تقدم لجنة ElCoM الاكاديمية

دفتر لمادة:

الكترونيات (2)

من شرح:

د.هادي العيثاوي

جزيل الشكر للطالب:

نمر عودة

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

2) Any Amp must have:-

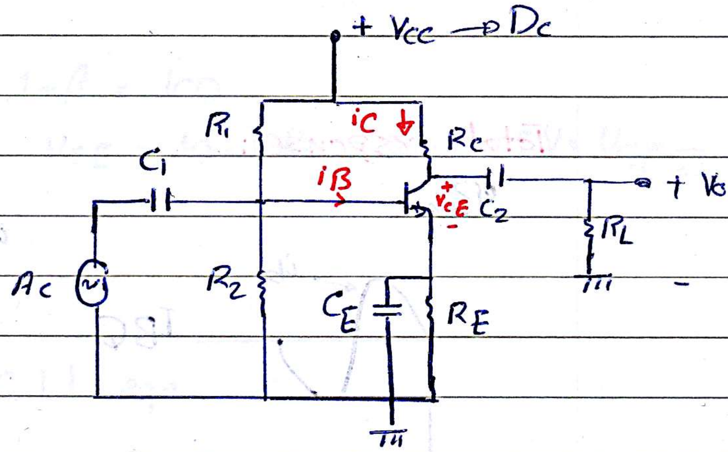
Dc source → To biase BJT in F.A.M

Ac source → To supply Ac signal.

Resistor or voltage & current limiting → biasing.

Capacitors → C_1, C_2 :- Coupling Cap (Coupling for Ac & Blocking Dc)

C_E :- bypass Cap.

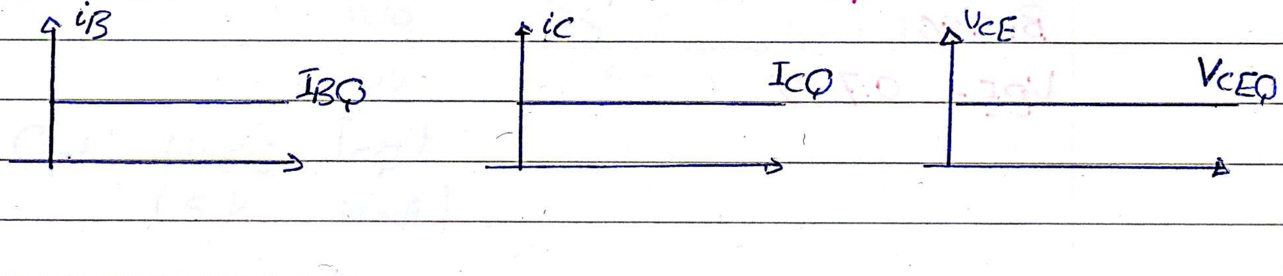


3) Amp is Linear circuit (so superposition is applied).

Total response
$$\begin{cases} i_B = I_{BQ} + i_b \\ i_C = I_{CQ} + i_c \\ V_{CE} = \underbrace{V_{CEQ}}_{D.C} + \underbrace{v_{ce}}_{A.C} \end{cases}$$

For No A.C :-

$i_B = I_{BQ}$, $i_C = I_{CQ}$, $v_{CEQ} = V_{CEQ}$



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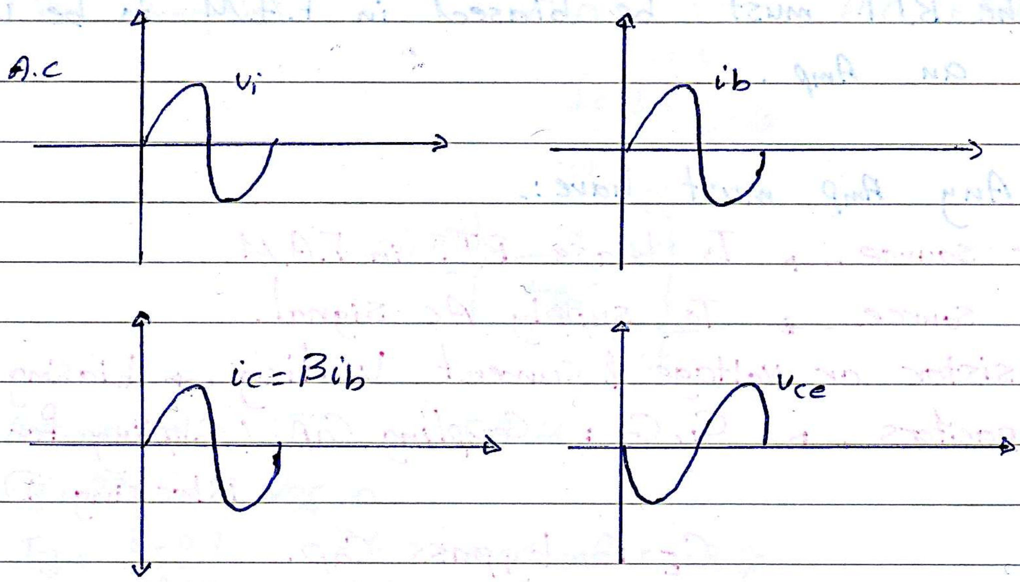
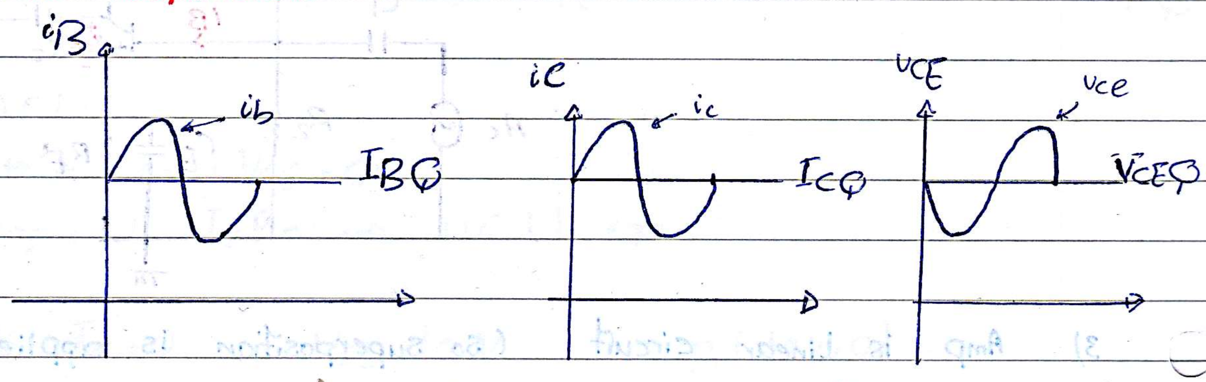
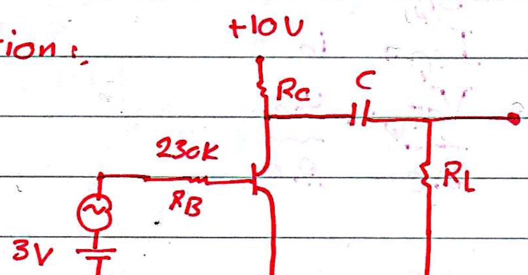
when AC is applied:-



Total response:-



Basic Amp. Operation:-

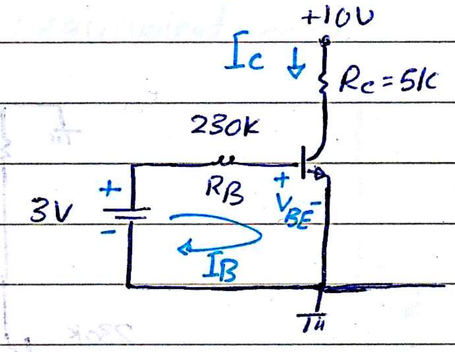


$\beta = 100$

$V_{BE} = 0.7\ V$

Using superposition :-

1) Dc Analysis ∴ Cap → O.C , A.C → Short cct.



Assume the BJT in F.A.M :-

$-3 + 230\, I_B + V_{BE} = 0$

$I_B = \dfrac{3-0.7}{230k} = \dfrac{2.3}{230k} = 0.01\ mA = I_{BQ}$

$I_C = \beta I_B = 100 \times 0.01 = 1\,mA = I_{CQ}$

$-10 + I_C R_C + V_{CE} = 0 \rightarrow V_{CE} = 10 - I_C R_C = 10 - 5 = 5V = V_{CEQ}$

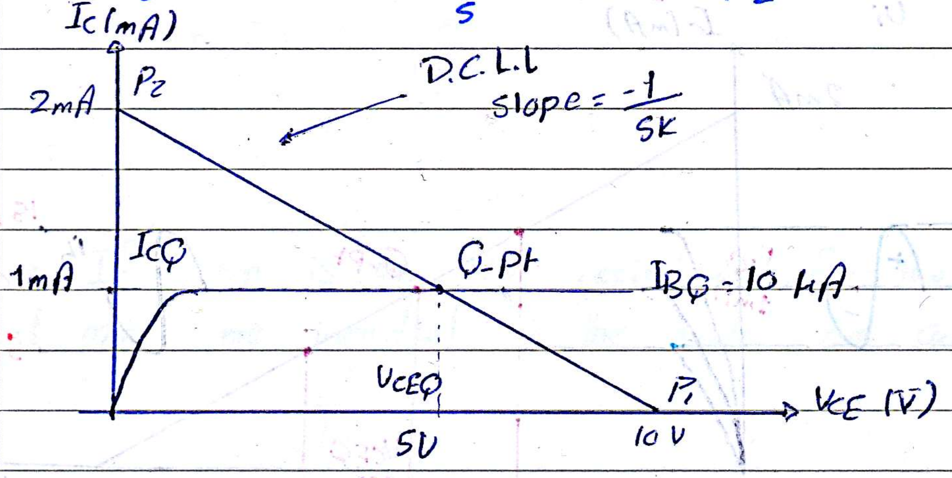
D.C.L.L

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

$V_{CE} = 10 - I_C R_C \Rightarrow$ D.C.L.L eqn.

For $I_C = 0$, $V_{CE} = 10\ V$, $P_1 (10V, 0)$

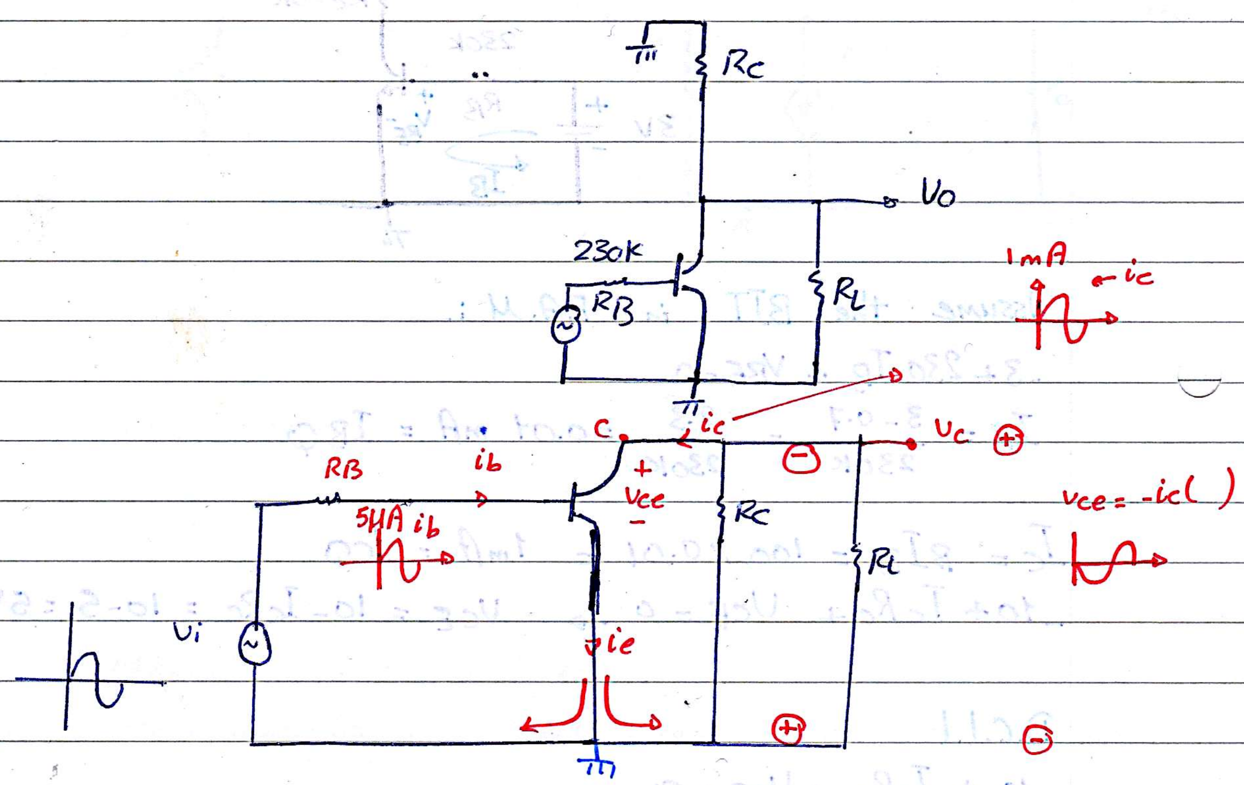
For $V_{CE} = 0$, $I_C = \dfrac{10}{5} = 2mA$, $P_2 (0, 2mA)$



Qpt (V_{CEQ}, I_{CQ})
$(5\ V, 1\ mA)$

For A.C Analysis

C → S.C D.C Source → S.C

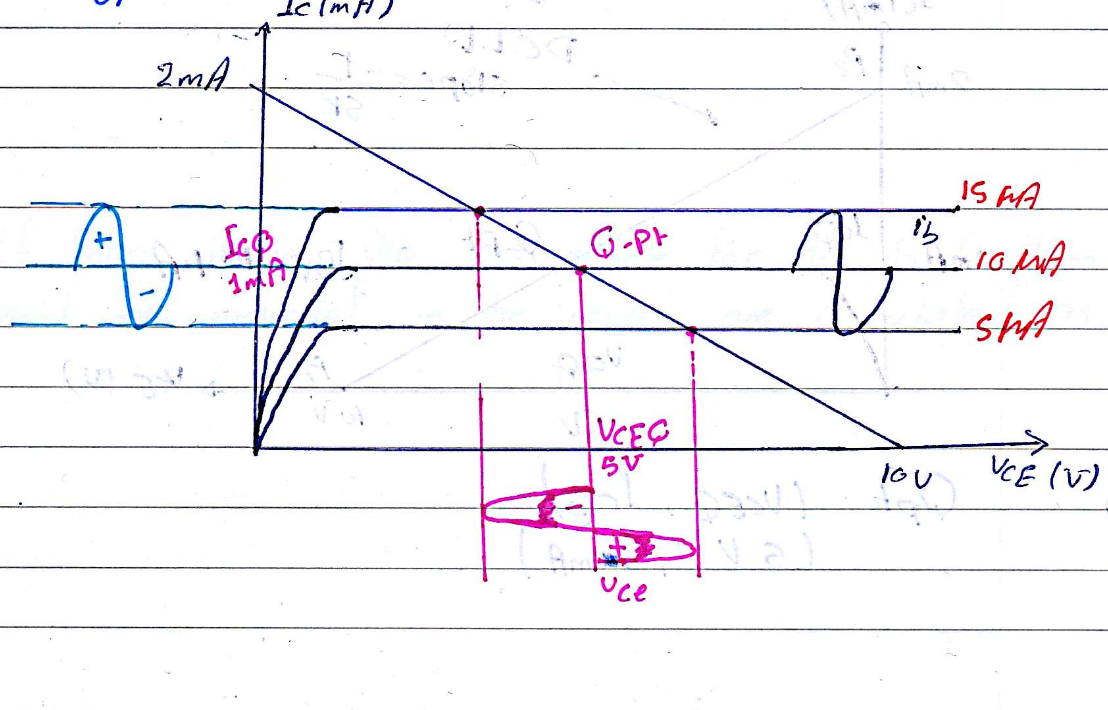


$v_{ce} + i_c(R_c // R_L) = 0$

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

$v_o = v_{ce}$

$A_V = \frac{v_o}{v_i}$ → Voltage gain



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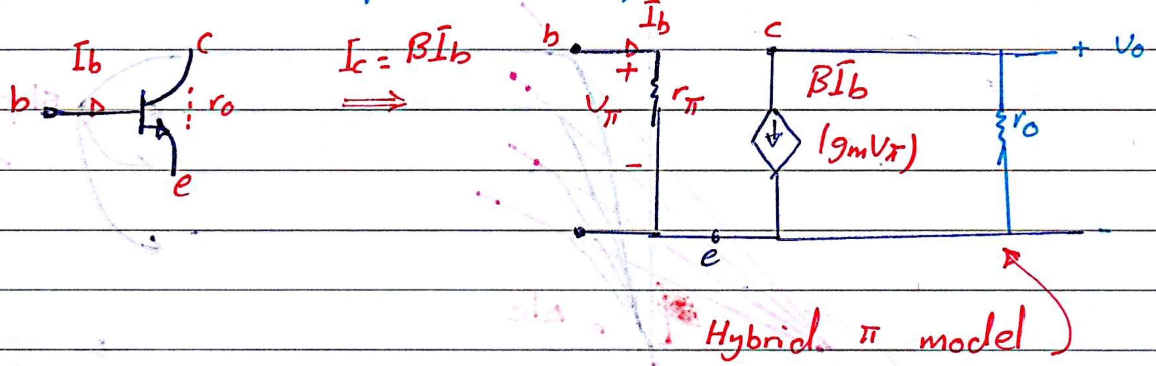
BJT Amp.

To perform A.c Analysis, the BJT is replaced by it's model (equivalent cct).



r_π : B.E resistance

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

V_T: Thermal voltage (26 mV)

g_m: Transconductance (A/V, mA/V, μA/V)

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

$$g_m V_\pi = \beta I_b$$

$$\frac{I_{CQ}}{V_T}(I_b r_\pi) = \frac{\beta V_T}{r_\pi} \qquad \# \ V_\pi = I_b r_\pi$$

$$g_m r_\pi = \beta$$

⇒ If there is an O/p resistance for the BJT then it must be included in the model are calculated as:

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

V_A: Early voltage

V_A: gain $(50 < V_A < 300)$ V

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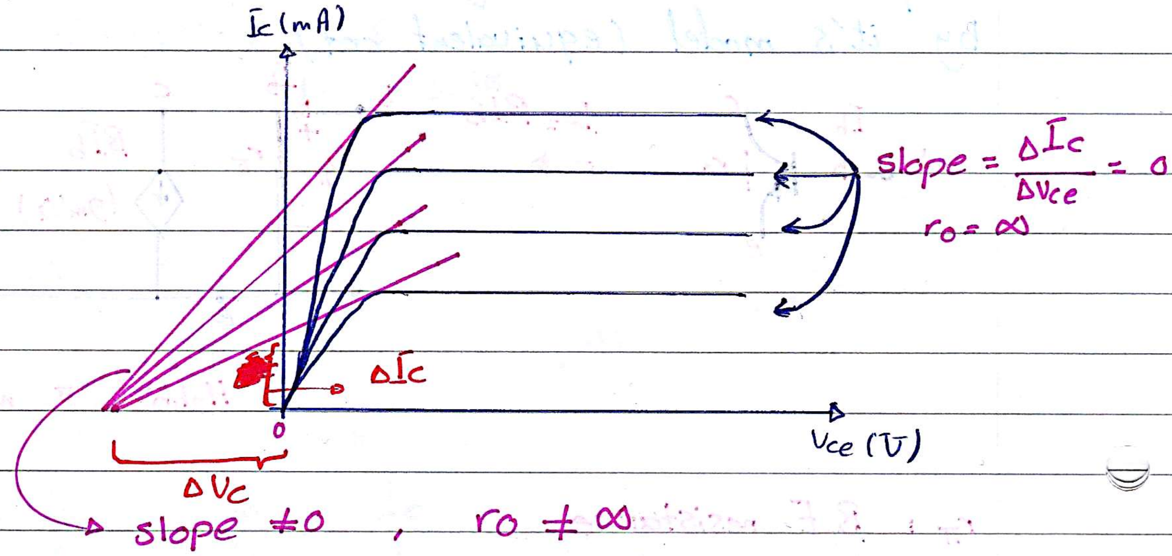
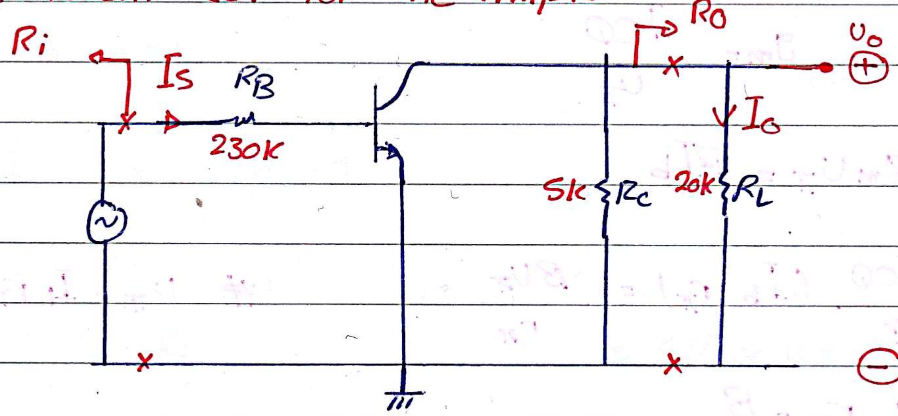
$$r_o = \frac{1}{\text{slope of } (I_c, V_{ce}) \text{ Line}}$$



$$\text{Slope} = \frac{\Delta I_c}{\Delta V_{ce}} = \frac{I_{CQ}}{V_A}$$

$$\frac{1}{\text{slope}} = r_o = \frac{V_A}{I_{CQ}}$$

A.c equivalent cct for the Ampi-



Back to the basic example:-

From D.C Analysis

$I_{CQ} = 1\,mA$

Find voltage - gain :- $A_V = \frac{V_o}{V_s}$

Current - gain :- $A_I = \frac{I_o}{I_s}$

input resistance $\underline{R_i}$

Output resistance $\underline{R_o}$

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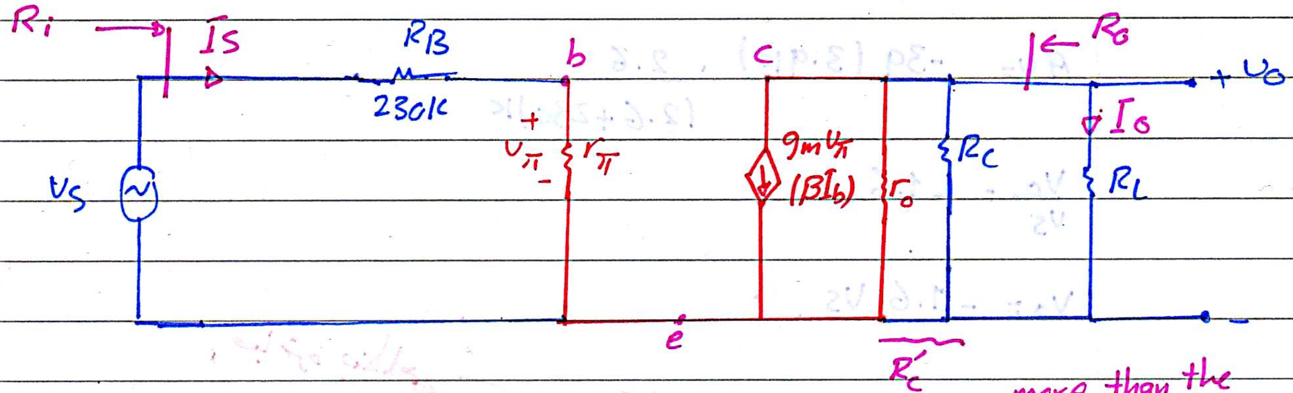
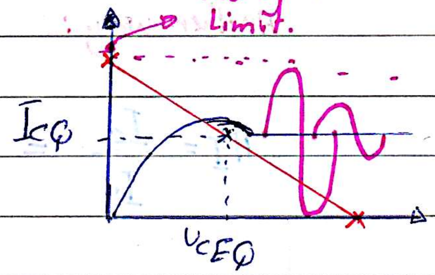
Given : $\beta = 100$, $V_T = 26\ mV$, $V_A = 100\ V$



Small signal A.C equivalent cct for the Amp.



