

$\underbrace{v_o = -2.4 v_{si}}$

* $R_{in} = R_{th} = 12K\Omega$

* $R_o = ??$



$R_o = \frac{v_x}{I_x}\Big|_{v_{si}=0}$

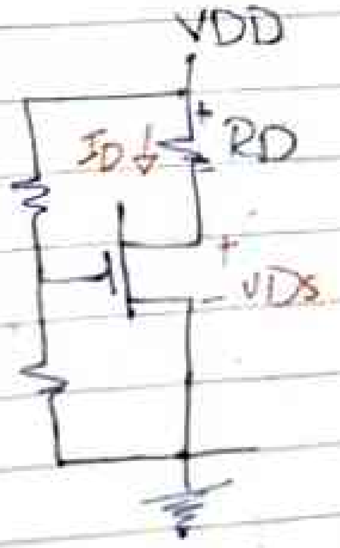
KCL at node d

$I_X = \frac{v_X}{R_D} + \frac{v_X}{r_o} + \cancel{g_m V_{GS}}$

$\frac{V_X}{I_X} = R_O = \underline{r_o // R_D}$

$R_o = 50K // 2K = 1.85\,K\Omega.$

③ Draw D.C & A.C L.L & find their slopes.



$-V_{DD} + I_D R_D + V_{DS} = 0$

$V_{DS} = V_{DD} - I_D R_D$, D.C.L.L

$\text{slope} = \frac{-1}{R_D} = \frac{-1}{2K}$

⇒

* $P_1 \Rightarrow$ cutt off voltage ($I=0$)

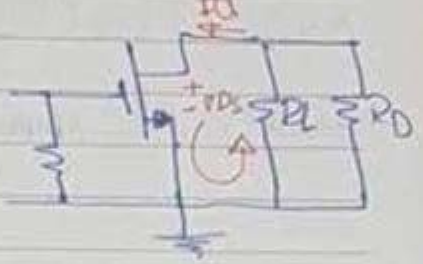
$P_2 \Rightarrow$ saturation point $\leadsto$ short cct ($V_{DS}=0$)

Sat. Reg ⟷

$V_{DS}+i_d(R_D//R_L)=0$

$V_{DS}=-i_d(R_D//R_L)$, A.C.L.L

$\text{Slope}=\dfrac{-1}{R_D//R_L}=\dfrac{-1}{1.6K}$



D.C.L.L

From D.C.L.L eq.

① For $I_D=0$, $V_{DS_{max}}=V_{DD}=5V$ * because the $\overset{max}{I_D}$ current $=0$

. $P_1(5V, 0mA)$

② for $V_{DS}=0$, $I_{D_{max}}=\dfrac{V_{DD}}{R_D}=2.5mA$ * because $V_{DS}=0$

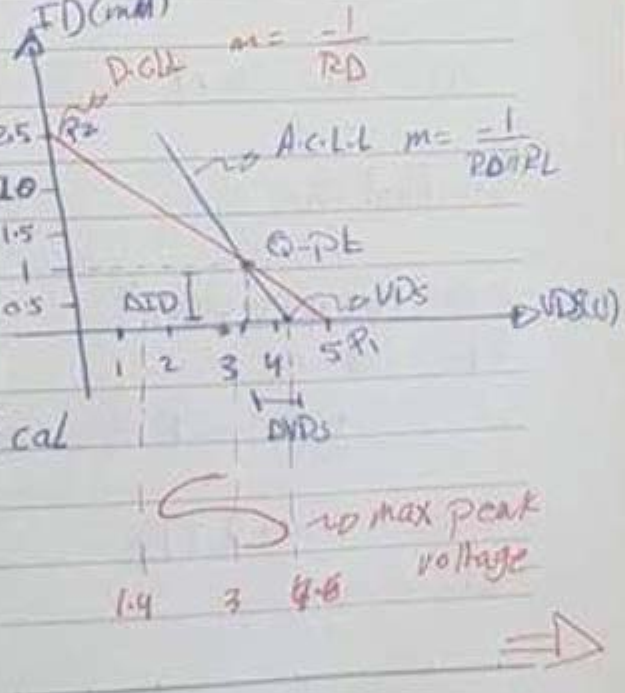
$P_2(0, 2.5mA)$

$\text{slope}=\dfrac{1}{(R_D//R_L)}=\dfrac{\Delta I_D}{\Delta V_{DS}}$

$\Delta V_{DS}=\Delta I_D(R_D//R_L)$

$\Delta I_D=I_{DQ}$

$\Delta V_{DS}=1(2//8)=\underline{1.6V}$



* ΔV_{DS} :- max peak symmetrical output voltage

⟹

$\Delta VDS = IDQ(RD // RL)$

max (P-P) symmetrical o/p voltage = $2IDQ(RD//RL)$

II C.S with Rs

→ for Kn=1

DC

($VGS = 2V$, $ID = 1mA$, $VDS = 3V$, $VDS(sat) = 1V$)

⇒ $Kn = 2.5$

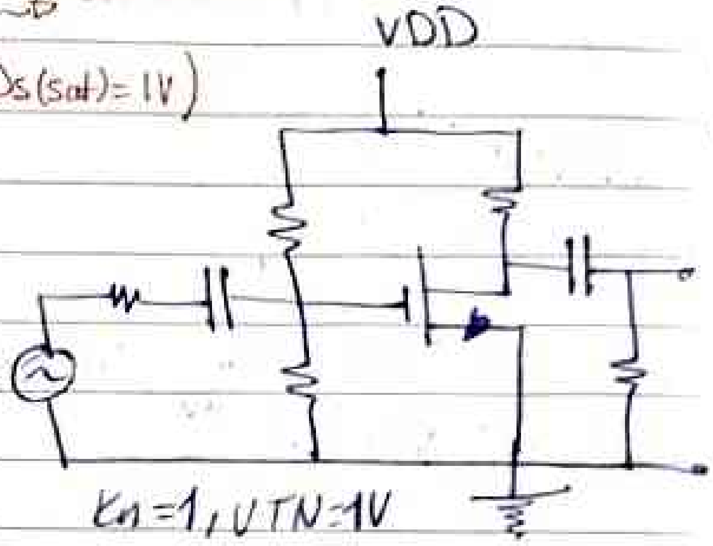
$VGS = \frac{5+20}{50} = \underline{2V}$ ✓

$ID = \cancel{25}(2-1)^2 = \underline{2.5}$ ×

$VDS = 5 - 2.5 * 2 = 0$

$VDS(sat) = 2 - 1 = \underline{1V}$

$VDS < VDS(sat)$ ⇒ Mosfet in Nonsat



D.C Analysis

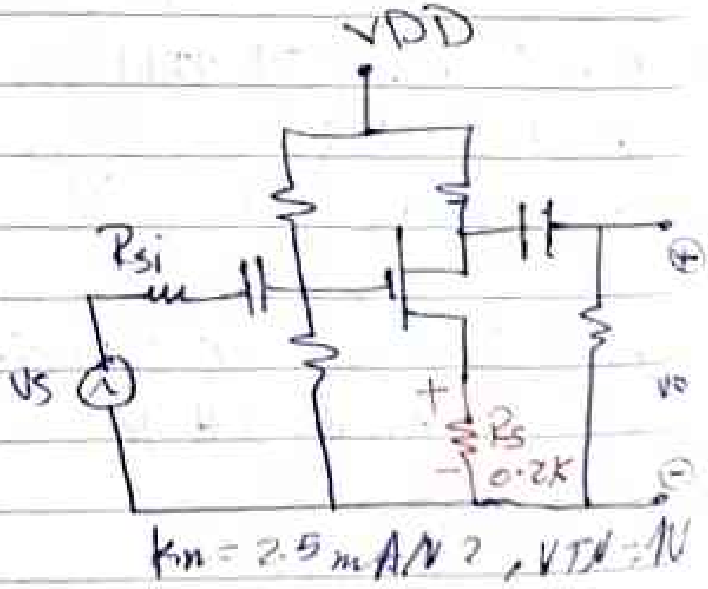
$ID = Kn(VGS - VTN)^2$

$VGS = VG - VS$

$= \frac{5*20}{50} - ID \cdot Rs$

$VGS = 2 - 0.2\, ID$

$ID = \frac{2 - VGS}{0.2}$



Rs ⇒ stabilize Q-pt against Kn variation ⇒

$ID = \frac{2-VGs}{0.2}$

$\frac{2-VGs}{0.2} = 2.5(VGs-1)^2$

$2-VGs = 0.5(VGs^2 - 2VGs+1)$

$2-VGs = 0.5VGs2 - VGs + 0.5$

$1.5 = 0.5\,VGs^2$

$VGs^2 = 3$

$VGs = \mp\sqrt{3} = \underline{\pm 1.73V}$

$ID = \frac{2-1.73V}{0.2} = \frac{0.27}{0.2}$

$\underline{ID = 1.35\,mA}$

$VDs = VDD - ID(RD+Rs)$

$= 5 - \frac{1.35 \cdot 2.2}{3} \Rightarrow \underline{VDs = 2.1V}$

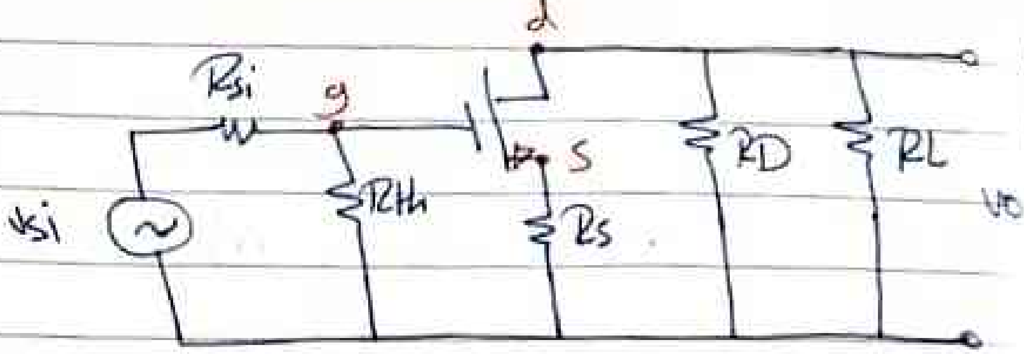
$VDs(sat) = VGs - VTN$

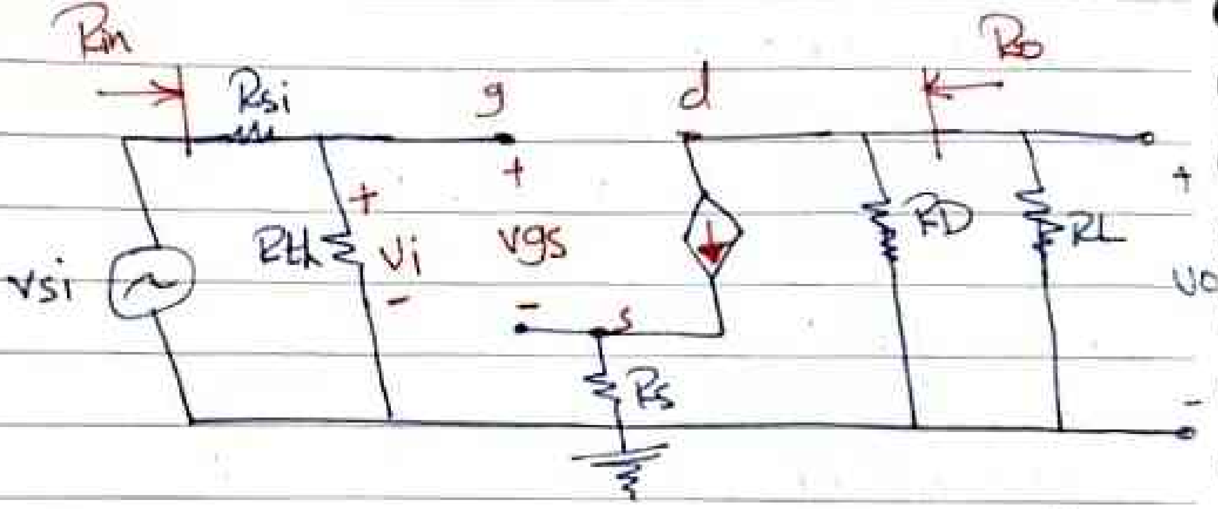
$= 1.73-1$ ∴ Mosfet in sat Region.

$VDs(sat) = 0.73\,V$

* Rs stablize Q-pt against Kn varyation.
* Rs decrease AV (disadvantage)

Ac





$$\Rightarrow AV = \frac{vo}{vsi} = \frac{vo}{vgs} * \frac{Vgs}{vi} * \frac{vi}{vsi}$$

$$vo = -gm\,Vgs\,(RD // RL)$$

$$* \frac{vo}{vgs} = -gm\,(RD // RL)$$

$$-vi + Vgs + VS = 0$$

$$Vi = Vgs + Vs$$

$$vi = Vgs + gmVgs * Rs$$

$$\Rightarrow vi = vgs(1 + gmRs)$$

$\Rightarrow$

* $\frac{v_i}{v_{gs}} = 1 + g_m R_s \Rightarrow \frac{v_{gs}}{v_i} = \frac{1}{1 + g_m R_s}$ ✓

$\Rightarrow \frac{v_i}{v_{si}} = \frac{R_{th}}{R_{th} + R_{si}}$

* R_s decrease AV (disadv.)

$AV = \frac{-g_m (R_D // R_L)}{1 + g_m R_s} \cdot \frac{R_{th}}{R_{th} + R_{si}}$

* $R_{in} = R_{th}$

* $R_o = \frac{V_x}{I_x}\Big|_{V_{si}=0}$

When $V_{si} = 0$, $V_i = 0$, $V_{gs} = 0$

$g_m V_{gs} = 0$ (D.C source is open)

$\Rightarrow R_o = R_D$

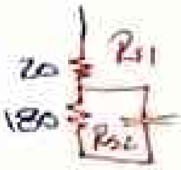
* If $R_{th} \gg R_{si}$ & $g_m R_s \gg 1$

$\Rightarrow AV \simeq -\frac{(R_D // R_L)}{R_s}$

$\Rightarrow$

← عشان احصل على افضل النتائج
والغي ال disadvantages

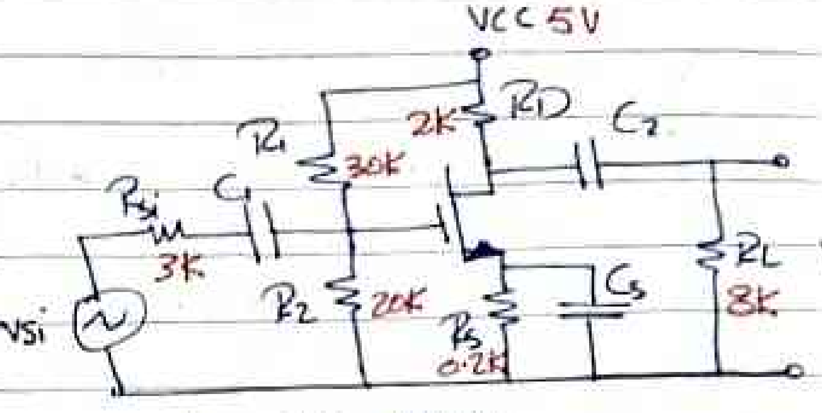
$R_S = 200 \Rightarrow$



III C.S with by pass capacitor C_s

① D.C Analysis

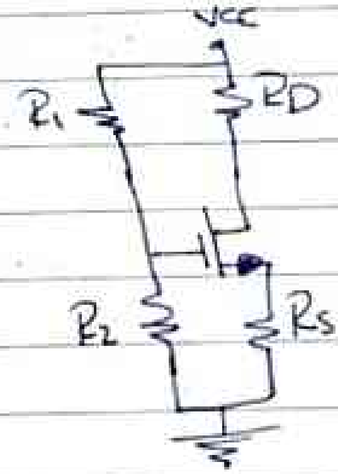
$R_D, C_S, C_1, C_2 \rightarrow$ O.C



* This cct. is analyzed as a C.S with Rs

$K_n = 2.5\ mA/V^2$

$V_{TN} = 1V$

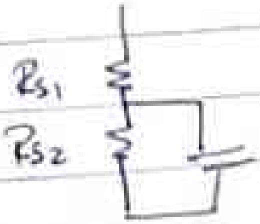


* $V_{GS} = 1.73\ V$
* $I_D = 1.35\ mA$
* $V_{DS} = 2.1\ V$

② A.C Analysis

$C \rightarrow$ S.C

* The cct behaves as a Basik



* D.C.L.L eqn :-

$-V_{DD} + I_D R_D + V_{DS} + I_D(R_{S1} + R_{S2})$

$V_{DS} = V_{DD} - I_D[(R_{S1} + R_{S2}) + R_D]$

$$\text{slope} = \frac{-1}{R_{S1} + R_{S2} + R_D}$$

$\Rightarrow$

* RD → Moderate to high.

× A.C.L.L eqn.

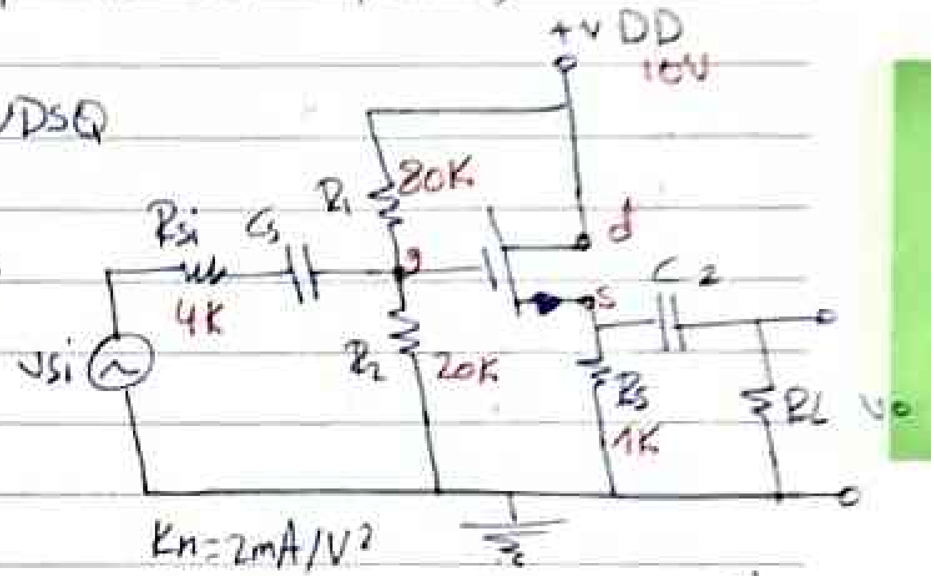
$-V_{ds} + I_d\,[R_{s1} + (R_D // R_L)]$

$$\text{slope} = \frac{-1}{R_{s1} + (R_D // R_L)}$$

② Common-Drain Amp (source follower)

1)- Determine IDQ , VDSQ

2)- Draw S.S.A.C eq cct. & find AV, Ri , Ro



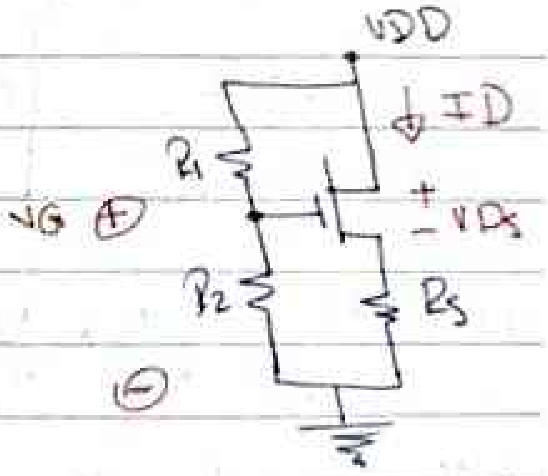
$K_n = 2\,mA/V^2$

$V_{TN} = 1V$, $\lambda = 0.01V^{-1}$

① D.C Analysis

Assume the mosfet in sat Reg.

$\Rightarrow I_D = K_n\,(V_{GS} - V_{TN})^2$



$$V_{GS} = V_G - V_S$$

$$V_{GS} = \overset{V_{R2}}{\underbrace{\frac{V_{DD}R_2}{R_1+R_2}}_{2}} - I_D R_s$$

$\Rightarrow V_{GS} = 2 - I_D$, $I_D = 2 - V_{GS}$

$\Rightarrow 2 - V_{GS} = 2(V_{GS}^2 - 2V_{GS} + 1)$

$\Rightarrow$

$\Rightarrow 2V_{GS}^2 - 3V_{GS} = 0$

$V_{GS}(2V_{GS} - 3) = 0$

$\Rightarrow V_{GS} = \overset{\times}{0} \ , \ V_{GS} = \overset{\checkmark}{1.5\,V}$

$I_D = 2 - 1.5 = 0.5\,mA$

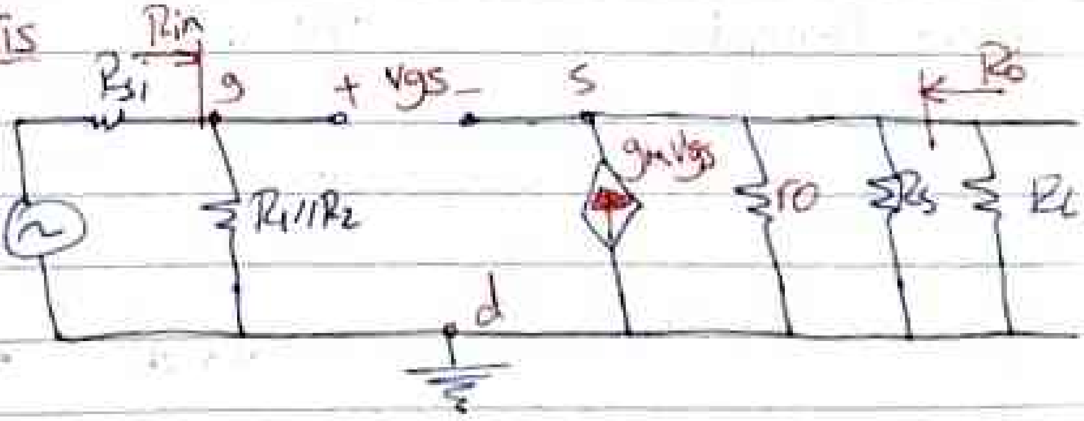
$\Rightarrow V_{DS} = 10 - 0.5 * 1$

$V_{DS} = 9.5V$

$\Rightarrow V_{DS(sat)} = 1.5 - 1$

$V_{DS(sat)} = 0.5$

② A-C Analysis



$\Rightarrow A_V = \frac{v_o}{v_{si}} = \frac{v_o}{v_{gs}} * \frac{v_{gs}}{v_i} * \frac{v_i}{v_{si}}$

$* \ v_o = g_m v_{gs}(r_o \,//\, R_S \,//\, R_L) \quad \overline{R_L}$

4 $\frac{v_o}{v_{gs}} = g_m \overline{R_L}$

$\Rightarrow$

① $\phi = 0°$ ③ Ri. depends on R_1 & R_2

② $AV < 1$ ④ Ro . Low

$\boxed{<5}$

$\Rightarrow -vi + vgs + vo = 0$

$vi = vgs + gm\,vgs\,\overline{RL}$

$vi = vgs(1 + gm\overline{RL})$

* $\frac{vgs}{vi} = \frac{1}{1 + gm\overline{RL}}$

$\Rightarrow \frac{vi}{vs} = \frac{Rth}{Rth + Rsi}$

$\Rightarrow AV = \frac{gm\overline{RL}}{1 + gm\overline{RL}} \times \frac{Rth}{Rth + Rsi}$

* If $Rth >> Rsi$ & $gm\overline{RL} >> 1$

$\Rightarrow AV = 1 = \frac{vo}{vsi}$

↳ * vo follows vsi in magnitude & phase & ro is taken from source, so it is called source follower

* $Rin = Rth$

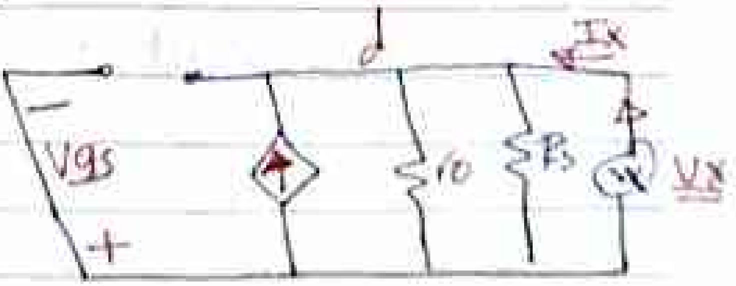
* $Ro = ??$ $\Rightarrow Ro = \left.\frac{Vx}{Ix}\right|_{vsi=0}$

* kcl at node d

$Ix + gm\,vgs = \frac{vx}{ro} + \frac{vx}{Rs}$

$vgs = -VX$

$IX = vx\left(gm + \frac{1}{ro} + \frac{1}{Rs}\right)$



$\Rightarrow$

$\Rightarrow R_o = \frac{1}{g_m} \| r_o \| R_s$

③ Common-Gate Amp (C.G)