1) Voltage gain : $A_v = \frac{v_o}{v_s}$

$v_o = -g_m V_\pi R_L'$, where $R_L' = r_o // R_C // R_L$

$V_\pi = V_s \frac{r_\pi}{r_\pi + R_B}$

$\therefore v_o = -g_m V_s \frac{r_\pi}{r_\pi + R_B} R_L'$

$\frac{v_o}{v_s} = A_v = \frac{-g_m r_\pi R_L'}{r_\pi + R_B}$

$\ominus$ means 180° phase shift between v_s & v_o

$g_m = \frac{I_{CQ}}{V_T} = \frac{1mA}{26\ mV} = 39\ mA/V$

$r_o = \frac{V_A}{I_{CQ}} = \frac{100\ V}{1mA} = 100\ k\Omega$

$R_L' = 100 // 5 // 20\ k$

$= 100 // 4k = 3.9\ k\Omega$.

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$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{100 \times 26mV}{1mA} = 2.6\ K\Omega$$

$$A_V = -39(3.9K) \cdot \frac{2.6}{(2.6+230)K}$$

$$\frac{V_o}{V_s} = -1.6$$

$$V_o = -1.6\ V_s.$$

مباشرة بنطلع

Another way :- $\frac{V_o}{V_s} = \frac{V_o}{V_\pi} \times \frac{V_\pi}{V_s}$

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

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

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

$$I_b = I_s \Rightarrow \frac{I_b}{I_s} = 1$$

$\therefore A_I = \frac{-\beta R_c'}{R_c' + R_L} \cdot 1$, where $R_c' = R_c // r_o$

$= 5 // 100K = 4.8K\Omega.$

$$A_I = \frac{-100(4.8)}{4.8+20} = -20$$

$$\frac{I_o}{I_s} = -20$$

$$I_o = -20\ I_s$$

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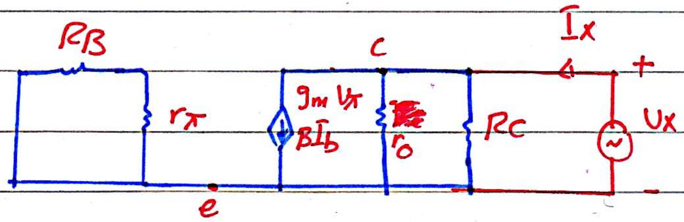
$$R_i = \frac{V_s}{I_s}$$

$$-V_s + I_s R_B + I_s r_\pi = 0$$

$$V_s = I_s (R_B + r_\pi)$$

$$R_i = \frac{V_s}{I_s} = R_B + r_\pi = 232.6\ K\Omega.$$

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



Kcl at C node:-

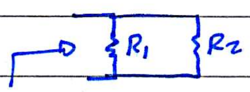
$$I_x = \cancel{g_m V_\pi}^{\,0} + \frac{V_x}{R_C} + \frac{V_x}{r_o}$$

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

$$I_x = V_x \left(\frac{1}{R_C} + \frac{1}{r_o} \right)$$

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

$$R_o = r_o // R_C$$



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{eq} = R_1 // R_2$$

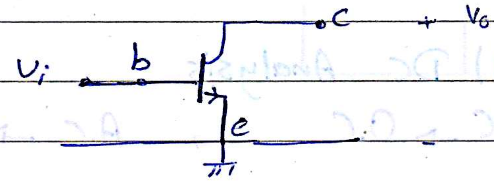
$$R_o = 5 // 100K = 4.8\ K\Omega.$$

CH6 — Wednesday 20.7.2016

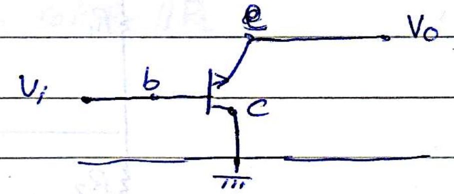
Single - stage BJT Amp.

BJT Configuration. (Connection)

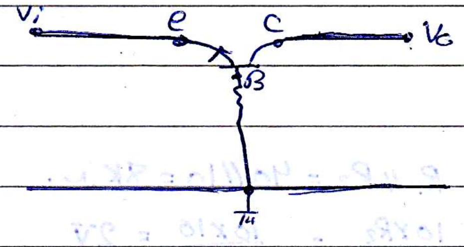
1) Common - Emitter Amp.



2) Common - Collector Amp.



3) Common - Base Amp.



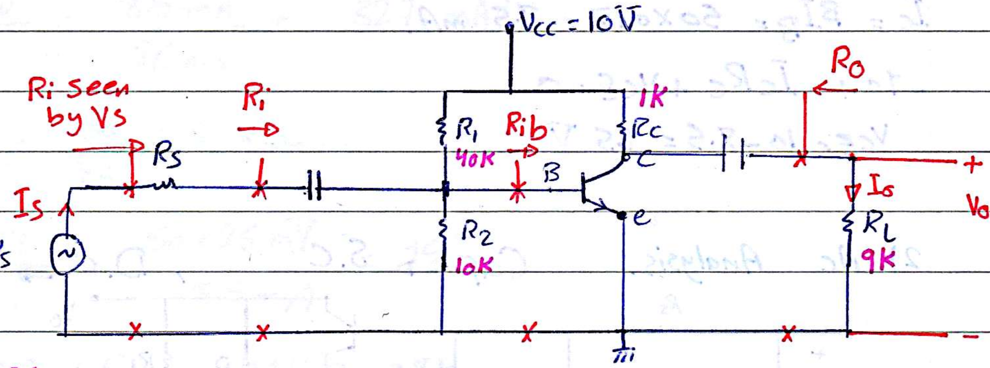
① C.E. Amplifier.

E → Common Terminal.

V_i to base

V_o from C

(i) Basic C.E Amp. (E is directly connected to the ground).



$V_{BE} = 0.6\ V$

$\beta = 50$

$V_A = 50\ V$

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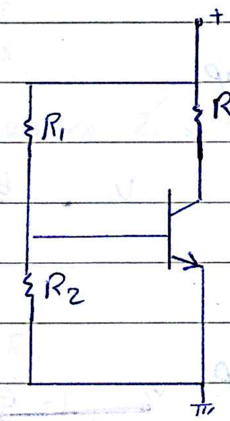
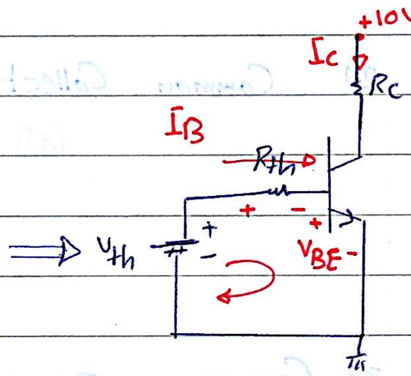
1) Calculate I_{CQ}, V_{CEQ}.

2) Draw S.S.A.C equivalent cct & find $A_v, A_i, R_o, R_i, R_{ib}$, R_i seen by Vs.

1) DC Analysis

C → O.C , A.C → S.C





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

$V_{th} = \frac{10 \times R_2}{R_1 + R_2} = \frac{10 \times 10}{50} = 2V$

Assume the BJT in F.A.M :-

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

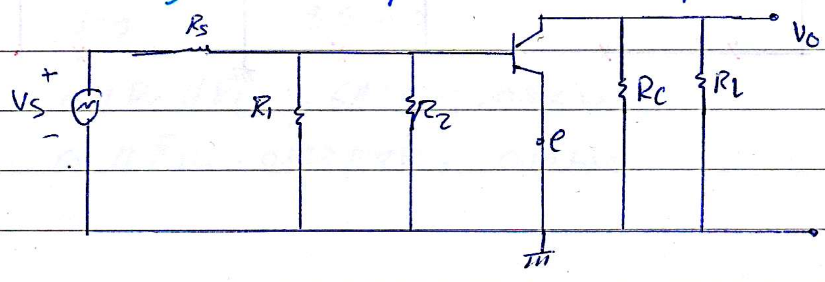
$I_B = \frac{2 - 0.6}{8K} = 0.17$ mA.

$I_C = \beta I_B = 50 \times 0.17 = 8.5$ mA.

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

$V_{CE} = 10 - 8.5 = 1.5$ V.

2) Ac Analysis. Cap → S.C , D.C → S.C



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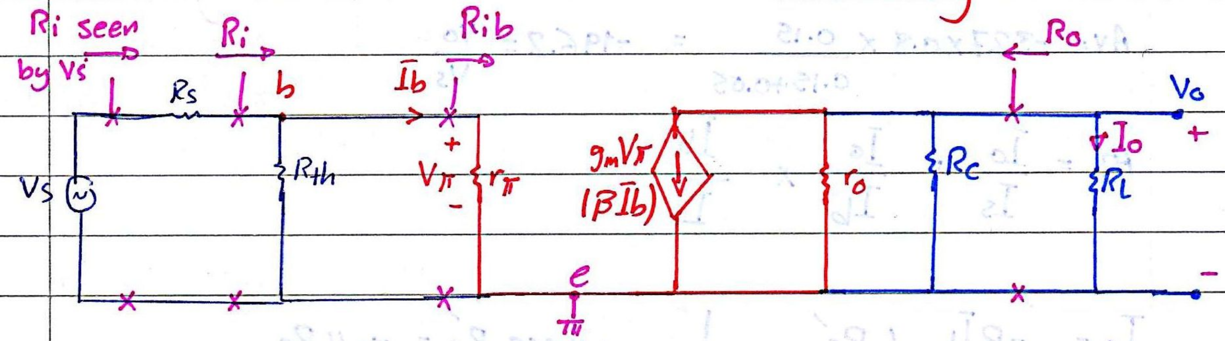
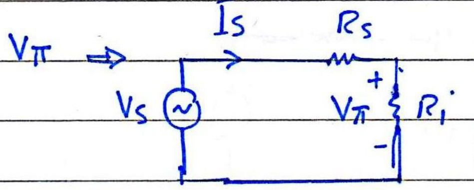


$$A_V = \frac{V_o}{V_s} = \frac{V_o}{V_\pi} \times \frac{V_\pi}{V_s}$$

$V_o = -g_m V_\pi R_L'$, where $R_L' = r_o \| R_C \| R_L$

$$\frac{V_o}{V_\pi} = -g_m R_L'$$



$$V_\pi = \frac{V_s R_i}{R_i + R_s} \quad (\text{VDR})$$

$$\frac{V_\pi}{V_s} = \frac{R_i}{R_i + R_s}$$

$$A_V = -g_m R_L' \quad \frac{R_i}{R_i + R_s}$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{8.5\ \text{mA}}{26\ \text{mV}} = 327\ \text{mA/V}$$

$$r_o = \frac{V_A}{I_{CQ}} = \frac{50}{8.5} = 6\ \text{k}\Omega.$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{50 \times 26\ \text{mV}}{8.5\ \text{mA}} = 153\ \Omega.$$

$R_L' = r_o \| R_C \| R_L = 6 \| 1 \| 9 = 0.8\ \text{k}\Omega.$

$R_i = r_\pi \| R_{th} = 0.153 \| 8\text{k} = 0.15\ \text{k}\Omega.$

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$A_V = -327 \times 0.8 \times \frac{0.15}{0.15+0.05} = -196.2 = \frac{V_o}{V_s}$

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

$I_o = -\beta I_b \left(\frac{R_c'}{R_c' + R_L} \right)$, where $R_c' = r_o // R_c$

$\rightarrow$ CDR

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

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

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

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

$R_c' = r_o // R_c = 6 // 1 = 0.857 \ K\Omega$.

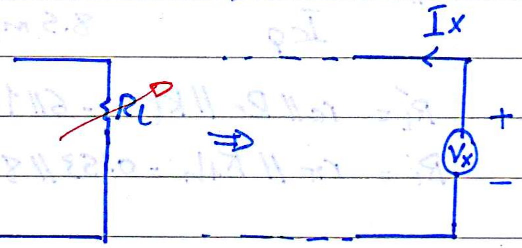
$A_I = \frac{-50 \times 0.85}{0.85 + 9} \times \frac{8}{8 + 0.153} = -4.2$

$R_{ib} = r_\pi = 0.153 \ K\Omega$.

$R_i = R_{th} // R_{ib} = 8 // 0.153 = 0.15 \ K\Omega$.

R_i seen by V_s $= R_s + R_i = 0.05 + 0.15 = 0.2 \ K\Omega$.

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



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

$\therefore g_m V_\pi = 0 \Rightarrow$ The dep. C.S is Open

So $R_o = r_o // R_c = 0.857 \ K\Omega$.

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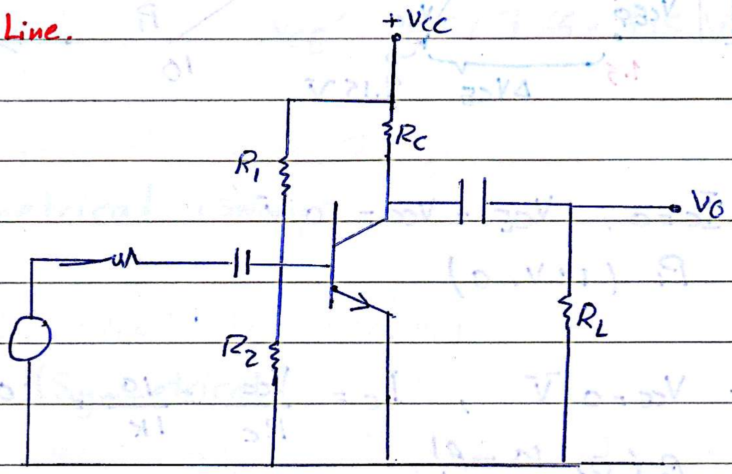
A_I in terms of A_V:-

$$A_I = \frac{I_o}{I_s} = \frac{V_o/R_L}{V_s/(R_s+R_i)} = \frac{V_o}{V_s}\left(\frac{R_s+R_i}{R_L}\right) = A_V \frac{R_s+R_i}{R_L}$$

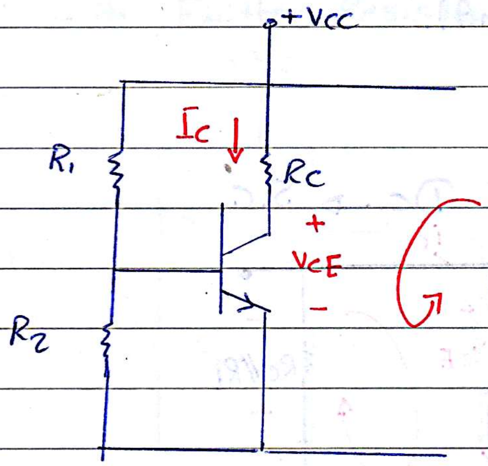
A_V in terms of A_I :-

$$A_V = \frac{V_o}{V_s} = \frac{I_o \times R_L}{I_s\,(R_s+R_i)} = A_I \frac{R_L}{R_s+R_i}$$

A.C Load Line.



D.C.L.L



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

$V_{CE} = V_{CC} - I_C R_C \Rightarrow$ ① D.C.L.L eq.

or

$$I_C = \frac{V_{CC}}{R_C} - \frac{V_{CE}}{R_C} \Rightarrow ②$$

$y = b + mx$.

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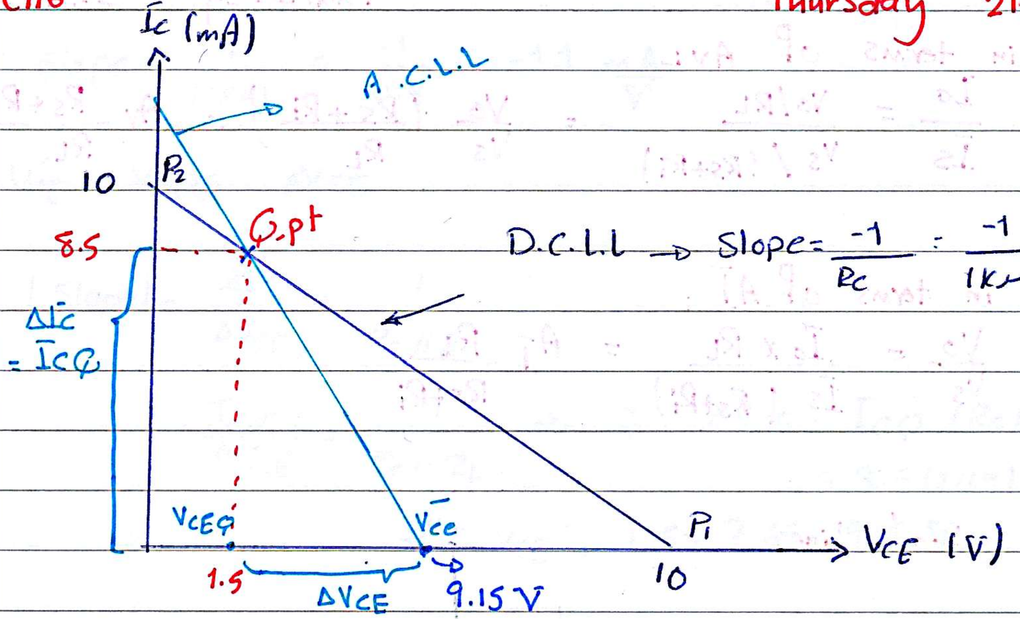


$D.C.L.L \rightarrow$ Slope $= \frac{-1}{R_C} = \frac{-1}{1k\Omega} = -1 \frac{mA}{V}$

(i) For $I_C = 0$, $V_{CE} = V_{CC} = 10\,V$

$P_1\ (10\,V, 0)$

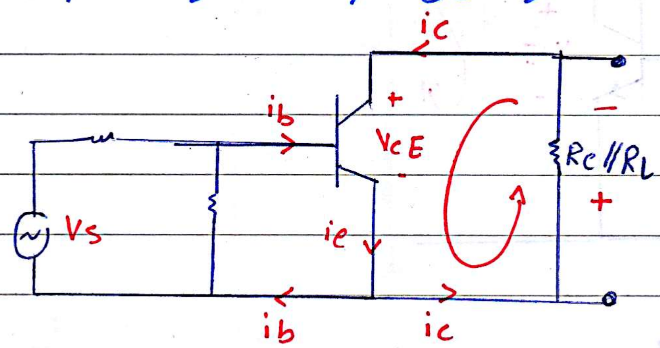
(ii) For $V_{CE} = 0\,V$, $I_C = \frac{V_{CC}}{R_C} = \frac{10}{1k} = 10\ mA.$

$P_2\ (0, 10\ mA)$

Q-pt $(1.5\,V, 8.5\ mA)$.

A.C.L.L $\rightarrow$

For Ac, $C \rightarrow S.C$, $Dc \rightarrow S.C$



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

Slope $= \frac{-1}{(R_C \parallel R_L)}$

A.C.L.L & D.C.L.L intersects at Q-pt.

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$Slope = \frac{-1}{(1//9)} = \frac{-1}{0.9} = -1.1 \frac{mA}{V}$

1st exam 1/8 Monday.

$V'_{CE} = V_{CEQ} + \Delta V_{CE}$

$|Slope| = \frac{\Delta I_c}{\Delta V_{CE}} = \frac{1}{R_c // R_L}$

$\frac{I_{CQ}}{\Delta V_{CE}} = \frac{1}{R_c // R_L} \Rightarrow \therefore \Delta V_{CE} = I_{CQ} (R_c // R_L)$

$= 8.5 (1//9) = 7.65 V$

$V'_{CE} = 1.5 + 7.65 = 9.15 V$

peak_Symmetrical Output Voltage.

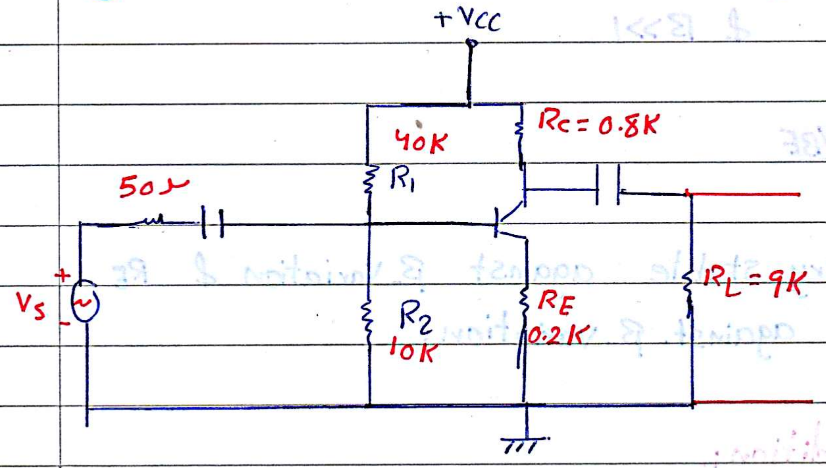
peak_Symmetrical (swing)

$V_{cep} (max) = \Delta V_{CE} = I_{CQ} (R_c // R_L)$

peak_peak (Symmetrical)

Output Voltage $= 2 \Delta V_{CE} = 2 I_{CQ} (R_c // R_L)$

(ii) C.E with Emitter Resistor R_E.



$\beta = 50$

$V_{BE} = 0.6 V$

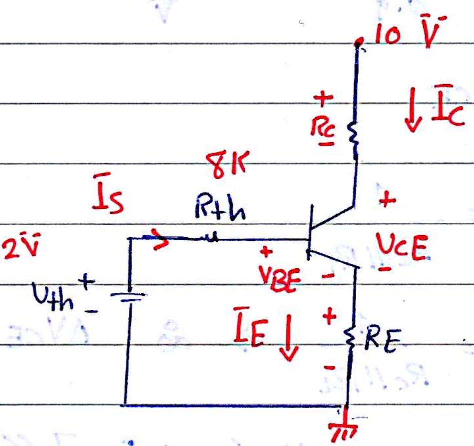
$V_A = 50 V$

1) Find I_{CQ}, V_{CEQ}.

2) Draw A.C eqnt cct & find A_v, A_I, R_{ib}, R_i

1) D.C Analysis : C → O.C , A.C → S.C

$V_{th} = \frac{10 \times 10}{50} = 2V$, $R_{th} = 10 \parallel 40 = 8K\Omega$.



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

$I_B = \frac{V_{th} - V_{BE}}{R_{th} + (\beta+1) R_E} = I_{BQ}$

$I_C = \beta I_B = \frac{\beta (V_{th} - V_{BE})}{R_{th} + (\beta+1) R_E}$

If $R_{th} \ll (\beta+1) R_E$ & $\beta \gg 1$

$I_{CQ} \simeq \frac{V_{th} - V_{BE}}{R_E}$

i.e. Q-pt is very stable against β-variation & R_E stabilize Q-pt against β-variation.

bias-stable Condition:-
$R_{th} = 0.1 (\beta+1) R_E$.

To check:-
$R_{th} \leq 0.1 (\beta+1) R_E$.

$I_B = \frac{12-0.6}{8+51\times0.2} = \frac{1.4\text{ V}}{9K} = 0.077\text{ mA} = I_{BQ}$.

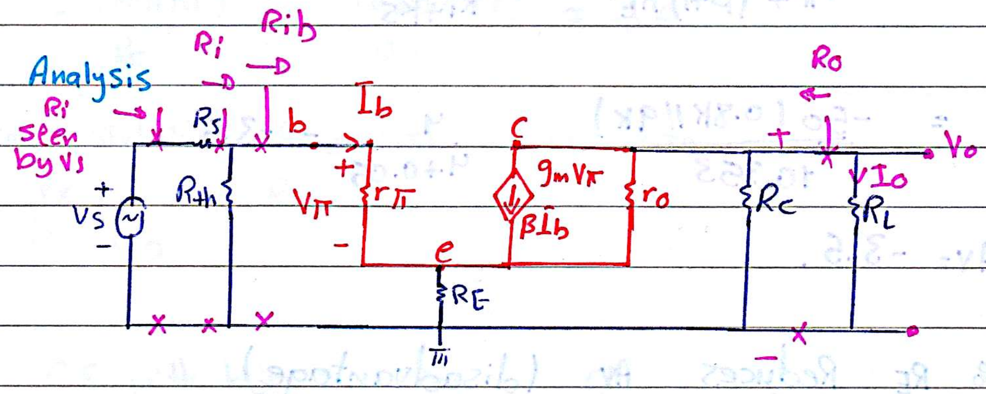
$I_{CQ} = \beta I_B = 3.85\text{ mA}$.

$I_{EQ} = (\beta+1) I_B = 3.93\text{ mA}$.

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

$V_{CE} = 10 - 3.85\times0.8 - 3.93\times0.2 = 6.1\text{ V}$.

A.C Analysis



$A_v = \frac{V_o}{V_s} = \frac{V_o}{V_i} \times \frac{V_i}{V_s}$

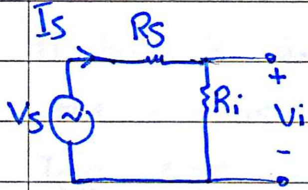
Neglecting the effect of r_o

$V_o = -\beta I_b (R_L // R_C)$

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

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

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



$\frac{v_i}{v_s} = \frac{R_i}{R_i + R_s}$, where $R_i = R_{th} // R_{ib}$

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

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{50 \times 26\ mV}{3.85\ mA} = 338\ \Omega .$$

$R_{ib} = 0.338 + 51 \times 0.2 = 10.353\ K\Omega .$

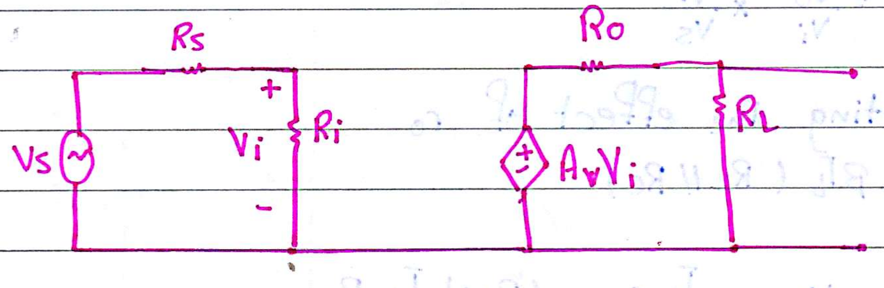
$R_i = 8 \parallel 10.353 = 4 K\Omega .$

$$A_V = \frac{-\beta (R_C \parallel R_L)}{r_\pi + (\beta+1) R_E} \cdot \frac{R_i}{R_i + R_s}$$

$$= \frac{-50 (0.8K \parallel 9K)}{10.353} \cdot \frac{4}{4+0.05} = -3.5$$

$A_V = -3.5 .$

- R_E Reduces A_V (disadvantage)
- R_E increases R_i (advantage)



$$V_i = \frac{V_s R_i}{R_i + R_s} , \quad V_o = \frac{A_V V_i R_L}{R_L + R_o}$$

As $R_i \uparrow$ and $R_o \downarrow$ the Amp becomes close to ideal voltage.

$\left.\begin{array}{l} R_i = \infty \\ R_o = 0 \end{array}\right\} \rightarrow$ ideal voltage Amp.

$$A_I = \frac{I_o}{I_s} = \frac{V_o}{R_L} \Big/ \frac{V_s}{R_s + R_i}$$

$$\overset{\uparrow}{A_I} = A_V \frac{R_s + \overset{\uparrow}{R_i}}{R_L}$$

$\therefore$ R_E increase A_I (Advantage).

$$= -4\left(\frac{0.05 + 10.3}{9}\right) = -4.5.$$

$$A_V = \frac{-\beta(R_C // R_L)}{(\beta+1)R_E} \cdot \frac{R_i}{R_i + R_S} = -3.5.$$

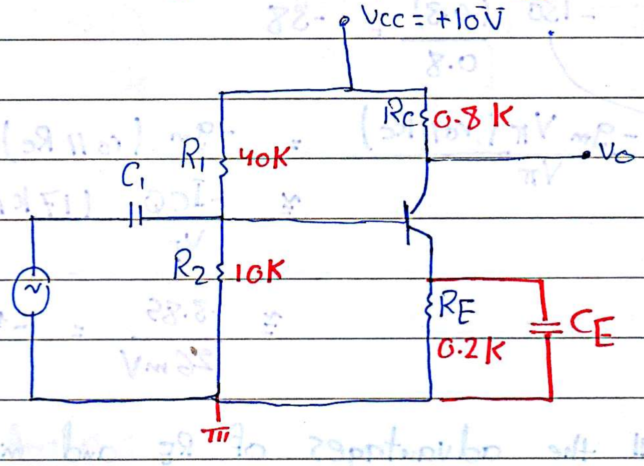
For $R_i \gg R_S$ & $(\beta+1)R_E \gg r_\pi$, $\beta+1 \gg 1$

$$A_V \cong -\frac{(R_C // R_L)}{R_E} \cong \frac{(0.8K // 9K)}{0.2} \cong -3.6.$$

$\therefore$ R_E stabilize A_V against β variation.

$$R_o = \left.\frac{V_X}{I_X}\right|_{V_S=0} = R_C.$$

(iii) C.E with bypass Cap. C_E



$\beta = 50$

$V_{BE} = 0.6$ V

$V_A = 50$ V

1) Find I_{CQ}, V_{CEQ}.

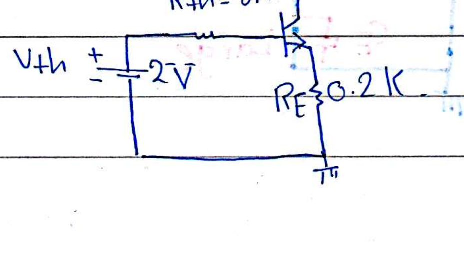
2) Draw S.S.A.C cct & Find A_V, A_I, R_i, R_o.

1) For DC Analysis , $C \to O.C$, $A.C \to S.C$

the cct is analyzed as C.E with R_E.

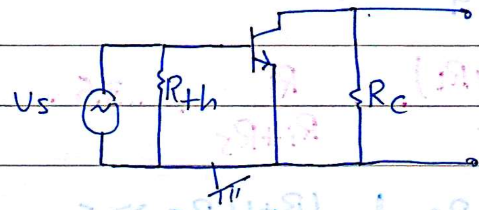
$I_{CQ} = 3.85$ mA.

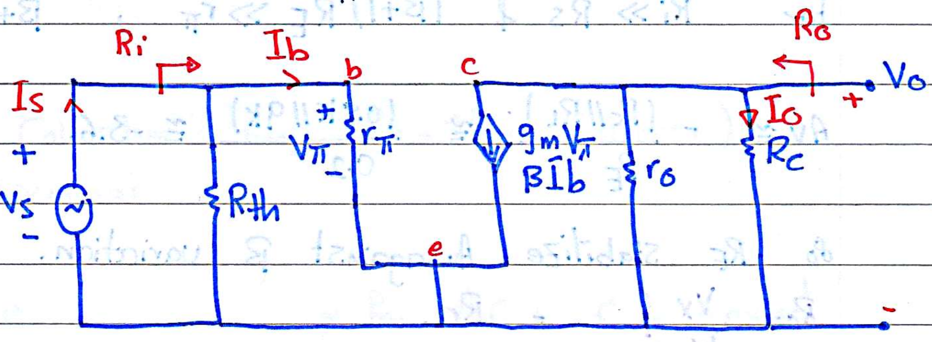
$V_{CEQ} = 6.1$ V



2) For A.C Analysis :-

C, CE → S. C   Dc → S.C





$R_i = r_\pi // R_{th} = 338 // 8k = 325\ \Omega.$

$R_o = R_C // r_o \cong 0.8\ k\Omega.$

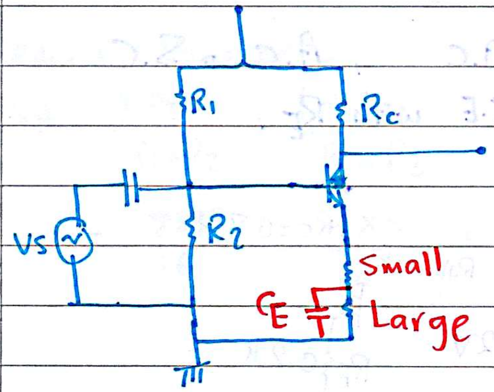
$A_I = A_V \dfrac{R_i}{R_C} = \dfrac{-130\ (0.3)}{0.8} = -38$

$A_V = \dfrac{V_o}{V_s} = \dfrac{-g_m V_\pi (r_o // R_C)}{V_\pi} = -g_m (r_o // R_C)$

$\cong \dfrac{-I_{CQ}}{V_T} (17k // 0.8)$

$\cong \dfrac{-3.85}{26\,mV} = -130.$

(*) To gain all the advantages of R_E and minimize disadvantages, R_E is made of two parts (Small R_E & Large R_E) then shortout Large R_E with bypass cap (CE).



: gain back depends On Dc

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Basic C.E →

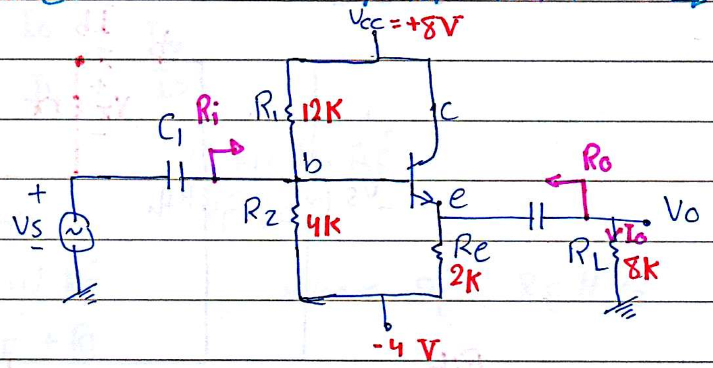
1) $A_V > 1$
2) $A_I > 1$
3) R_o moderate to high
4) R_i moderate to high.
5) phase shift = 180° = ϕ

2) Common - Collector Amp (Emitter - Follower)

C → Common terminal.

V_i → Base

V_o → From e. * For A.C : C → ground.



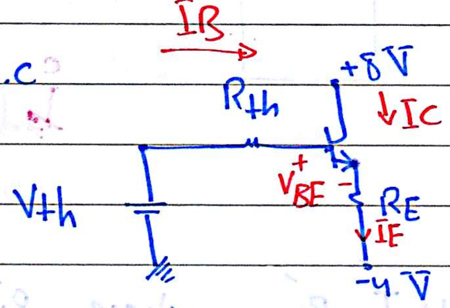
$\beta = 49$, $V_A = 50\ V$, $V_{BE} = 0.7\ V$

1) Find I_{CQ} , V_{CEQ}.

2) Draw S.S.A.C eqnt cct & Find A_V, A_I, R_i, R_o

1) D.C Analysis

C → O.C , A.C → S.C



$R_{th} = R_1 // R_2 = 3K\Omega$.

$$V_{th} = \frac{8 R_2}{R_1 + R_2} + \frac{(-4) R_1}{R_1 + R_2}$$

$$= \frac{8 \times 12}{16} - \frac{4 \times 4}{16} = \frac{96}{16} - \frac{16}{16} = 5\ V.$$

$-V_{th} + I_B R_{th} + V_{BE} + (\beta+1) I_B R_E - 4 = 0$

$$I_B = \frac{5+4-0.7\ V}{R_{th}+50\times 2} = \frac{8.3}{103\,k} = 0.08\ mA.$$

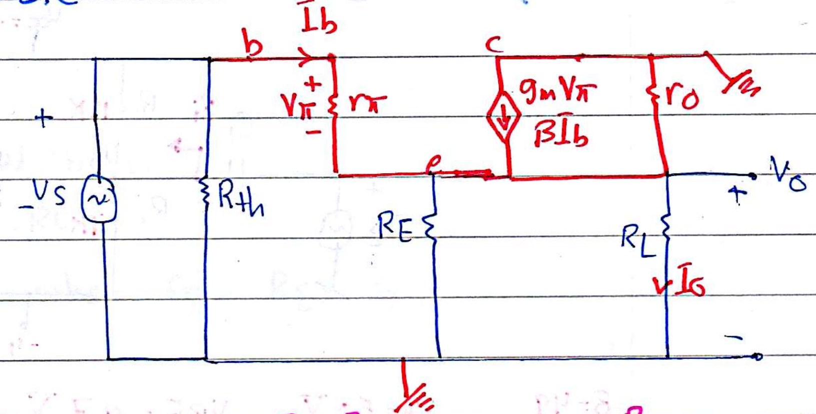
$I_{CQ} = \beta I_B = 0.08 \times 49 \simeq 4\,mA.$

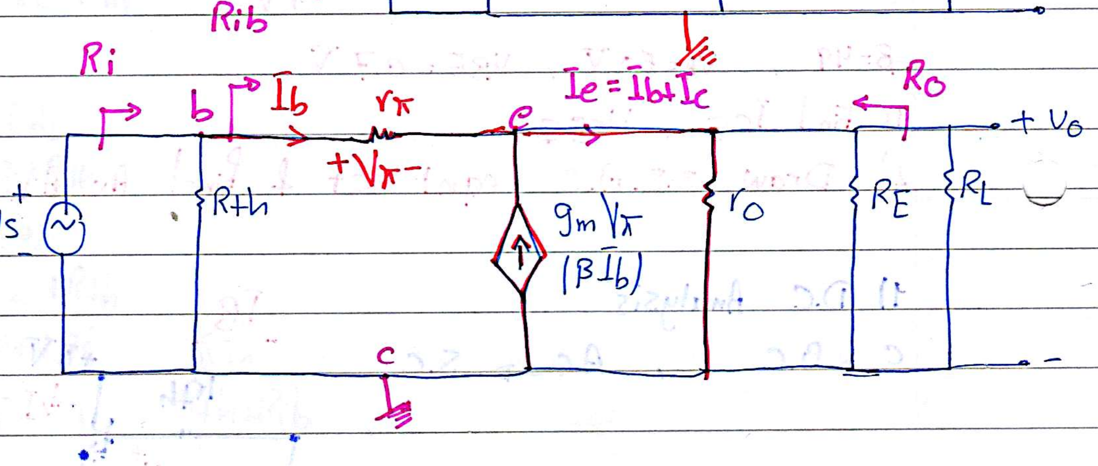
$-8 + V_{CE} + I_E R_E - 4 = 0$

$V_{CE} = 12 - (50\times 0.08)\times 2 = 4\,V$

2) A.C Analysis.

$C \rightarrow S.C$: $D.C \rightarrow S.C$





$$AV = \frac{V_o}{V_s}$$

$V_o = (\beta+1) I_b R_L'$, where $R_L' = r_o \parallel R_E \parallel R_L$

$-V_s + V_\pi + V_o = 0$

$V_s = I_b r_\pi + (\beta+1) I_b R_L'$

$$AV = \frac{(\beta+1) R_L'}{r_\pi + (\beta+1) R_L'} < 1$$

because : $-V_s + V_{be} + V_o = 0$

$V_o = V_s - V_{be}$

V_o always less than V_s

1) $AV < 1$. 2) $\phi = 0$

For $(\beta+1)R_L' \gg r_\pi$ & $\beta \gg 1$

$A_v \simeq 1 = \frac{V_o}{V_s} \rightarrow V_s = V_o$

i.e. V_o Follows V_s in magnitude and sign, and since V_o is taken from Emitter so it is called (Emitter Follower).

$R_i = R_{th} \parallel R_{ib}$

$R_{ib} = \frac{V_i}{I_b} = \frac{V_\pi + V_o}{I_b} = \frac{\cancel{I_b} r_\pi + (\beta+1)\cancel{I_b} R_L'}{\cancel{I_b}}$

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

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

$I_o = \frac{I_e R_E'}{R_E' + R_L} = \frac{(\beta+1) I_b R_E'}{R_E' + R_L}$

$\frac{I_o}{I_b} = \frac{(\beta+1) R_E'}{R_E' + R_L}$, where $R_E' = R_E \parallel r_o$

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

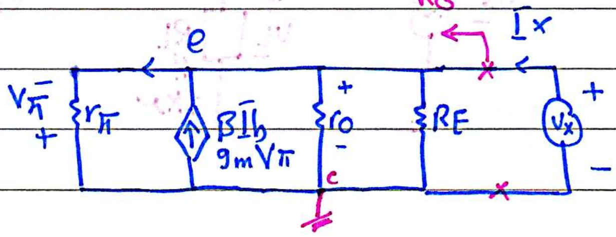
$\frac{I_b}{I_s} = \frac{R_{th}}{R_{ib} + R_{th}}$

$\therefore A_I = \frac{(\beta+1) R_E'}{R_E' + R_L} \cdot \frac{R_{th}}{R_{th} + R_{ib}}$

IF $R_E' \gg R_L$ & $R_{th} \gg R_{ib}$

$A_I(max) \simeq (\beta+1)$

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



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KCL at node e

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

but when $V_s = 0$

$V_\pi = -V_x$

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

$$\frac{I_x}{V_x} = g_m + \frac{1}{r_\pi} + \frac{1}{R_E} + \frac{1}{r_o} \rightarrow g_m r_\pi = \frac{I_{CQ}}{V_T} \cdot \frac{\beta V_T}{I_{CQ}} = \beta$$

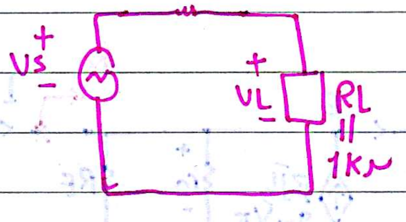
$$\frac{I_x}{V_x} = \frac{\beta+1}{r_\pi} + \frac{1}{R_E} + \frac{1}{r_o}$$

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

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

1) $A_v < 1$
2) $\phi = 0°$
3) $A_I = 1$
4) $R_o \rightarrow$ Low
5) $R_i \rightarrow$ High.

Emitter Follower is used to minimize a Loading effect (Solve the problem of Loading effect).



Let $V_s = 10 \sin\omega t$

$$V_l = \frac{V_s R_L}{R_s + R_L} = \frac{V_s}{100+1} \approx 0.01 V_s$$

sever Loading effect.

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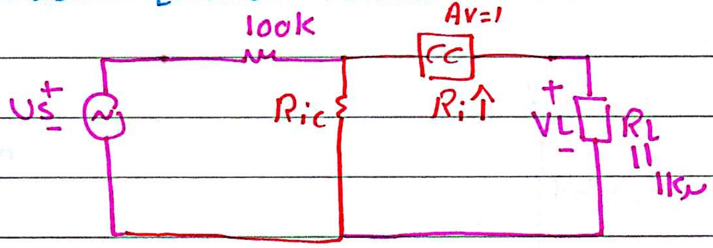
but when we use Emitter Follower



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

but $R_{ic} \gg R_s$

$V_i \simeq V_s$

$V_L = V_i \qquad (A_v = 1 = \frac{V_L}{V_i})$

& $V_L = V_i = V_s = 10 \sin wt$

(No Loading effect).

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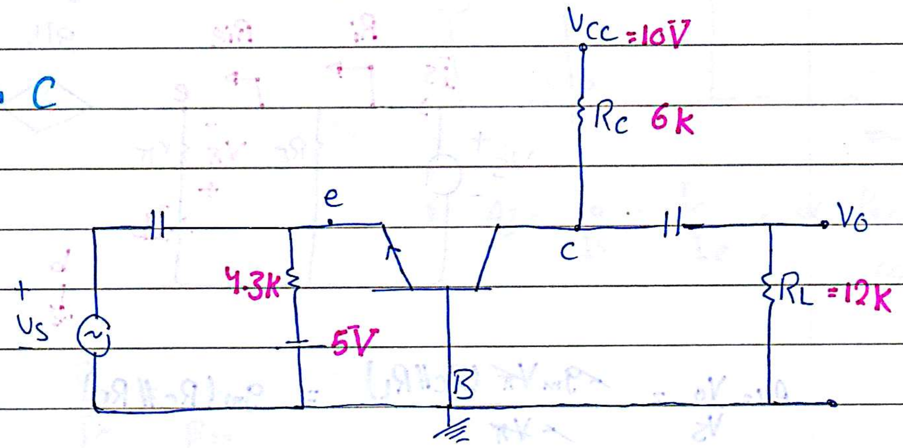
3) Common Base Amp. (C.B)

B → Common

Vi → Emitter

Vo → From C

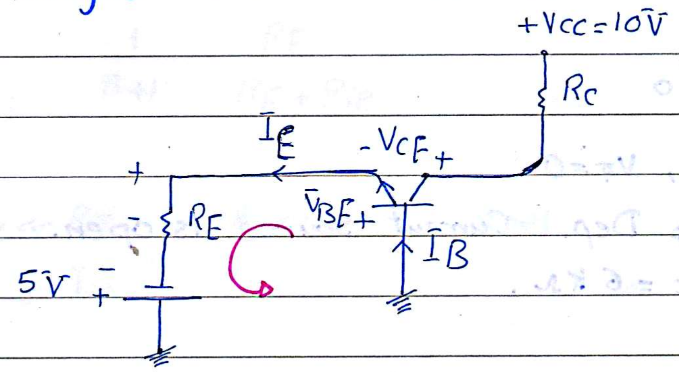


$\beta = 100$, $V_{BE} = 0.7\ V$, $V_A = \infty$

1) Find I_{CQ} , V_{CEQ}

2) Draw S.S.A.C eqnt cct & Find A_v, A_I, R_i, R_o

1) D.C Analysis



$V_{BE} + I_E R_E - 5 = 0 \rightarrow I_E = \frac{5-0.7}{4.3k} = 1\ mA$.

$I_c = \alpha I_E = \frac{100}{101} \times 1 = 0.99\ mA$.