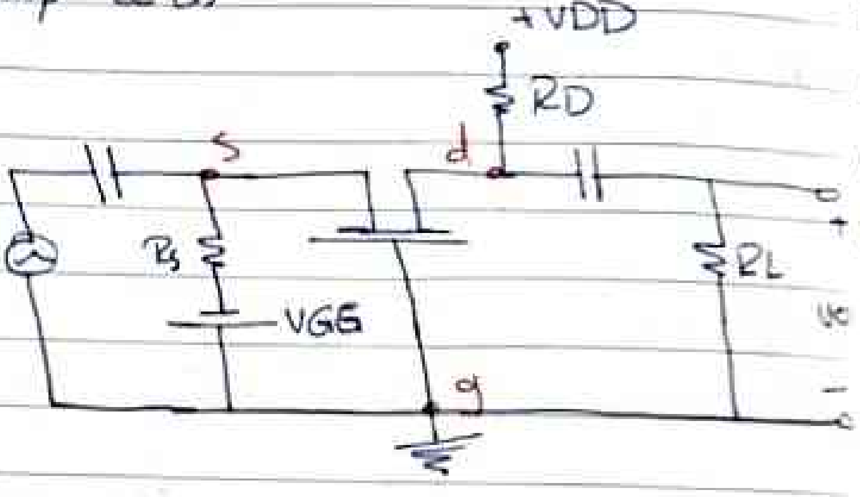
DC

v_i = source

v_o = Drain

Gate → common term

Solve for V_{GS}, I_D & V_{DS}



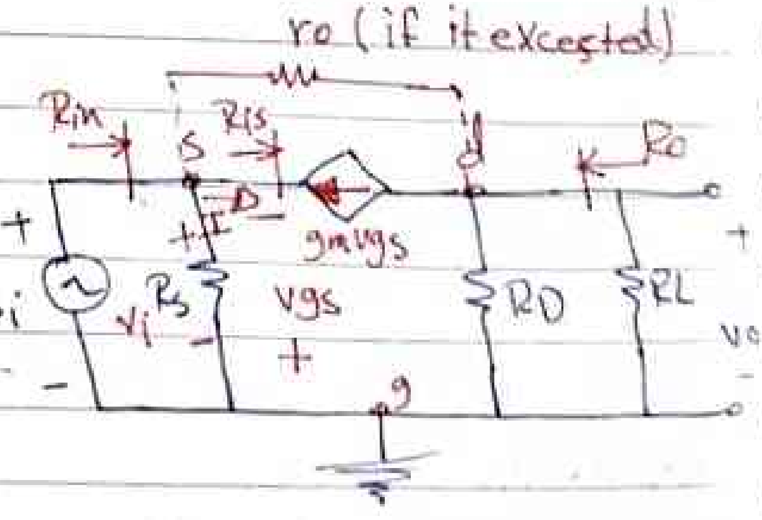
$\Rightarrow I_D = k_n (V_{GS} - V_{TN})^2$

$V_{GS} + I_D R_s - V_{GG} = 0$

$V_{GS} = V_{GG} - I_D R_s$

$I_D = \frac{V_{GG} - V_{GS}}{R_s}$

AC



$V_o = -g_m v_{gs} (R_D \| R_L)$

$v_{gs} = -v_{si}$

$\frac{v_o}{v_{si}} = g_m (R_D \| R_L)$

$\Rightarrow$ ① $\phi = 0^{\circ}$

② $AV \geq 1$

* $R_{in} = R_s \,//\, R_{is}$

$\Rightarrow R_{is} = \frac{v_i}{I} = \frac{-v_{gs}}{-g_m v_{gs}} = \frac{1}{g_m}$

$\Rightarrow R_{in} = R_s \,//\, \frac{1}{g_m}$ $\Rightarrow$ ③ Low R_{in}

* $R_o = ??$

$\Rightarrow R_o = \left. \frac{V_x}{I_x} \right|_{v_{si} = 0}$

when $v_{si} = 0$, $v_{gs} = 0$

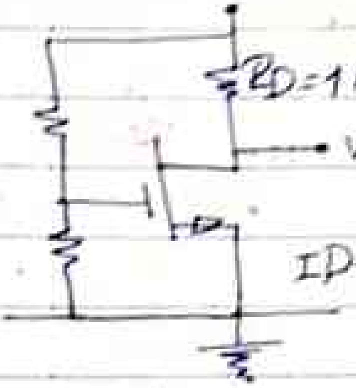
$g_m v_{gs} = 0$ (D.C source $\Rightarrow$ O.C)

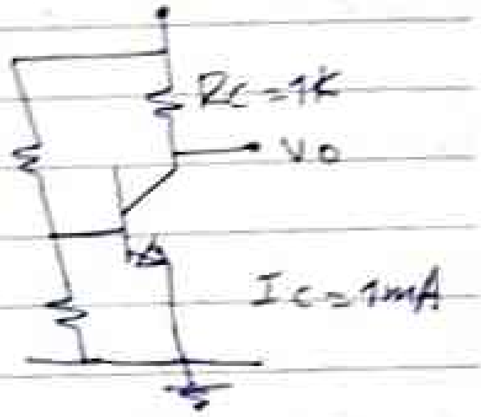
$\Rightarrow R_o = R_D$

* CD & CG used to Loading   for the same current value ≠ gm ثابت *

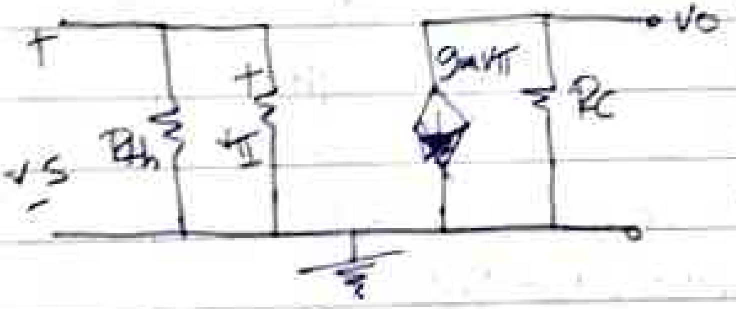
68

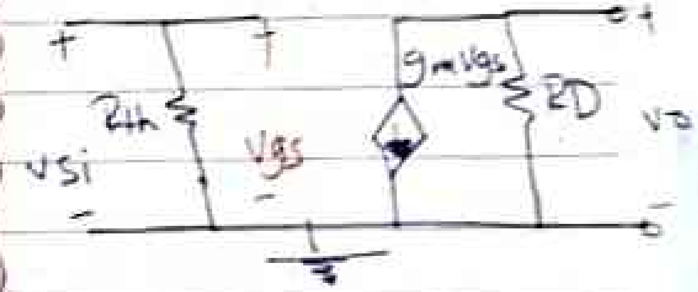
* AV for Mosfet Amp is less than AV for BJT Amp due to Low gm value for the same current level





⊜ تشابه





$AV = -gm Rc$

$= \frac{-1mA}{0.026} \cdot 1K$

$AV = -38.5$

$AV = -gm RD$

$gm = 2\sqrt{Kn Id}$

For $Kn = 10$

$gm = 2\sqrt{10 \times 1} = 6.6 \ mA/V$

$AV = -6.6$

Amp	C.S	C.D	C.G
AV	>1	<1	>1
AI	—	—	1
Ri	Rth	Rth	Low
Ro	mod-high	Low	mod-high
Ø	180°	Ø	Ø

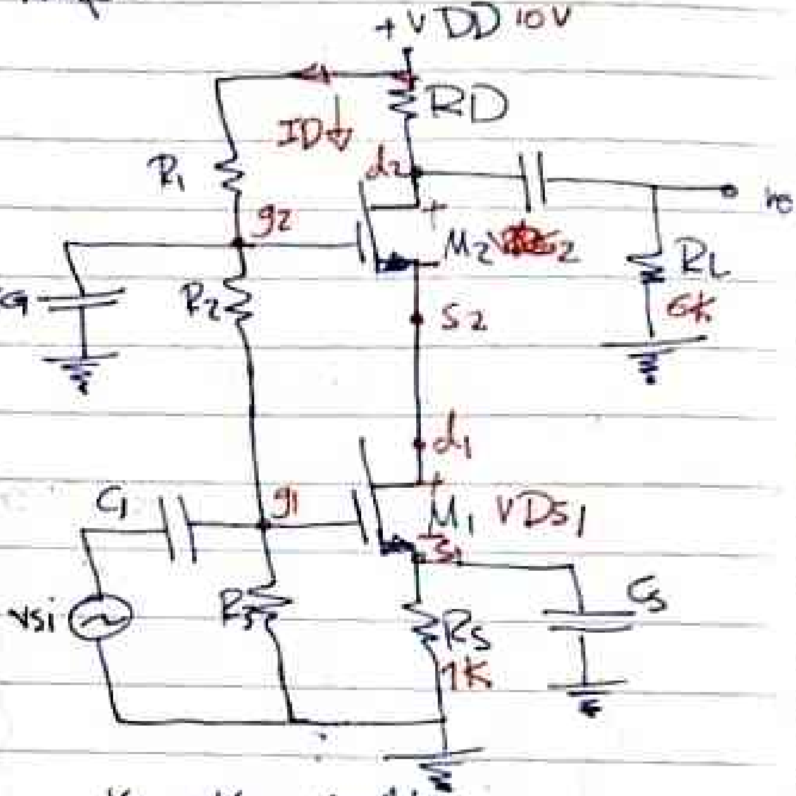
* cascode => C.S & C.G => المشترك بينهم هو التيار

multistage Amp.

① cascode multistage Amp.

* Design the cct to have
$I_{DQ} = 1mA$
$V_{DS1} = V_{DS2} = 3V$

① Find R_1, R_2, R_3, R_D
② Draw S.S.A.C eq cct
& Find A_V, R_i, R_o
– Let $I = 10\% \, I_D$



$K_{n1} = K_{n2} = 1mA/V^2$

$V_{TN1} = V_{TN2} = 1V$

sol:-

RD ??

$-10 + I_D R_D + V_{DS2} + V_{DS1} + I_D R_s = 0$

$I_D R_D = 10 - V_{DS1} - V_{DS2} - 1 * 1 = 3V$

$R_D = \frac{3V}{I_D} = 3K\Omega$ ✓

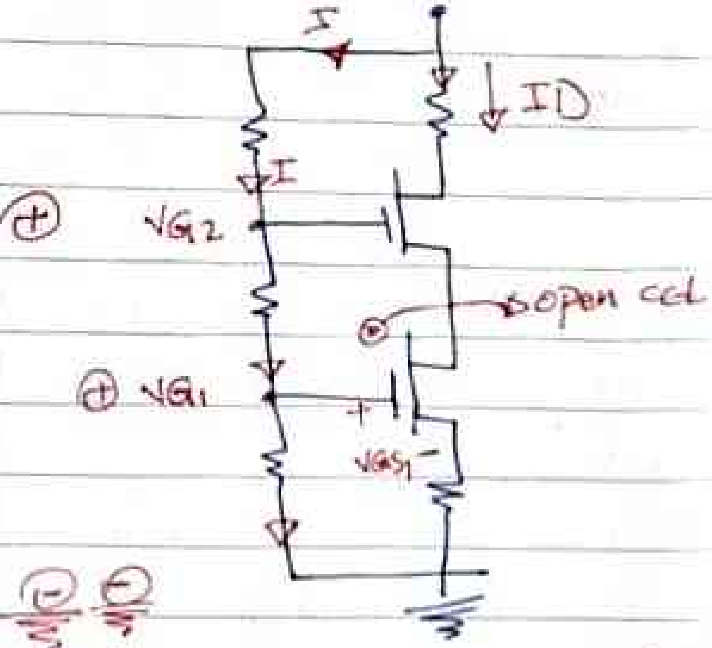
$R_3 = \frac{V_{G1}}{I}$, $R_2 = \frac{V_{G2} - V_{G1}}{I}$

$R_1 = \frac{V_{DD} - V_{G2}}{I}$

$-V_{G1} + V_{GS1} + I_D R_s = 0$

$V_{G1} = V_{GS1} + I_D R_s$

$I_D = K_n (V_{GS} - V_{TN})^2$



=>

$V_{GS} = V_{TN} \mp \sqrt{\frac{I_D}{K_n}}$

$V_{GS1} = 1 \mp \sqrt{\frac{1}{1}} = 2V$ OR $0 = V_{GS2}$

$V_{G1} = 2 + 1*1 = 3V$

$I = 0.1 * I_D = 0.1 mA$

* $R_3 = \frac{3V}{0.1} = 30 K\Omega$

$-V_{G2} + V_{GS2} + V_{DS1} + I_D R_S = 0$

$V_{G2} = 2 + 3 + 1*1 = 6V$

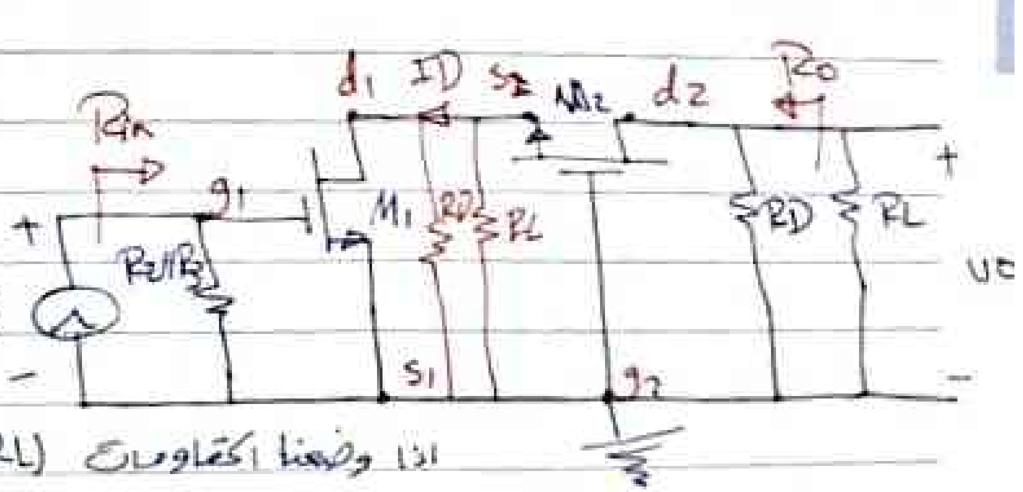
* $R_2 = \frac{6-3}{0.1} = 30 K\Omega$

* $R_1 = \frac{10-6}{0.1} = 40 K\Omega$

$R_T = 30 + 30 + 40 = 100 K\Omega$

$R_T = \frac{V_{DD}}{I_D} = \frac{10V}{0.1} = 100 K\Omega$ (for check)

② Ac Analysis



اذا وضعنا المقاومات (RD, RL) عند ال M2

فإن ال Vo ما رح يختلف لانه الدارة الثانية

هي CG وال CG هي AI=1 وال Vo

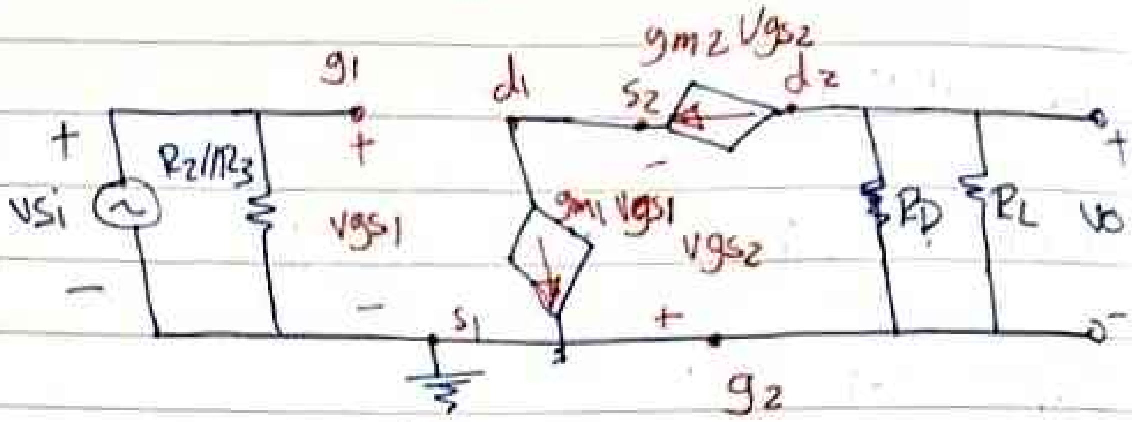
لل CG بدخل في حسابات التيار وعامل التيار

هو unity current فإذ ال $\underline{Vo} = 1$

$\Rightarrow$

* this cct is used to Amplify frequency & as a wide band Amplifier.

$\boxed{71}$



$$AV = \frac{v_o}{v_{si}} = \frac{-g_{m1} v_{gs1}(R_D//R_L)}{v_{gs1}}$$

$$= -g_m(R_D//R_L)$$

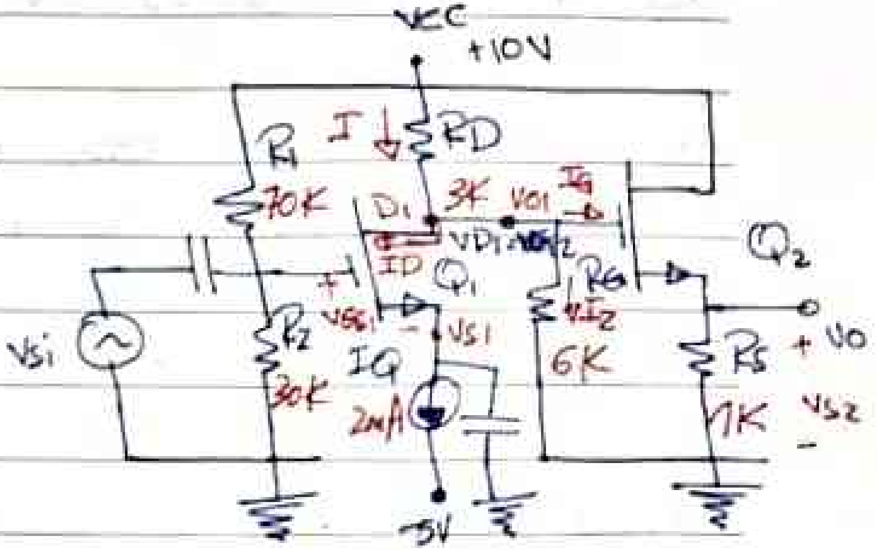
$R_i = R_2//R_3 = 15K\Omega$

$R_o = \frac{v_x}{I_x}\Big|_{v_{si}=0} = R_D$

$g_{m1} = g_{m2} = 2\sqrt{K_n I_D} = 2\ mA/V$

$AV = -2(3//6) = -4$

② cascade multistage



1)- Find VD_1, ID_2, VDS_2, VS_1

2)- Draw S.S.A.C eq cct

& Find $AV = \frac{VO}{VSi}$, Rin

Ro, Rin_2, $AV_1 = \frac{VO1}{VSi}$

Sol:-

① D.C Analysis

$Kn_1 = Kn_2 = 2mA/V^2$

$VTN = ?$ $\lambda = 0.02V^{-1}$

$VTN_1 = VTN_2 = 1\ V$

$ID_1 = 2mA$

KCL at node $\underline{D_1}$

$I = ID + I_2$

$$\frac{10 - VD_1}{3} = 2 + \frac{VD_1}{6}$$

$20 - 2VD_1 = 12 + VD_1 \Rightarrow VD_1 = \frac{8}{3} = 2.66V$, $\underline{VD_1 = VG_2}$

$ID_2 = Kn(VGS_2 - VTN)^2$

$VGS_1 = VG_1 - VS_1$

$VGS = VTN \mp \sqrt{\frac{ID_1}{Kn_1}} = 1 \mp \sqrt{\frac{2}{2}} = 2V$ $\underline{OR}$ ∅

$VS_1 = VG_1 - VGS_1$

$= \frac{10 * 30}{100} - 2 = \underline{\underline{1V}}$ ✓

$VDS_1 = VD_1 - VS_1 = 2.66 - 1 = 1.66V$

$VDS_1(sat) = VGS_1 - VTN = \underline{1V}$

$V_{GS2} = V_{G2} - V_{S2} = 2.66 - I_{D2} R_S = 2.66 - I_{D2}$

$I_{D2} = \frac{2.66 - V_{GS2}}{1} = 2.66 - V_{GS2}$

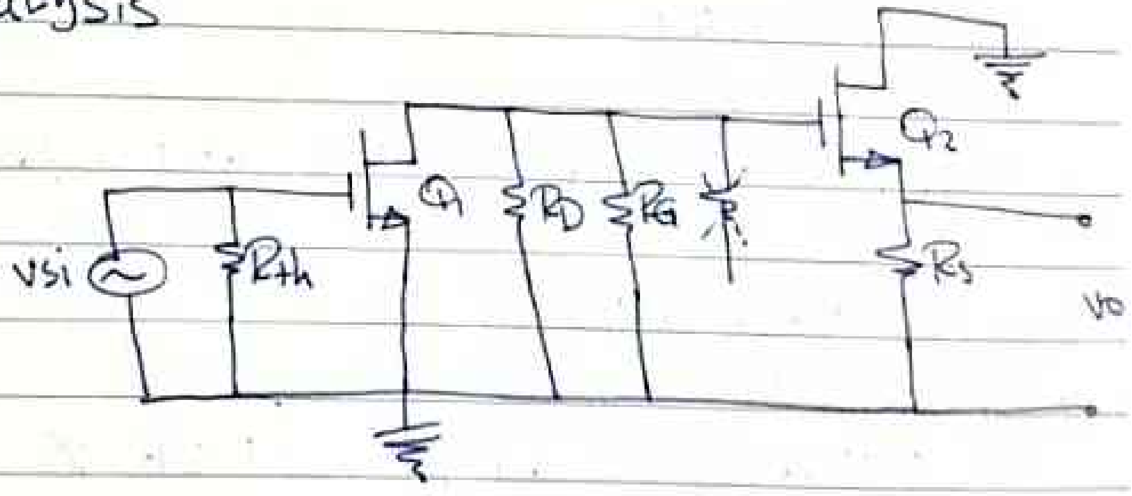
$2.66 - V_{GS2} = 2 \left(V_{GS2}^2 - 2V_{GS2} + 1 \right)$

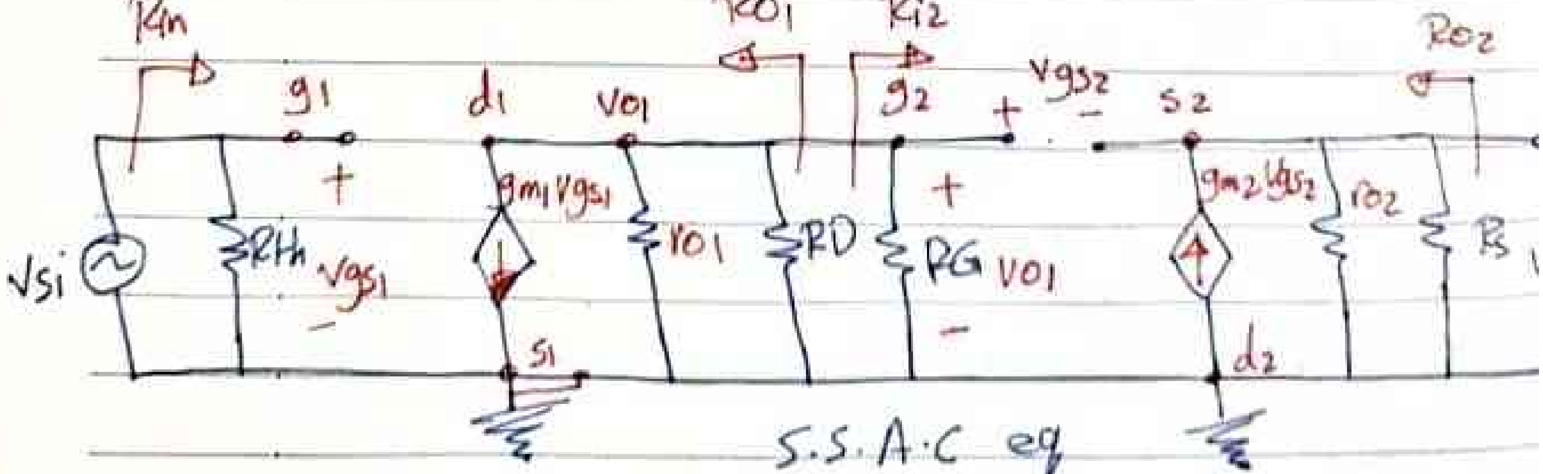
$2V_{GS2}^2 - 3V_{GS2} - 0.66 = 0$

$V_{GS2} = \frac{3 \mp \sqrt{9 + 4 * 2 * 0.66}}{4}$

$V_{GS2} = \frac{3 \mp \sqrt{14}}{4} = \frac{3 \mp 3.6}{4} = \underline{1.66\,V}$

② A.C Analysis





S.S.A.C eq
cct

ال RD جزء من الload للstage الاولى وليس من الثانية معنى ما بتدخل بال <u>Ri2</u>

* $R_{in} = R_{in1} = R_{th}$

$(70 // 30) = 21\,K\Omega$

$A_V = \frac{v_o}{v_{si}} = \frac{v_o}{v_{o1}} * \frac{v_{o1}}{v_{si}}$

$v_o = g_{m2} V_{gs2} (R_s // r_{o2})$. $g_{m1} \neq g_{m2}$ becuase ID

$-v_{o1} + v_{gs2} + g_{m2} v_{gs} (R_s // r_{o2})$

$v_{o1} = v_{gs2} (1 + g_{m2} R_s // r_{o2})$

$\frac{v_o}{v_{o1}} = \frac{g_{m2}(R_s // r_{o2})}{1 + g_{m2}(R_s // r_{o2})} \Rightarrow A_{V2}$

$v_{o1} = -g_{m1} v_{gs1} (r_{o1} // R_D // R_G)$

$v_{gs1} = v_{si}$

$\frac{v_{o1}}{v_{si}} = -g_{m1} (r_{o1} // R_D // R_G) \Rightarrow A_{V1}$

$$A_V = \underbrace{\frac{g_{m2}(r_{o2} // R_s)}{1 + g_{m2}(r_{o2} // R_s)}}_{A_{V2}} \cdot \underbrace{(-g_{m1}\ r_{o1} // R_D // R_G)}_{A_{V1}}$$

$r_{o1} = \frac{1}{\lambda I_{D1}} = \frac{1}{0.02 * 2 * 10^{-3}} = \frac{10^5}{4} = 25\,K\Omega$

$r_{o2} = \frac{1}{0.02 * 1 * 10^{-3}} = 50\,K\Omega$

$g_{m1} = 2\sqrt{K_{n1} I_{D1}} = 4m\,A/V$

طلع ال AV ـ سالب ـ لانو ال stage الاولى ← بتعطي سالب

اذا منو $\underline{R_L}$ ع ترانزستور $\underline{A_{V2}}$

$g_{m2} = 2\sqrt{K_{n2} I_{D2}}$

$A_{V1} = -4 * (25 // 3 // 6) = -7.2$ volt

$A_{V2} = \frac{2.82 * 1}{1 + 2.8} = 0.9$

$\Rightarrow A_V = -7.2 (0.9) \Rightarrow A_V = -6.7$

$R_{in2} = R_G = 6 K\Omega$

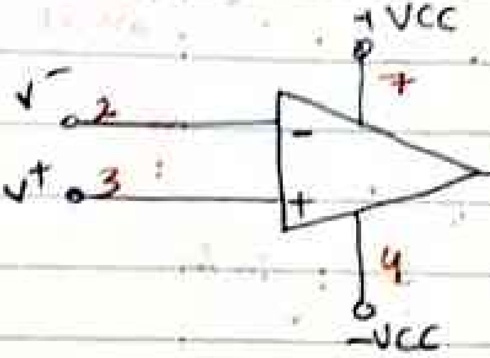
$R_{o1} = R_D // r_{o1} = 2.5 K\Omega$

$R_o = R_{o2} = \frac{V_x}{I_x} \Big|_{V_{si} = 0}$

$R_o = R_{o2} = \frac{1}{g_{m2}} // r_{o2} // R_s$

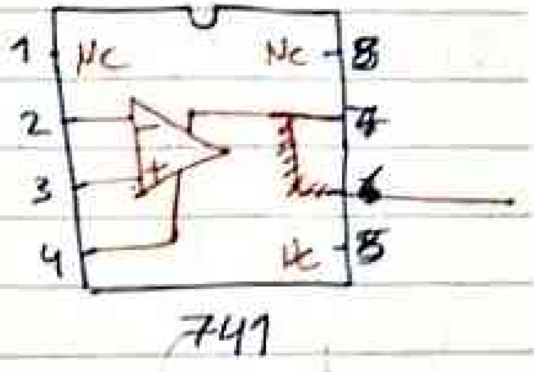
$= \frac{10^2}{2.8} // 50K // 1K = 500\Omega$

Operational Amplifier (OP-Amp)

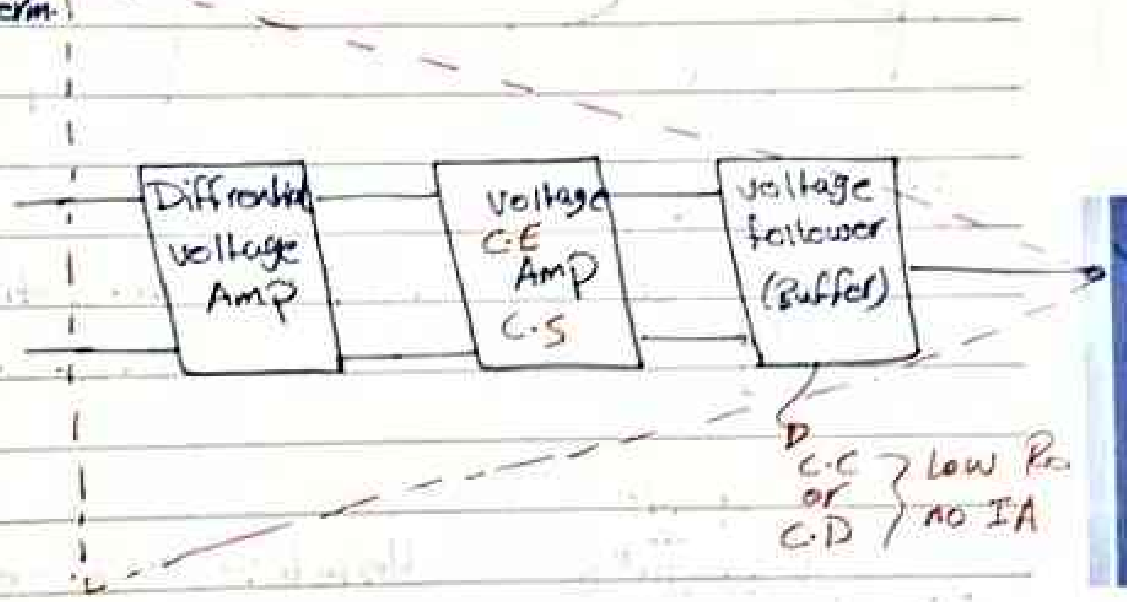


$V_o = AV(V^+ - V^-)$

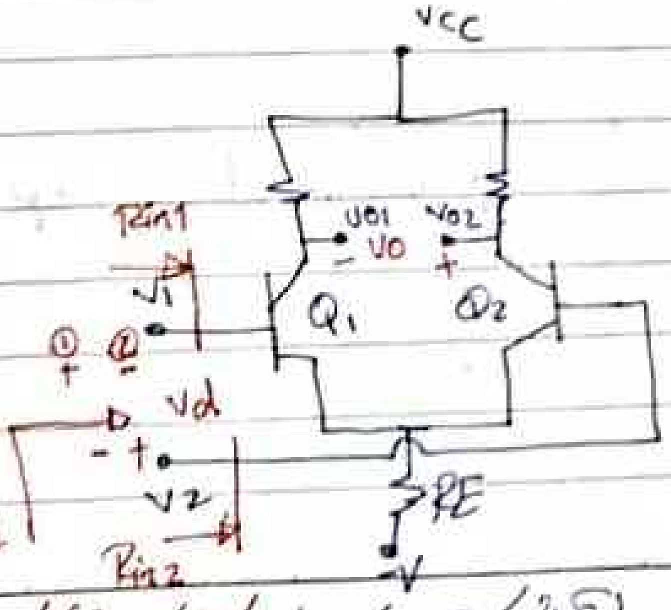
$V_o \propto V_d$



* V^{+} :- non invertor terminal
* V^{+} :- invertor term.



$$v_o = A_d \cdot v_d$$
$$= \frac{v_o}{v \pm v^-}$$



Rin diffrential (تكون كبيرة جداً)

* Rin for Mos op-Amp $\approx \infty$

* ~~BJT~~ op-Amp ⇒ بيتعامل مع ال AC& DC عشان ما في cap

+ its avery high gain direct coupled voltage Amp

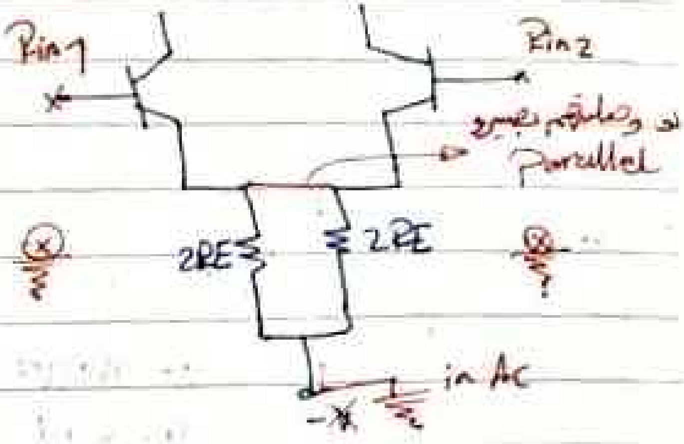
$\boxed{77}$

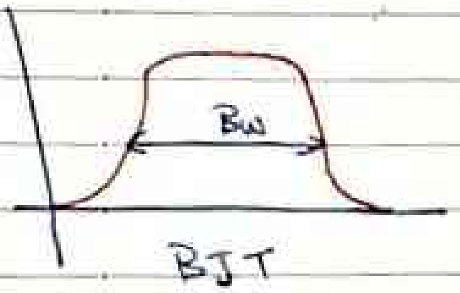
$Rin_1 = 2RE(\beta+1) + r\pi_1$

$Rin_2 = 2RE(\beta+1) + r\pi_2$

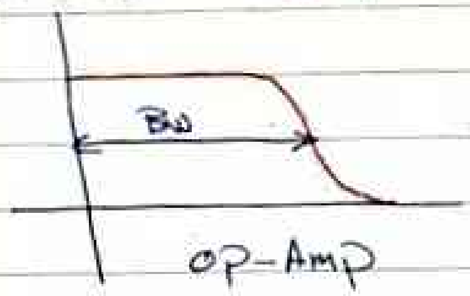
$Rid = Rin_1 + Rin_2$

$= 4RE(\beta+1) + r\pi_1 + r\pi_2$

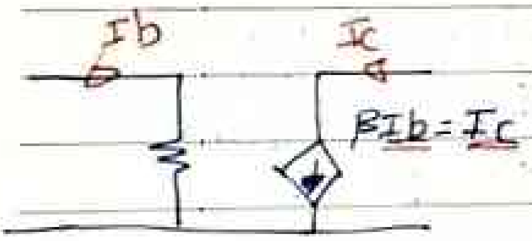




BJT



op-Amp

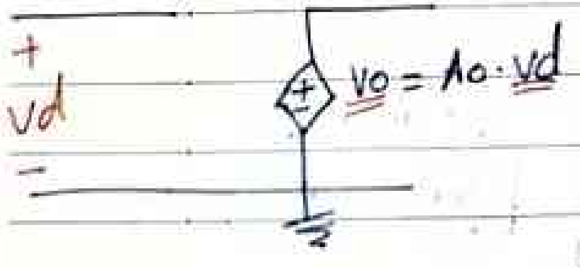


BJT :- Curr. control. Curr. source

C.C.C.S

Mosfet :- volt. cont. curr. source

V.C.C.S



op-Amp :- Volt. curr. volt. source

V.C.V.S

ما في سيطرة على ال gain (تتغير جداً)

* open Loop ⇒ بتطبيق اشارة

closed Loop بتدخل [illegible]

closed Loop ⇒ AV بعطيني

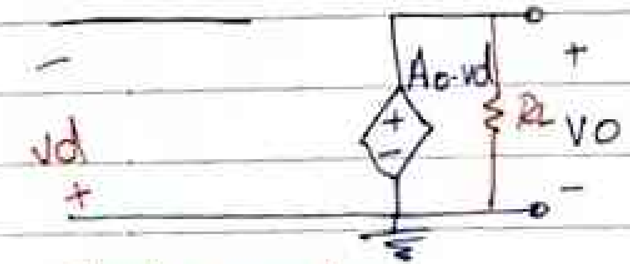
open Loop مش ما بعتمد على ال

→ in data sheet (given)

OP-Amp cks

	ideal op-Amp	LM 13600 (Mosfet)	NoN-ideal (741 → Bipolar)
R_i	∞	$10^{12}\,\Omega$	$2M\,\Omega$
R_o	0	$80\,\Omega$	$(60 \rightarrow 75)\,\Omega$
open Loop gain (A_o)	∞	10^4	$2 * 10^5$
Band width BW	∞	$2MH_z$	$1M\,H_z$
I/P bias current	0	< 10 FA $F = 10^{15}$	(1 → 10) PA

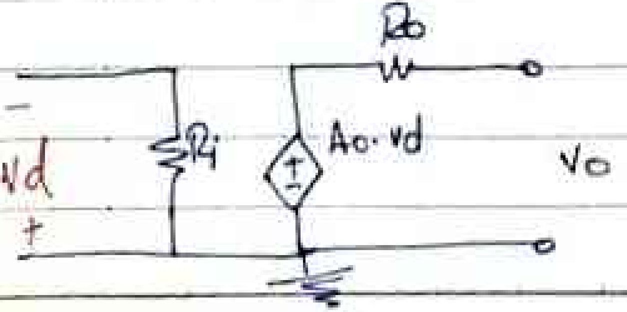
↳ for knowledge.



$v_o = A_o \cdot v_d$

⇒ vo is independente ON RL

Ideal op-Amp

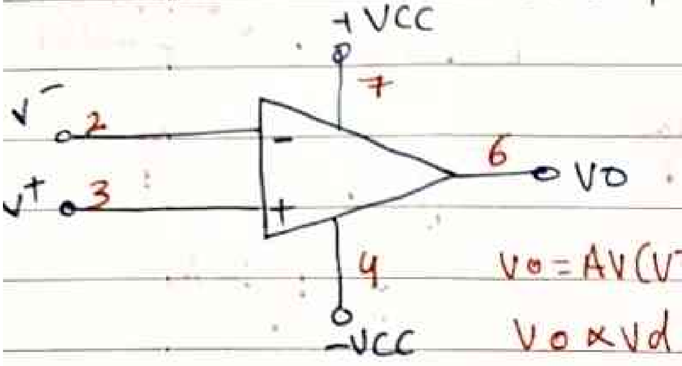


$$v_o = \frac{A_o \cdot V_d \cdot R_L}{R_L + R_o}$$

⇒ vo depends on RL

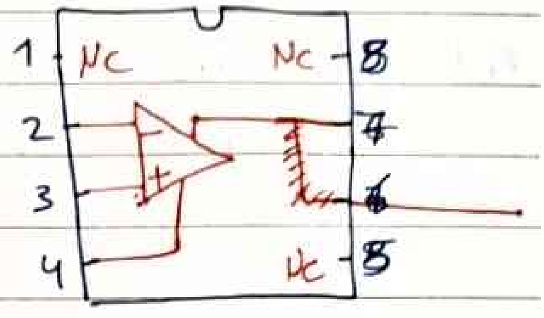
NoNeIdeal-Amp

Operational Amplifier
(OP-Amp)



$V_o = AV(V^+ - V^-)$

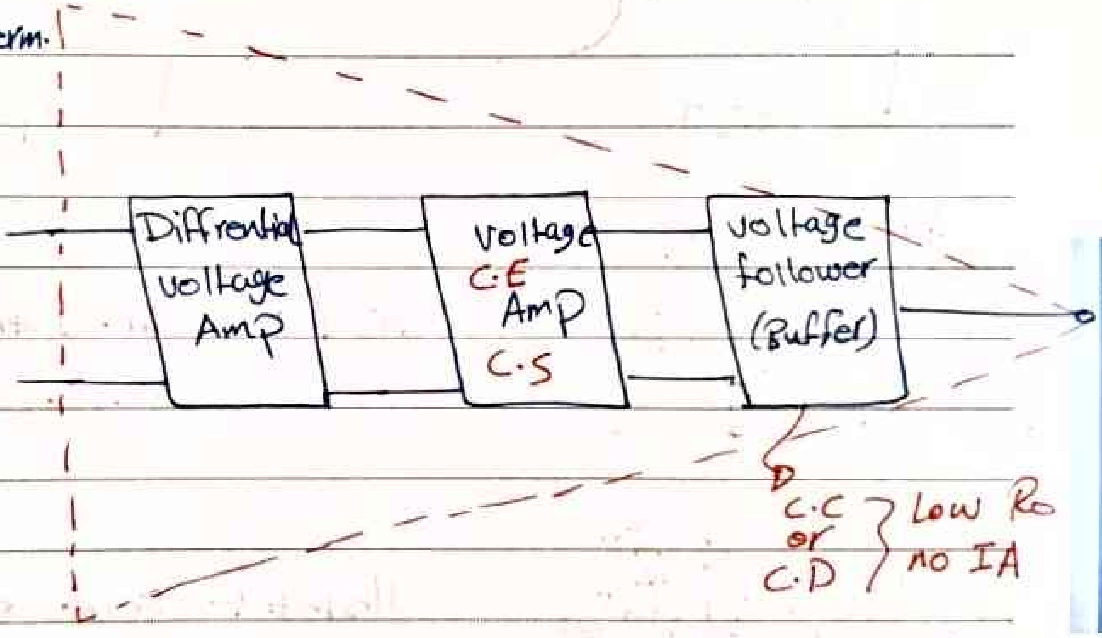
$V_o \propto V_d$



741

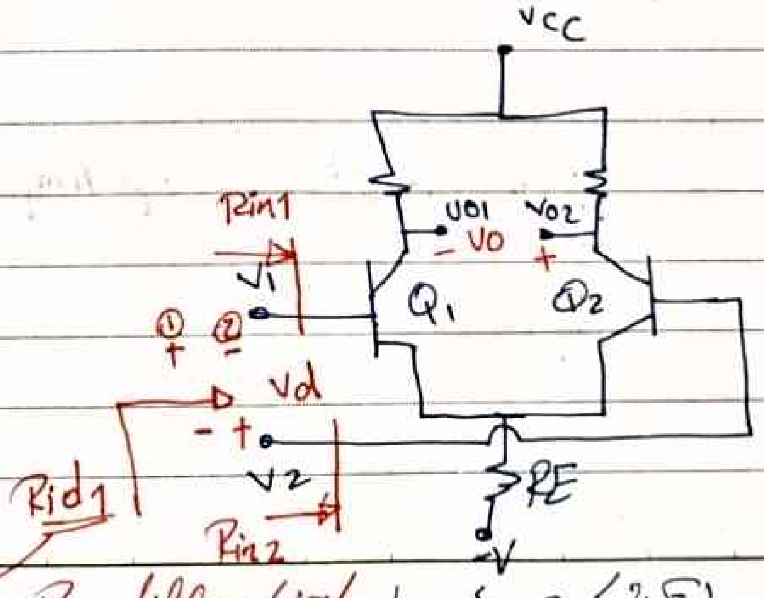
V^+:- non invertor terminal

V^+:- invertor term.



$v_a = A_d \cdot v_d$

$= \frac{V_o}{V^+ \pm V^-}$



Rin diffrential (تكون كبيرة جداً)

* Rin for Mos op-Amp ≈ ∞

* ~~BJT~~ op-Amp ⇒ بتكبرلها فيه ال AC & DC عشان ما فيه cap

* its avery high gain direct coupled voltage Amp

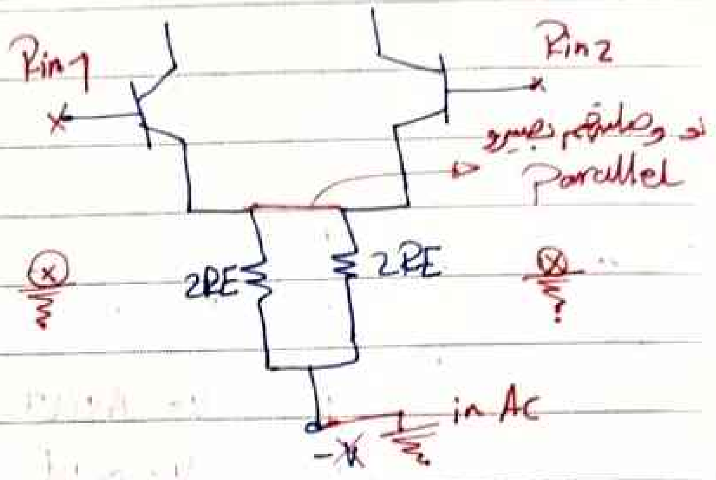
$\boxed{77}$

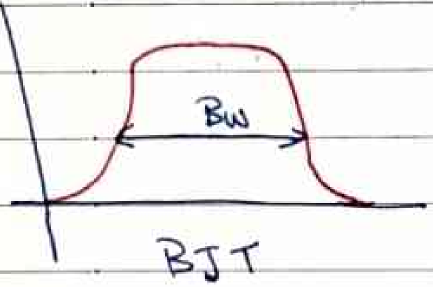
$R_{in1} = 2RE(\beta+1) + r\pi_1$

$R_{in2} = 2RE(\beta+1) + r\pi_2$

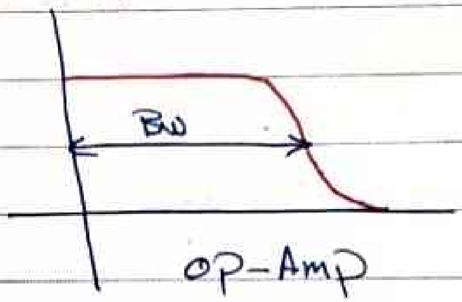
$R_{id} = R_{in1} + R_{in2}$

$= 4RE(\beta+1) + r\pi_1 + r\pi_2$

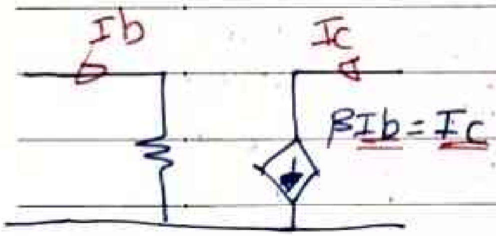




BJT

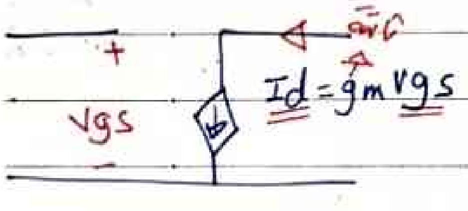


op-Amp



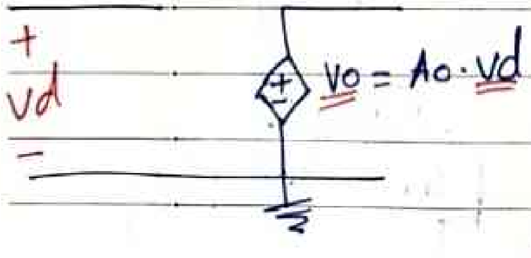
BJT :- Curr. control. curr. source

C.C.C.S



Mosfet :- Volt. cont. curr. source

V.C.C.S



op-Amp :- Volt. curr. volt. source

V.C.V.S

ما في سيطرة على ال gain (كبير جداً)

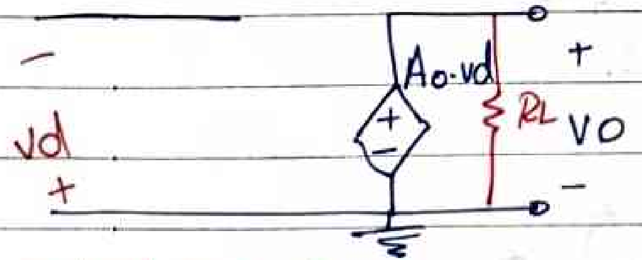
* open Loop ⇒ بطبقش اشارة } closed Loop ⇒ AV بنطلع

closed Loop بتدخل عشان أصلح } open Loop بس ما بنعتمد على ال ⇒ in data sheet (given)

OP-Amp c/cs

	ideal op-Amp	LM 13600 (Mosfet)	NON-ideal (741 → Bipolar)
R_i	∞	$10^{12}\ \Omega$	$2M\ \Omega$
R_o	0	$80\ \Omega$	$(60 \rightarrow 75)\ \Omega$
open loop gain (A_o)	∞	10^4	$2 * 10^5$
Band width BW	∞	$2MH_z$	$1M\ H_z$
I/P bias current	0	$< 10\ FA$ $F = 10^{15}$	$(1 \rightarrow 10)\ PA$

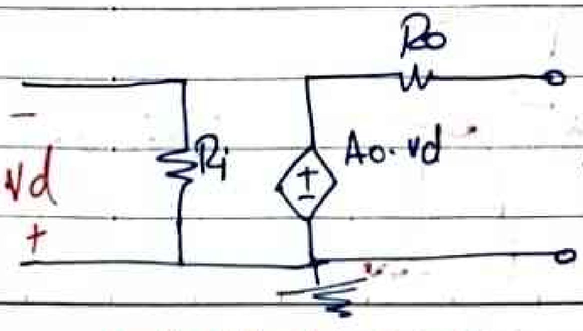
→ for knowledge.



Ideal op-Amp

$v_o = A_o \cdot v_d$

$\Rightarrow v_o$ is independente ON $\underline{\underline{RL}}$



NON-Ideal-Amp

$$v_o = \frac{A_o \cdot V_d \cdot RL}{RL + R_o}$$

$\Rightarrow v_o$ depends on $\underline{\underline{RL}}$

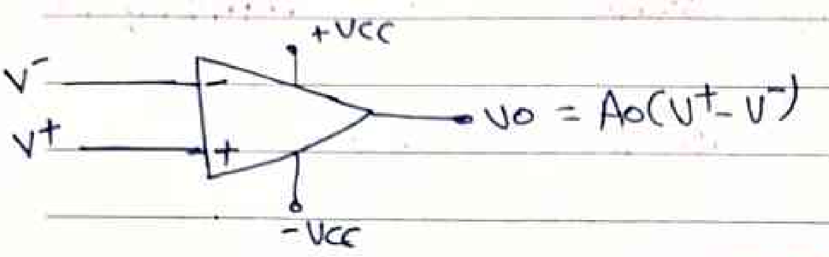
* I should operate the Amp under closed Loop so the voltage gain is maintain (equal a value, $\neq \infty$)

$\mp V_{cc}$ (max) Volt gain

* برضو بال closed بقدر ادخل $\boxed{79}$ I/P أكبر من ال 75μ وبطلع ال متحكم فيه

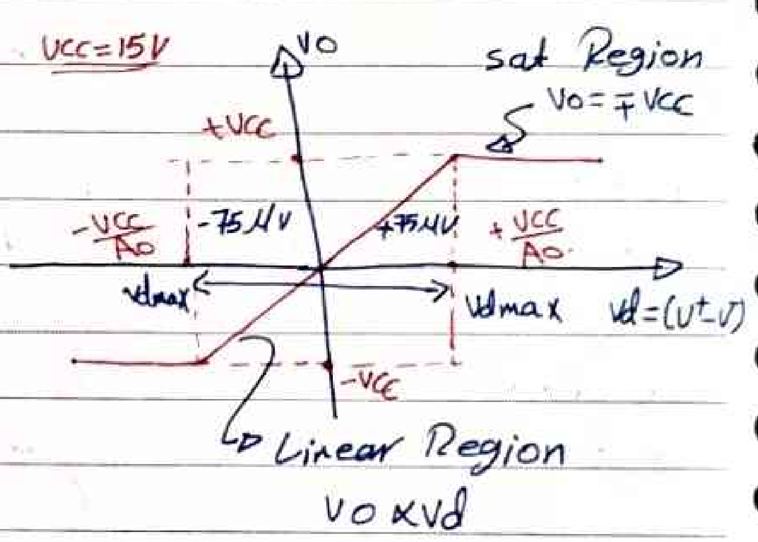
بس اذا ادخلت لأنه على ال open ال 2 تطلع عندي طلا = 200kV وهذا غير معقول

* Transfer c/c and operating Regions of op. Amp



$v_o = A_o(V^+ - V^-)$

(741)



$v_o max = \mp V_{cc}$

$v_o max = A_o \cdot V_d = \mp V_{CC}$

$v_d max = \mp \frac{V_{cc}}{A_o}$

$v_o = A_o(V^+ - V^-) = A_o \cdot v_d$

① For $v_d > 0$ $(V^+ > V^-)$

f ideal op-Amp $(A_o = \infty)$

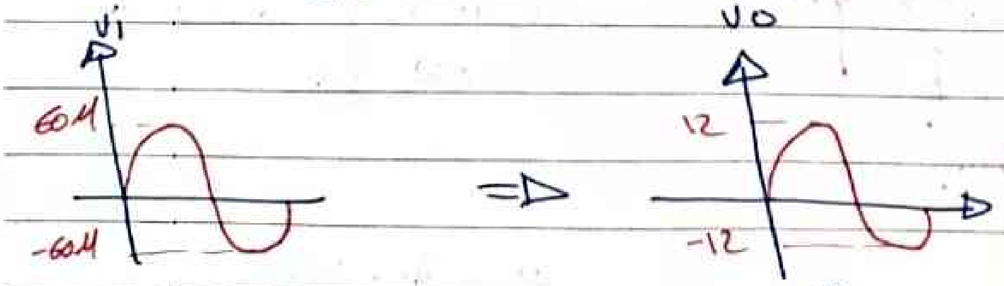
$v_o = \infty \cdot v_d \Rightarrow = +\infty = +V_{CC}$

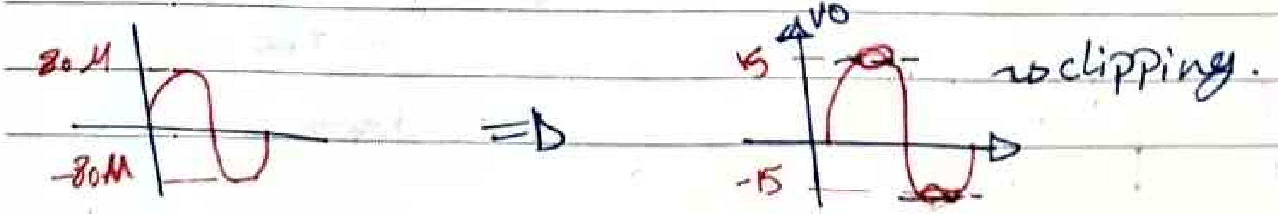
② For $V^+ < V^-$, $v_d < 0$

$v_o = \infty \cdot (-ve) = -V_{CC}$

* for 741, $A_o = 2*10^5$, $V_{CC} = \mp 15$

$v_d max = \mp \frac{15V}{2*10^5} = \mp 75 \mu V$





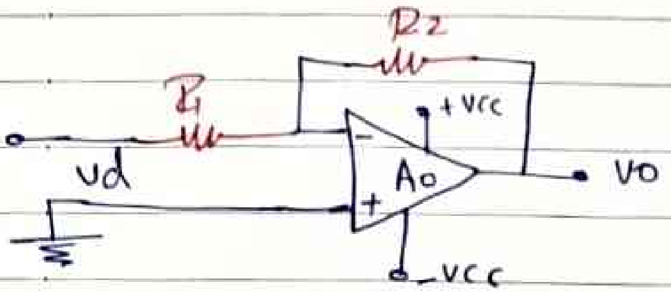
→ clipping.