$-10 + I_C R_C + V_{CE} + I_E R_E - 5 = 0$

$V_{CE} = 15 - I_C R_C - I_E R_E = 15 - 0.99 \times 6 - 1 \times 4.3 = 4.76\ V$

$V_{CE} = 4.76\ V$

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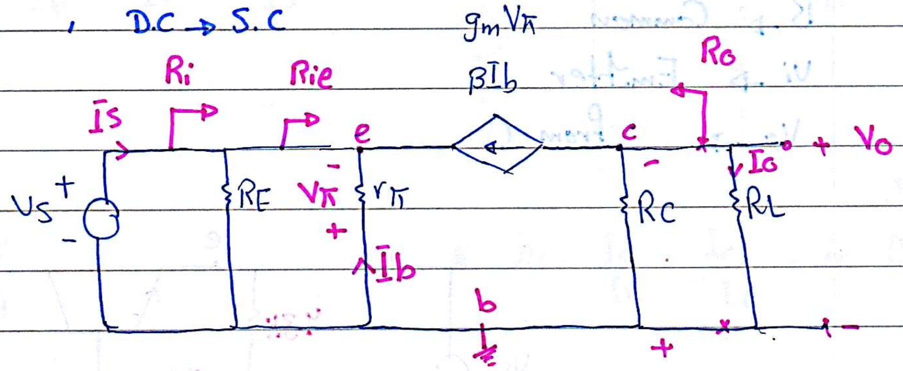
2) Ac Analysis :-

C $\rightarrow$ S.C , D.C $\rightarrow$ S.C



$$A_V = \frac{V_o}{V_s} = \frac{\cancel{-}g_m \cancel{V_\pi}(R_C \parallel R_L)}{\cancel{-V_\pi}} = g_m (R_C \parallel R_L)$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{0.99\ mA}{2.6\ mV} = 40\ mA/V$$

$A_V = 40 \times (6 \parallel 12)$

1) $A_V > 1$, 2) $\phi = 0°$

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

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

$g_m V_\pi = 0 \rightarrow$ Dep. Current source is open.

$R_o = R_C = 6\ K\Omega$.

$R_i = R_E \parallel R_{ie}$

$$R_{ie} = \frac{-V_\pi}{I} = \frac{-V_\pi}{-I_e} = \frac{V_\pi}{I_e} = \frac{I_b r_\pi}{(\beta+1) I_b} = \frac{r_\pi}{\beta+1}$$

$$R_{ie} = \frac{r_\pi}{\beta+1} \Rightarrow r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{100 \times 26}{0.99\ mA} = 2.65\ K\Omega.$$

$$R_{ie} = \frac{2.65k}{101} = 26\ \Omega.$$

$R_i = 4.3k \parallel 26\Omega \cong 25\ \Omega$. $\therefore$ 3) $R_i \rightarrow$ Low

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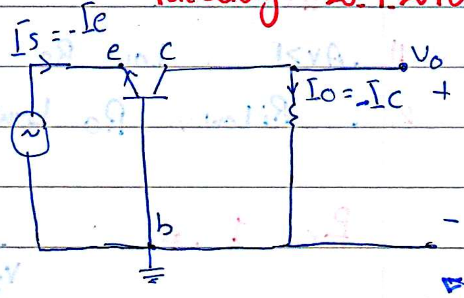
$$A_I = \frac{I_o}{I_s} = \frac{I_o}{I_b} \cdot \frac{I_b}{I_e} \cdot \frac{I_e}{I_s}$$

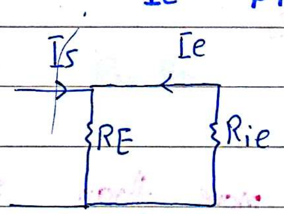


$$I_o = \frac{-\beta I_b R_c}{R_c + R_L}$$

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

$*\ A_I = \frac{I_o}{I_s} = \frac{-I_c}{-I_e} = \alpha$, for this cct

$$I_e = (\beta+1) I_b \rightarrow \frac{I_b}{I_e} = \frac{1}{\beta+1}$$



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

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

$$A_I = \frac{\beta R_c}{R_c + R_L} \cdot \frac{1}{\beta+1} \cdot \frac{R_E}{R_E + R_{ie}}$$

For $R_{ie} \ll R_E$, $R_L \ll R_c$, $\beta \gg 1$

$A_I \simeq 1 \rightarrow I_o = I_s$

4) $A_I < 1$. R_o moderate to high.

Comparission of S.S. BJT Amp.

Amp	A_v	A_I	ϕ	R_i	R_o
C.E	>1	>1	180°	moderate	moderate to high
C.C	<1	>1	0°	high	Low
C.B	>1	<1	0°	Low	moderate to high

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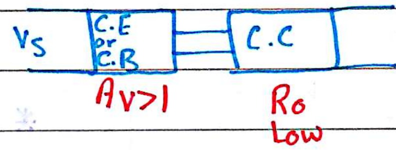
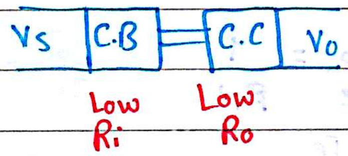
1) . $A_V > 1$, Low R_o } we will use multi_Stage.
2) : R_i Low , R_o Low

For 1 →



Cascade.

For 2 →



Cascade.

. Multi_Stage BJT Amp:

They are ccts contain more than single_Stage (at least two stages) used to achieve certain specifications which can't be obtained from single_Stage.

Such as:.

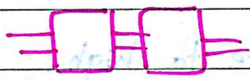
1) $A_V > 1$, Low R_o

2) Low R_i , Low R_o

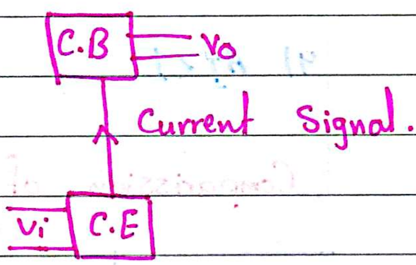
3) very high A_V or A_I

There are two types

1) Cascade



2) Cascode



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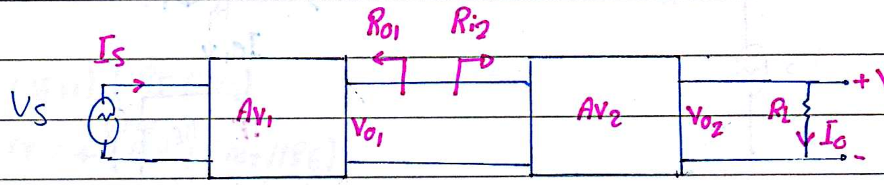
Multistage Amps.

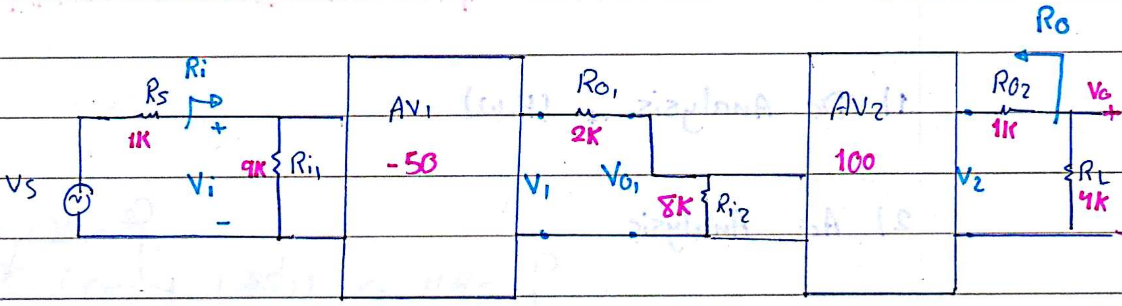
1) Cascade Multi-S.



$Av_T = \frac{V_o}{V_s}$, $A_{I_T} = \frac{I_o}{I_s}$

$R_i = R_{i1}$, $R_o = R_{o2}$

Ex



Calculate overall A_v, A_I, R_i, R_o.

$R_i = R_{i1} = 9K$ $R_o = R_{o2} = 1K$.

$$A_v = \frac{V_o}{V_s} = \frac{V_o}{V_2} \cdot \frac{V_2}{V_{o1}} \cdot \frac{V_{o1}}{V_1} \cdot \frac{V_1}{V_i} \cdot \frac{V_i}{V_s}$$

$$= \frac{R_L}{R_L + R_{o2}} \cdot Av_2 \cdot \frac{R_{i2}}{R_{o1} + R_{i2}} \cdot Av_1 \cdot \frac{R_{i1}}{R_{i1} + R_s}$$

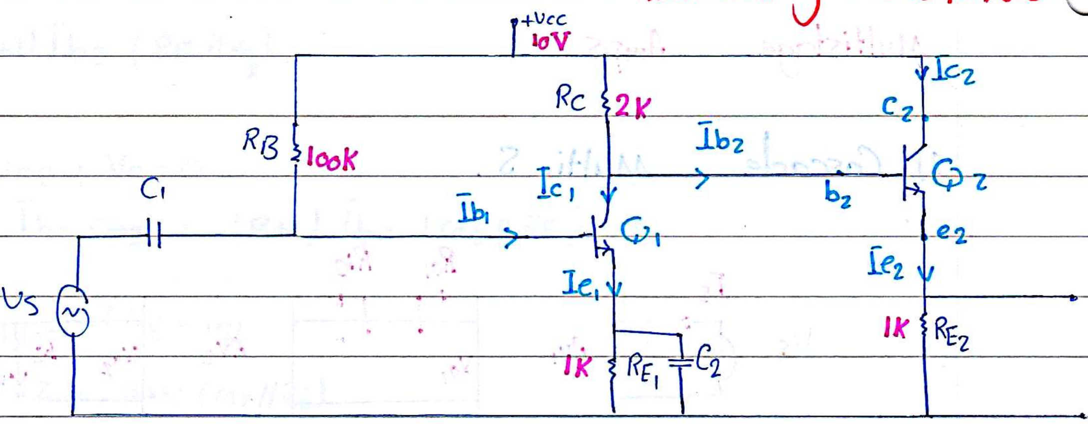
$$= \frac{4}{4+1} \cdot 100 \cdot \frac{8}{8+2} \cdot (-50) \cdot \frac{9}{9+1} = -2880.$$

$$A_I = \frac{I_o}{I_s} = \frac{V_o / R_L}{V_s / (R_s + R_{i1})} = A_v \frac{R_s + R_{i1}}{R_L} = -2880 \left(\frac{1+9}{4} \right) = -2880 \times 2.5$$

$$= -7200.$$

CH6 wednesday 27-7-2016

Exa.



if $B_1 = B_2 = 100$

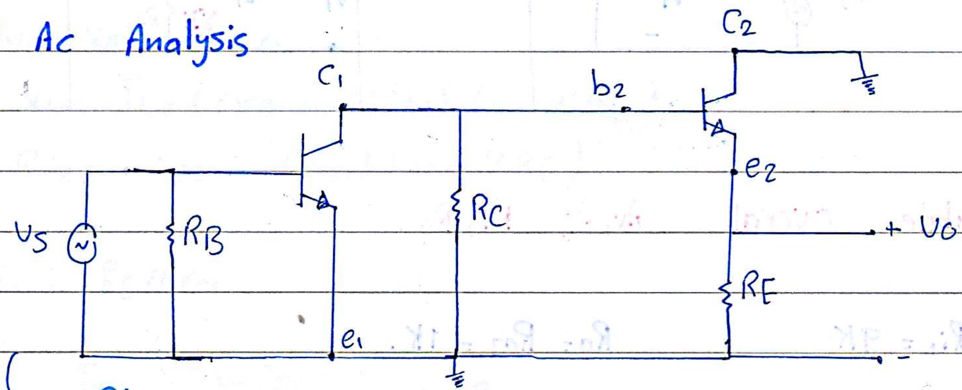
$V_{A1} = V_{A2} = 100V$

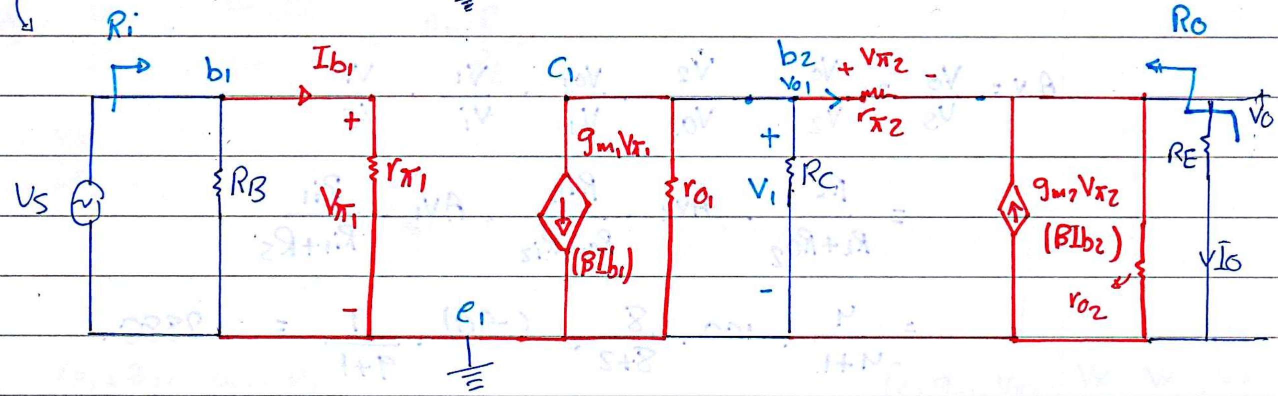
1) Find I_{CQ_1}, I_{CQ_2}, V_{CEQ_1}, V_{CEQ_2}

2) Draw S.S.A.C eqnt cct & Find A_v, A_I, R_i, R_o

1) Dc Analysis → (H.W)

2) Ac Analysis





S.S.A.C eqnt cct:

$R_i(\text{input}) = (R_B // r_{\pi_1})$

$A_v = \frac{V_o}{V_s} = \frac{V_o}{V_{o1}} \cdot \frac{V_{o1}}{V_s}$

• Base Floating → Does not make The BJT in F.A.M.

CH6 — wednesday 27.7.2016

$V_o = (\beta+1) I_{b2} (R_E \parallel r_{o2})$

$-V_{o1} + V_{\pi 2} + V_o = 0$

$V_{o1} = I_{b2} r_{\pi 2} + (\beta+1) I_{b2} (r_{o2} \parallel R_E)$

$$\frac{V_o}{V_{o1}} = \frac{(\beta+1)(R_E \parallel r_{o2})}{r_{\pi 2} + (\beta+1)(r_{o2} \parallel R_E)}$$

$V_{o1} = -g_{m1} V_{\pi 1} (r_{o1} \parallel R_C \parallel R_{i2})$

$$A_V = -g_{m1} (r_{o1} \parallel R_C \parallel R_{i2}) \frac{(\beta+1)(R_E \parallel r_{o2})}{r_{\pi 2} + (\beta+1)(r_{o2} \parallel R_E)}$$

$$R_{i2} = \frac{V_1}{I_{b2}}$$

$-V_1 + V_{\pi 2} + V_o = 0$

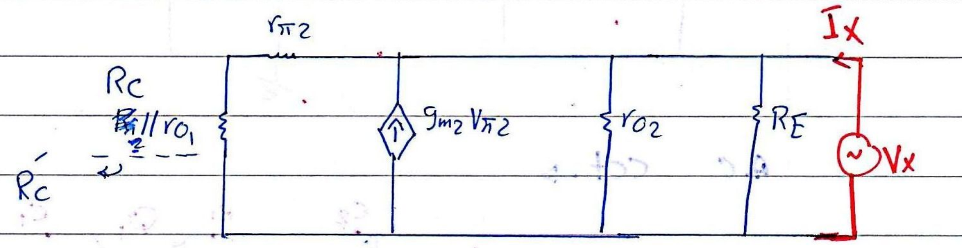
$V_1 = I_{b2} (r_{\pi 2} + (\beta+1)(r_{o2} \parallel R_E))$

$R_{i2} = r_{\pi 2} + (\beta+1)(r_{o2} \parallel R_E)$

$R_{o1} = R_C \parallel r_{o1}$

$$A_I = \frac{I_o}{I_S} = \frac{V_o / R_E}{V_S / R_i} = A_V \frac{R_i}{R_E}$$

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

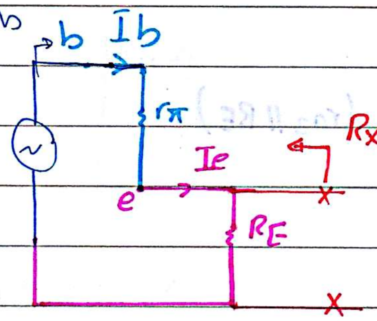


$$R_o = \frac{r_{\pi 2} + R_C'}{\beta+1} \parallel r_{o1} \parallel R_E$$

$$I_x + g_{m2} V_{\pi 2} = \frac{V_x}{R_E} + \frac{V_x}{r_{o2}} + \frac{V}{(r_{\pi}}$$

CH6 wednesday 27-7-2016

Resistance Reflection Rule.



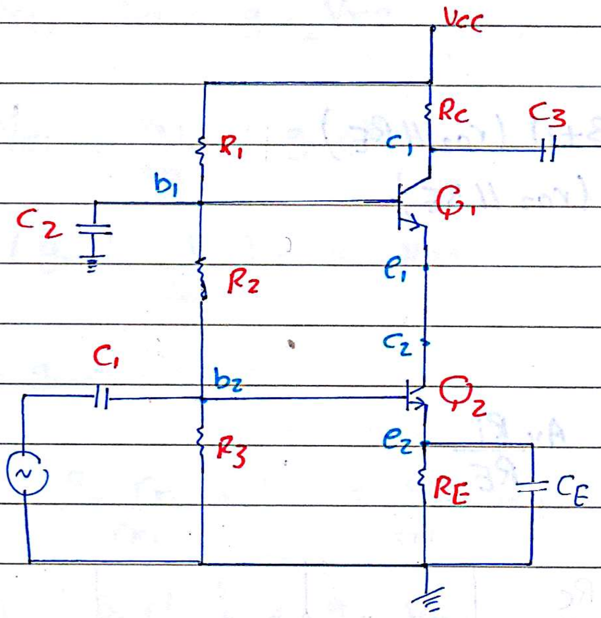
E → B Multiply by (β+1)
B → E Devide by (β+1)

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

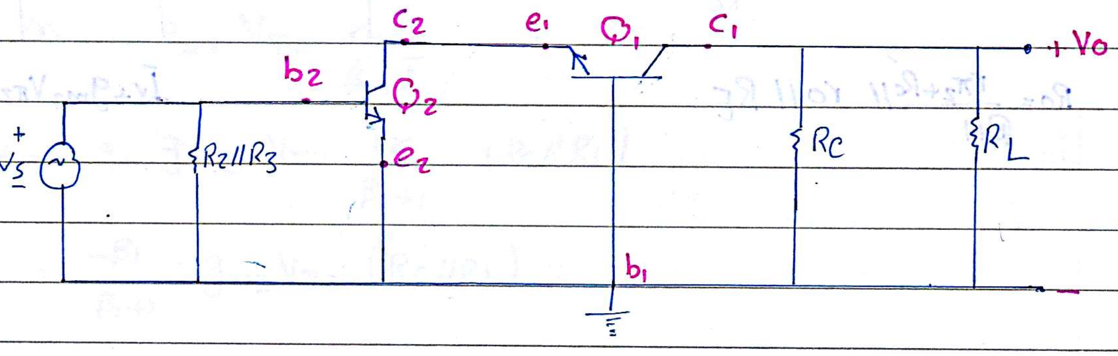
$R_x = \frac{r_\pi}{\beta+1} + R_E$

Cascode Amp.

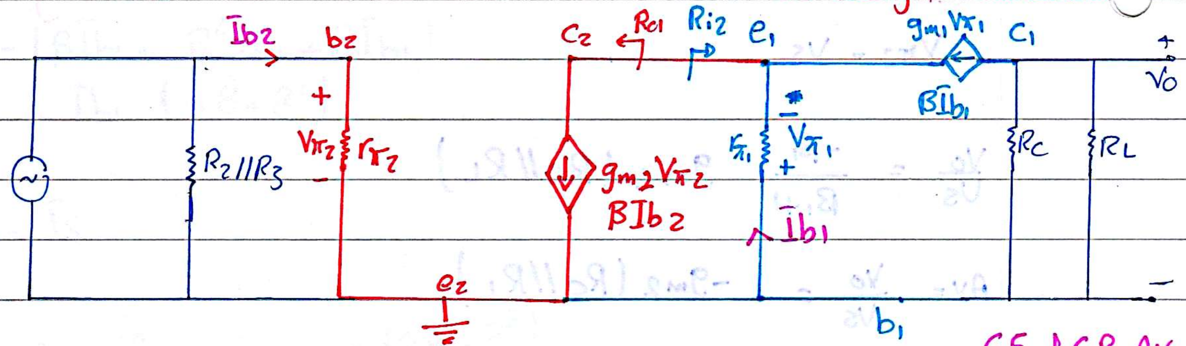
Exa.



A.C cct →



CH6 Thursday 28-7-2016



S.S.A.C

C.E & C.B AV like Av For (2) [C.E] Because $I_{e1} = I_{c2}$ & AI For common Base $\simeq$ unity

$$A_V = \frac{V_o}{V_s} \quad , \quad V_o = -g_{m1} V_{\pi 1} (R_C // R_L)$$

KCl at e_1:

$$g_{m1} V_{\pi 1} + I_{b1} = g_{m2} V_{\pi 2} \quad , \quad I_{b1} = \frac{V_{\pi 1}}{r_{\pi 1}}$$

$$g_{m1} V_{\pi 1} + \frac{V_{\pi 1}}{r_{\pi 1}} = g_{m2} V_{\pi 2}$$

$$V_{\pi 1} \left(g_{m1} + \frac{1}{r_{\pi 1}} \right) = g_{m2} V_{\pi 2}$$

$$\beta = g_m r_\pi$$

$$V_{\pi 1} \left(\frac{g_{m1} r_{\pi 1} + 1}{r_{\pi 1}} \right) = g_{m2} V_{\pi 2}$$

$$V_{\pi 1} \left(\frac{\beta_1 + 1}{r_{\pi 1}} \right) = g_{m2} V_{\pi 2}$$

$$V_{\pi 1} = g_{m2} V_{\pi 2} \frac{r_{\pi 1}}{\beta_1 + 1}$$

$$V_o = -g_{m1} g_{m2} V_{\pi 2} \frac{r_{\pi 1}}{\beta_1 + 1} (R_C // R_L)$$

$$= \frac{-\beta_1}{\beta_1 + 1} g_{m2} V_{\pi 2} (R_C // R_L)$$

CH6 Thursday 28.7.2016

$V_{\pi 2} = V_s$

$$\frac{V_o}{V_s} = \frac{-\beta_1}{\beta_1+1} g_{m2} (R_C // R_L)$$

$$A_V = \frac{V_o}{V_s} = -g_{m2} (R_C // R_L)$$

$$A_I = \frac{I_o}{I_s} = \frac{V_o / R_L}{V_s / R_i} = \frac{V_o}{V_s} \cdot \frac{R_i}{R_L} = A_V \frac{R_i}{R_L}$$

$$R_i = R_2 // R_3 // r_{\pi 2}$$

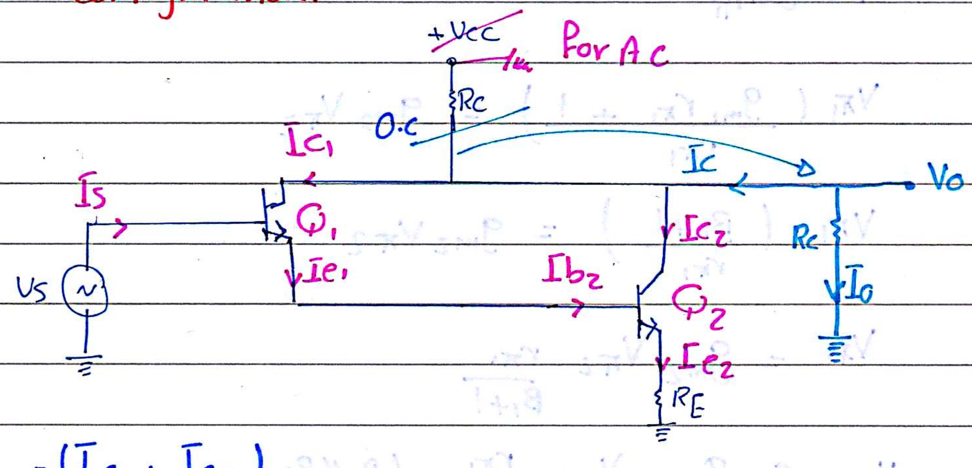
$$R_o = \frac{V_x}{I_x} \Big|_{V_s=0} = R_c \Rightarrow V_{\pi 1} = V_{\pi 2} = V_s = 0$$

$$R_{o1} = \infty$$

$$R_{i2} = \frac{r_{\pi 1}}{\beta+1}$$

. Cascode is used as a wide band Amp to Amplify high Freq. signals.