* open Loop ⇒ comparator Amp.

2 voltage

* virtual short ⇒ Vnode1 = Vnode2 & neither goes to Gnd
* virtual Gnd ⇒ Vnode1 = Vnode2 & one of them " " "

$\boxed{80}$



$\Rightarrow v_o = \underbrace{\frac{R_2}{R_1}}\, v_i$

(closed Loop)

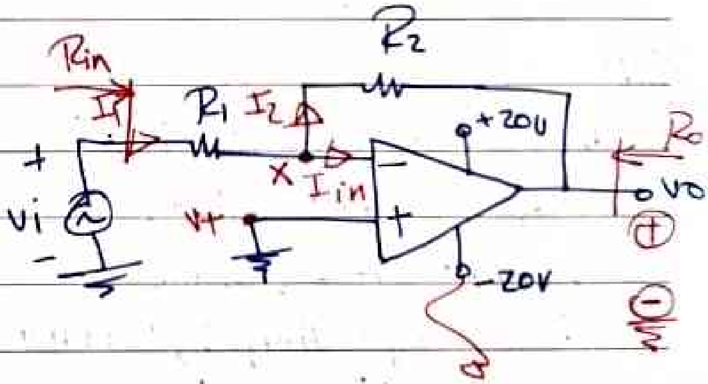
↳ من خلال هذا
ال ratio بقدر اتحكم بال vo
بحيث تطلع محصور بين ال -Vcc
وال +Vcc

op-Amp Applications

Ⓐ Linear Applications
($v_o \propto v_i$)

↳ C.E & C.S

① Inverting Amplifier



* KCL at node x
$I_1 = I_2 + I_{in}$
$\frac{v_i - v_x}{R_1} = \frac{V^- - v_o}{R_2} + I_{in}$

but for ideal op-Amp.
$I_{in} = 0$, $(R_{in} = \infty)$
$V^- = V^+ = 0$, (virtual Ground)

* هنا ما دام اعطاني قيمة اي
vo يطلعه اذا كان اكثر من
20V لازم اقصه (اقطعه)
اما اذا اعطاني ±Vcc
لو طلع ال vo = 1000 بتركه عادي
(بدون قطع)

$v_o = A_o (V^+ - V^-)$
For ideal op-Amp : $A_o = \infty$
$V^+ - V^- = \frac{v_o}{\infty} = 0 \Rightarrow \underbrace{V^+ = V^-} \rightarrow$ virtual short
but $V^+ = 0$, ∴ $V^- = 0$ (Virtual Ground)

* every
  - ↳ virtual Ground = virtual short
  - ↳ Virtual short ≠ virtual Ground

$v_x = V^-$ ضروري

$$\frac{V_i}{R_1} = \frac{-V_o}{R_2}$$

$$\Rightarrow V_o = \frac{-R_2}{R_1} V_i$$

* closed-Loop gain

$$\therefore AV = \frac{V_o}{V_i} = \frac{-R_2}{R_1}$$

* $R_{in} \Rightarrow -V_i + I_1 R_1 + 0 = 0$, R_{in} for cct = value

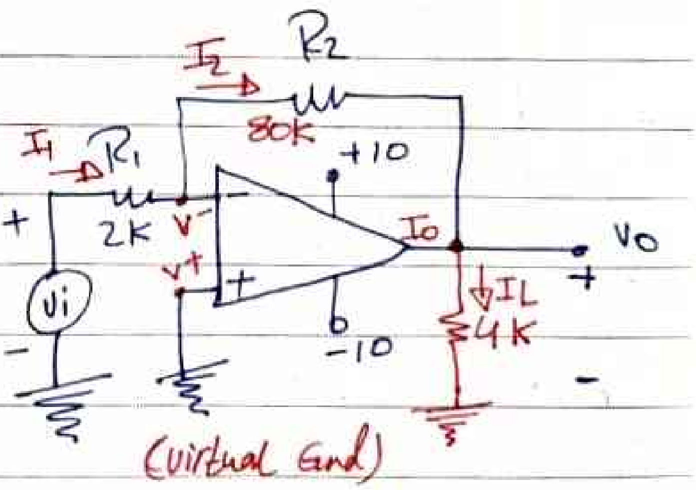
$$R_{in} = \frac{V_i}{I_1} = R_1$$

R_{in} for operational Amp $= \infty$

* $R_o = R_{o\,op\text{-}Amp} = 0$

EX:-

1)- Design an Inverting Amp to have $AV = -40$ & $R_{in} = 2K\Omega$ (assume ideal op-Amp), $V_{CC} = \pm 10V$.



2)- If $V_i = 0.3\sin(\omega t)$ [V] $\Rightarrow$ draw $V_o(t)$

3)- If $R_L = 4K\Omega$, $V_i = 0.2$ V (d.c) , calculate I_L, I_1, I_2, I_o

Sol:-

$R_{in} = R_1 = 2K\Omega$

$$AV = \frac{-R_2}{R_1} \Rightarrow -40 = \frac{-R_2}{2K} \quad , \quad R_2 = 80K\Omega$$

$\Rightarrow$

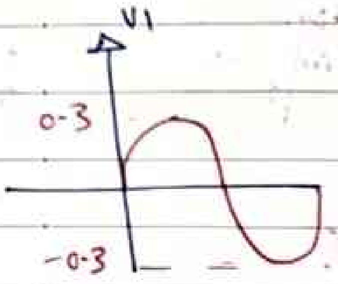
* اتجاه ال I_o بحدده بعد ما اطلع قيم باقي التيارات وبحدد اتجاههم الاصلي .

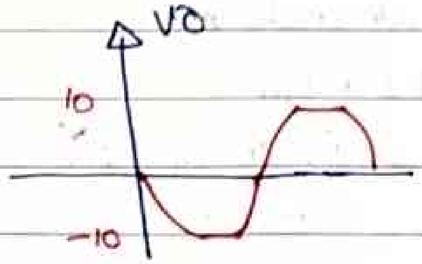
* $\underline{\underline{I_o}}$ ⇝ ~~out~~ in ⇒ sinks op-Amp

* $\underline{\underline{I_o}}$ ⇝ out ⇒ source op-Amp.

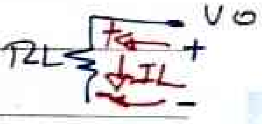
② $v_o(t) = A_V \cdot v_i = -40(0.3 \sin \omega t)$

$= -12 \sin \omega t$ [V]





③ $I_L = \frac{v_o}{R_L}$



$v_o = A_V \cdot v_i = -40(0.2) = -8V$

$I_L = \frac{-8}{4} = -2mA$

↓ $I_L = -2mA$

↑ $I_L = 2mA$ ↙

$I_1 = \frac{v_i - v^-}{R_1}$

$v^- = v^+ = 0$ (V.G)

$\Rightarrow I_1 = \frac{0.2V}{R_1} = \underline{\underline{0.1mA}}$

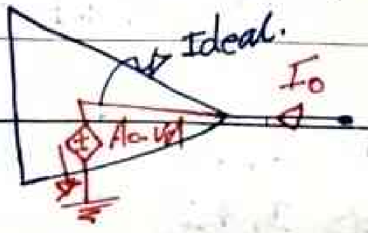
$\Rightarrow I_2 = \frac{v^- - v_o}{R_2} = \frac{0-(-8)}{80} = \underline{\underline{0.1mA}}$

must be the same becuase the op-Amp Ideal.

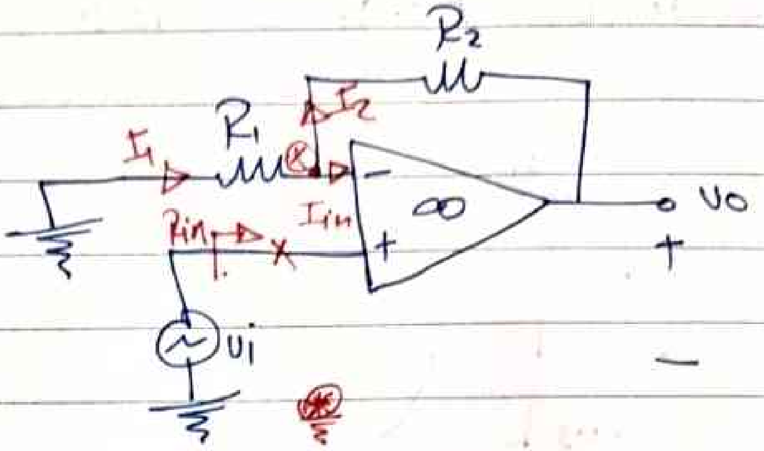
$I_2 = I_o + I_L$

$\Rightarrow I_o = I_2 - I_L = 0.1-(-2) = \underline{\underline{2.1\,mA}}$

⇒ The op-Amp sinks current



Ⅱ NoN Inverting Amp.



* KcL at node ⊗

$I_1 = I_2 + I_{in}$

$$\frac{0 - V^-}{R_1} = \frac{V^- - V_0}{R_2} + \cancel{I_{in}}^{0}$$

but $V^- = V^+ = V_i$ (virtual short)
$I_{in} = 0$] ⇒ for Ideal op-Amp

$$\frac{-V_i}{R_1} = \frac{V_i - V_0}{R_2}$$

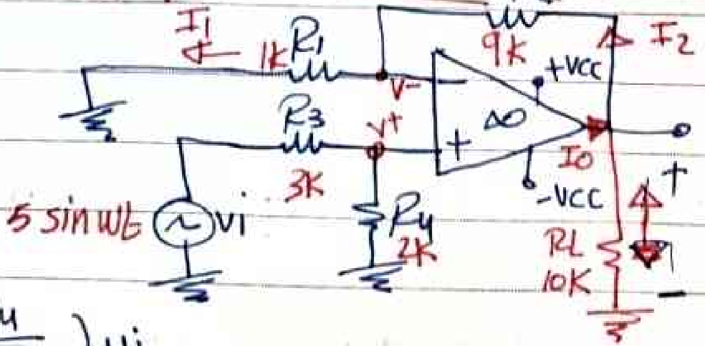
$$\frac{V_0}{R_2} = \frac{V_i}{R_2} + \frac{V_i}{R_1}$$

$$V_0 = V_i\left(1 + \frac{R_2}{R_1}\right)$$

$$\Rightarrow A_V = \frac{V_0}{V_i} = 1 + \frac{R_2}{R_1}$$

* $R_{in} = R_i\,(\text{OP-Amp}) = \infty$

Ex:-



$$V_0 = \left(1 + \frac{R_2}{R_1}\right)V^+$$

$$V^+ = \frac{V_i \cdot R_4}{R_3 + R_4}$$

$$V_0 = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_4 + R_3}\right)V_i$$

بتحكم فيه عن
طريقة Rin

⇒

* $V_0 = \overset{}{\underset{(+)}{+}}ve$ ⇒ I_1 & I_2 ↺ (counter clock wise) , IL ↓ , I_0 →
* $V_0 = \underset{(-)}{-}ve$ ⇒ I_1 & I_2 ↻ (C.W) , IL ↑ , I_0 ←

$$AV = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3+R_4}\right)$$

* For the previous figure :-

calculate :- $AV, I_1, I_2, I_L, V_{o1}, I_o$

sol:-

$$AV = \left(1+\frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3+R_4}\right) = \left(1+\frac{9}{1}\right)\left(\frac{2}{2+3}\right) = 10 * 0.4 = 4$$

$$V_o = AV \cdot V_i = 4 * 5 \sin wt = 20 \sin wt \ \underline{V}$$ ($V_o = +ve$)

$\Rightarrow$ source

$\Rightarrow$ I_o = Dow

$$\Rightarrow I_L = \frac{V_o}{R_L} = \frac{20 \sin wt}{10} = 2 \sin wt \ \underline{mA}$$

$$\Rightarrow I_1 = \frac{V^- - 0}{R_1} \ ; \ V^- = V^+ = \frac{V_i * R_4}{R_3 + R_4} = 2 \sin wt \ \underline{V}$$

$$\therefore I_1 = \frac{2 \sin wt}{1K} = 2 \sin wt \ \underline{mA}$$

$$\Rightarrow I_2 = \frac{V_o - V^-}{R_2} = \frac{(20 \sin wt - 2 \sin wt)}{9}$$

$\therefore I_2 = 2 \sin wt \ mA$, $\underline{I_1 = I_2}$ (Ideal)

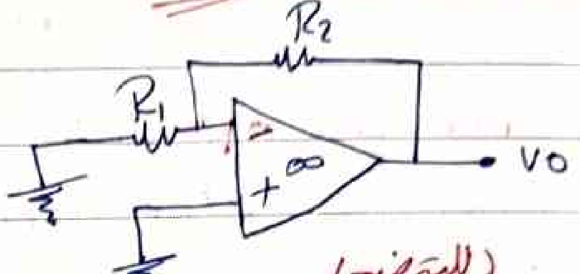
$$\Rightarrow I_o = I_2 + I_L = 2 \sin wt + 2 \sin wt$$
$$= 4 \sin wt \ \underline{mA}$$

$\therefore$ op-Amp $\Rightarrow$ source current.

* Ideal Buffer ≈ Common Drain (~~B~~ Mosfet)
(op-Amp)

(III) voltage follower (Buffer) →

حالة خاصة من ال Non-Inv.



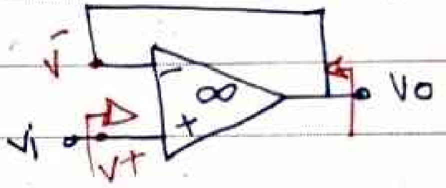
(للتوضيح)

$R_1=\infty \Rightarrow V_o=(1+\frac{R_2}{R_1})V_i$
(o.c)
$\therefore V_o=V_i$

$R_2=0 \Rightarrow V_o=(1+\frac{0}{R_1})V_i$
(s.c)
$\Rightarrow V_o=V_i$

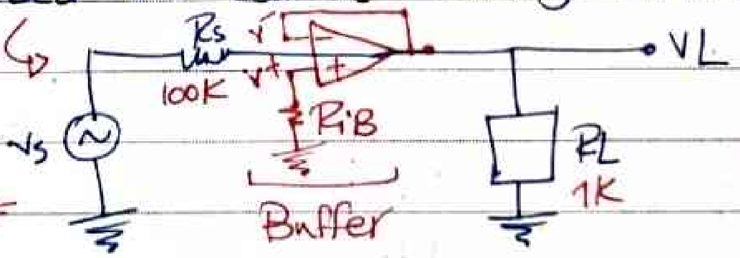
⇓

=(C.D)



$\frac{V_o}{V_i}=1 \Rightarrow V_o=V_i$

① $A_V=1$
② $\phi=0°$
③ $R_{in}=\infty$
④ $R_o=0$
⑤ It is used to cancle Loading effect.



$V_L=\frac{V_S \cdot R_L}{R_L+R_S}=0.01V_S$

↳ only 1% of Vs. is across Load. (sever loading effect) كل هذه المشكلة بتركيب *
Buffer

* after adding a Buffer.

$V_x=\frac{V_S \cdot R_{iB}}{R_{iB}+R_S}$

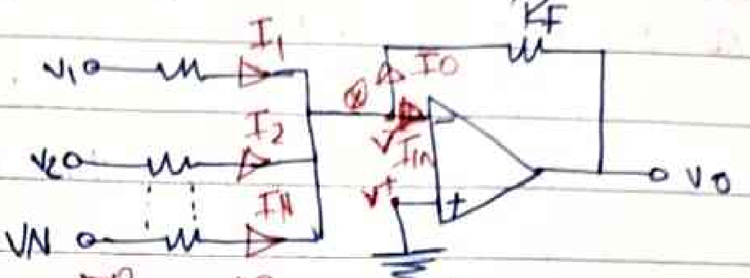
Since $R_{iB} \gg R_s$

$V_x \simeq V_S$, but $V_x=V^+=V^-=V_L$

$\therefore V_L=V_S$

$\Rightarrow$ No Loading effect.

Ⓘⓥ Inverting summing Amp



KCL at node ⓧ

$I_1+I_2+ \cdots I_N = I_o+I_{in}$

$$\Rightarrow \frac{V_1-\overset{\to 0}{V^-}}{R_1}+\frac{V_2-\overset{\to 0}{V^-}}{R_2}+\cdots+\frac{V_N-\overset{\to 0}{V^-}}{R_N}=\frac{\overset{\to 0}{V^-}-V_o}{R_F}+\overset{\to 0}{I_{in}}$$

but $V^-=V^+=0$ $\underline{(V \cdot G)}$

$I_{in}=0$

$$\frac{V_1}{R_1}+\frac{V_2}{R_2}+\frac{V_N}{R_N}=\frac{-V_o}{R_F}$$

$$V_o=-\left(\frac{R_F}{R_1}V_1+\frac{R_F}{R_2}V_2+\cdots+\frac{R_F V_N}{R_N}\right)$$

* V_1, V_2 & V_N can be
A.C, D.C, or A.C & D.C

* Special case.

$R_1=R_2=R$ ⟶ <u>Gain</u> التوصيل

$$\Rightarrow V_o=-\frac{R_F}{R}(V_1+V_2+\cdots+V_N)$$

EX:- use ideal op-Amp. to design a. cct to give:-

Ⓘ $V_o=-10\,(V_1+V_2)$

Ⓘⓘ $V_o=-(10V_1+5V_2+3V_2)$

⟹

Sol:-

① $V_o = -\frac{R_F}{R}(V_1 + V_2)$

compared to $V_o = -10(V_1 + V_2)$

$\frac{R_F}{R} = 10 \rightarrow$ let $R_1 = 1K\Omega$

$\therefore R_F = 10K\Omega$

② $V_o = -\left(\frac{R_F}{R_1}V_1 + \frac{R_F}{R_2}V_2 + \frac{R_F}{R_3}V_3\right)$

$\frac{R_F}{R_1} = 10$, $\frac{R_F}{R_2} = 5$, $\frac{R_f}{R_3} = 3$

Let $R_F = 15K\Omega$ $\rightarrow$ * انا بفرضه عشان بدي تحقق ال Design

وانا حكالي $\# < R_1 < \#$ لازم تطلع

بال Range وانا ما طلعت بغير فرضي RF

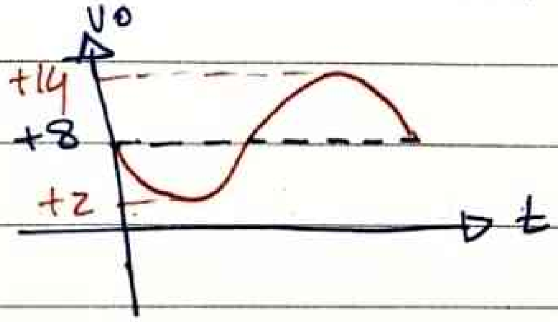
$\therefore R_2 = 3K\Omega, R_1 = 1.5K\Omega$

$R_3 = 5K\Omega$

EX:- Calculate & Draw $V_o(t)$ for $V_1 = -2V\,d.c$,
$V_2 = 3\sin\omega t$ (V). , $V_o = -(4V_1 + 2V_2)$.

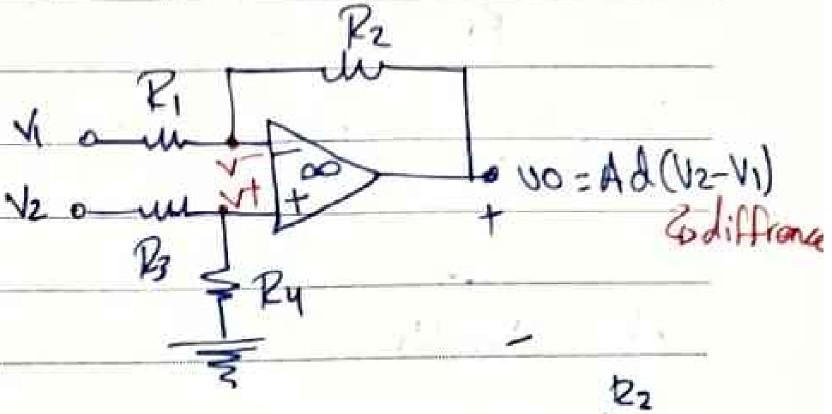
Sol:-

$$V_o = -(-4 * 2 + 2 * 3\sin\omega t)$$
$$= (8V - 6\sin\omega t)$$



→ Amp the diffrence between 2 signals

Ⓥ Diffrence Amplifier



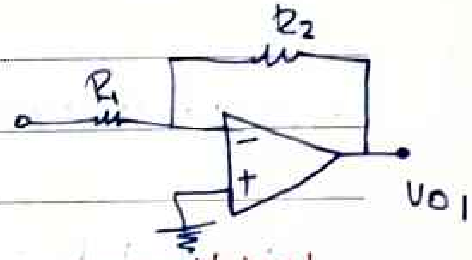
* use super position

① Effect of V_1 ($V_2 = 0$)

$$V^+ = \frac{V_2 \cdot R_4}{R_3 + R_4} = 0$$

↳

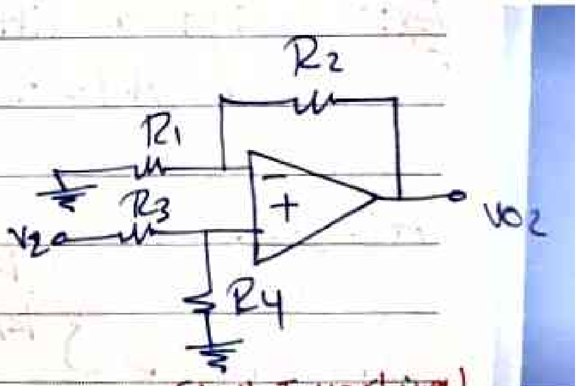
$$v_{o1} = -\frac{R_2}{R_1} V_1 \quad \Leftarrow$$



(Inverting)

② Effect of V_2 ($V_1 = 0$)

$$V^+ = \frac{V_2 \cdot R_4}{R_4 + R_3} = V^-$$



(NON-Inverting)

↳

$$v_{o2} = \left(1 + \frac{R_2}{R_1}\right) V^+$$

$$\Rightarrow v_{o2} = \left(1 + \frac{R_2}{R_1}\right) \cdot \left(\frac{\frac{R_4}{R_3}}{1 + \frac{R_4}{R_3}} \right) V_2$$

$$\therefore v_o = v_{o1} + v_{o2}$$

$$\Rightarrow v_o = \left[\left(1 + \frac{R_2}{R_1}\right) \cdot \frac{\frac{R_4}{R_3}}{\left(1 + \frac{R_4}{R_3}\right)} \cdot V_2 - \frac{R_2}{R_1} V_1 \right]$$

* If we choose $\frac{R_4}{R_3} = \frac{R_2}{R_1}$ → then ⇒

ratio = ratio ✓

~~*~~

مش مهم تكون المقاومات
متساوية المهم اشي النسبة

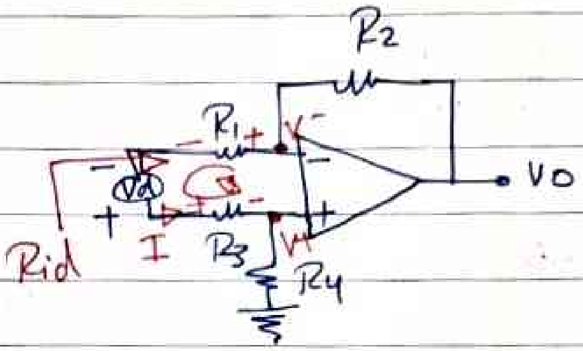
* بين ال branch اللي تحت والدائرة ⇐ Rin R3 & بين ال branch اللي فوق والدائرة $R_{in} = R_1$

بين ال 2 branches ⇐ $R_{in} = R_1 + R_3$ ← الدائرة [illegible]

$$V_o = \frac{R_2}{R_1} = \frac{R_4}{R_3} (v_2 - V_1)$$

$$\therefore \frac{V_o}{V_2 - V_1} = A_d = \frac{R_2}{R_1} = \frac{R_4}{R_3}$$

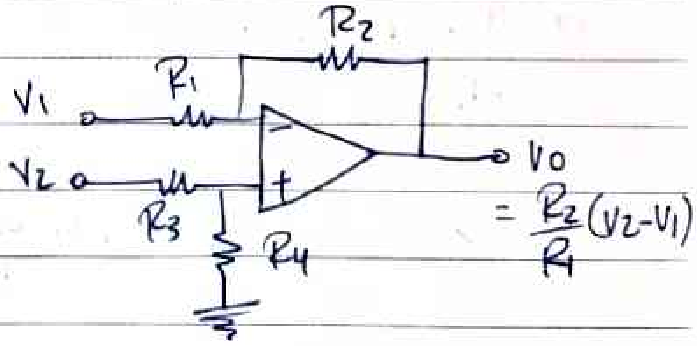
$$V_d = V_2 - V_1$$



? $-V_d + IR_3 + IR_1 = 0$

$$\frac{V_d}{I} = R_{id} = R_1 + R_3$$

Ex:- Design a diffrence Amp. to have $R_{in} = 20 K\Omega$ and $A_d = 500$.