. Darlington Configuration.



$$I_o = -I_C = -(I_{C1} + I_{C2})$$
$$= -(\beta I_{b1} + \beta I_{b2})$$
$$= -(\beta I_{b1} + \beta(\beta+1) I_{b1})$$

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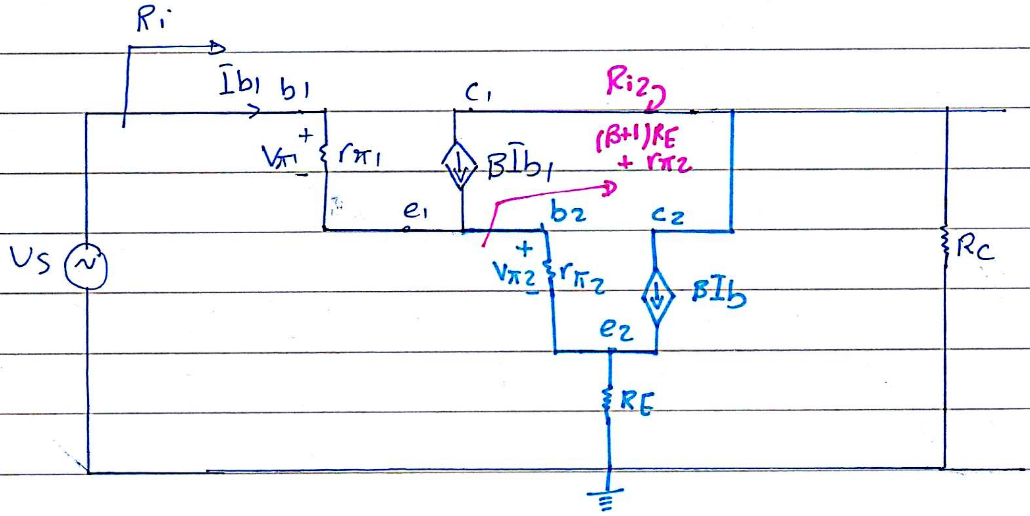
$I_o = -(\beta I_{b1} + \beta^2 I_{b1} + \beta I_{b1})$

$I_o = -I_{b1}(2\beta + \beta^2)$

$I_{b1} = I_s$

$$\frac{I_o}{I_{b1}} = \frac{I_o}{I_s} = A_I = -(2\beta + \beta^2)$$



$R_i = [R_E(\beta+1) + r_{\pi2}](\beta+1) + r_{\pi1}$

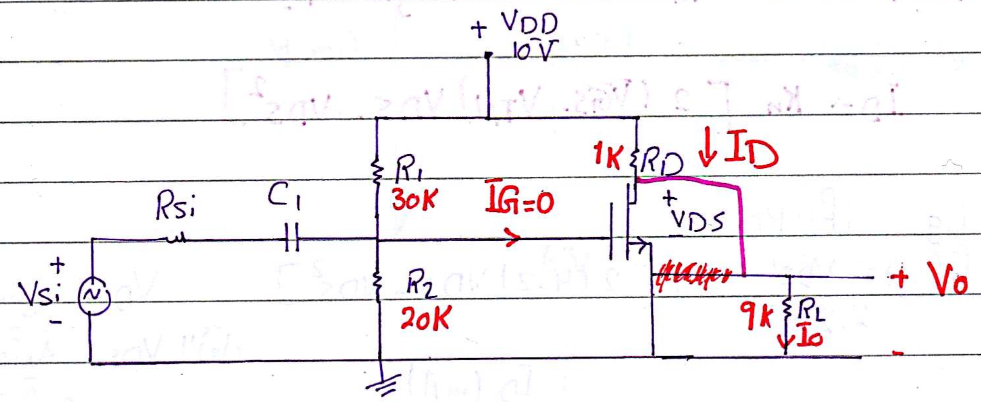
using (R.R.R)

$$A_V = \frac{V_o}{V_s} = \frac{I_o R_L}{I_s R_i} = A_I \frac{R_L}{R_i}$$

CH4: MOSFET Amplifiers. Sunday 31-7-2016

1) The MOSFET must be biased in saturation Region to be used as an Amplifier.

Ex.



$K_n = 1\,mA/V^2$

$V_{TN} = 2V$

_ Calculate I_D, V_{DS}.

In D.C Analysis Cap → O.C.

Assume the MOSFET in Sat. Region.

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

$V_{GS} = V_G - V_S$, $V_{GS} = \frac{10 \times 20}{20+30} - 0 = 4V$.

$I_D = 1(4-2)^2 = 4\,mA$.

$-V_{DD} + I_D R_D + V_{DS} = 0 \rightarrow V_{DS} = 10 - I_D R_D$

$= 10 - 4 \times 1 = 6\,V$

$V_{DS(sat)} = V_{GS} - V_{TN} = 4 - 2 = 2V$.

Since $V_{DS} > V_{DS(sat)}$, then the MOSFET is in Sat. Region

$P_D = I_D V_{DS} = 4 \times 6 = 24\,mW$

→ In Sat. Region :

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

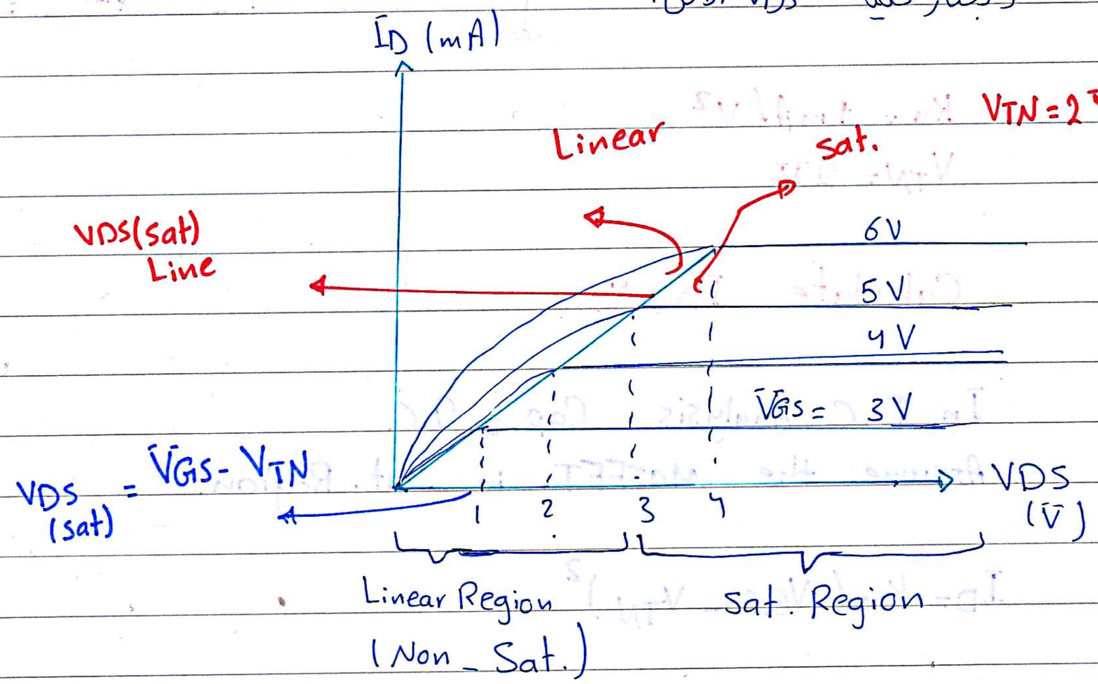
if it was in linear Region :

$$I_D = K_n \left[2 (V_{GS} - V_{TN}) V_{DS} - V_{DS}^2 \right]$$

i.g. if $R_D = 2.2K$ →

$$\frac{10 - V_{DS}}{2.2K} = 1 \left[2 (4 - 2) V_{DS} - V_{DS}^2 \right]$$

بطلع قيمتين V_{DS}
وبختار قيمة V_{DS} الأقل.



D.C.L.L :

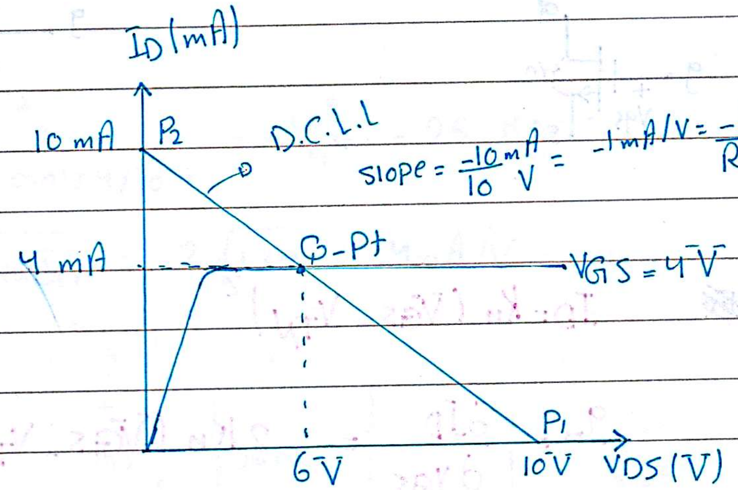
$-V_{DD} + I_D R_D + V_{DS} = 0$, $V_{DS} = V_{DD} - I_D R_D$ → (D.C.L.L eqn)

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

for $I_D = 0$ → $V_{DS} = V_{DD} = 10\ V$ $P_1 (10\ V, 0\ mA)$

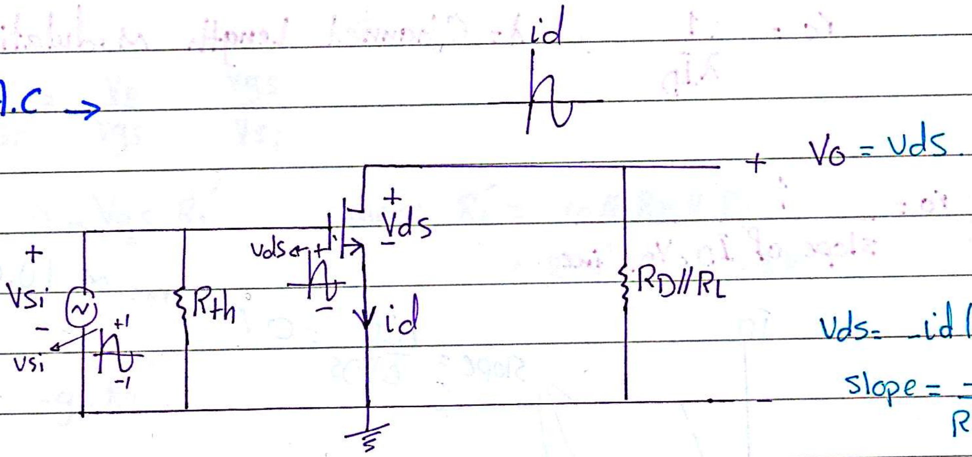
for $V_{DS} = 0$ → $I_D = 10\ mA$, $P_2 (0\ V, 10\ mA)$

Q_pt → $(V_{DSQ}, I_{DQ}) = (6\ V, 4\ mA)$



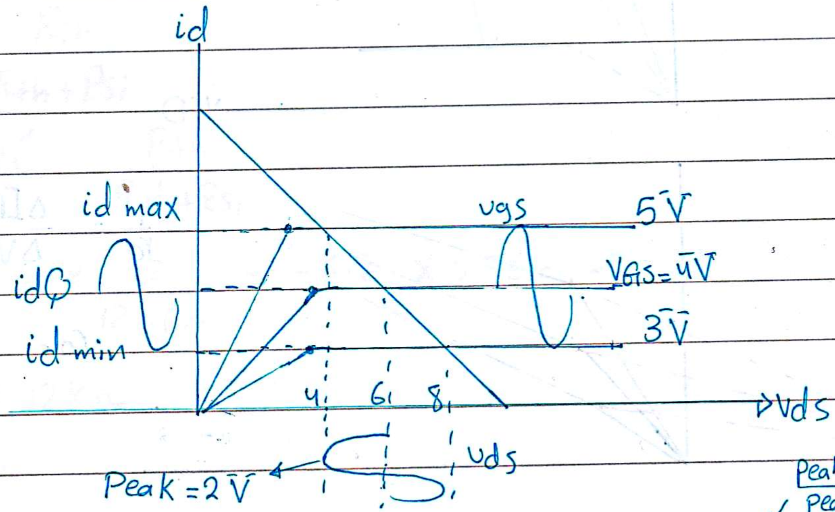
$$\text{slope} = \frac{-10\,mA}{10\,V} = -1\,mA/V = \frac{-1}{R_D}$$

For A.C →



$$V_{ds} = -i_d (R_D // R_L)$$

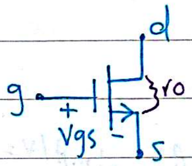
$$\text{slope} = \frac{-1}{R_D // R_L}$$

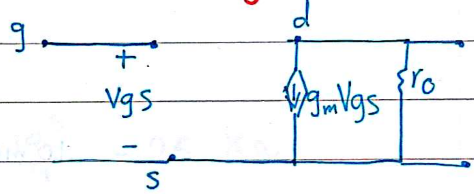


$$\frac{\text{Peak}}{\text{Peak}} = \frac{\text{Peak to peak}}{\text{Peak to peak}}$$

$$A_v = \frac{V_{ds}}{V_{si}} = \frac{2}{1} = \frac{4}{2} = 2$$

CH4 Wednesday 3-8-2016



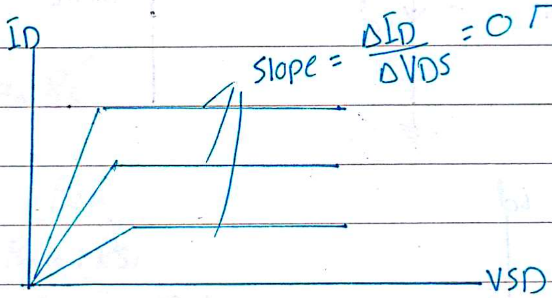


~~Ex~~. $I_D = K_n (V_{GS} - V_{TN})^2$

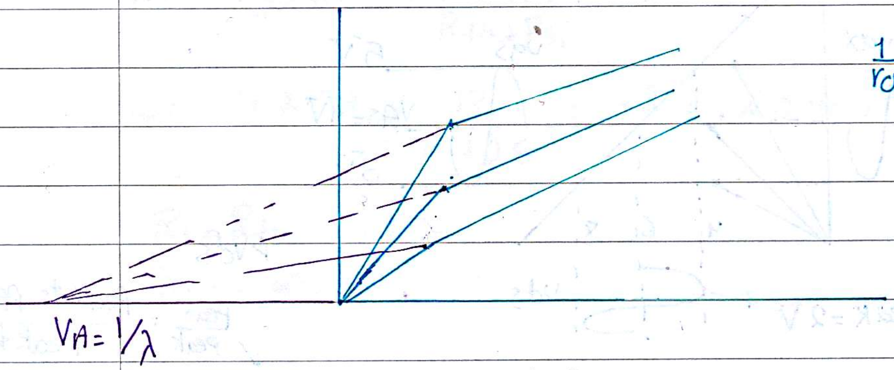
$$g_m = \frac{\partial I_D}{\partial V_{GS}} = 2K_n(V_{GS} - V_{TN}) = 2\sqrt{K_n I_D}$$

$$r_o = \frac{1}{\lambda I_D}$$, λ = Channel Length Modulation parameter

$$r_o = \frac{1}{\text{slope of } I_D, V_{DS} \text{ line}}$$



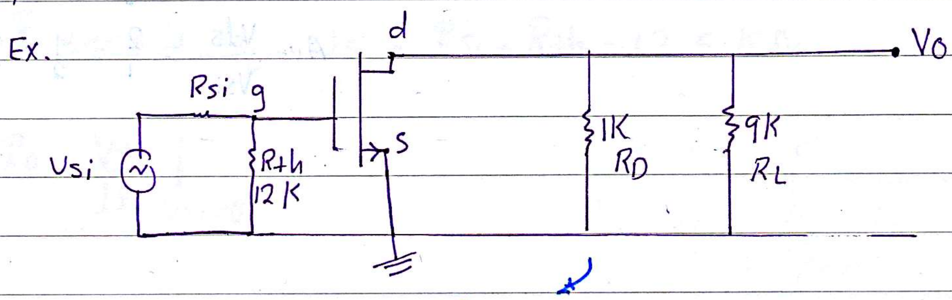
$\text{slope} = \frac{\Delta I_D}{\Delta V_{DS}} = 0 \rightarrow r_o = \infty$ (O.C)



$$\frac{1}{r_o} = \frac{\Delta I_D}{\Delta V_{DS}} = \frac{I_D}{1/\lambda} = \lambda I_D$$

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

Ex.



From the ~~per~~ previous example.

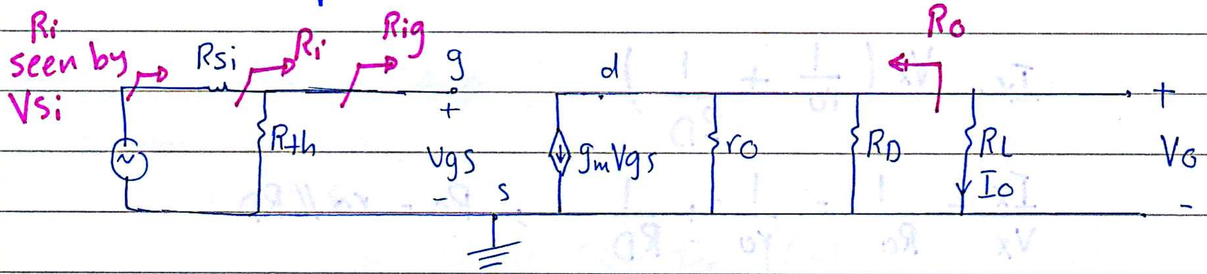
CH4 Wednesday 3-8-2016

For → $\lambda = 0.01\ V^{-1}$

$I_D = 4\ mA$

$$r_o = \frac{1}{0.01 \times 4 \times 10^{-3}} = \frac{10^5}{4} = 25\ K\Omega.$$

$$g_m = 2\sqrt{K_n I_D} = 2\sqrt{1 \times 4} = 4\ mA/V$$



$$A_V = \frac{V_o}{V_{si}} = \frac{V_o}{V_{gs}} \cdot \frac{V_{gs}}{V_{si}}$$

$V_o = -g_m V_{gs} R_L'$; where $R_L' = r_o \parallel R_D \parallel R_L$

$= 25 \parallel 1 \parallel 9 = 0.8K$

$$\frac{V_o}{V_{gs}} = -g_m R_L'$$

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

$$A_V = -g_m R_L' \cdot \frac{R_{th}}{R_{th} + R_{si}}$$

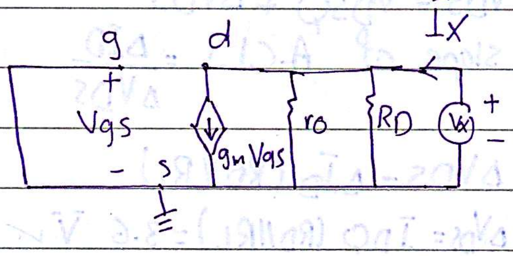
$$= -4 \times 0.8 \times \frac{12}{12 + 0.5} = -3.2 \times 0.96 = -3$$

$R_i = R_{th} = 12 K\Omega.$

$R_{ig} = \infty.$

R_i seen by $V_{si} = R_{si} + R_{th} = 12.5\ K\Omega.$

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



KCl at Node d

$I_x = \cancel{g_m V_{GS}}_{\,0} + \frac{V_x}{r_o} + \frac{V_x}{R_D}$

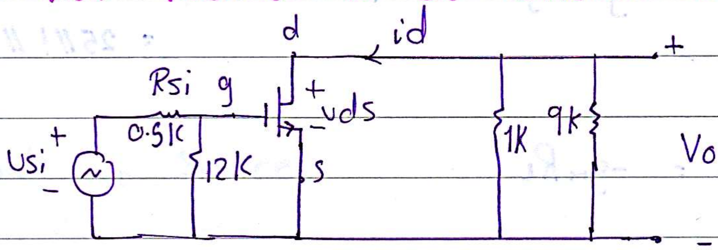
but when $U_{Si} = 0$, $V_{gs} = 0$, dep. s. $\rightarrow$ O.C

$I_x = V_x \left(\frac{1}{r_o} + \frac{1}{R_D} \right)$

$\frac{I_x}{V_x} = \frac{1}{R_o} = \frac{1}{r_o} + \frac{1}{R_D}$, $R_o = r_o // R_D$

The MosFET is a Voltage control device
So AI is not needed to be calculated.

A.C.L.L :.



$U_{ds} + i_d (R_D // R_L) = 0$

$U_{ds} = -i_d (R_D // R_L)$

A.C.L.L eqn.

Slope $= \frac{-1}{R_D // R_L}$

Remark:

The D.C.L.L eqn was:

$U_{ds} = 10 - I_D R_D$

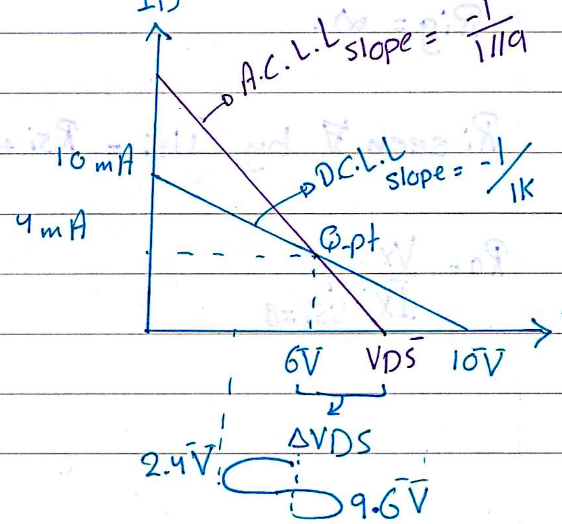
$\bar{VDS} = VDS_Q + \Delta VDS$

slope of A.C.L.L $= \frac{\Delta I_D}{\Delta VDS}$

$\Delta VDS = \Delta I_D (R_D // R_L)$

$\Delta V_{DS} = I_{DQ} (R_D // R_L) = 3.6 \ \bar{V}$ ✓

$\bar{VDS} = 6 + 3.6 = 9.6 \ \bar{V}$



 Thursday 4-8-2016.

Max peak to peak symmetrical output Voltage :

$$V_{o(p-p)max} = 2\Delta V_{DS} = 2 I_{DQ} (R_D // R_L) = 7.2\,V$$

MOSFET Amps:-

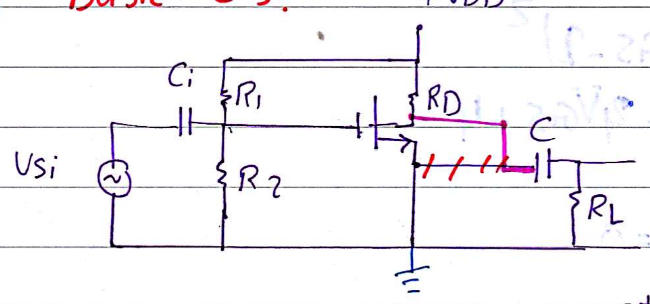
1) Common _ Source Amp.
   i) Basic C.S Amp.
   ii) C.S Amp with R_S
   iii) C.S Amp with bypass Capacitor (C_S)

2) Common _ Drain Amp (Source Follower)
3) Common _ Gate Amp

C.S. Amp.

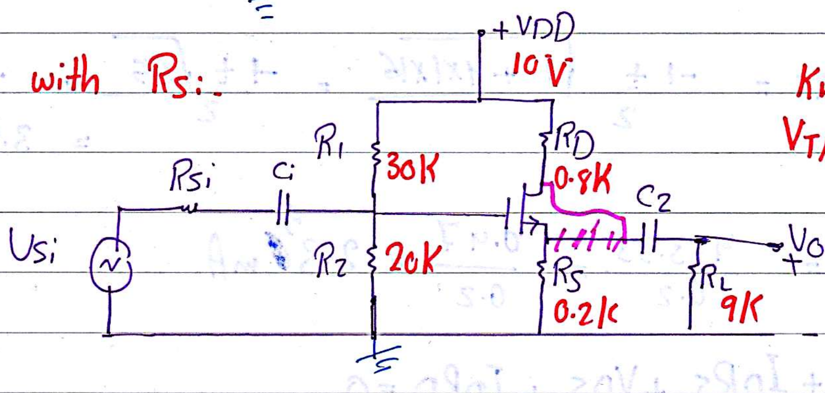
Common Terminal → Source
Vin to gate
Vo from drain

i) Basic C.S.



$A_v = -g_m (R_D // R_L)$
$R_o = R_D // R_L$
$R_i = R_{th}$.

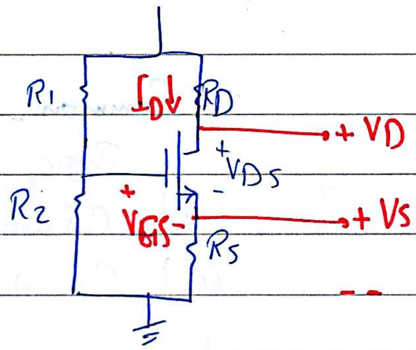
ii) C.S. with R_s:-



$K_n = 1 mA/V^2$
$V_{TN} = 2\,V$
$\lambda = 0.01\,V^{-1}$

1) D.C Analysis:. Cap ⇒ O.C.
Rs is used to stabilize Q-pt against Kn paramenter variation.

Assume The MOSFET in Sat. Region:-



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

$V_G = \frac{10 \times 20}{20+30} = 4 \ V$

$-V_S + I_D R_S = 0$
$V_S = I_D R_S = 0.2 I_D$.

$V_{GS} = 4 - 0.2 I_D$

$\therefore I_D = \frac{4 - V_{GS}}{0.2}$

$\frac{4 - V_{GS}}{0.2} = 1 (V_{GS} - 2)^2$

$4 - V_{GS} = 0.2 (V_{GS} - 2)^2$
$20 - 5V_{GS} = V_{GS}^2 - 4V_{GS} + 4$

$V_{GS}^2 + V_{GS} - 16 = 0$

$V_{GS} = \frac{-1 \pm \sqrt{1 + 4 \times 1 \times 16}}{2} = \frac{-1 \pm \sqrt{65}}{2} = -4.5 \ V$ X
$= 3.53 \ V$ ✓

$I_D = \frac{4 - 3.53}{0.2} = \frac{0.47}{0.2} = 2.35 \ mA$

$-10 + I_D R_S + V_{DS} + I_D R_D = 0$
$V_{DS} = 10 - 2.35 (0.8 + 0.2) = 7.65 \ V$

CH4 Thursday 4-8-2016

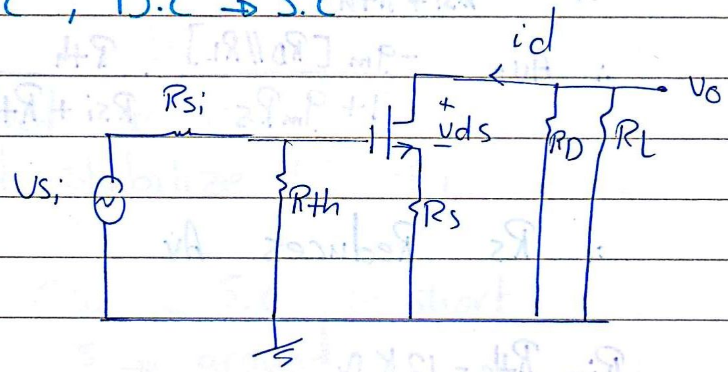
D.C.L.L

$$-10 + I_D R_D + V_{DS} + I_D R_S = 0$$

$$V_{DS} = 10 - I_D (R_S + R_D)$$

$$\text{slope} = \frac{-1}{R_S + R_D}$$

A.C.L.L , Cap → S.C , D.C → S.C

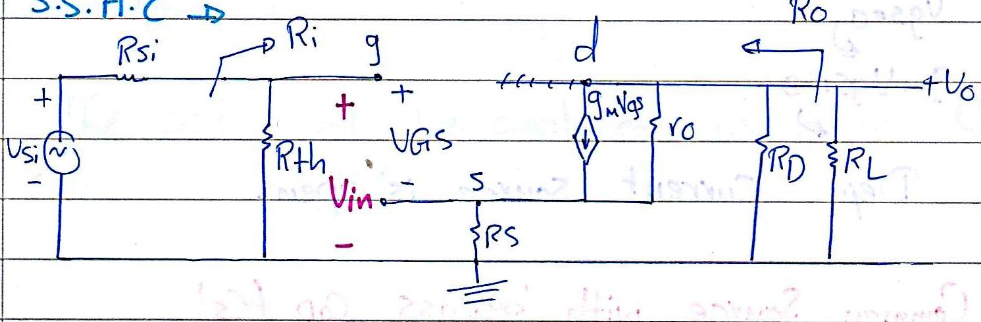


$$v_{ds} + i_d R_S + i_d (R_D // R_L) = 0$$

$$v_{ds} = -i_d (R_S + R_D // R_L)$$

$$\text{slope} = \frac{-1}{R_S + R_D // R_L}$$

S.S.A.C →



$$A_V = \frac{V_o}{V_{si}} = \frac{V_o}{V_{in}} \cdot \frac{V_{in}}{V_{si}}$$

, $V_o = -g_m V_{gs} [R_D // R_L]$

Neglecting r_o :↗

$$-V_i + V_{gs} + V_s = 0$$

$$V_i = V_{gs} + V_s = V_{gs} + g_m V_{gs} R_S$$

$$V_i = V_{gs}(1 + g_m R_S)$$

$$\frac{V_o}{V_i} = \frac{-g_m [R_D // R_L]}{1 + g_m R_S}$$

$$\frac{V_i}{V_{si}} = \frac{R_{th}}{R_{si} + R_{th}}$$

$$\therefore A_V = \frac{-g_m [R_D // R_L]}{1 + g_m R_S} \cdot \frac{R_{th}}{R_{si} + R_{th}}$$

$\therefore$ R_S Reduces A_V

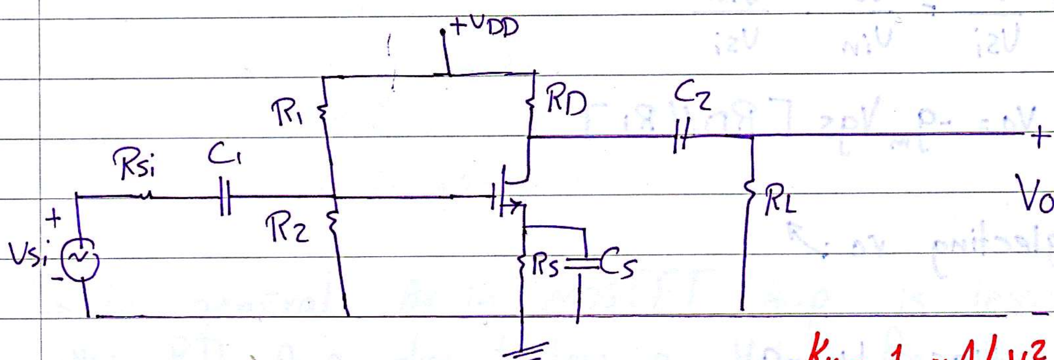
$R_i = R_{th} = 12\,K\Omega.$

$$R_o = \left.\frac{V_x}{I_x}\right|_{V_{si}=0} = R_D = 0.8\,K\Omega.$$

$V_{si} = 0$
$V_i = 0$
$V_{gs} = 0$
$g_m V_{gs} = 0$

Dep. Current source is open.

iii) Common Source with bypass Cap (C_S)



$K_n = 1\ mA/V^2$
$V_{TN} = 2V$
$\lambda = 0.01\ V^{-1}$

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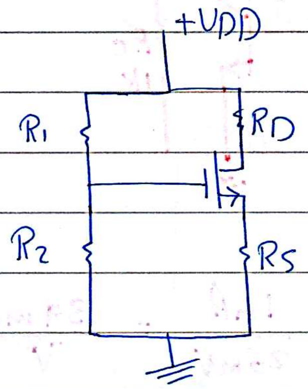
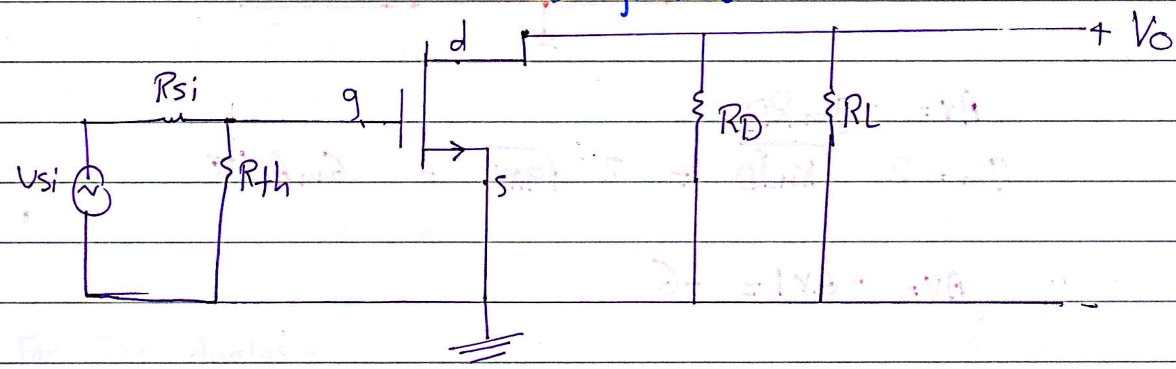
For D.C Analysis Cs → O.C



The cct is analyzed as C.S. with Rs
(Rs is present and stabilize Q-pt)

For A.C Analysis C.S. → S.C is short
S → ground.



The cct will be analyzed as Basic C.S. Amp.
Av↑

C.S.
$A_v > 1$
$R_i = R_{th}$
$R_o \rightarrow R_D$ or $R_D // r_o$
$\phi = 180°$
A_I = Not important.

→ In general Av in MOSFET Amp is less than Av in the BJT Amp due to low g_m Value for the same Current

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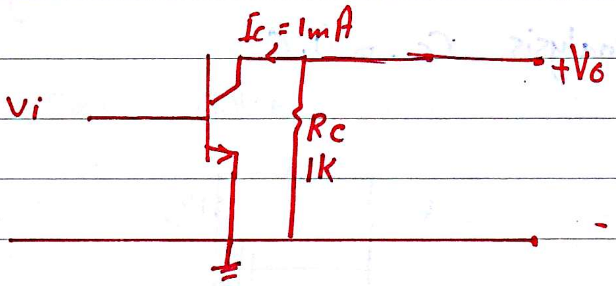
BJT

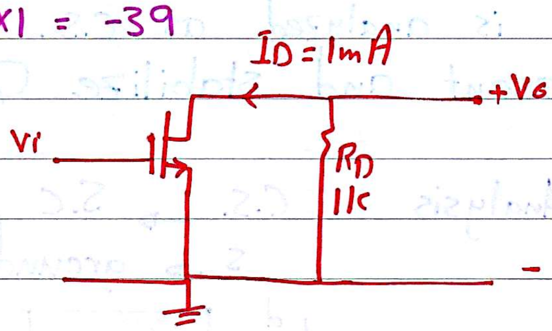


$$A_V = -g_m R_C$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{1mA}{26mV} = \frac{39\,mA}{V}$$

$$A_V = -39 \times 1 = -39$$

MOSFET



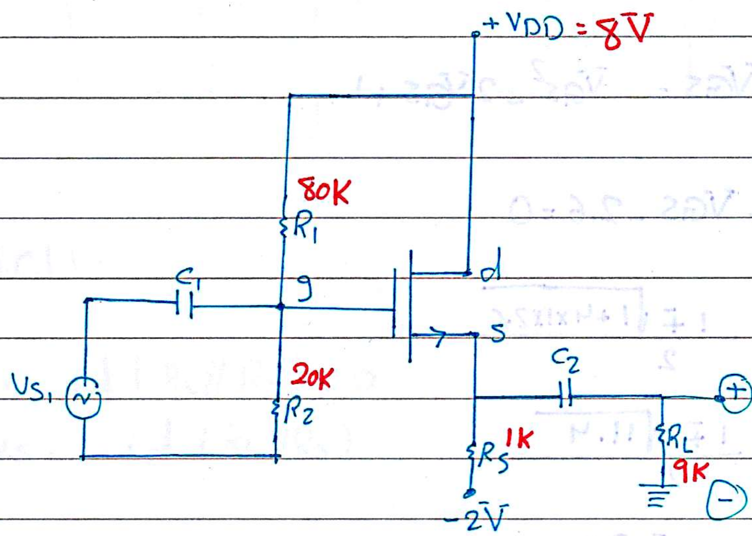
$$A_V = -g_m R_D$$

$$g_m = 2\sqrt{K_n I_D} = 2\sqrt{9 \times 1} = 6\,mA/V$$

$$A_V = -6 \times 1 = -6$$

$\therefore$ The gain in BJT > gain in MOSFET

2) Common - Drain Amp (source - Follower)



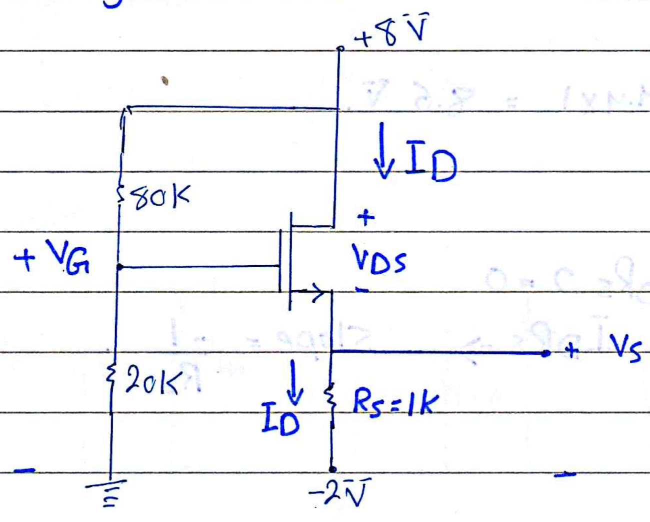
$V_{TN} = 1V$

$K_n = 1mA/V^2$

$\lambda = 0.01 V^{-1}$

1) Calculate I_{DQ}, V_{DSQ}.
2) Draw S.S.A.C eqnt cct. & Find A_v, R_i, R_o
3) Write A.C.L.L eqn. & Find slope.
4) Determine Max. peak symmetrical o/p Voltage.

→ For Dc Analysis.



$-V_S + I_D R_S - 2 = 0 \rightarrow V_S = I_D R_S - 2$

$V_{GS} = 1.6 - 1 \times I_D + 2$

$V_{GS} = 3.6 - I_D$

$$I_D = \frac{3.6 - V_{GS}}{1} = 3.6 - V_{GS}$$

$$3.6 - V_{GS} = 1\,(V_{GS} - 1)^2$$

$$3.6 - V_{GS} = V_{GS}^2 - 2V_{GS} + 1$$

$$V_{GS}^2 - V_{GS} - 2.6 = 0$$

$$V_{GS} = \frac{1 \mp \sqrt{1 + 4 \times 1 \times 2.6}}{2}$$

$$= \frac{1 \mp \sqrt{11.4}}{2}$$

$$= \frac{1 \mp 3.4}{2}$$

$$V_{GS} = 2.2\,V$$

$$I_D = 3.6 - 2.2 = 1.4\ mA.$$

$$-8 + V_{DS} + I_D R_S - 2 = 0$$

$$V_{DS} = 10 - 1.4 \times 1 = 8.6\ V.$$

D.C.L.L 8-

$$-8 + V_{DS} + I_D R_S - 2 = 0$$

$$V_{DS} = 10 - I_D R_S \Rightarrow \quad slope = \frac{-1}{R_S}.$$

For A.C

D → ground

Vi → gate

Vo → from source.

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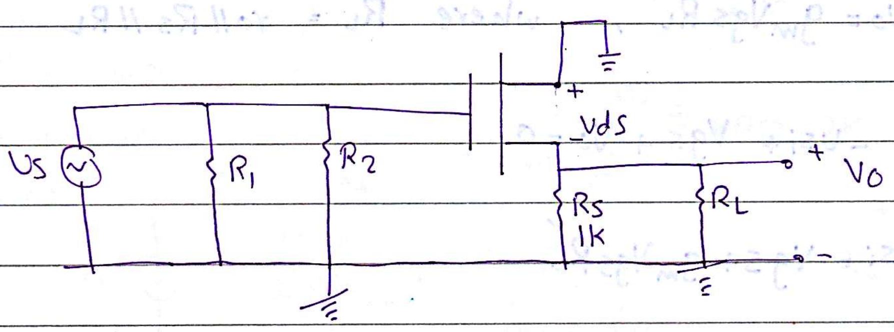


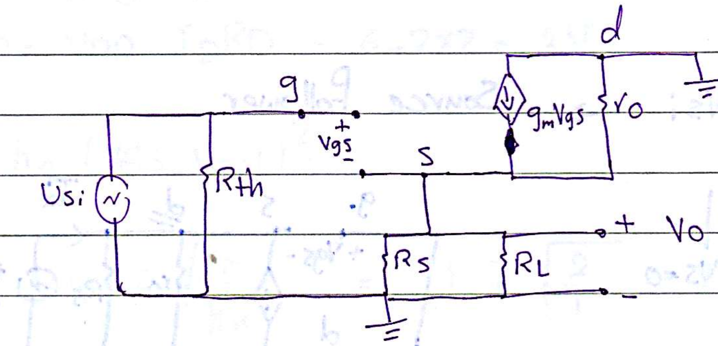
A.C.L.L :-

$V_{ds} + i_d (R_L // R_S) = 0$

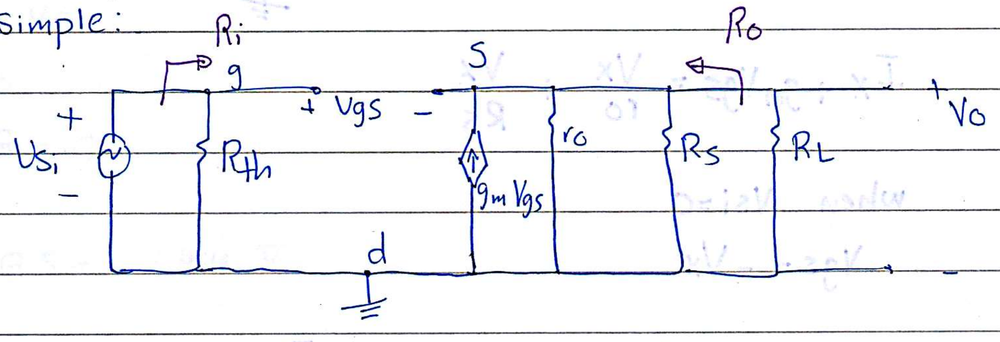
$V_{ds} = -i_d (R_L // R_S)$

$\text{slope} = \frac{-1}{R_L // R_S}$

S.S.A.C



More simple:



$R_i = R_{th} = 80 // 20 = 16\ K\Omega$

$A_V = \frac{V_o}{V_{s_i}}$

$V_o = g_m V_{gs} R_L'$, where $R_L' = r_o // R_S // R_L$

$-V_{si} + V_{gs} + V_o = 0$

$V_{si} = V_{gs} + g_m V_{gs} R_L'$

$= V_{gs} (1 + g_m R_L')$

$$A_v = \frac{g_m \cancel{V_{gs}} R_L'}{\cancel{V_{gs}}(1 + g_m R_L')} = \frac{g_m R_L'}{1 + g_m R_L'}$$

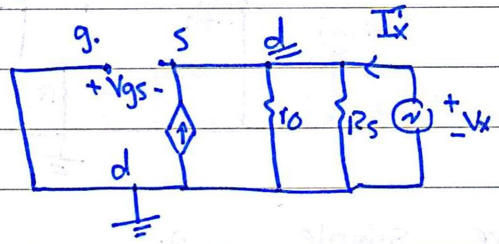
$A_v < 1$, $\phi = 0°$

If $g_m R_L' \gg 1$

$A_v \approx 1 = \frac{V_o}{V_{si}}$

$\therefore$ $V_o = V_{si}$ $\rightarrow$ Source Follower.

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



KCl at d.

$$I_x + g_m V_{gs} = \frac{V_x}{r_o} + \frac{V_x}{R_S}$$

when $V_{si} = 0$

$V_{gs} = -V_x$

$$I_x = V_x \left[g_m + \frac{1}{r_o} + \frac{1}{R_S} \right]$$

$$\frac{I_x}{V_x} = \frac{1}{R_o} = g_m + \frac{1}{r_o} + \frac{1}{R_S}$$ $\therefore R_o = \frac{1}{g_m} // r_o // R_S$

, $R_o \rightarrow$ Low.

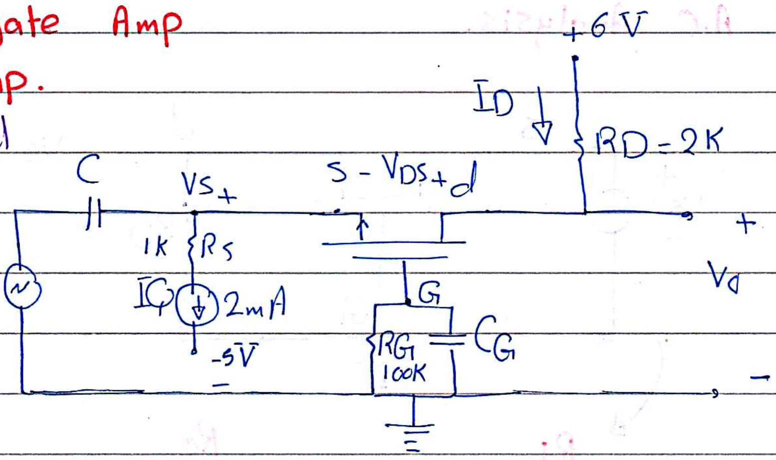
3) Common - gate Amp

C.G Amp.