$A_V = \frac{R_2}{R_1}$ ✓

$R_{in} = R_1 + R_3$ ✓

$\frac{R_2}{R_1} = \frac{R_4}{R_3}$

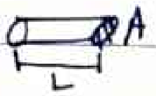
To satisfy $\frac{R_2}{R_1} = \frac{R_4}{R_3}$

we can choose $R_1 = R_3$ & $R_2 = R_4$

$\therefore R_{in} = R_1 + R_3 = 2R_1 = 2R_3$

$R_1 = R_3 = 10 \ K\Omega$

$A_d = \frac{R_2}{R_1} = 500$



$R = \rho \frac{L}{A}$

⇒ $L_{5M} = 500 \ L_{10k}$ (pract. X)

* to increase A_d, R_{in} ⇒ R_2 should be very big and that's undesired in Design

⇒

=> very High Rin, gain => adjustable

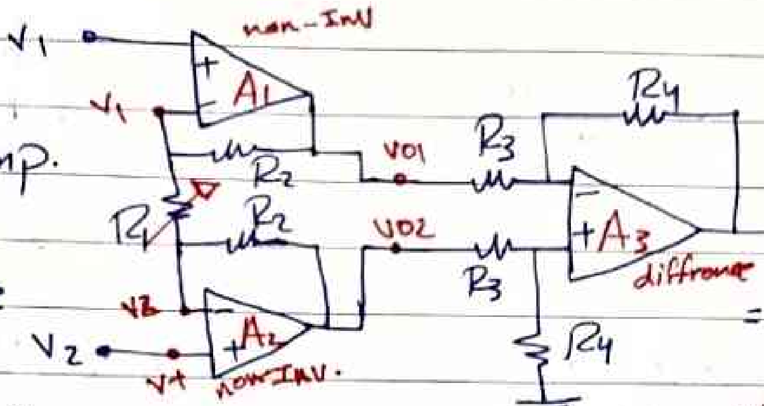
=> ~~signal~~ single element dependent

=> using resonable values $\boxed{\text{Ad}}$ of Resistance (in kΩ Range)

$R_2 = 500 * 10 = 5M\Omega$

$R_2 = R_4 = 5M\Omega$

Ⓥ Instrumentation Amp.



$= \frac{R_4}{R_3}(V_{O2} - V_{O1})$

$V_o = \$A(V_2 - V_1)$

→ desired o/p

a)- contains:- diffrence Amp → A_3

Two non-Inverting Amp → A_1 & A_2

[It is used to achive, high, adjustable and single element dependent gain, also very high i/p Resistance values (kΩ) range]

$\Rightarrow V_o = \frac{R_4}{R_3}(V_{O2} - V_{O1})$

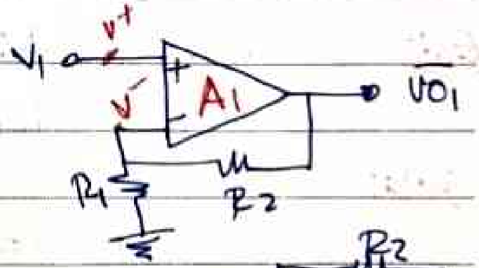
* using super position.

For $\underline{A_1}$:-

① effect of $V_1 (V_2 = 0)$

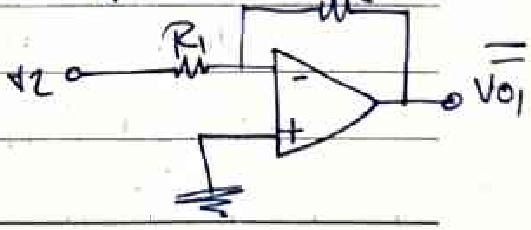
$\underset{\sim}{V^+ = V^- = V_1}$

$\bar{V_{O1}} = \left(1 + \frac{R_2}{R_1}\right) V_1$



② effect of $V_2 (V_1 = 0)$

$\bar{\bar{V_{O1}}} = \frac{-R_2}{R_1} V_2$



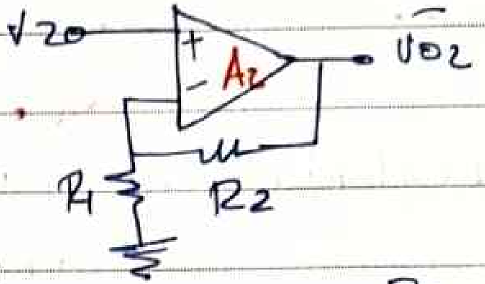
$\Rightarrow V_{O1} = \bar{V_{O1}} + \bar{\bar{V_{O1}}} = \left(1 + \frac{R_2}{R_1}\right) V_1 - \frac{R_2}{R_1} V_2$

* $R_1 \triangleright$ => to control $\underline{A}$ (gain)

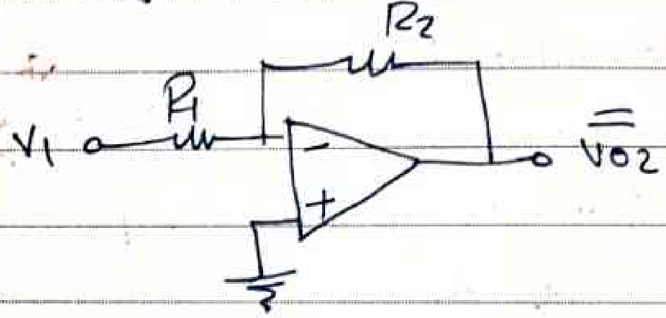
=>

For $\underline{A_2}$:-

* $V_{o2} = \bar{V}_{o2} + \bar{\bar{V}}_{o2}$



$$\bar{V}_{o2} = \left(1+\frac{R_2}{R_1}\right)V_2$$



$$\bar{\bar{V}}_{o2} = -\frac{R_2}{R_1}V_1$$

$$\Rightarrow V_{o2} = \left(1+\frac{R_2}{R_1}\right)V_2 - \frac{R_2}{R_1}V_1$$

$$\Rightarrow V_o = \frac{R_4}{R_3}\left[\left\{\left(1+\frac{R_2}{R_1}\right)V_2 - \frac{R_2}{R_1}V_1\right\} - \left\{\left(1+\frac{R_2}{R_1}V_1\right) - \frac{R_2}{R_1}V_2\right\}\right]$$

$$V_o = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)(V_2-V_1)$$

$$\frac{V_o}{V_2-V_1} = A_d = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)$$

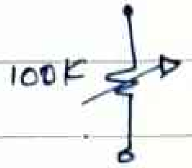
Ex:- Design an AI to have adjustable gain (5→500) The max Resistor must Not exceed 100 kΩ.

Sol:-

$$\underset{A_{min}}{5} \rightarrow \underset{A_{max}}{500}$$

$$A_d = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1 \triangledown}\right)$$

Choose R_1 to be variable Resistor



$(0 \rightarrow 100 K\Omega)$

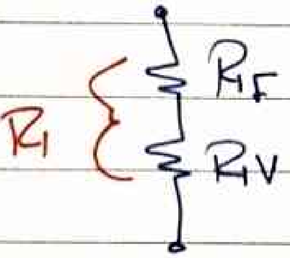
$\rightarrow$ but at $R=0 \Rightarrow A_d = \text{-----} \left(1+ \frac{2R_2}{\cancel{0}}\right) \overset{\infty}{\uparrow}$

so the gain will equal ∞

& the op-Amp enter the sat mode

so I should seperate $\underline{R}$ into two Resistor's, one fixed & the other variable

$\Rightarrow$



* $A_{min} \rightarrow R_1$ max

* $A_{max} \rightarrow R_1$ min

Let R_{1V} to be a Potenchometer of $100 k\Omega$

$R_{1max} = R_{1F} + R_{1V}(max) = R_{1F} + 100K$

$R_{1}\,min = R_{1F} + R_{1V}(min) = R_{1F}$

$$5 = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_{1F}+100}\right)$$

Let $\frac{R_4}{R_3} = 2 \rightarrow \underset{\text{Ratio}}{\underline{A_{min}}} > 1$ احساب العزمن *

$\rightarrow$ الا بعزفنه

$$5 = 2\left(\left(1 + \frac{2R_2}{R_{1F}+100}\right)\right.$$

$$1.5 = \frac{2R_2}{R_{1F}+100K}$$

$$2R_2 = 1.5R_{1F} + 150K \quad ---- ①$$

$$\Rightarrow 500 = 2\left[1 + \frac{2R_2}{R_{1F}}\right]$$

$$249 = \frac{2R_2}{R_{1F}}$$

$$2R_2 = 249\,R_{1F} \quad --- ②$$

equate $\underline{1}$ & $\underline{2}$

$$1.5R_{1F} + 150 = 249\,R_{1F}$$

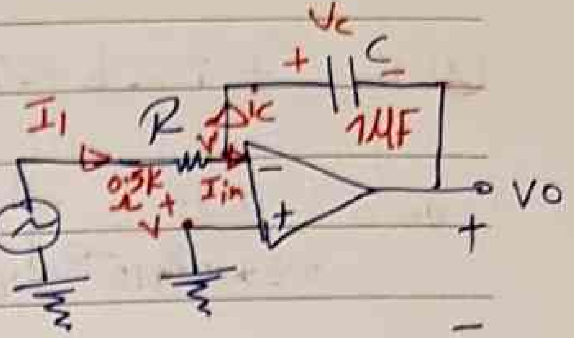
$$R_{1F} = \frac{150}{247} = 0.62k\Omega$$

$$R_2 = \frac{249 * 0.62}{2} = 75\,k\Omega$$

Let $R_3 = 1K\Omega$

$R_4 = 2K\Omega$

Ⅶ Integrator



$I_1 = I_{in} + i_C$

$\frac{v_i - v^-}{R} = \overset{0}{\cancel{I_{in}}} + C\frac{dv_c}{dt}$

$v_c = v^- - v_o \rightarrow v_o = v_c$

but for ideal op-Amp

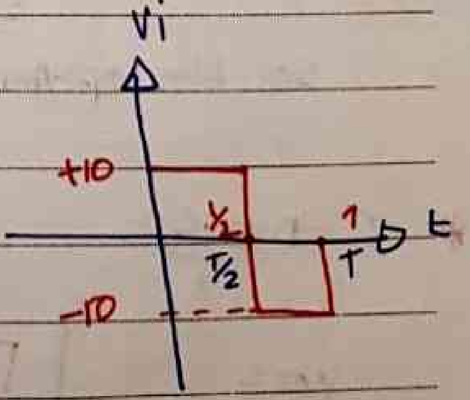
$I_{in} = 0$, $v^+ = v^- = 0$ (V.G)

$\Rightarrow \frac{v_i}{R} = -C\frac{dv_o}{dt} \Rightarrow dv_o = \frac{-v_i}{Rc}$

$\int dv_o = \int -\frac{v_i}{Rc} \cdot dt$

$\Rightarrow \underline{v_o = -\frac{1}{Rc}\int v_i \, dt} + \overset{0}{\cancel{K}}$

* Draw vo(t) for the input shown.



① for $0 < t < T/2 \Rightarrow V_i = 10V$

$v_o = -\frac{1}{Rc}\int_0^{T/2} 10 \cdot dt = \frac{-10t}{Rc}\Big]_0^{0.5ms}$

$\Rightarrow v_o = -\frac{10t}{0.5*10^3*1*10^{-6}}\Big]_0^{0.5ms}$

$F = 1KHz$, $T = \frac{1}{1K} = \underline{1ms}$

$v_o = \frac{-10*10^3}{0.5}(0.5-0)*10^{-3} = \frac{-5}{0.5} = \underline{-10}$

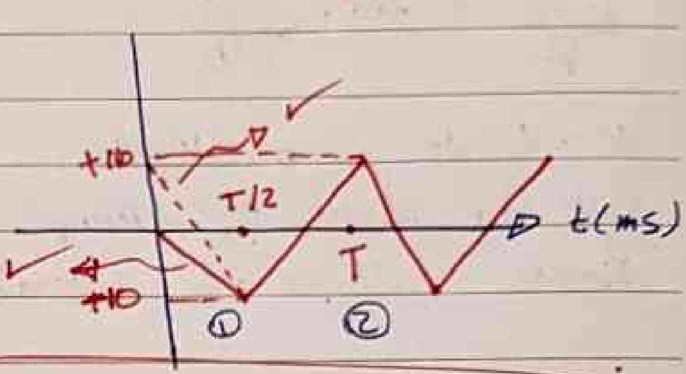
* $-\frac{1}{RC}$ ⇒ Gain

* Amp & Integrate at the same time ⇝ [illegible]

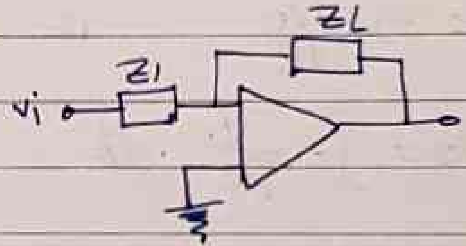
95

② For $\frac{1}{2}T < t < T$, $v_i = -10V$

$$v_o = \frac{10t}{0.5 \times 10^3 \times 10^{-6}} \Big]_{0.5}^{1} = +10V$$



* $A_V = -\frac{Z_L}{Z_1}$, $Z_1 \rightarrow R_1$



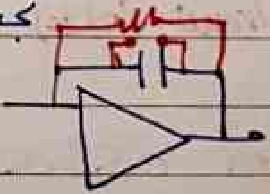
$Z_L = X_C = \frac{1}{2\pi f C}$

fc:- Low freq ⇒ $X_C = \infty$, $A_V = \infty$

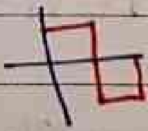
لهيك بنحط R عالية بركب parallel تكون Res.

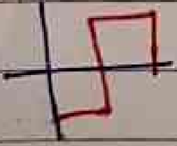
بحيث انو لا تصير $C = \infty$ ⇐ O.C.

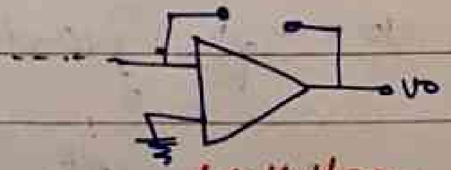
so the op-Amp in sat. ⇐



* C → O.C

Vi = 

vo =  ,



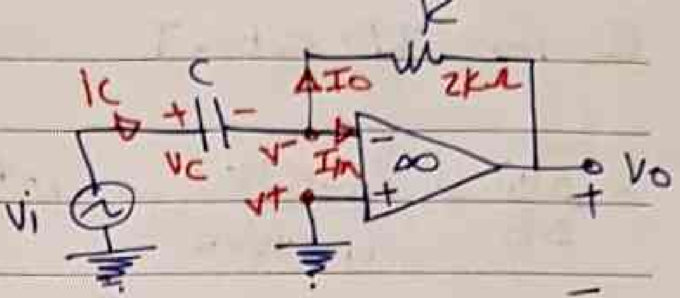
↳ Voltage comparator

* C → S.C ⇝ Buffer ($V^+ \rightarrow$ Gnd)

* dc OR very low freq. signal ⇝ not practical.

* vin = very high freq. signal => problem (38)

(IX) Diffrentiator



$i_c = I_o + I_{in}$

$$\frac{c\,dv_c}{dt} = \frac{\overset{0}{\cancel{v^-}} - v_o}{R} + \overset{0}{\cancel{I_{in}}}$$

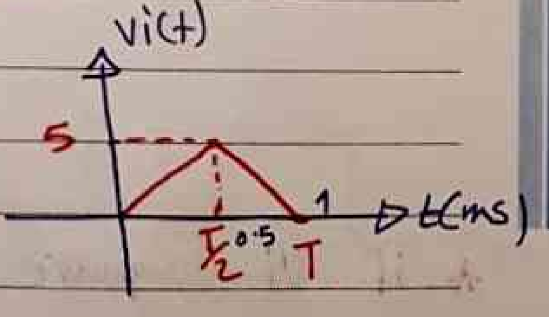
but $I_{in} = 0$, $v^- = v^+ = 0$ } ideal op-Amp.

$v_c = v_i - \overset{0}{\cancel{v^-}} \rightarrow \underline{v_c = v_i}$

$$\Rightarrow c\frac{dv_i}{dt} = -\frac{v_o}{R}$$

$v_o = -Rc\,\frac{dv_i}{dt}$ $\Rightarrow \underline{v_o \propto \frac{dv_i}{dt}}$

* Draw vo(t) for the shown vi(t).



F= 1 KHz

① For $0 < t < T/2$

$v_o = -Rc\,\frac{dv_i}{dt}$

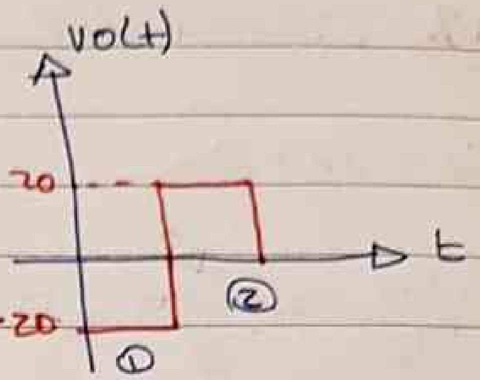
$$\frac{dv_i}{dt} = \frac{\Delta v_i}{\Delta t} = \frac{(5-0)v}{(0.5-0)ms}$$

$= 10*10^3$ v/S

$\Rightarrow v_o = -2*10^3 * 1*10^{-6} * 10^4$

$v_o = -20$ Volt.

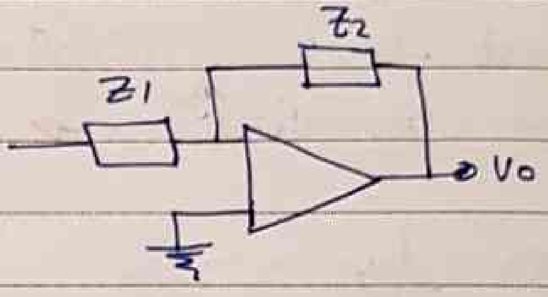
② For $T/2 < t < T$



$$\frac{\Delta Vi}{\Delta t} = \frac{(0-5)V}{(1-0.5)ms} = -10^4 V/s$$

$$\Rightarrow Vo = -2*10^3*10^{-6}(-10^4)$$

$$Vo = +20 \text{ Volt.}$$

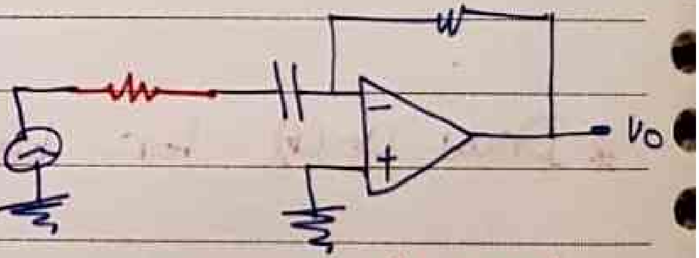


* $AV = \frac{-Z2}{Z_1}$

$Z_1 = Xc = \frac{1}{2\pi fc}$, fc :- very big

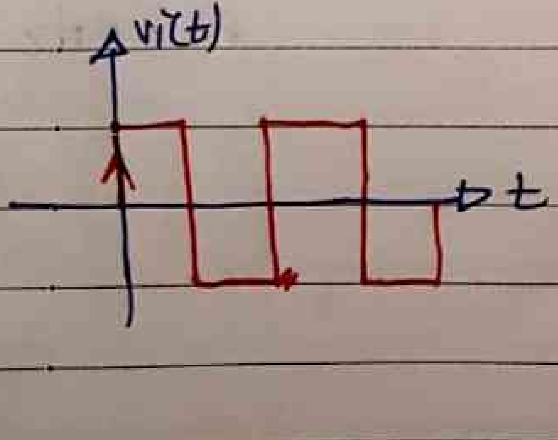
$\therefore Xc = 0 \Rightarrow AV = \infty$

↳



(practical diff.)

* if Vi = square



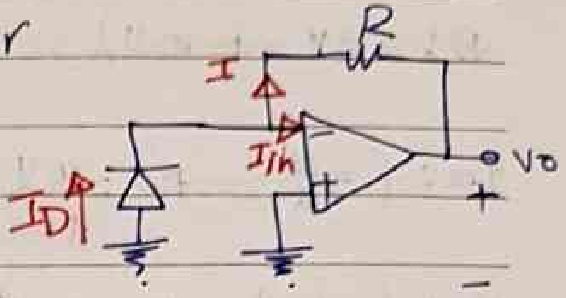
(Trigger)

Train Pulse ↵

⇒

* ID → تتغير حسب شدة الضوء

IX current-to-voltage convertor



$V_o \propto I_D$

$I_D = I_{in} + I$

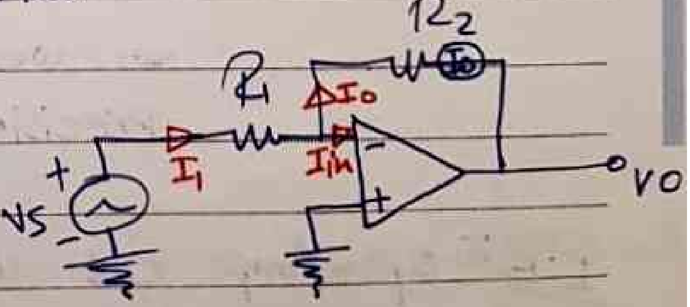
$I_D = \overset{\to 0}{\cancel{I_{in}}} + \frac{\overset{\to 0}{\cancel{V^-}} - V_o}{R}$

but $I_{in} = 0$, $V^- = V^+ = 0$ (V·G)

$\Rightarrow V_o = -R I_D$

ID (mA)	Vo
1mA	-1V
2mA	-2V
3	-3
5	-5V

X Voltage-to-current convertor.



$I_1 = I_o + I_{in}$

$\frac{V_s - \overset{\to 0}{\cancel{V^-}}}{R_1} = I_o + \overset{\to 0}{\cancel{I_{in}}}$

for ideal op-Amp

$V^+ = V^- = 0$ (V·G) , $I_{in} = 0$

$I_o = \frac{-V_s}{R_1}$, $I_o \propto V_s$

for $R_1 = 1k\Omega$

⇒

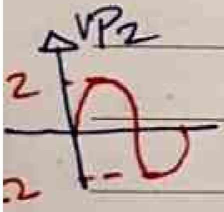
V_s : ($2V \rightarrow 10V$)

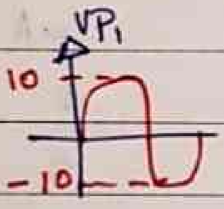
I_o : ($\frac{-2V}{1K} \rightarrow \frac{-10V}{1K}$)

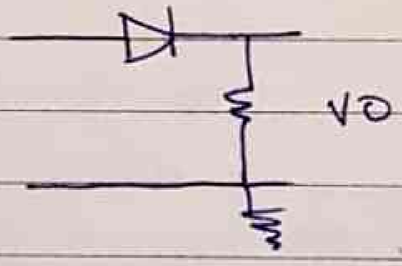
I_o : ($-2mA \rightarrow -10mA$).

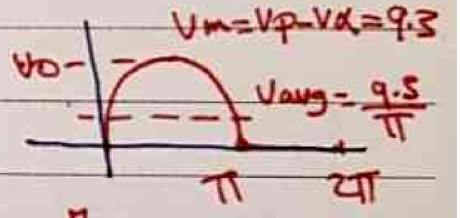
NoN Linear Applications

① Precision Rectifier.