G → Common Terminal

Vi → Source

Vo → from Drain



$V_{TN} = 1\,V$

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

$\lambda = 0$

1) Find V_D, V_S, V_{DS}

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

$V_D = V_{DD} - I_D R_D = 6 - 2\times 2 = 2\,V.$

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

$V_{GS} = V_{TN} \mp \sqrt{\dfrac{I_D}{K_n}} = 1 \mp \sqrt{\dfrac{2}{1}} = 2.414\,V.$

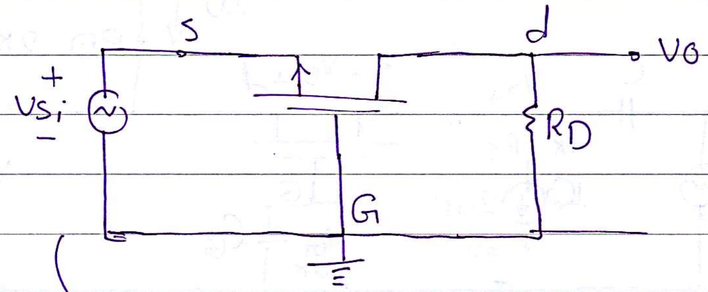
$V_{GS} = V_G - V_S$

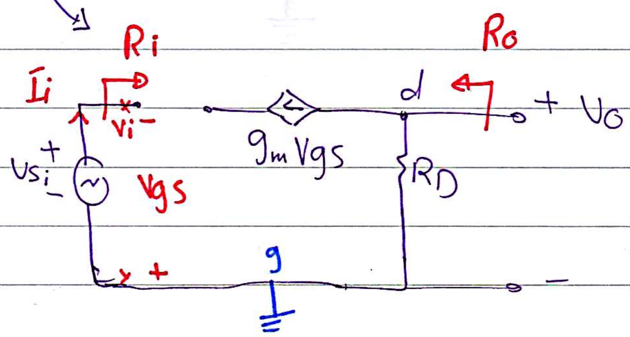
$V_G = \cancel{I_G}^{\,0} R_G = 0$

$V_S = -V_{GS} = -2.414\,V.$

$V_{DS} = V_D - V_S = 4.414\,V.$

2) A.C Analysis.





$$A_V = \frac{V_o}{V_{si}} = \frac{-g_m V_{gs} R_D}{-V_{gs}} = g_m R_D$$

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

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

$g_m V_{gs}=0$, $C.S \rightarrow O.C$

$R_o = R_D$

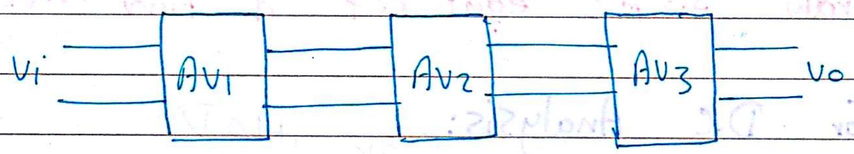
$$A_I = \frac{I_o}{I_s} = \frac{-g_m V_{gs}}{-g_m V_{gs}} = 1$$, I_o, I_i (current Follower)

$$R_i = \frac{V_i}{I_i} = \frac{-V_{gs}}{-g_m V_{gs}} = \frac{1}{g_m}$$ (Low)

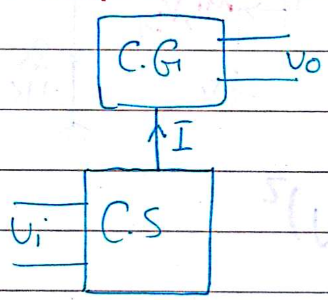
Amp	A_v	A_I	ϕ	R_i	R_o
C.S	>1	–	180°	R_{th}	moderate to high
C.D	<1	–	0	R_{th}	Low
C.G	>1	≤ 1	0	low	moderate to high

→ To achieve certain specifications which can't be obtained from Single stage (S.S), multi-Stage Amps are used.

1) Cascade Amp (series Connection).



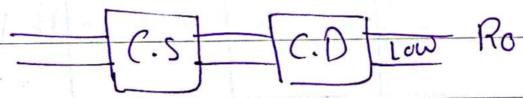
2) Cascode Amp

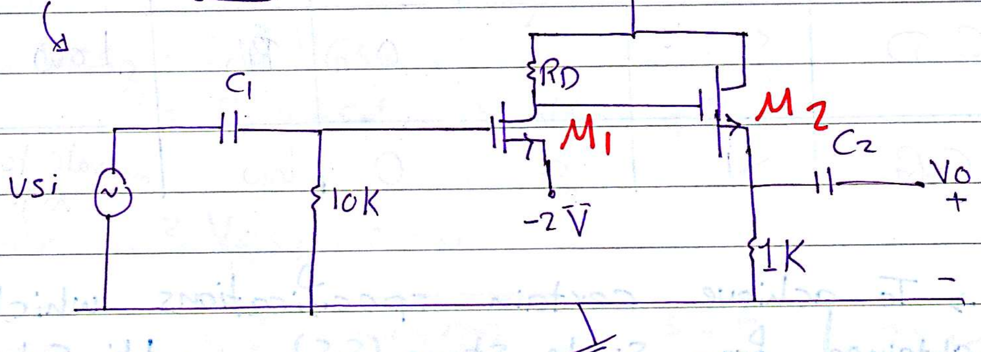


CH4 Tuesday 9-8-2016

1) Cascade Amp.

Ex. It is required to have $A_v > 1$ & low R_o & 180°





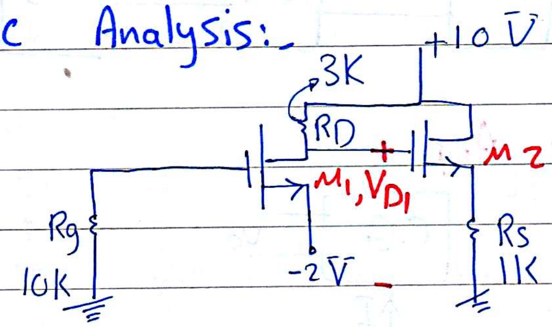
M_1 & M_2 are identical with:

$K_n = 2\,mA/V^2$, $V_{TN} = 1\,V$, $\lambda = 0.02\,V^{-1}$

1) Find I_{DQ_1} , I_{DQ_2}, V_{DS_1}, V_{DS_2}

2) Draw S.S.A.C eqnt cct & find $A_v = \frac{V_o}{V_{si}}$, R_i, R_o

1) For D.C Analysis:



$$I_{D1} = K_n\,(V_{GS_1} - V_{TN})^2$$

$$V_{GS_1} = V_{G_1} - V_{S_1} = 0 - (-2) = 2\,V$$

$$I_{D_1} = 2(2-1)^2 = 2\,mA.$$

$$-10 + I_{D_1}R_D + V_{D_1} = 0$$

$$V_{D1} = 10 - I_{D1}R_D = 10 - 2\times 3 = 4\,V$$

$$V_{DS_1} = V_{D1} - V_{S_1} = 4 - (-2) = +6\,V$$

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$I_{D2} = K_n(V_{GS_2} - V_{TN})^2$

$V_{GS_2} = V_{G2} - V_{S2} \Rightarrow V_{G2} = V_{D1} = 4\,V$

$V_{S2} = I_{D2}R_S = 1 \times I_{D2} = I_{D2}$

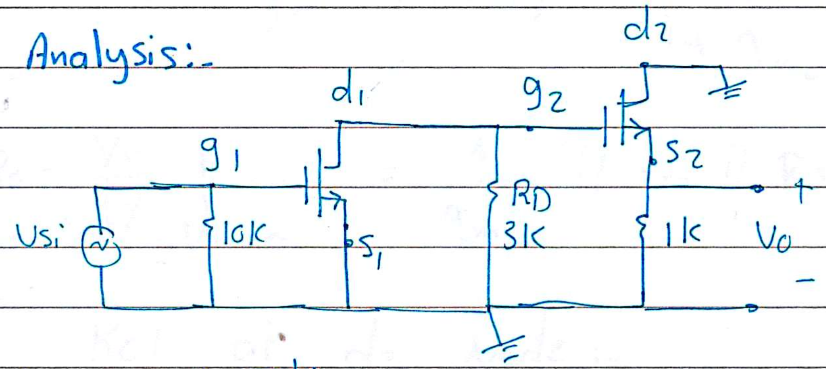
$V_{GS2} = 4 - I_{D2} \rightarrow I_{D2} = 4 - V_{GS2}$

$$4 - V_{GS_2} = 2(V_{GS_2} - 1)^2$$
$$= 2V_{GS_2}^2 - 4V_{GS_2} + 2$$

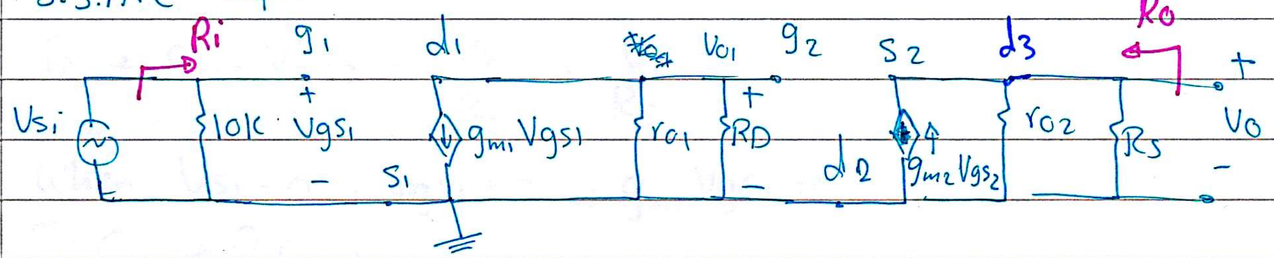
$$2V_{GS_2}^2 - 3V_{GS_2} - 2 = 0$$

$$V_{GS_2} = \frac{3 \mp \sqrt{9+4\times2\times2}}{4} = \frac{3\mp5}{4} = 2V \checkmark$$
$$= -0.5\,V \times$$

A.C Analysis:-



S.S.A.C eqnt cct:-



$R_i = 10\,K$

$$A_V = \underbrace{\frac{V_o}{V_{o1}}}_{A_{V2}} \times \underbrace{\frac{V_{o1}}{V_{si}}}_{A_{V1}}$$

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$V_o = g_{m2} V_{gs2} (r_{o2} // R_s)$

$-V_{o1} + V_{gs2} + V_o = 0$

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

$$A_{V2} = \frac{V_o}{V_{o1}} = \frac{g_{m2} (r_{o2} // R_s)}{1 + g_{m2} (r_{o2} // R_s)}$$

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

$V_{si} = V_{gs1}$

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

$$\therefore A_V = -g_{m1} (r_{o1} // R_D) \cdot \frac{g_{m2} (r_{o2} // R_s)}{1 + g_{m2} (r_{o2} // R_s)}$$

$$R_o = \left.\frac{V_x}{I_x}\right|_{V_{si}=0} = \frac{1}{g_{m2}} // r_{o2} // R_s$$

or KCl at d_3 Node :-

$$I_x + g_{m2} V_{gs2} = \frac{V_x}{r_{o2}} + \frac{V_x}{R_s}$$

When $V_{si} = 0$, $V_{gs1} = 0$, $g_{m1} V_{gs1} = 0$

D.C $\rightarrow$ O.C

$(V_{r_{o1}} \& R_D) = 0$, $V_{gs2} = -V_x$

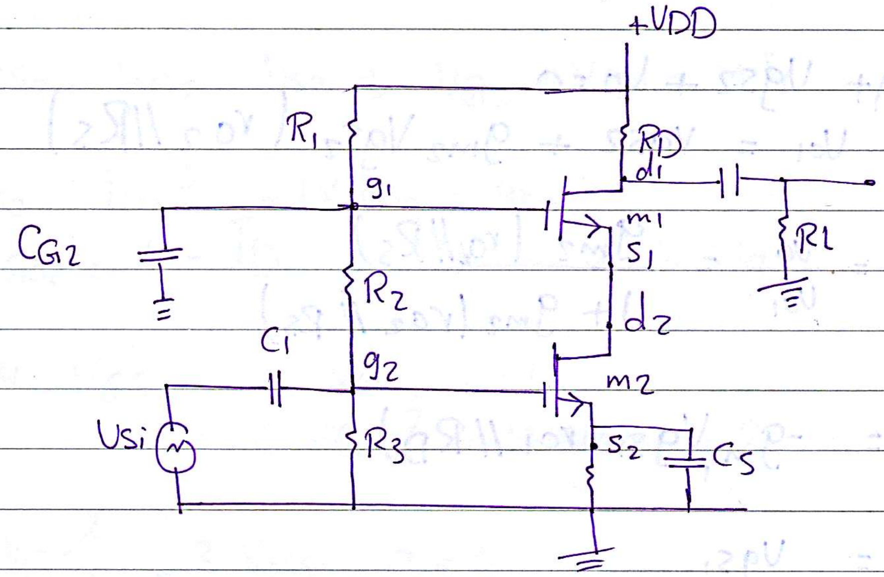
$$I_x = V_x \left(g_{m2} + \frac{1}{r_{o2}} + \frac{1}{R_s} \right)$$

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

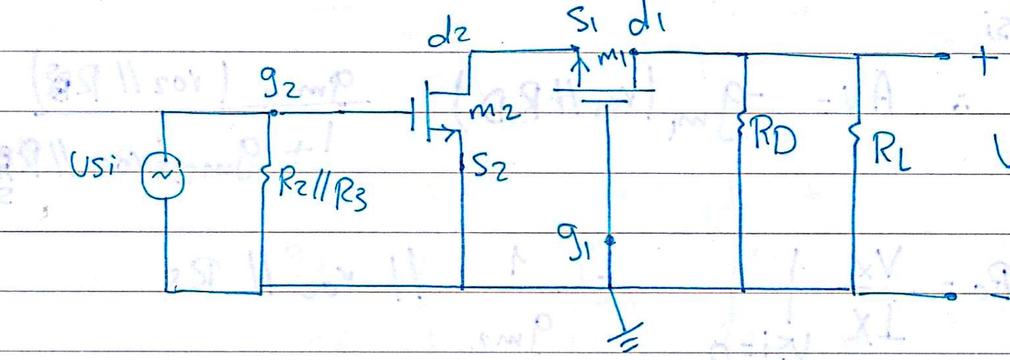
CHY

Tuesday 9-8-2016.

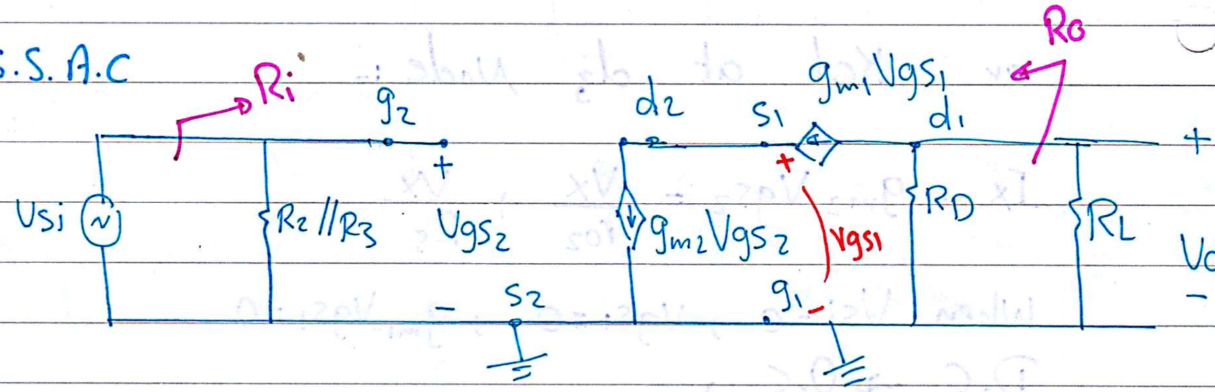
2) Cascode Amp:



A.C cct:



S.S.A.C

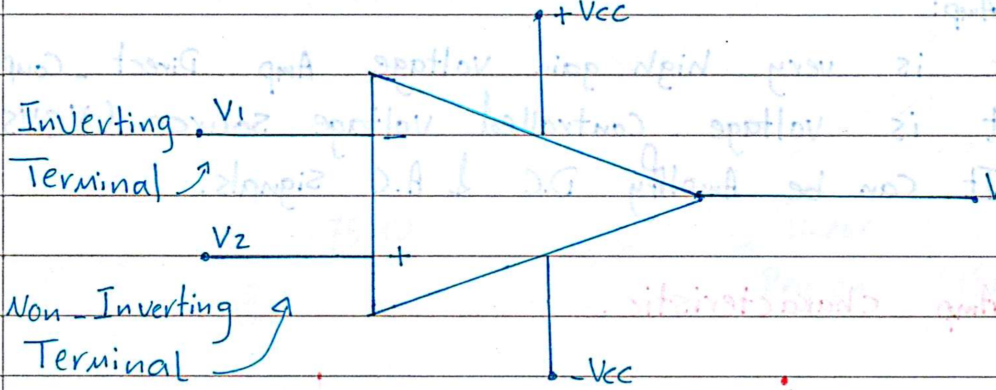


$R_i = R_2 // R_3$

$R_o = R_D$

$$A_V = \frac{V_o}{V_i} = \frac{-g_{m2} V_{gs2} (R_D // R_L)}{V_{gs2}} = -g_{m2} (R_D // R_L)$$

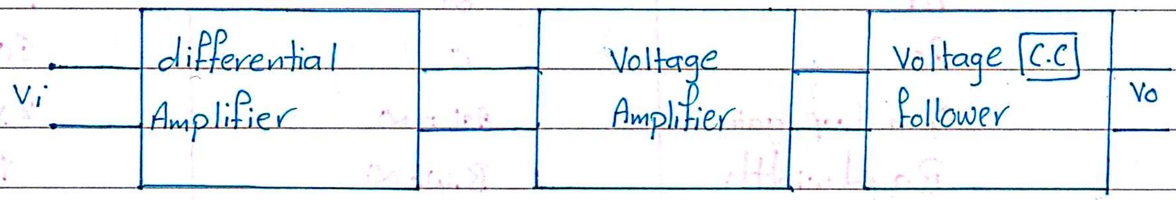
CH9 Operational Amplifier (Op_Amp) Thursday 11_8_2016

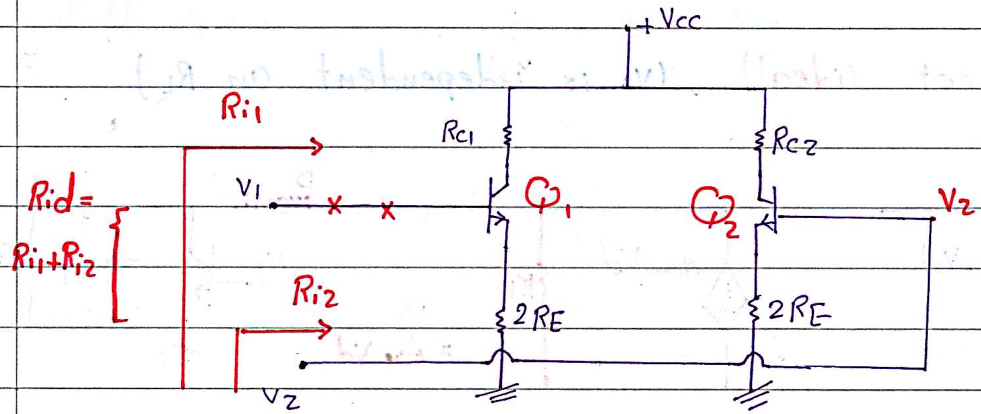


$V_o = A_V(V_2 - V_1)$

$\Rightarrow V_o \propto V_i$

Block diagram for Simple Op_Amp.



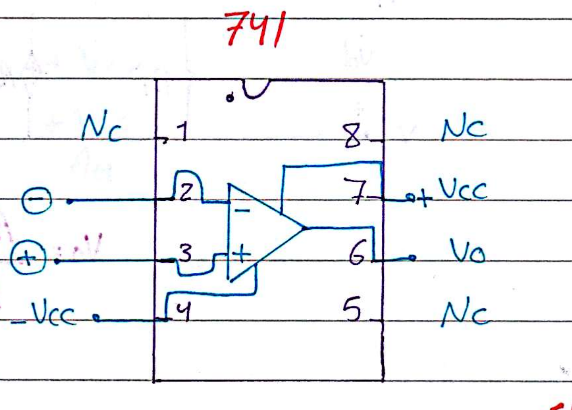


$R_{i1} = (\beta+1)2R_E + r_{\pi 1}$

$R_{i2} = (\beta+1)2R_E + r_{\pi 2}$

$R_{id} = [4(\beta+1)R_E + 2r_\pi]$.

741 Op_Amp.



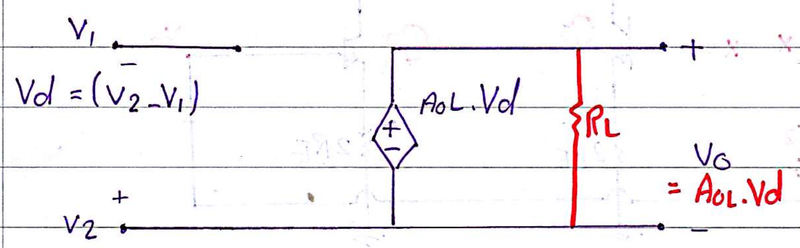
Op Amp:-

1) It is very high gain voltage Amp Direct - Coupled.
2) It is voltage - Controlled voltage source (VCVS)
3) It can be Amplify D.C & A.C signals.