→ For VP1

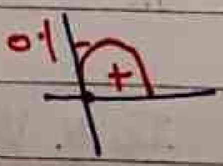
For VP2 → no Rectify becuase VP < Vα

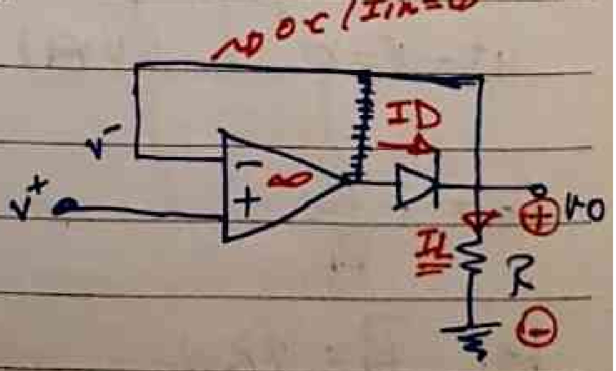
so we use → Precision Rectifier

P.R:- Op-Amp cct with Diode(s) used to Rectify A.C signal with $V_P < V_\alpha$

P.HWR

① during to +ve cycle



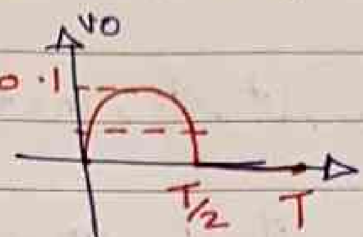


$\Rightarrow V_o = V_i \rightarrow$ +ve H.C , $i_L \downarrow$

* the op-Amp cancle the effect of $\underline{\underline{V\gamma}}$ when D→off

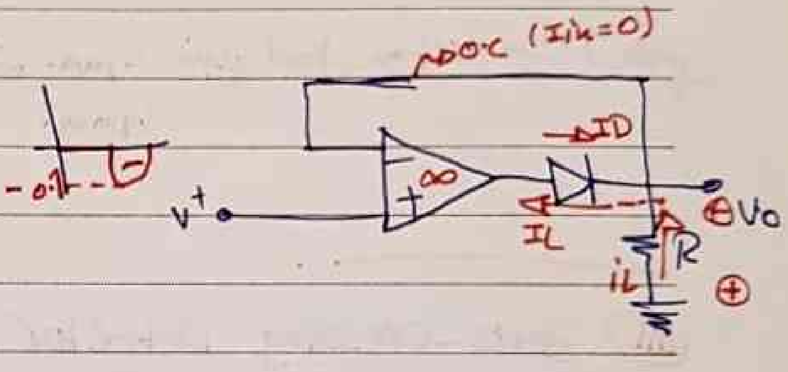
$\boxed{100}$

$i_L = i_d$, the Loop will be closed and $v_o = v_i$



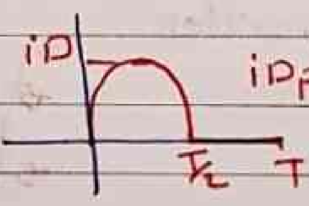
(II) For -ve Half cycle

$v_o = v_i \Rightarrow -ve$, so $i_L \uparrow$



$I_D = -I_L \Rightarrow$ (D-off)

Loop is open $\Rightarrow V_o = 0$

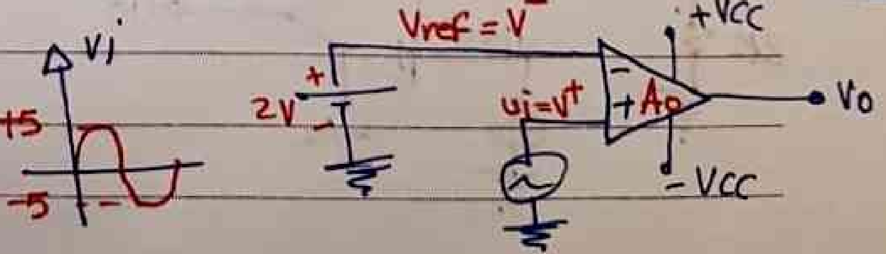


$i_{Dp} = \frac{0.1}{R}$

(III) voltage comparator

→ op-Amp works in open -Loop mode

→ $V_o = \mp V_{CC}$



$V_o = A_o \underbrace{(v^+ - v^-)}_{vd}$

For Ideal op-Amp , $A_o = \infty$

(i) For $v^+ > v^-$, $vd = +ve$, $V_o = +V_{CC}$

(ii) for $v^+ < v^-$, $vd = -ve$, $V_o = -V_{CC}$

⇒

- * op-Amp → open Loop
- * o/p → symmetrical square wave
- * Zero crossing Detector $\boxed{101}$ = volt. comp with Vref=0

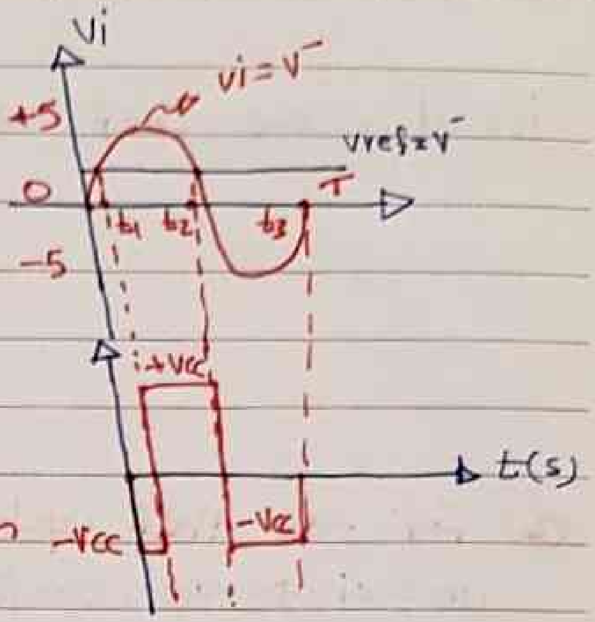
① $0<t<t_1$, $V^+<V^-$, $V_o=-V_{CC}$

② $t_1<t<t_2$, $V^+>V^-$, $V_o=+V_{CC}$

③ $t_2<t<t_3$, $V^+<V^-$, $V_o=-V_{CC}$

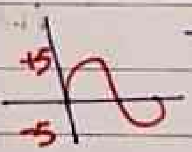
on مش symm. ضبطي لعمل Vref≠0 حتى لا تغير

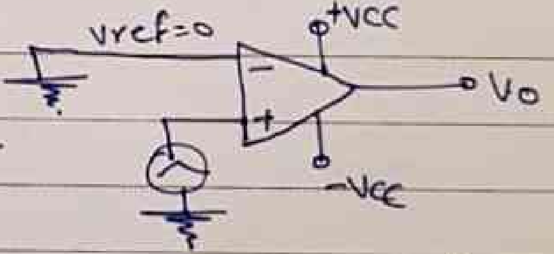
symm.



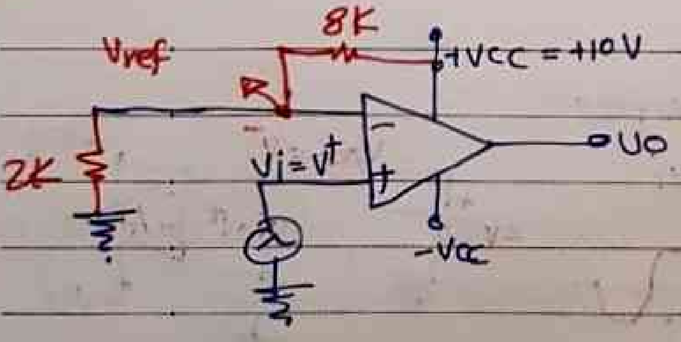
Ⅲ Zero-crossing Detector (sin → square wave)

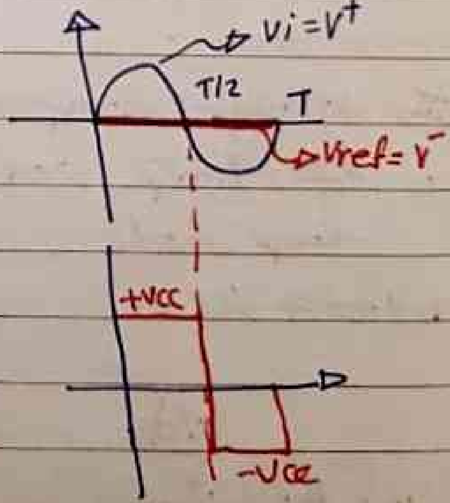
- * voltage comparator which Vref=0





- * If we add R(s)



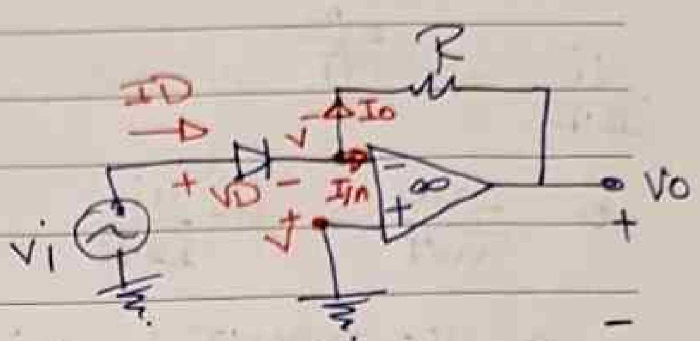


$$\Rightarrow V_{ref}=\frac{10*2}{8+2}=2V$$

→ no connection with $\underline{V_o}$

- * no connection between Vo & V(inv)
- * open Loop ⇒ $V^+\neq V^-$

4 IX Exponential Amp.



$I_D = I_{in} + I_o$

$I_s e^{\frac{V_D}{nV_T}} = \overset{0}{\cancel{I_{in}}} + \frac{\overset{0}{\cancel{V^-}} - V_o}{R}$

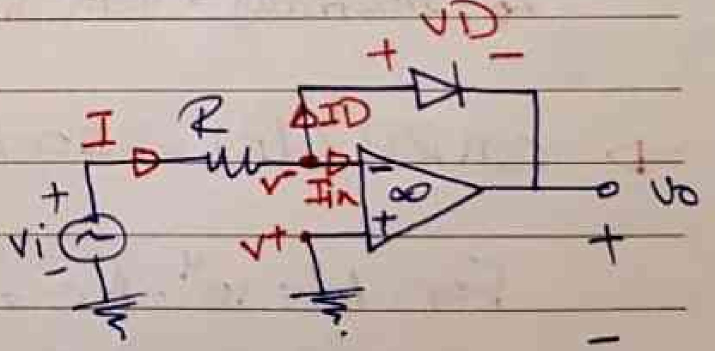
but $v^+ = v^- = 0$ (V.G) }
$I_{in} = 0$

$\Rightarrow V_D = V_i - \overset{0}{\cancel{V^-}} = V_i$

$I_s e^{\frac{V_i}{nV_T}} = -\frac{V_o}{R}$ $\Rightarrow$ $V_o = -I_s e^{\frac{V_i}{nV_T}} \cdot R$

$n=1$, $V_T = 0.026V$, $I_s \rightarrow$ given

X Logarithmic Amp.



$I = I_D + I_{in}$

$\frac{V_i - \overset{0}{\cancel{V^-}}}{R} = I_s e^{\frac{V_D}{nV_T}} + \overset{0}{\cancel{I_{in}}}$

but $V^- = V^+ = 0$ (V-G) }
$I_{in} = 0$ ($R_i = \infty$)

$V_D = \overset{0}{\cancel{V^-}} - V_o$

$\Rightarrow$ $\frac{V_i}{R} = I_s e^{-\frac{V_o}{nV_T}}$

$\Rightarrow$

$$\frac{Vi}{IS \cdot R} = e^{\frac{-Vo}{nVT}}$$

$$\Rightarrow \frac{-Vo}{nVT} = \ln \frac{Vi}{IS \cdot R}$$

$$\Rightarrow Vo = -nVT \ln \frac{Vi}{IS \cdot R}$$

---

* **C.M.R.R** :- Common - mode - Rejection Ratio

→ given in data sheet

$CMRR = \frac{Ad}{Ac}$, Ad :- diff mode gain
Ac :- common - mode gain

→ Ideally = ∞
→ Practically = very high #

$$\Rightarrow CMRR(dB) = 20 \log \frac{Ad}{Ac}$$

For $Ad = 10^4 \cdot Ac = 0.1$

$$CMRR(dB) = 20 \log \frac{10^4}{0.1}$$

$$= 20 \log 10^5$$

$$= \underline{\underline{100\,dB}}$$

* for this cct $Ac = 0$ ⇒ CMMR close to Ideal

---

* CMMR ↑ → اقرب لل Ideal → يعني احسن ⇒

* $CMMR_1 = 80$, $CMMR_2 = 100$, 2 best than 1

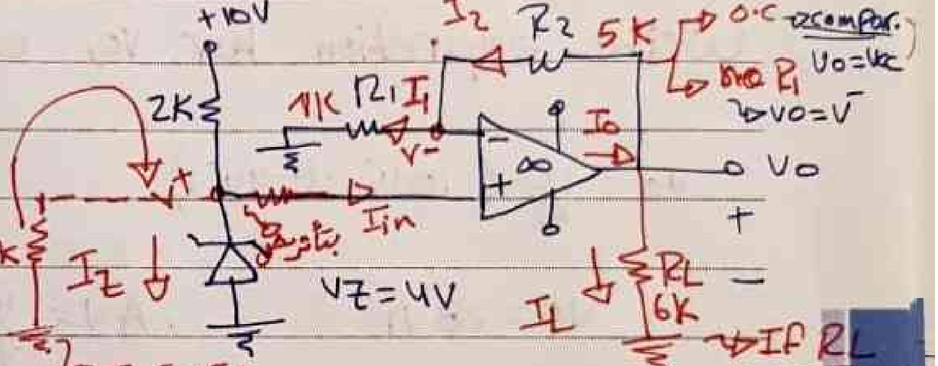
Ex:- Given CMRR = 80 dB , $A_d = 10^3$, $A_c = ??$

sol:-

$$80 = 20 \, \text{Log} \, \frac{A_d}{A_c}$$

$$\frac{80}{20} = \text{Log} \, \frac{A_d}{A_c} \Rightarrow 4 = \text{Log} \, \frac{A_d}{A_c}$$

$$\frac{A_d}{A_c} = 10^4 \Rightarrow A_c = \frac{10^3}{104} = \underline{0.1}$$



$-10 + I_Z \cdot 2K + V_Z = 0$

$I_Z = \frac{10 - V_Z}{2K} = \frac{10-4}{2}$

$\to I = I_1 + I_Z$

$3mA = 2mA + I_Z$

$\Rightarrow I_Z = 2mA$

$\to$ Z-D on

$I_Z = 3mA$

$V_O = (1 + \frac{5K}{1K}) V^+$

since $I_Z > 0$ ∴ Z-D is ON

$\Rightarrow V^+ = V_Z = 4V$ — $V_Z = 4V$

كأنه
(بطارية)

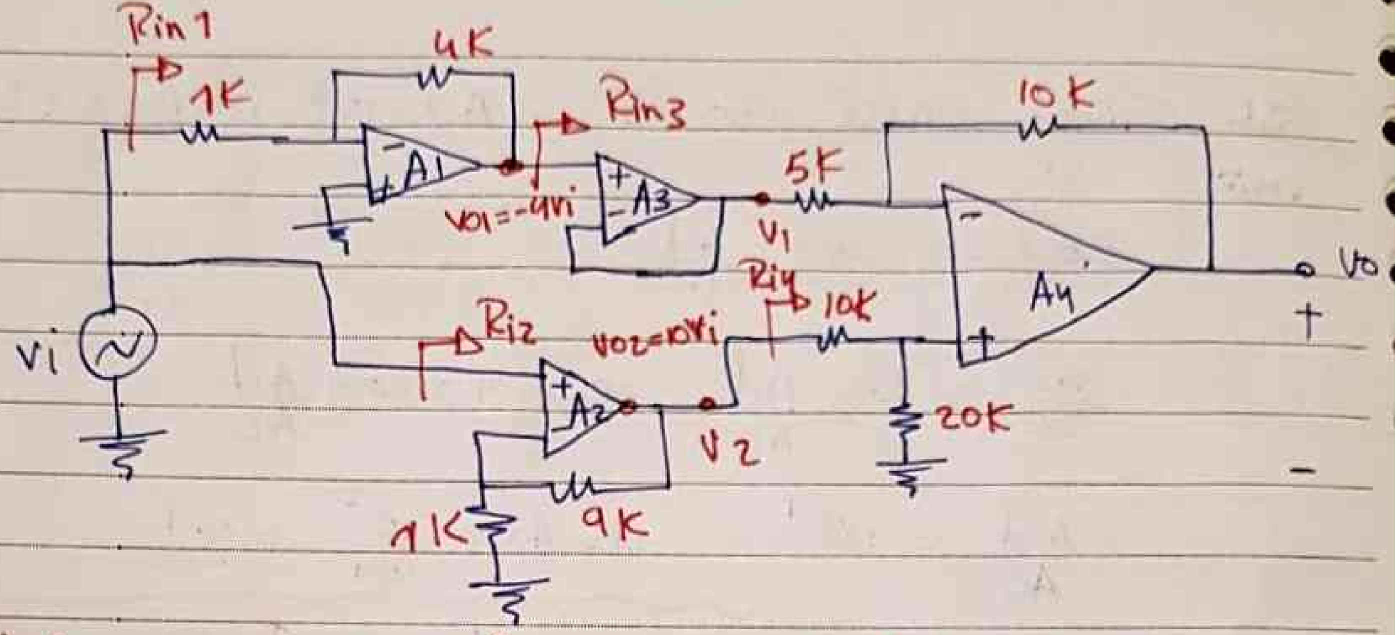
↳ becuase Zinner Diode is off

$V^+ = +10V$ on off + Z.D

اذا ★ ⇒

* اول اشي بجي المسأله بشيك على ال Ratio واذا ما زبط بحل superposition

$\boxed{105}$



Write expretion for Vo, calculate AV.

$$V_o = \frac{10}{5}\left(10V_i - (-4V_i)\right)$$

$$V_o = 28V_i \qquad , AV = \frac{V_o}{V_i} = 28 .$$

* $R_{in1} = 1K$

* $R_{in2} = \infty$

* $R_{in3} = \infty$

* $R_{in4} = 5+10$

Ex:- Design the cct such

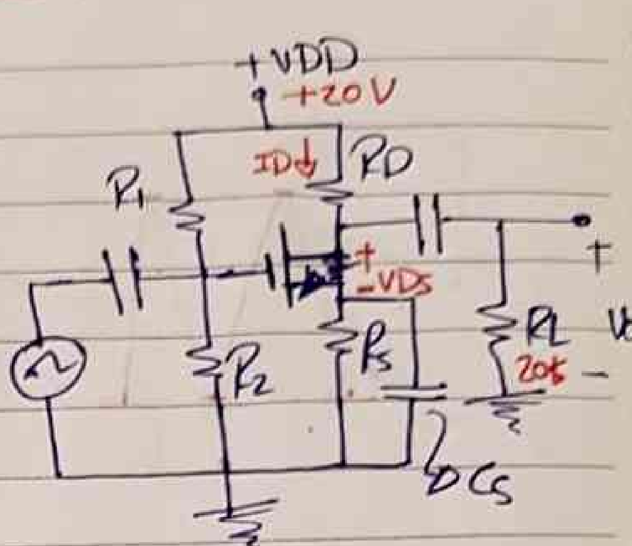
1)- that $AV=-8$, $IDQ=1mA$

$VDSQ=10V$, * $I_1 = 10\% ID$

Find (RD, Rs, R1, R2) ??

2)- Draw s.s.A.C eq cct

& find Ri & Ro.



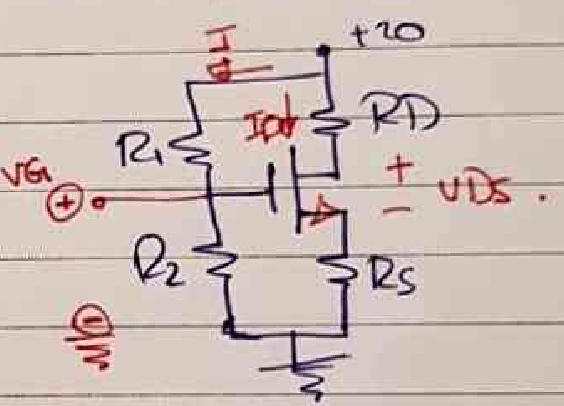
Given:- VTN=1V, Kn=1mA/V²

SoL:-

* From D-C

$-20+IDRD+VDS+IDRs=0$

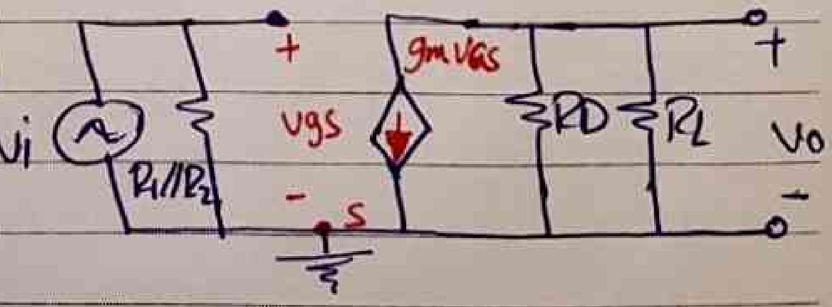
$RD+Rs = \frac{(20-10)V}{1mA} = \underline{\underline{10K\Omega}}$



* Ac Analysis

$AV = \frac{Vo}{Vi} = \frac{-gm\,\cancel{vgs}(RD//RL)}{\cancel{vgs}}$

$\Rightarrow AV = -gm(RD//RL)$



$\hookrightarrow gm = 2\sqrt{KnID} = 2\sqrt{1*1} = 2mA/V$

$-8 = -2(RD//RL) \rightsquigarrow (RD//RL) = 4K\Omega$

$4 = \frac{RD\cdot 20K}{RD+20} \rightsquigarrow RD = \frac{20*4}{20-4} = 5K\Omega$

$\therefore Rs = 10-5 = 5K\Omega.$

if * $R_{in} = 45$ ممكن يعطيني اياها بدل ما يعطيني معلومة عن التيار

if * $R_o = 5K$ ممكن يعطيني اياه المعلومة بدل ال AV

$\rightsquigarrow R_o = RD$

$\boxed{107}$

$I = 0.1 * 1 = 0.1 mA$

$-20 + I(R_1 + R_2) = 0$

$\therefore R_1 + R_2 = \frac{20}{0.1} = 200 k\Omega$

$\rightsquigarrow R_2 = \frac{VG}{I}$, $VGS = VG - Vs$

$\rightsquigarrow VG = VGS - Vs$

$* VGS = VTN \mp \sqrt{\frac{ID}{Kn}}$

$= 1 \pm \sqrt{1/1} = \underline{2V}$ OR $\underline{0V}$ ✓

$* Vs = ID \cdot Rs = 1m * 5K = \underline{5V}$

$\rightsquigarrow VG = 5 + 2 = \underline{7V}$

$\Rightarrow R_2 = \frac{VG}{I} = \frac{7V}{0.1} = 70 \cdot K\Omega$

$R_1 + R_2 = 200 K\Omega$

$\Rightarrow \underline{R_1 = 130 K\Omega}$

$\boxed{*}$ D-c slope $\Rightarrow \frac{-1}{RD + R_s}$

$\boxed{*}$ A-c slop $\Rightarrow \frac{-1}{RD // RL}$

$\boxed{*}$ $R_{in} = R_1 // R_2 = 130 // 70 = \frac{130 \cdot 70}{200} = 45.5 K\Omega$

$\boxed{*}$ $R_o = RD = 5K\Omega$

$\Rightarrow$

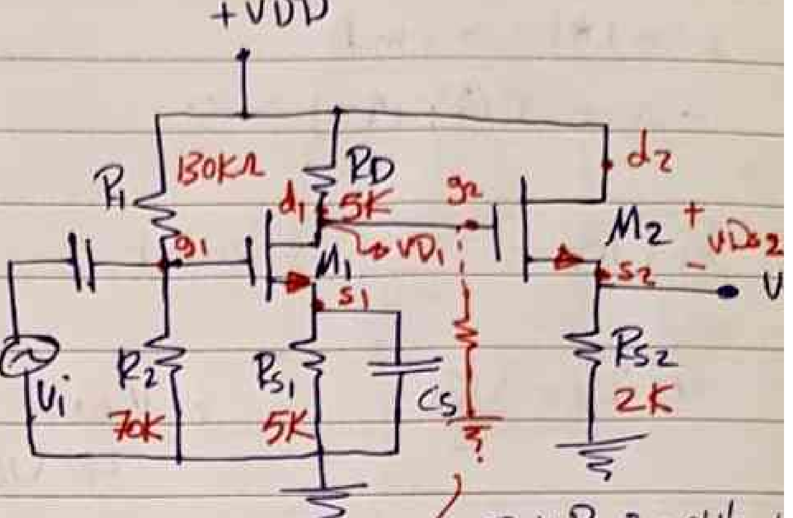
Ex:-

① & ② ⟹ as the previous Ex.

③ I_{D2}, V_{DS2}

④ Draw s.s. A.C eq cct & Find A_{V2},

$A_V = \frac{V_o}{V_i}$



ID ال R لو حطينا صورة
لا تتفرق على المكافئة

$K_{n1} = K_{n2} = 1mA/V^2$

$V_{TN1} = V_{TN2} = \underline{1V}$

$\lambda_1 = \lambda_2 = 0$

Sol:-

$I_{D2} = K_{n2}(V_{GS2} - V_{TN2})^2$

$V_{GS2} = V_{G2} - V_{S2}$

$V_{S2} = I_{D2} \cdot R_{S2}$

$\rightarrow V_{G2} = V_{D1} = 20 - I_D R_D \Rightarrow V_{G2} = 15V.$

$V_{GS2} = 15 - 2I_{D2}$

$I_{D2} = \frac{15 - V_{GS2}}{2} \Rightarrow \frac{15 - V_{GS2}}{2} = 1(V_{GS2} - 1)^2$

$\rightarrow \quad = V_{GS2}^2 - 2V_{GS2} + 1$

$\boxed{2V_{GS2}}^2 - 3V_{GS2} - 13 = 0$

$V_{GS2} = \frac{3 \pm \sqrt{9 + 104}}{4} \rightarrow V_{GS2} = \frac{3 \pm 10.5}{4} = \overset{✓}{\underline{3.9V}}$ oR

-ve ×

$\Rightarrow V_{GS2} = 3.9 \underline{\underline{V}}$

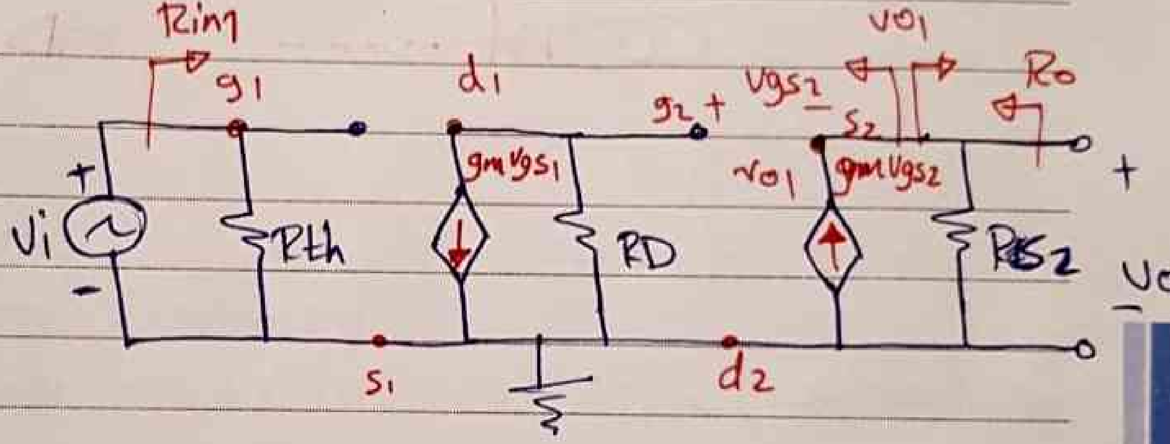
$\Rightarrow I_D = \frac{15-3.9}{2}$ ⇝ $I_D = 5.4mA$.

$-20 + V_{DS2} + I_{D2} + R_{S2} = 0$

$V_{DS2} = 20 - 5*4*2 = 9.2V$.

$V_{DS}(sat) = V_{GS} - V_{TN}$

⇝ $V_{DS}(sat) = 2.9V$.

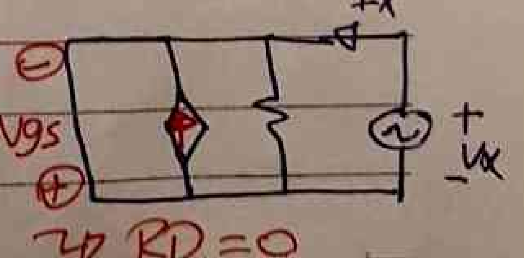


- * $A_V > 1$
- * R_o ⇝ قليلة $= R_S // \frac{1}{g_{m2}}$ C.D
- * $\phi = 180°$
- * $R_{in1} = R_{th}$
- * $R_{o1} = R_D$
- * $R_{in2} = \infty$

$\Rightarrow A_V = A_{V1} * A_{V2}$

$= -g_{m1} R_D \cdot \frac{g_{m2} R_{S2}}{1 + g_{m2} R_{S2}}$

$\Rightarrow R_o = \frac{I_x}{V_x}\Big|_{v_i=0}$

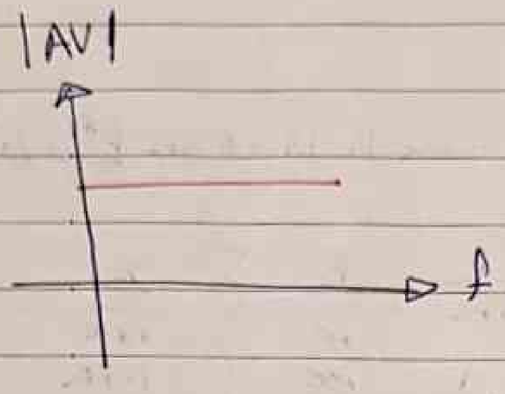


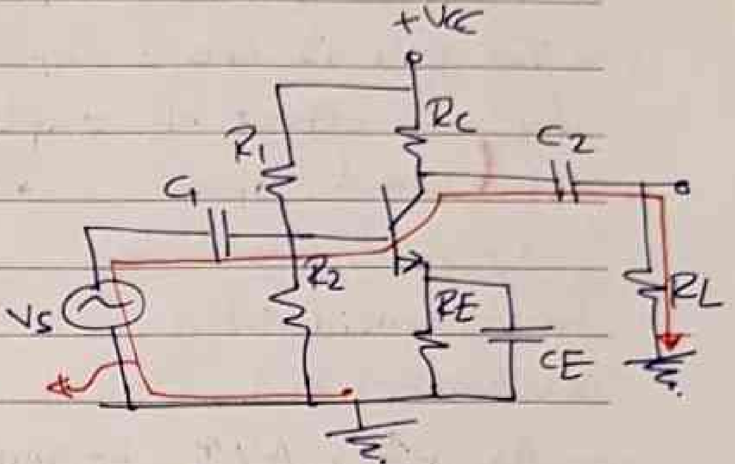
⇝ $R_D = 0$

* كيفية تغيير ال Gain تبع ال Amp مع ال frequency.

* Any Amp. should have at least coupling <u>OR</u> bypass capacitors $\boxed{110}$

Frequency Response of Amp.





β ✓, VBE ✓.

* <u>F.R</u> :- Is a plot of Amp gain AV or AI versus frequency.

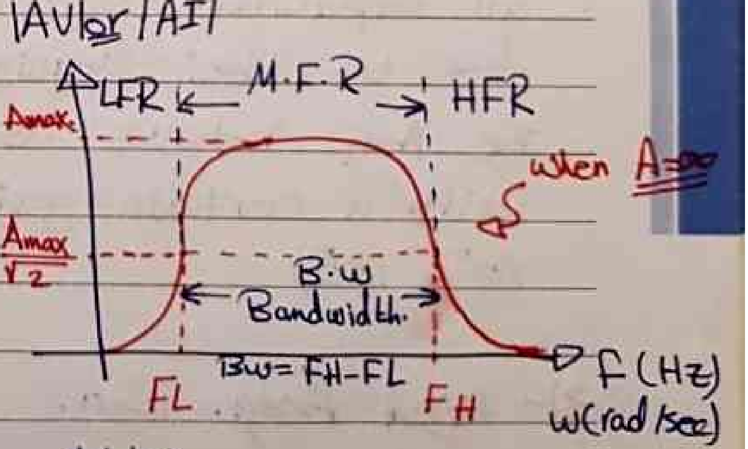
- The frequency can be in (Hz) or ω → rad/sec

- The gain can be unitless

$AV = \frac{VO}{VS}$, $AI = \frac{IO}{IS}$ <u>OR</u>

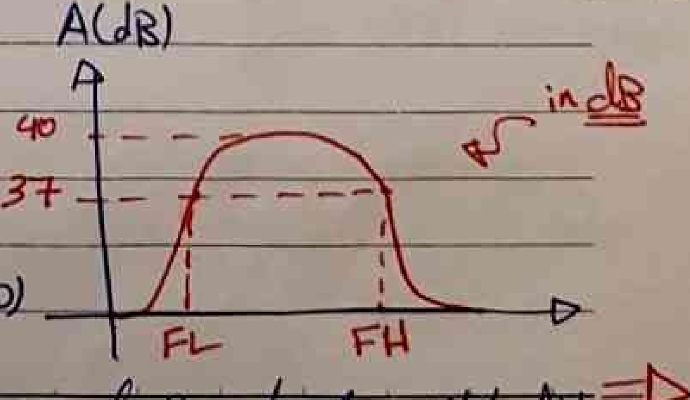
in dB → $AV(dB) = 20 \log \frac{VO}{VS}$

$AI(dB) = 20 \log \frac{IO}{IS}$



* $A = \left|\frac{VO}{VS}\right|$, $VS = 2 \sin 2\pi ft$

→ so. VO change equally with A, becuase VS = cons. (Amp)



* in Low & high → frequency dependent with AV ⇒

Low → $f \propto AV$ high → $f \propto \frac{1}{AV}$

* In meduim AV & F → Independent

① Typical frequency Response has 3 main Regions.

1)- Low-freq Region. (LFR)

- extends from $(0 \rightarrow f_L)$
- The gain is freq. dependant. such that as $\underline{f}\uparrow$, $\underline{A}\uparrow$ due to effect of coupling $(C_1 \& C_2)$ and bypass cap (C_E), where they have considerable reactance (X_C)

* $X_C = \frac{1}{2\pi f C}$

* $\underline{\underline{X_C \propto \frac{1}{f}}}$

F	XC
10	17K
100	1.7K
1K	170
10K	17
100K	1.7

- As $f\uparrow$, $AV\uparrow$ becuase these cap's are in the series path of Input signal, as $\underline{f}\uparrow$, $\underline{\underline{X_C}}\downarrow$, voltage drop across $\underline{\underline{X_C}}\downarrow$, $\underline{\underline{V_o}}\uparrow$, $\underline{\underline{AV}}\uparrow$

2)- medium freq. Reg. (MFR)

- all capacitors are considered short cct. due to their Negligible reactances $X_C \simeq 0$, The Amp behaves as a pure resistive Amp. with a certain gain $\underline{\underline{AV_m}}$ & a certain Phase (0°, 188)

3)- High freq. Reg. (HFR).

=D

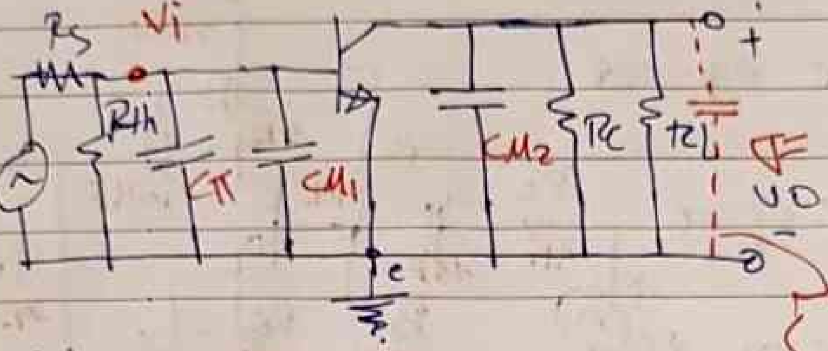
*at medium Reg. the capacitor's values (Xc) can be neghigble.

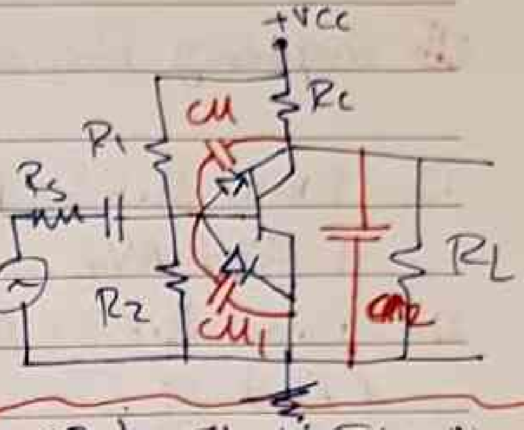
④ In Reverse bias junction the diodes acts as a capacitors / هنا بنحدد ال FL بس ال FH بتعتمد على ال structure of cap's . ✱

✱ FL → C1, C2, C3

112

CM ← → Cπ

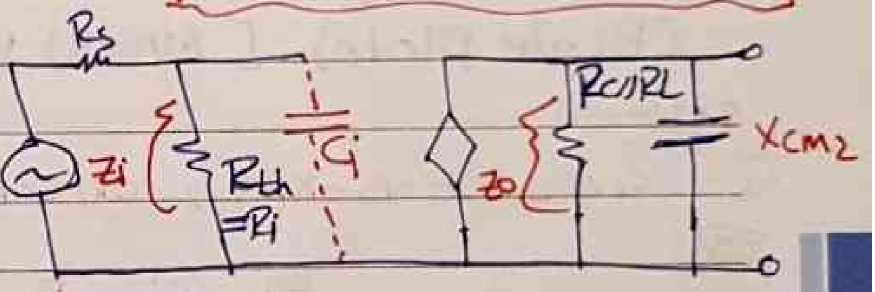




انا بدي اتحكم بال FH بربط cap.
بتكون parallel مع CM2 ~~بحيث~~ بحيث
انو ال eq ساوي حاصل جمع ال cap
لانهم Par. وهيك بتحكم بقيمة FH.

$V_O = -g_m V_\pi \, (R_C // R_L // X_{cm2})$

$Z_O = R_C // R_L // X_{cm2}$



$A_V = \frac{V_O}{V_\pi} * \frac{V_\pi}{V_S}$

$C_i = C_{M1} + C_\pi$

$\xrightarrow{2} \frac{V_O}{V_\pi} = -g_m Z_O$

$\frac{V_\pi}{V_S} = \frac{Z_i}{R_S + Z_i} \rightarrow Z_i = R_1 // R_2 // X_{ci}$

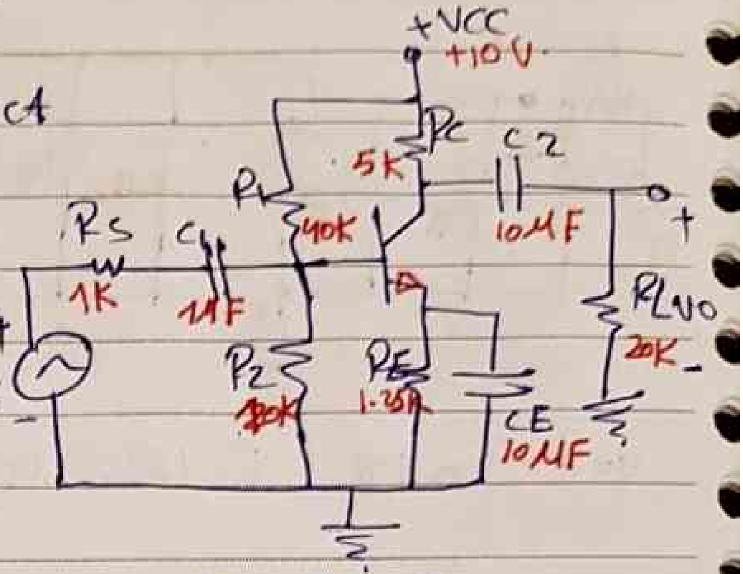
* f↑, X_{cm2}↓, Zo↓, VO↓, AV↓

- The gain is freq. dependent Due to effect of Junction & Diffusion capacitor [emerge effecitivily] (No physical existance) becuase of physical structure of transistor
- The gain decrease as frequency increase because these cap's. have shunting effect at I/P & O/P side as f↑, Xc↓, Vo↓, AV↓.

* the gain is freq. dep, why??

ans. due to Junction & Diffusion capacitors.

(II) Frequency Response Analysis.



1)- Draw M.F.S.S.A.C eq. cct & Find AVm.

2)- Draw M.F.S.S.A.C eq cct & Find FL.

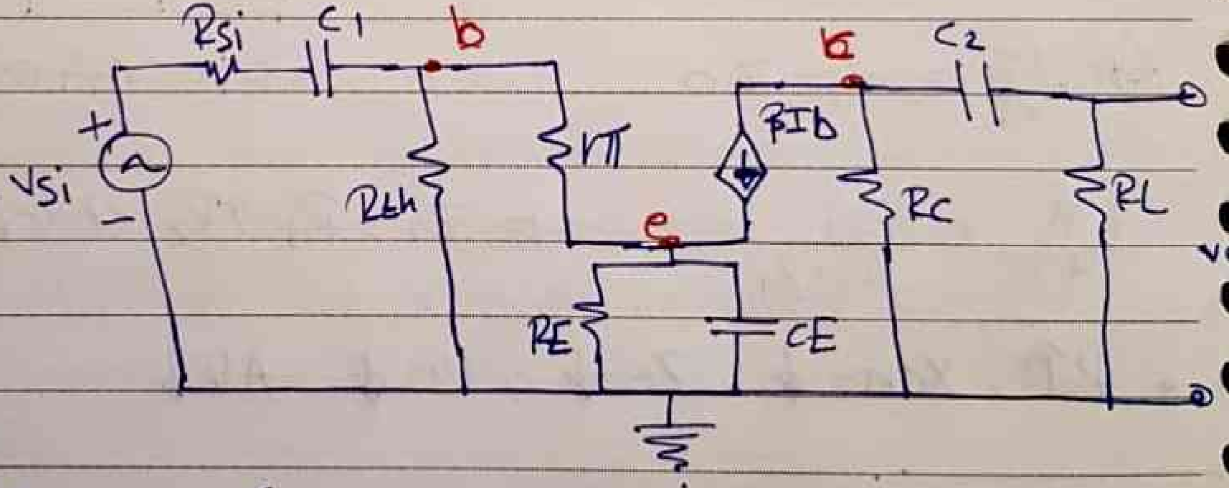
3)- Draw H.F.S.S.A.C eq cct & Find FH.

4)- sketch freq Response (BLode plote). [AV(dB) versus freq.]

$\beta=100$, $V_{BE}=0.7V$
$V_A=\infty$, $C_\pi=20PF$
$C_\mu=5PF$

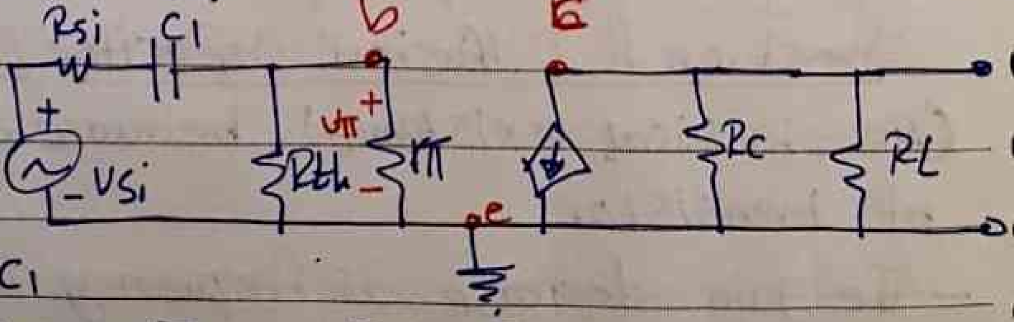
Sol:-

① $C_1, C_2, C_E \Rightarrow$ exist , $C_\pi, C_\mu = 0$ $(X_C=0)$



(I) Effect of C_1 (C_2 & C_E s.c)

$$F_{L1} = \frac{1}{2\pi C_1 R_{eq1}}$$



R_{eq1} = Rth seen by C_1

$\therefore R_{eq1} = [R_{si} + (R_{th} // r_\pi)]$, $R_{th} = R_1 // R_2$

$r_\pi = \frac{\beta V_T}{I_{CQ}}$ $\Rightarrow$

* $C=0 \Rightarrow O.C$
* $C=\infty \Rightarrow S.C$

$\boxed{114}$

D.C Analysis (to Find ICQ)

$V_{th} = \frac{10*10}{50} = 2V$, $R_{th} = 8k\Omega$

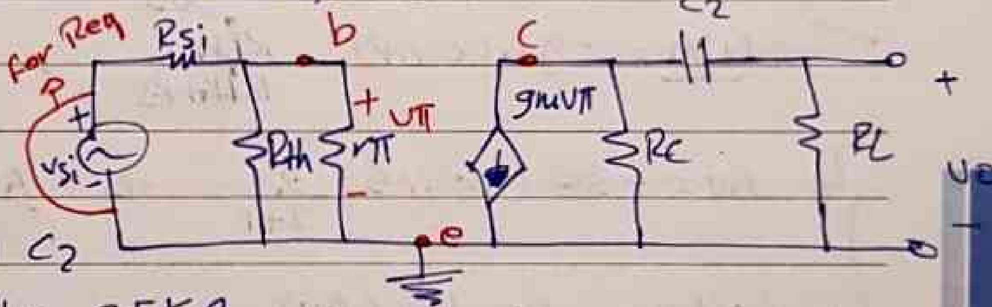
$\Rightarrow I_B = \frac{(2-0.7)}{8+101*1.25} = \frac{1.3}{13} = 0.01mA$, $I_{CQ} = 1mA.$

$\Rightarrow r\pi = \frac{100*26}{1mA} \overset{52}{\Rightarrow} R_{eq} = [1+(9//2.6)] = 3k\Omega$

$\Rightarrow F_{L1} = \frac{1}{2\pi*1*10^{-6}*3*10^{3}} \Rightarrow F_{L1} = \frac{10^3}{20} \Rightarrow \boxed{F_{L1} = 50\ Hz}$.

II Effect of C2 (C1 & C.E ⇝ S.C)

$F_{L2} = \frac{1}{2\pi\ C_2\ R_{eq2}}$



R_{eq2} = Rth seen by C_2

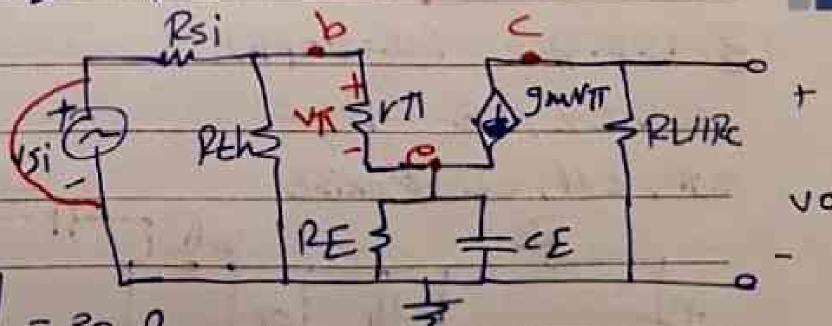
$\Rightarrow R_{eq2} = R_C + R_L = 25k\Omega$

$\Rightarrow F_{L2} = \frac{1}{2\pi*1*10^{-6}*25*10^{3}} \Rightarrow F_{L2} = \frac{10^3}{50\pi} = 6.4\ Hz$.

III Effect of CE (C1 & C2 ⇝ S.C)

$F_{L3} = \frac{1}{2\pi\ C_3\ R_{eq3}}$

R_{eq3} = Rth seen by CE



$R_{eq} = \left[\frac{(R_{si}//R_{th})+r\pi}{\beta+1} // R_E\right] = 30\Omega$

$F_{L3} = \frac{1}{2\pi*10*10^{-6}*30} \Rightarrow F_{L3} = \frac{10^4}{20} = 500\ Hz$

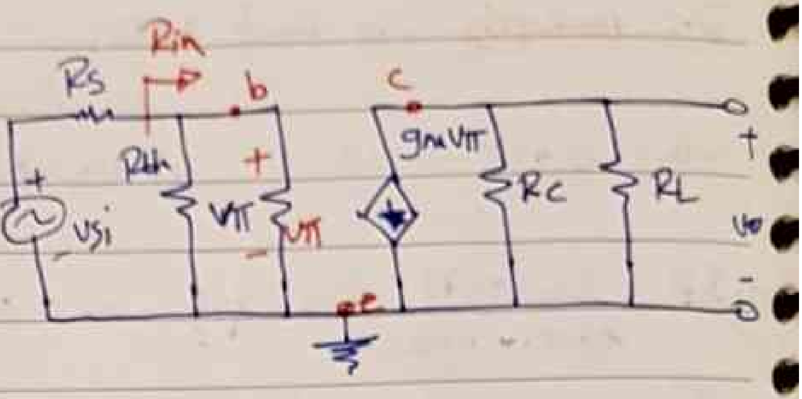
$\Rightarrow$ FL is the high value $= 500Hz$.

⇝ طيب

② M.F.R

$C_1, C_2, C_E \rightarrow \infty$ (S.C)

$C\pi, C_M \rightarrow 0$ (O.C)



$$AV = \frac{vo}{vs} = \frac{vo}{V\pi} \cdot \frac{V\pi}{Vs}$$

$$\rightarrow vo = -gmV\pi(Rc//RL) \quad , \quad V\pi = \frac{Vs * R_{th}}{Rs + R_{th}} \rightarrow Rin$$

$$\rightarrow AV = \frac{-gm\cancel{V\pi}(Rc//RL)}{\cancel{V\pi}} \cdot \frac{\frac{\cancel{Vs}*Rth}{Rs+Rth}}{\cancel{Vs}}$$

$\boxed{* Rin = Rth // r\pi}$

$\rightarrow Rin = 2$

$$\Rightarrow AVm = -gm(Rc//RL) \cdot \frac{R_{th}}{R_{th}+Rs} \quad , \quad gm = \frac{ICQ}{VT} = \frac{1m}{26m} = 38\frac{mA}{V}$$

$$\rightarrow AV = -38(20//5)\frac{2}{2+1} \Rightarrow AVm = -100.$$

$$\rightarrow AV(dB) = 20 \ Log(AV)$$
$$= 20 \ Log(100)$$

* بهمل السالب

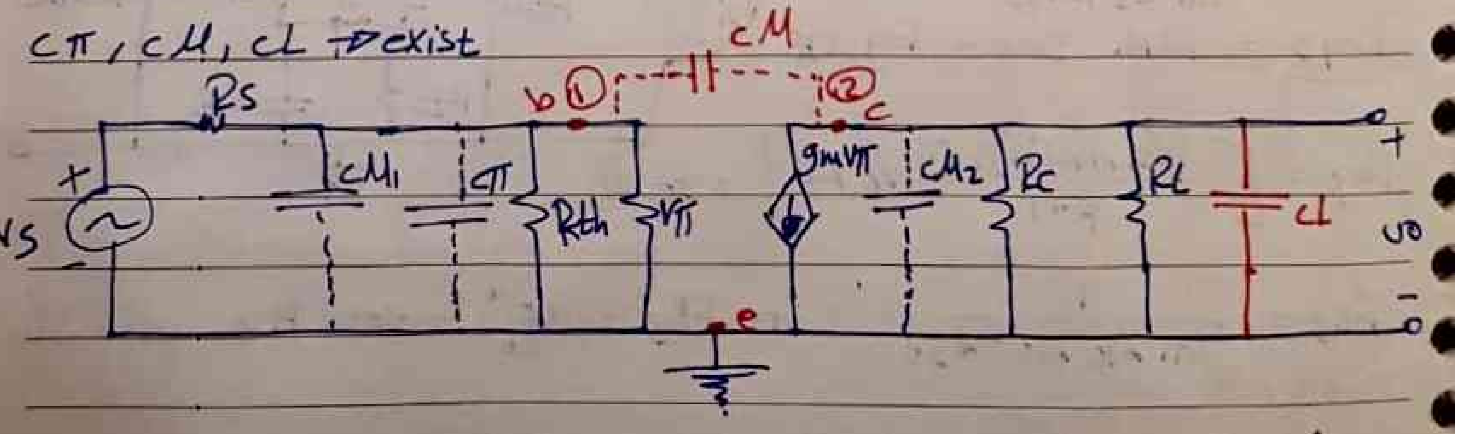
Phase shift. = السالب *

$$\Rightarrow AV(dB) = 40 dB$$

③ H.F.R (cL = 200pF)

$C_1, C_2, C_E \rightarrow$ S.C

$C\pi, C_M, C_L \rightarrow$ exist



⇒

☒ لا تنساه ان موقع ال $C_i = (C_{M1} + C\pi)$ والي بيجي محلها دائماً بعد ال Rs مباشرة. وقبل ال Rin.

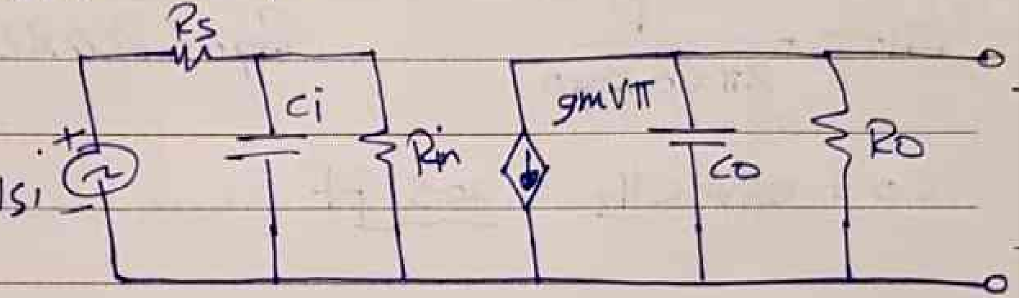
* $C_{M_1} = C_M(1-K)$
* $C_{M_2} = C_M(1-\frac{1}{K})$
* $K = \frac{V_2}{V_1} = \frac{V_O}{V_\pi} = \frac{-g_m V_\pi (R_C // R_L)}{V_\pi}$ $\Rightarrow K = -152$

$\Rightarrow C_{M_1} = 5(1-(-152)) = 765$ PF

$\Rightarrow C_{M_2} = 5(1-(\frac{-1}{152})) = 5$ PF

~~D.C Analysis~~

~~Vth = 10 * 10~~



* $R_{in} = r_\pi // R_{th} = 2 K\Omega$
* $C_i = C_{M_1} + C_\pi = 785$ PF
* $C_o = C_{M_2} + C_L = 205$ PF
* $R_o = R_C // R_L = 4 K\Omega$

↳ $F_{Hi} = \frac{1}{2\pi C_i R_{eq}}$ (effect of Ci)

↳ $F_{Ho} = \frac{1}{2\pi C_o R_{eqo}}$ (Co) , R_{eqi} :- Rth seen by Ci

$R_{eqi} = R_S // R_{in} = 0.66 K\Omega$

$\Rightarrow F_{Hi} = \frac{1}{2\pi * 0.66 * 785 * 10^{-12}}$ $\Rightarrow F_{Hi} = \frac{10}{3140} = 0.3$ MHz

$\Rightarrow F_{Ho} = 0.194$ MHz

* نأخذ أقل FH وهي التي تكون المؤثرة:

*

- $f_{Hi} = \frac{1}{2\pi * 0.7 * 10^3 * 785 * 10^{-12}} \Rightarrow = \frac{10^9}{1.4 * 785 * \pi}$

$\Rightarrow F_{Hi} = \frac{10^9}{3200} = \frac{10^7}{32} = \overset{0.298}{\cancel{0.32}} * 10^6 . = 298\,\text{kHz}$

- $F_{H0} = \frac{1}{2\pi C_0 R_{eq0}}$, $R_{eq0} = R_C // R_L = 4\,K\Omega$

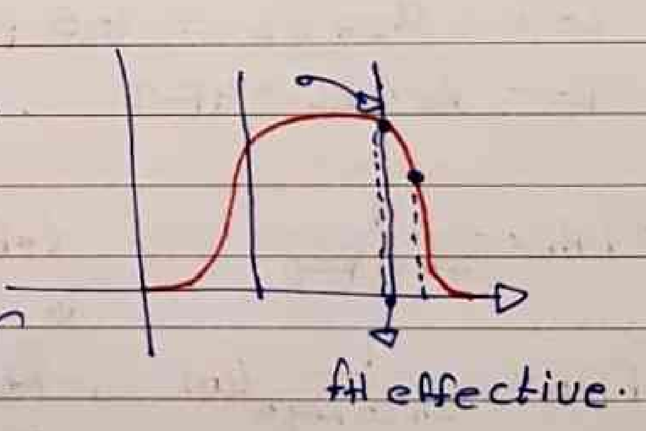
$C_0 = C_L + C_{M_2} = 205\ PF$

$f_0 = \frac{1}{2\pi * 4 * 10^3 * 2.05 * 10^{-10}} = \frac{10^7}{16\pi} = 194\ \text{kHz}.$

$\therefore$ FH effective = the lowest value

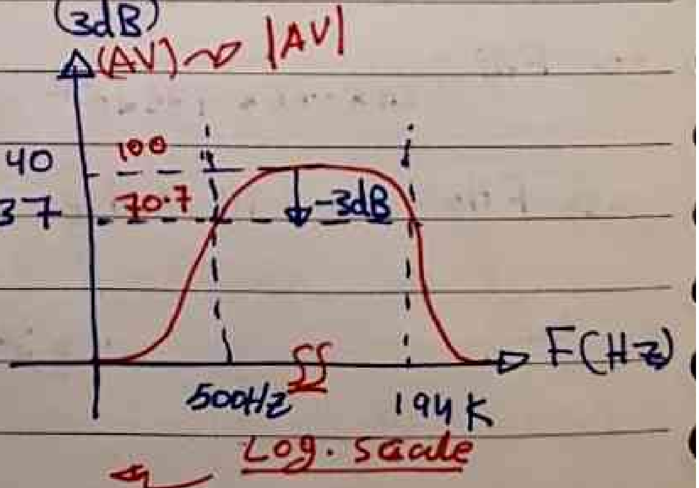
$\therefore f_H = 194\ \text{kHz}$

دايماً باخذ الأقل.



100

$\frac{\cancel{Avm}}{\sqrt{2}}$, $A_{vm} = 40$
, $A_{vm} - 3 = 37$



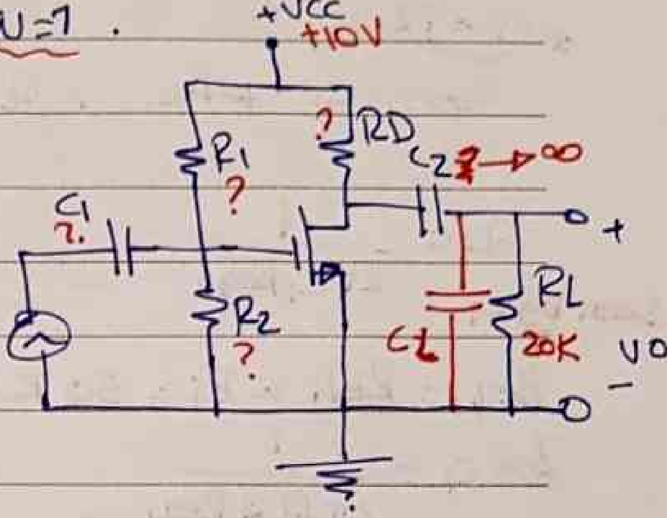
يا بركم هاي الإشارة SS او بكتب Log.scale
عند الرسمة عشان البعد الكبير بين الـ
500Hz & 194k Hz

$\Rightarrow$

* Design the cct shown to have $f_L = 200\,Hz$

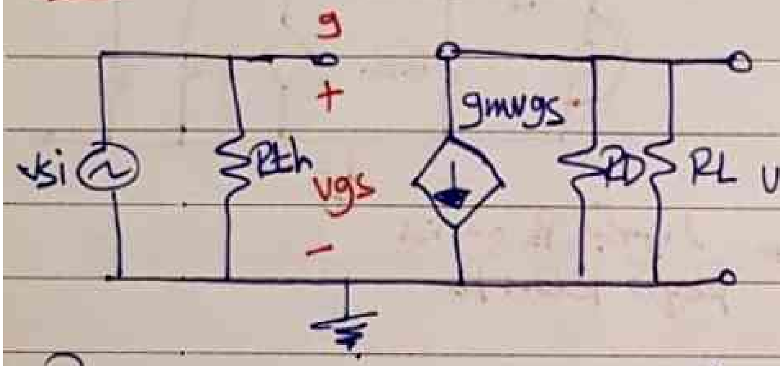
$F_H = 500\,KHz$, $A_{vm} = 20\,dB$. , $R_{in} = 50\,K\Omega$

⇒ Given: $K_n = 1\,mA/V^2$, $I_D = 1\,mA$, $V_{TN} = 1$.



Sol:-

M.F.R



$$\Rightarrow A_V = \frac{V_O}{V_{Si}} = \frac{-g_m \cancel{v_{gs}}(R_D // R_L)}{\cancel{v_{gs}}} \Rightarrow A_V = -g_m (R_D // R_L)$$

$$\Rightarrow A_V(dB) = 20 \log A_V = 20\,dB$$

$$\therefore A_V = 10 = g_m(R_D // R_L) \quad , g_m = 2\sqrt{K_n I_D} = 2\,mA/V$$

$$\Rightarrow R_D // \overset{\text{given}}{R_L} = 5\,K\Omega$$

$$\Rightarrow R_D = \frac{5 * 20}{20-5} = \frac{100}{15} \Rightarrow R_D = 6.66\,K\Omega \checkmark$$

$$I_D = K_n (V_{GS} - V_{TN})^2$$

$$V_{GS} = V_{TN} \pm \sqrt{\frac{I_D}{K_n}} = 1 \pm 1 \Rightarrow 2 \text{ OR } 0 \rightarrow \underline{V_{GS} = 2}$$

$$\Rightarrow V_G = V_{GS} + \overset{0\,(Gnd)}{\cancel{V_S}} = 2V \checkmark$$

$$R^* \; V_G = \frac{V_{DD} \cdot R_2 * R_1}{R_1 + R_2} \quad \rightarrow R_{in}\,(\text{given})$$

$$\Rightarrow R_1 = \frac{10}{2} * 50 = 250\,K\Omega \checkmark$$

⇒

* Any cap. in parallel determine (FH)

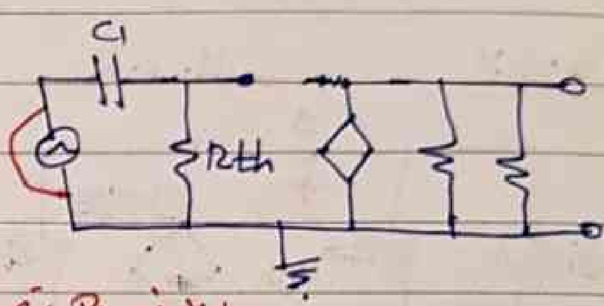
* Any cap. in series 〃 (FL)

$\boxed{119}$

$Re = \frac{250*50}{250-50} = \frac{12500}{200} = 62.5\ K\Omega$

* $C_1 = ??$

⇒ C_1 → FL , CL → FH



$FL = \frac{1}{2\pi C_1 Req_1}$

Seen by C1

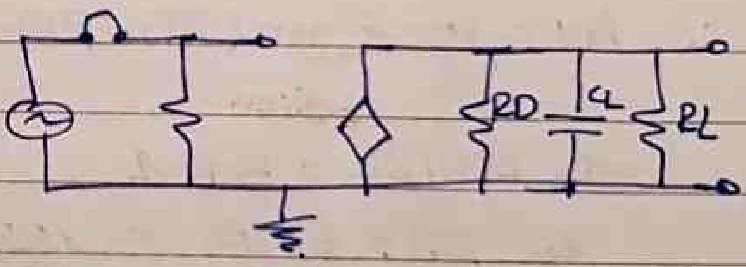
$Req_1 = Rth = R_i = 50\ K\Omega$

⇒ $C_1 = \frac{1}{2\pi\ fL * Req_1}$

⇒ اذا في Rs بتصير
$Req = Rth + Rs$

$= \frac{1*10^6}{2\pi * 200 * 50 * 10^3} = \frac{1}{20\pi}\ \mu F = \underline{17nf}$ ✓

* $CL = ??$



$FH = \frac{1}{2\pi CL\ Req}$

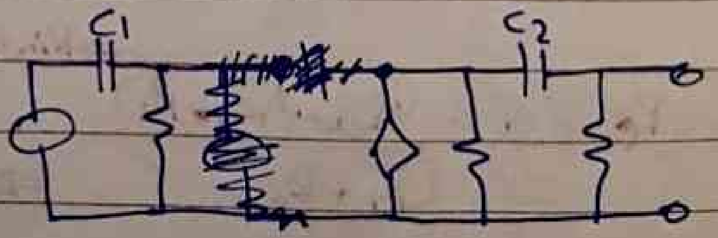
Seen by CL

$Req = RD // RL = 5\ K\Omega$

⇒ $CL = \frac{1}{2\pi * FH * Req} = \frac{1}{2\pi * 5 * 10^5 * 10^3} = \frac{10^{-8}}{50\pi} = \frac{10^{-8} * 10^{12}}{50\pi}$

$CL = 630\ PF.$

* if C_2 has a value



$C_2 = \frac{1}{2\pi\ fL\ Req_2}$

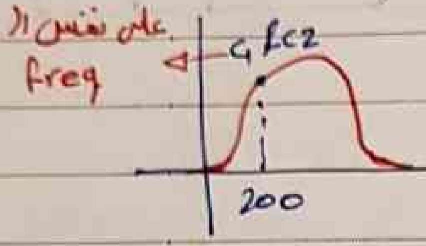
$Req_2 = RD ~~+~~ RL$

⇒

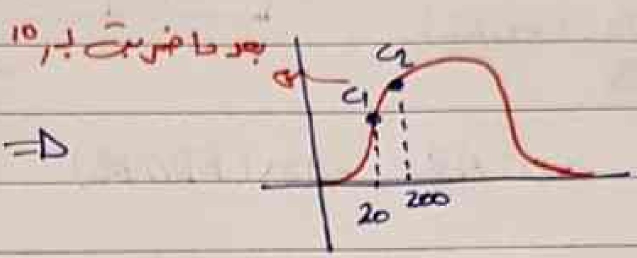
$$C_2 = \frac{10^6}{2\pi * 200 * 26.6 * 10^3} = \frac{10^4}{106\pi} \simeq \underline{30 nF}$$

* هون بدي اثبت الـ C2 ونضرب C1 بـ 10 وضيلك الـ FL تكون لـ C2

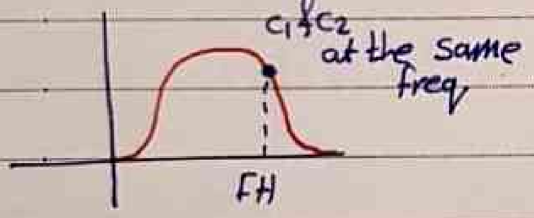
(LF)



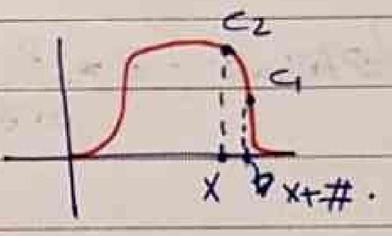
⇒



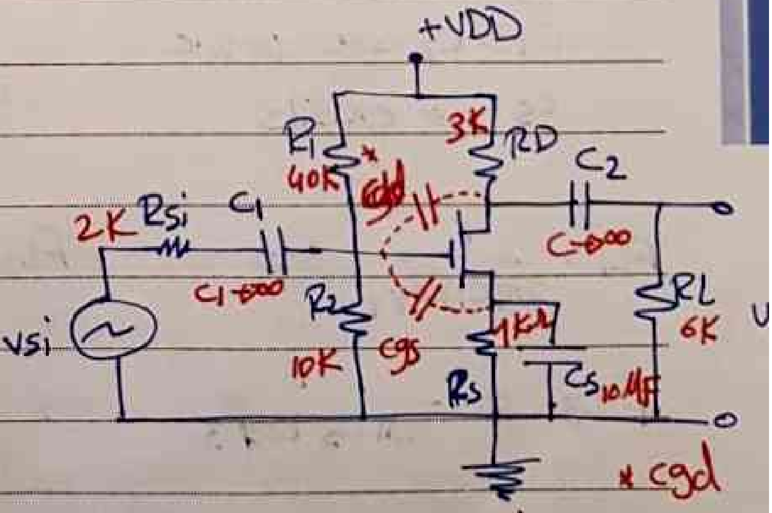
* بالـ (HF) بدي اثبت C2 (او اي cap بدي اياها) ونقسم الثانية على 10 عشان الـ Freq تزيد لانو شغال على الـ HF



⇒



* Freq. Resp. of Mosfet. Amp.



ID=2mA , Cgs= 5PF, Cgd=2PF

1)- Draw MF.S.S. eq cct & Find Vm

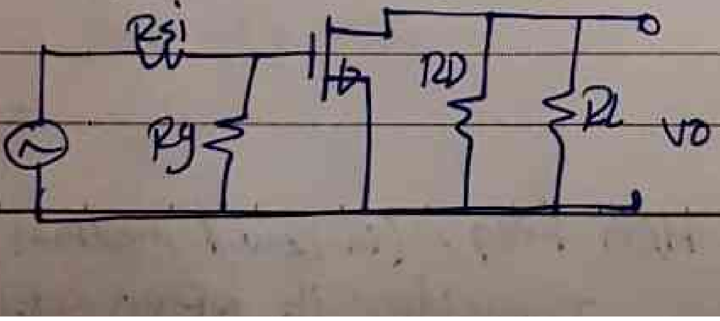
2)- " L.F.SS. " " " " FL

3)- " H.F.S.S. " " " " FH

4)- sketch Bode plote of Amp.

Sol:-

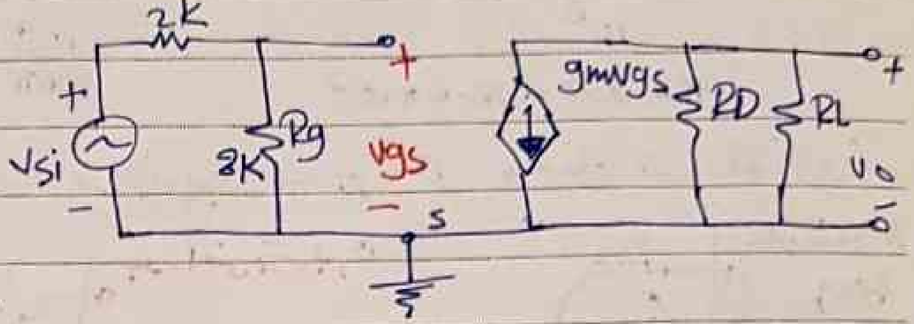
① C1, C2, CS → S.C , Cgd , Cgs → O.C $\underline{Kn = 2mA/V^2}$



⇒

* $c_{gd} \rightarrow C_M$

* $c_{gs} \rightarrow C_\pi$



$\Rightarrow AV = \frac{v_o}{v_{si}} = \frac{v_o}{v_{gs}} * \frac{v_{gs}}{v_{si}}$

$AV = \frac{-g_m \cancel{v_{gs}} (R_D // R_L)}{\cancel{v_{gs}}}$

* $\frac{R_g}{R_g + R_{si}}$ $\rightarrow AV = -g_m (R_D // R_L)$

* $g_m = 2\sqrt{k_n I_D} = 4 \frac{mA}{V^2}$

$\rightarrow \frac{\cancel{AV}\, v_o}{v_{gs}} \left[-(2\sqrt{k_n I_D})(3//6)\right] = -8$

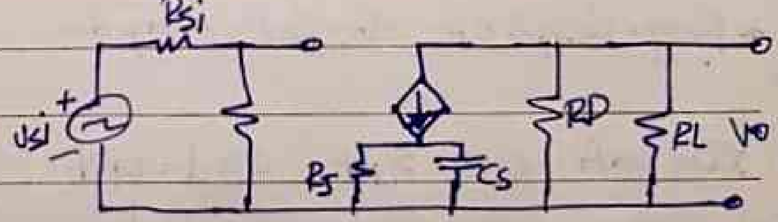
$\rightarrow AV_m = -8 * \frac{8}{2+8} = -6.4$.

② L.F.R

$\rightarrow c_{gd} = c_{gs} = 0 \Rightarrow$ O.C

$C_1 = C_2 = \infty \Rightarrow$ S.C

C_S → exisits



$FL_1 = \frac{1}{2\pi C_1 R_{eq_1}} = 0$, $FL_2 = \frac{1}{2\pi C_2 R_{eq_2}} = 0$

$FL_3 = \frac{1}{2\pi C_S R_{eq3}}$, R_{eq3} :- Rth seen by C_S

$R_{eq} = R_S$

⇒

* any cap in parallel ⇒ High freq. (in Low & medium I consider it open cct)

* K in Mosfet I can't Ignore it becuase it has a low value. $\boxed{122}$

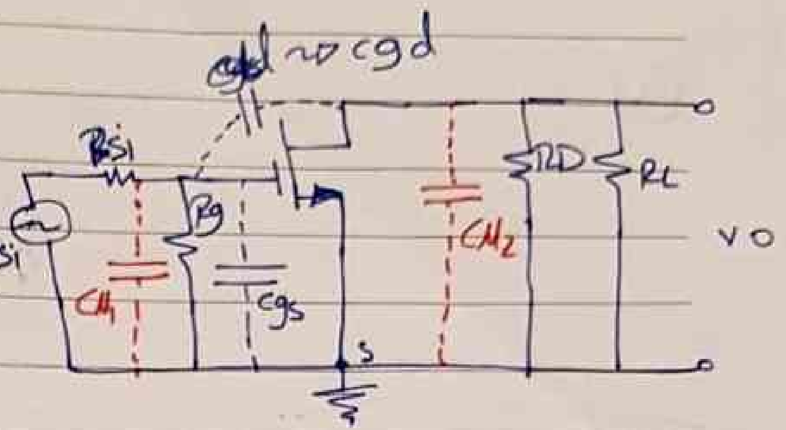
او (أقل) ؟؟ ✓

* أكبر واحد من ال FH هو المؤثر (يعني اللي باخذه) وطبعاً هاض الحكي اذا كان ال C1&C2 الهم قيم ، عشان هيك بطلع عندي أكثر من FH .

③ H.F.R

$C_1, C_2, C_S \rightarrow S.C$

$C_{gd}, C_{gs} \rightarrow$ exist.

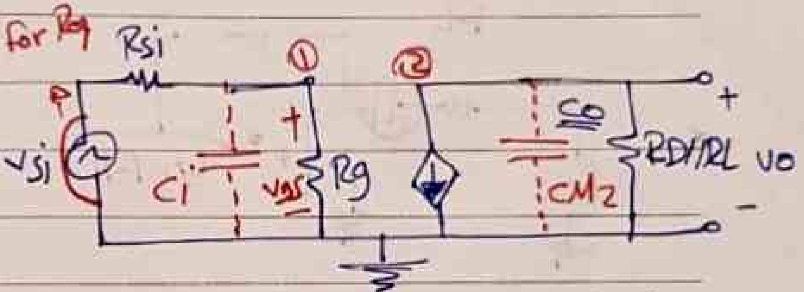


$C_i = C_{M1} + C_{gs}$

$C_{M1} = C_{gd}(1-K)$

$C_{M2} = C_{gd}(1-\frac{1}{K})$

$K = \frac{V_2}{V_1} = \frac{V_o}{V_{gs}} = \frac{-g_m \cancel{v_{gs}}(R_D//R_L)}{\cancel{v_{gs}}}$



$K = -g_m(R_D//R_L) = -4*2 = -8$

$\Rightarrow C_{M1} = 2(1-(-8)) = 18\,PF$

$C_{M2} = 2(1-(\frac{-1}{8})) = 2.25\,PF$

* اذا في CL اذن ال Co=CL+CM2

$F_{Hi} = \frac{1}{2\pi C_i R_{eq}}$, R_{eq} = Rth seen by C_i

$= R_{si}//R_g = 1.6\,K\Omega$

$C_i = 18+5 = 23\,PF.$

$F_{Hi} = \frac{1}{2\pi * 1.6*10^3 * 23*10^{-12}} = \frac{10^9}{230} = \underline{4.3\,MHz}$

$F_{Ho} = \frac{1}{2\pi C_o R_{eq}}$, R_{eq} = Rth seen by C_o

$= R_D//R_L = 2K\Omega$

$C_o = C_{M2} = 2.25\,PF$

$F_H = \frac{1}{2\pi * 2.25*10^{-12} * 2*10^3} = \frac{10^9}{9\pi} = \frac{1000}{9\pi}\,MHZ = 33\,MHZ$

$\therefore F_H = 4.3\,MHz.$

⇒

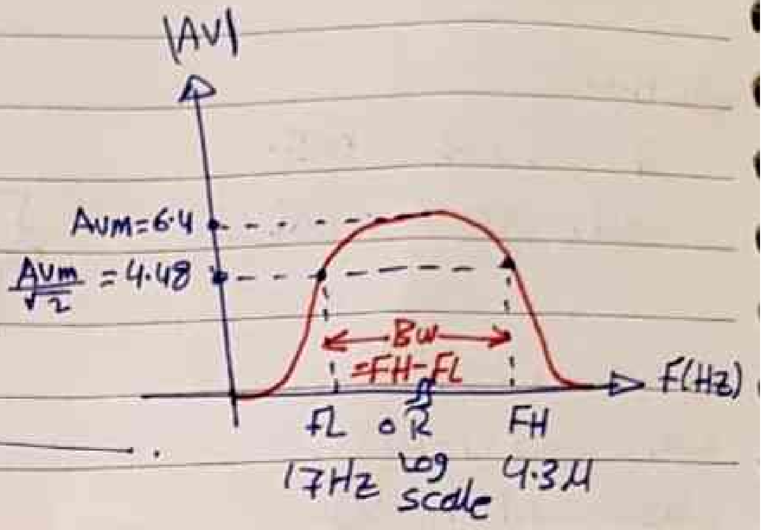
* C.D & C.C → CM1 ✓ , CM2 ✗ (-ve)

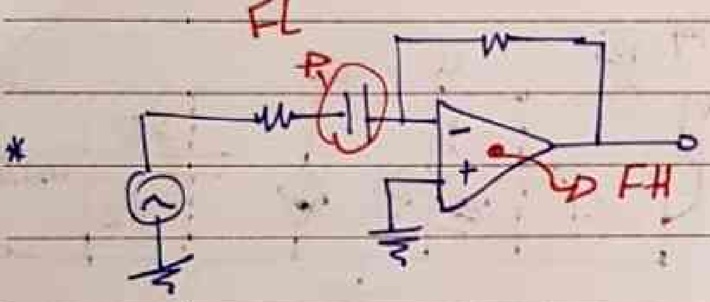
* C.R & C.G → CM1 ✗(-ve), CM2 ✓

* frequency Response for C.S & C.E → [illegible] *

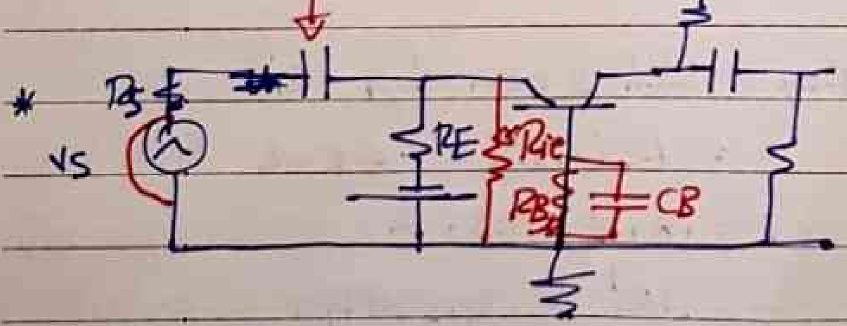
$\boxed{123}$

④





$$FL=\frac{1}{2\pi C_1 Req}$$

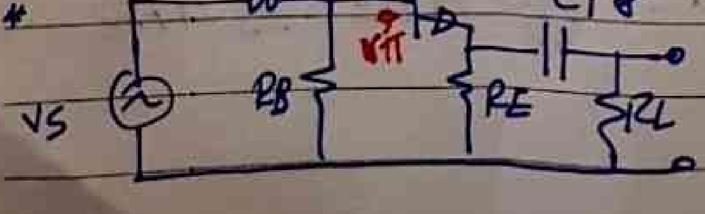


$Req = Ric // RE + Rs$

$, \; Ric=\frac{r\pi}{\beta+1}$

* If RB & CB exisit. ⟹ $FLB=\frac{1}{2\pi\, CB\, Req}$

$Req = (Rs // RE)(\beta+1) // r\pi // RB$



$$\Rightarrow Req=\left[\left(\frac{(Rs//RB)+r\pi}{\beta+1}\right)//RE\right]+RL$$