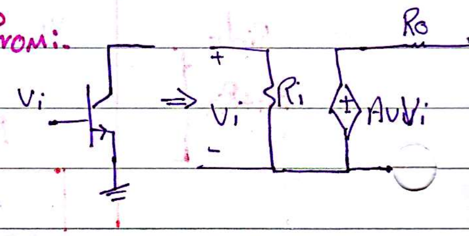
Op - Amp characteristic.

parameter	Ideal Op-Amp	Real Op-Amp (741)
R_i	∞	1 $M\Omega$
R_o	0	60 Ω
Open Loop gain	$A_{OL} = \infty$	2×10^5
Bandwidth	$B.W = \infty$	1 MHZ

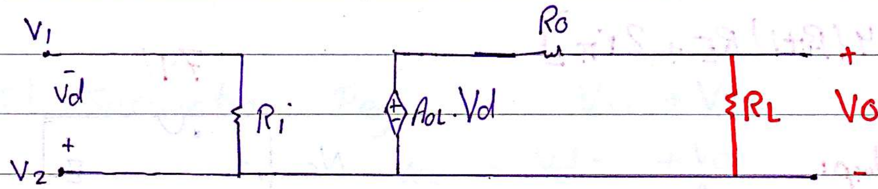
Eqnt cct (ideal), (V_o is independent on R_L)



From:



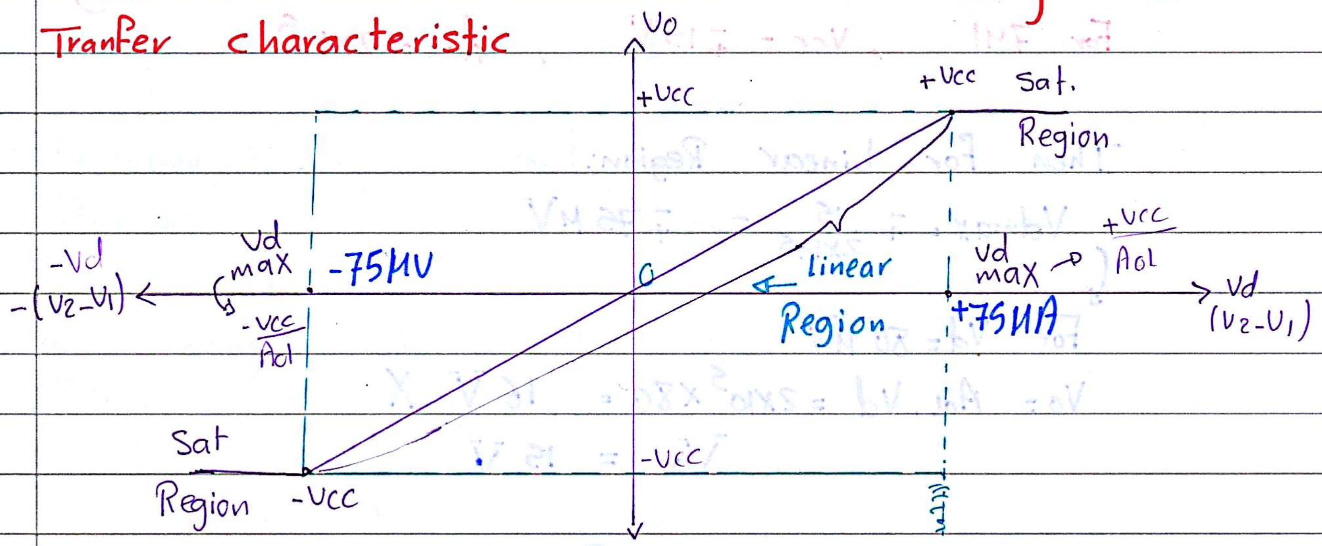
Eqnt cct (Real), (V_o depends on R_L)



$$V_o = \frac{A_{OL} \cdot V_d \, R_L}{R_L + R_o}$$

CH9 Thursday 11-8-2016.

Tranfer characteristic



$V_o = A_{OL} \cdot (V_2 - V_1) = A_{OL} \cdot V_d$

For ideal op-Amp : $A_{OL} = \infty$

i) If $V_2 > V_1 \longrightarrow V_o = \infty$; $V_o = +V_{cc}$

ii) If $V_2 < V_1 \longrightarrow V_o = -\infty$; $V_o = -V_{cc}$

$\therefore V_{o\,max} = \pm V_{cc}$

For $V_o = V_{cc} \rightarrow V_d = \frac{+V_{cc}}{A_{OL}}$

For $V_o = -V_{cc} \rightarrow V_d = \frac{-V_{cc}}{A_{OL}}$

Operating Regn.

1) Linear Regn $V_o \propto V_d$

$$\frac{-V_{cc}}{A_{OL}} < V_d < \frac{+V_{cc}}{A_{OL}}$$

2) Saturation Regn , $V_o = \pm V_{cc}$

$$\frac{-V_{cc}}{A_{OL}} > V_d > \frac{+V_{cc}}{A_{OL}}$$

For 741 , $V_{cc} = \mp 15V$, $A_{OL} = 2\times10^5$

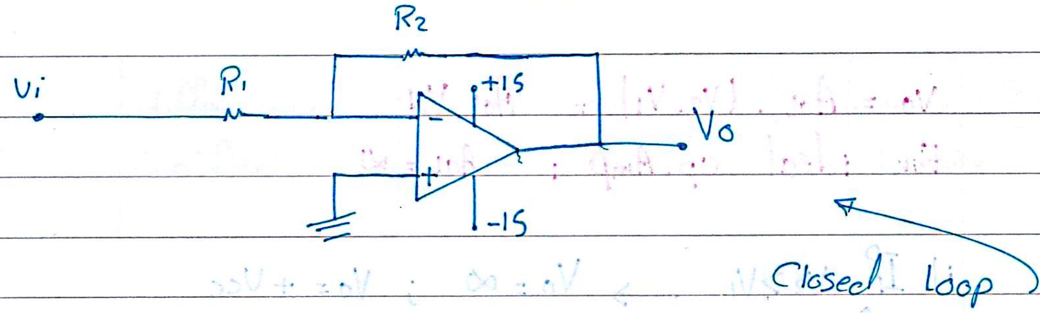
Then for Linear Region:

$V_{dmax} = \mp \frac{15}{2\times10^5} = \mp 75\,\mu V$

For $V_d = 80\,\mu V$

$V_o = A_{OL} . V_d = 2\times10^5 \times 80 = 16\,V$ X

$V_o = 15\,V$



- For Open-loop made the input signal to be proceed is very Small → $V_{dmax} = \mp \frac{V_{cc}}{A_{OL}}$

- To Amplify any signal we must be Operating the Op-Amp in closed Loop mode.

- In this case $A_V \neq A_{OL}$, but A_V will be a resistor ratio.

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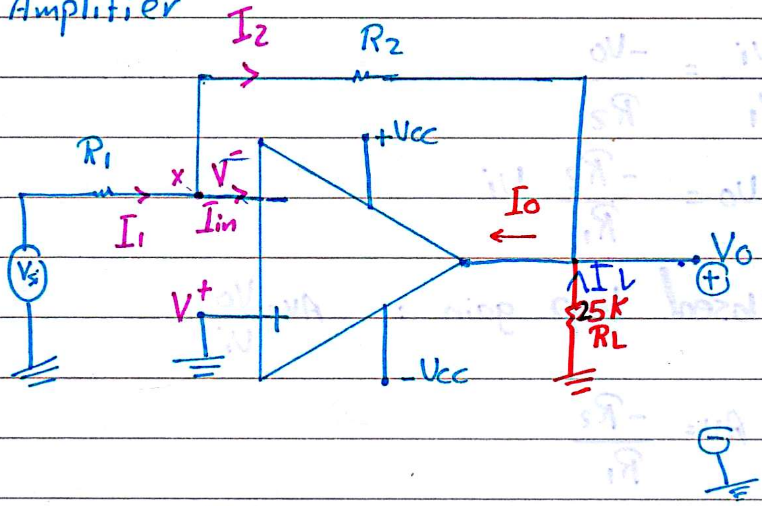
Op_Amp Applications:- Sunday 14_8_2016

A) Linear Applications.

1) Inverting Amplifier

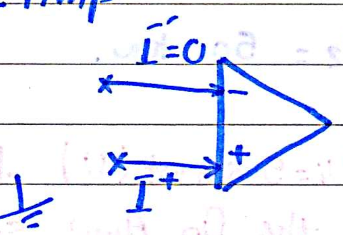


KCL at node x:

$$I_1 = I_2 + I_{in}$$

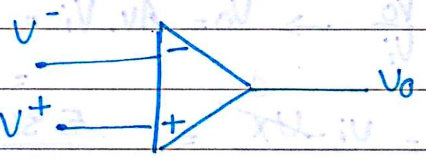
$$\frac{V_i - V_X}{R_1} = \frac{V_X - V_O}{R_2} + I_{in}$$

but for ideal op_Amp



$I_{in} = 0$

$R_i = \infty$



$V_o = A_{OL}(V^+ - V^-)$

For ideal op_Amp

$A_{OL} = \infty$

$V^+ - V^- = \frac{V_O}{\infty} = 0$

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$v^+ = v^-$ (virtual short)

$v^+ = v^- = V_x = 0$ (virtual ground)

$$\frac{v_i}{R_1} = \frac{-v_o}{R_2}$$

$$v_o = \frac{-R_2}{R_1} v_i$$

closed loop gain : $A_V = \frac{V_o}{V_i}$

$$A_V = \frac{-R_2}{R_1}$$

$$R_i = \frac{v_i}{I_1} \rightarrow \quad -v_i + I_1 R_1 = 0$$

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

Ex) 1) Design an I.A to have $A_V = -10$ and $R_i = 5K$

$R_i = R_1 = 5K\Omega$.

$$A_V = \frac{-R_2}{R_1} = -10 = \frac{-R_2}{5}$$

$$\therefore R_2 = 50 \ K\Omega.$$

2) For $V_i = 5 \sin wt$ (V) determine, I_1, I_2, I_L, I_o, does the Op-Amp sink or source current.

$$A_V = \frac{V_o}{V_i} \rightarrow V_o = A_V . V_i = -10 \times 5 \sin wt$$

$$= -50 \sin wt$$

$$I_1 = \frac{v_i - \cancel{V_x}^{0}}{R_1} = \frac{5 \sin wt}{5k} = 1 \sin wt \ mA$$

$$I_2 = \frac{V_x - V_o}{50k} = \frac{0 - (-50) \sin wt}{50k} = 1 \sin wt \ mA.$$

$$I_L = \frac{0 - V_o}{R_L} = \frac{50 \sin wt}{25k} = 2 \sin wt \ mA.$$

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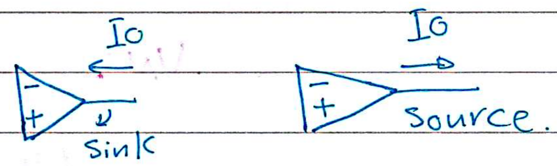
$I_o = I_2 + I_L = (1+2)\sin\omega t = 3\sin\omega t\ mA$.

The Op-Amp is a sink current.

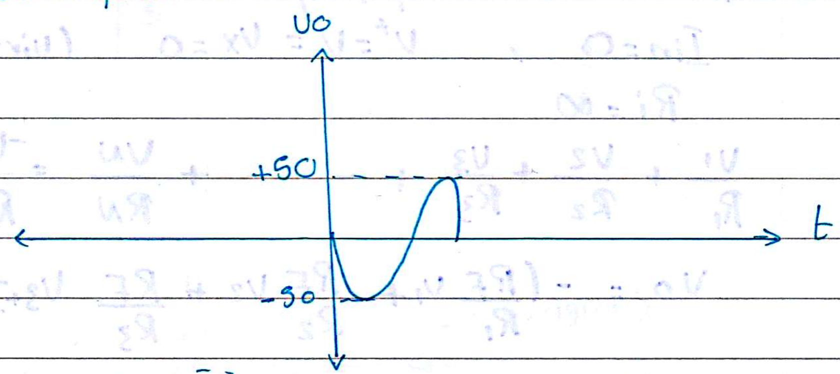


3) Draw $V_o(t)$ when: i) $V_{cc} = \mp 60\ \bar{V}$

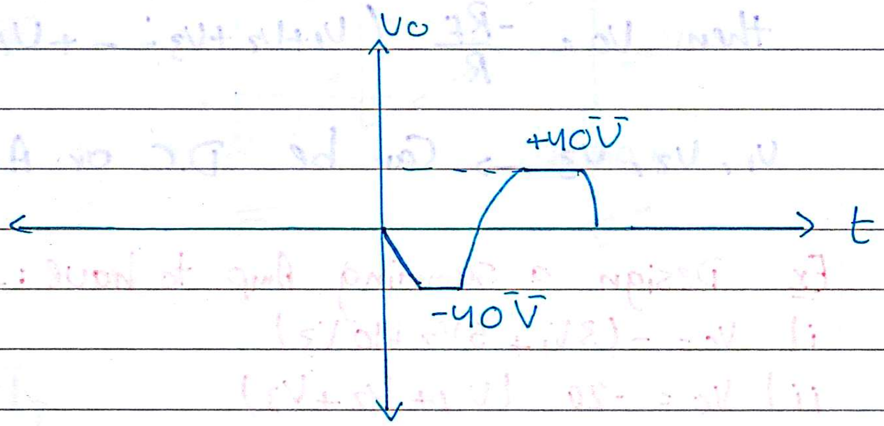
ii) $V_{cc} = \mp 40\ \bar{V}$

from answer 2:

i) For $V_{cc} = \mp 60\ \bar{V}$



ii) For $V_{cc} = \mp 40\ \bar{V}$



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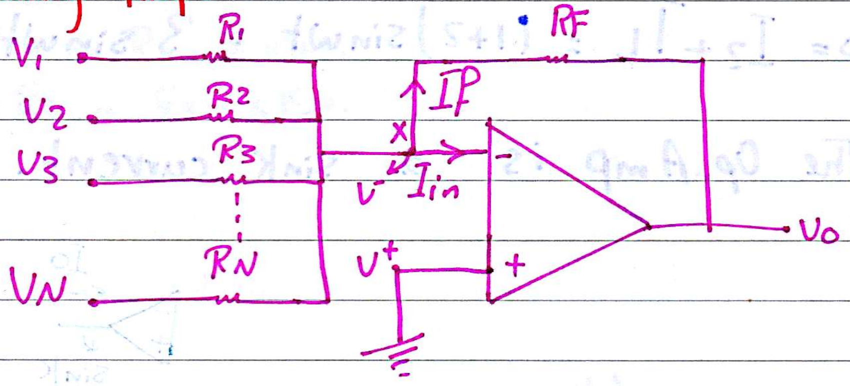
2) Summing Amp.



Kcl at node x:

$$I_1 + I_2 + I_3 + \dots + I_N = I_{in} + I_f$$

$$\frac{V_1 - \cancel{V_x}^{0}}{R_1} + \frac{V_2 - \cancel{V_x}^{0}}{R_2} + \frac{V_3 - \cancel{V_x}^{0}}{R_3} + \dots + \frac{V_N - \cancel{V_x}^{0}}{R_N} = \cancel{I_{in}}^{0} + \frac{\cancel{V_x}^{0} - V_o}{R_F}$$

Assume ideal Op-Amp

$I_{in} = 0$, $V^+ = V^- = V_x = 0$ (virtual ground)

$R_i = \infty$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \dots + \frac{V_N}{R_N} = \frac{-V_o}{R_F}$$

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

special Case: when $R_1 = R_2 = R_3 = \dots = R_N = R$

then $V_o = \frac{-R_F}{R}(V_1 + V_2 + V_3 + \dots + V_N)$

$V_1, V_2, V_3 \rightarrow$ Can be D.C or A.C signals.

Ex Design a summing Amp to have:-

i) $V_o = -(3V_1 + 5V_2 + 10V_3)$

ii) $V_o = -20(V_1 + V_2 + V_3)$

Soln: i) $\frac{R_F}{R_1} = 3$, $\frac{R_F}{R_2} = 5$, $\frac{R_F}{R_3} = 10$

Let $R_F = 30\ k\Omega$.

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$30 = 3R_1 \rightarrow R_1 = 10\,K\Omega$.

$30 = 5R_2 \rightarrow R_2 = 6\,K\Omega$.

$30 = 10\,R_3 \rightarrow R_3 = 3\,K\Omega$.

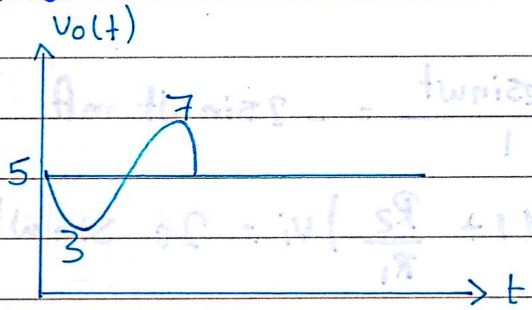
2) For $V_1 = -5\,V\,d.c$, $V_2 = 2\,V\,d.c$, $V_3 = 0.2\sin(\omega t)$

Find $v_o(t)$ & draw $v_o(t)$

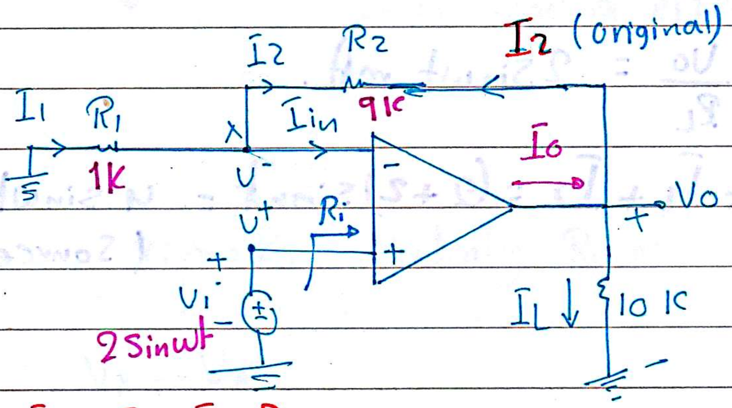
i) $V_o = -(-5\times3 + 5\times2 + 10\times0.2\sin\omega t)$

$= -(-5 + 2\sin\omega t)$

$= 5 - 2\sin\omega t$



3) Non-Inverting Amp:



Find I_1, I_2, I_L, I_o ?

$I_1 = I_{in} + I_2$

$$\frac{0 - V_x}{R_1} = \cancel{I_{in}}^{\,0} + \frac{V_x - V_o}{R_2}$$

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but for ideal op-Amp:

$I_{in} = 0$

$v^+ = v^- = v_x = v_i$ (virtual short).

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

$$-\frac{V_i R_2}{R_1} = V_i - V_o \rightarrow V_o = V_i\left(1 + \frac{R_2}{R_1}\right)$$

$$A_V = \frac{V_o}{V_i} = 1 + \frac{R_2}{R_1}$$ closed loop gain.

$R_{in} = \infty$

$$I_1 = \frac{0 - 2\sin\omega t}{1} = -2\sin\omega t \text{ mA}$$

$$V_o = \left(1 + \frac{R_2}{R_1}\right)V_i = 20 \sin\omega t \ \bar{V}$$

$$I_2 = \frac{V_x - V_o}{R_2} = \frac{2\sin\omega t - 20\sin\omega t}{9} = \frac{-18\sin\omega t}{9}$$

$$= -2\sin\omega t.$$

$$I_L = \frac{V_o}{R_L} = 2\sin\omega t \text{ mA}.$$

$$I_o = I_L + I_2 = (2+2)\sin\omega t = 4\sin\omega t$$

(Source current).

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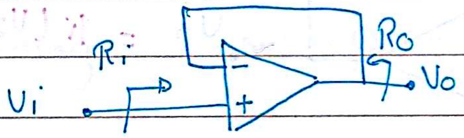
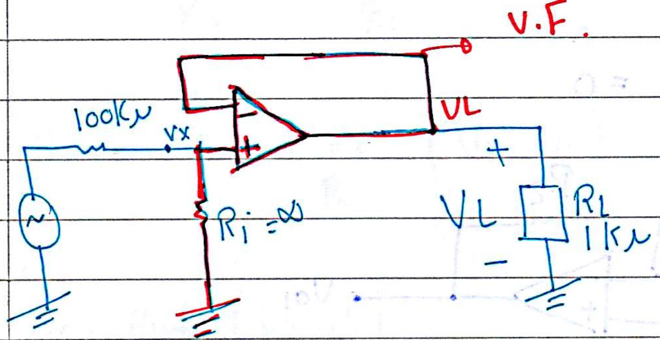
4) Voltage Follower
(special case of Non-Inverting Amp)



. used to solve the loading effect problem.

$V_o = V_i \rightarrow A_V = 1$
$R_i = \infty$
$R_o = 0$. # Ideal voltage follower
$\emptyset = 0^\circ$



$V_L = \frac{V_S R_L}{R_L + R_S} = \frac{V_S \cdot 1}{101} = 0.01 V_S$

sever Loading effect.

with V.F:-

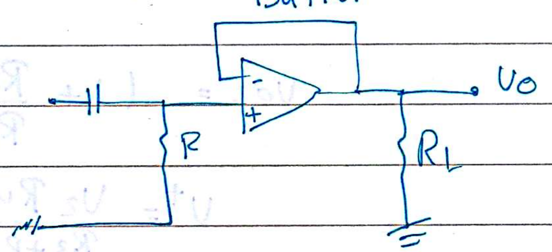
$V_X = \frac{V_S R_i}{R_i + R_S}$, $R_i >> R_S$ (idealy $R_i = \infty$)

$V_X = V_S$

but $V_L = V_X$ ∴ $A_V = 1$

∴ $V_L = V_X = V_S = 10 \sin \omega t$.

Buffer



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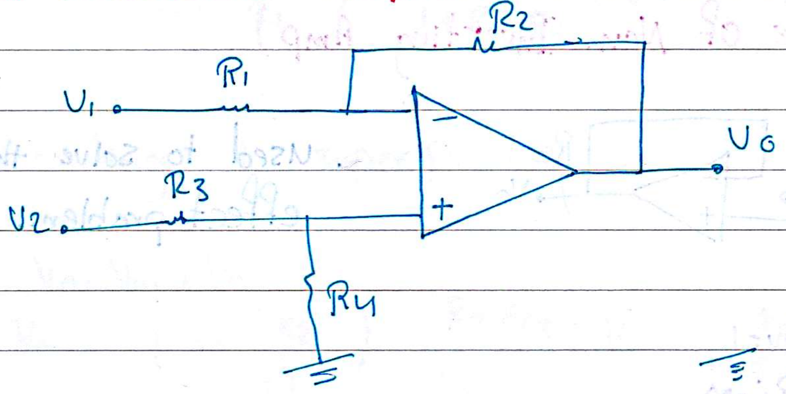
5) Difference Amplifier

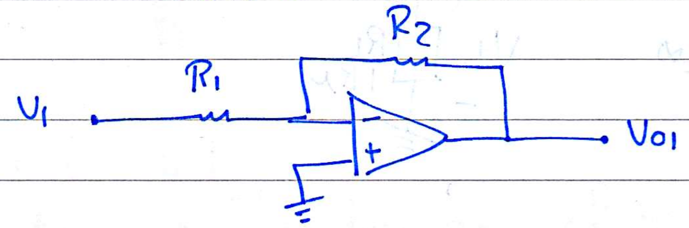


$V_o = K(V_2 - V_1)$

Using Superposition :-

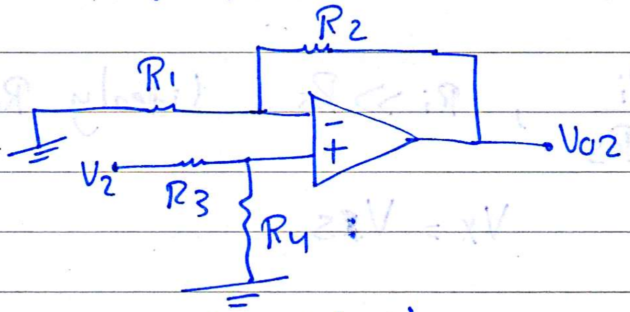
1) effect of (V_1) : $V_2 = 0$

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



$$V_{o1} = \frac{-R_2}{R_1} V_1 \quad \text{(inverting Amp)}$$

2) For V_2, $(V_1 = 0)$



(non inverting Amp)

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

$$V^+ = \frac{V_2 R_4}{R_3 + R_4} = \frac{R_4 / R_3}{1 + R_4/R_3} V_2$$

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$$V_{o2} = \left(1+\frac{R_2}{R_1}\right)\frac{R_4/R_3}{1+R_4/R_3}\,V_2$$

According to super position :-

$$V_o = V_{o1} + V_{o2}$$

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

For $\dfrac{R_4}{R_3} = \dfrac{R_2}{R_1}$

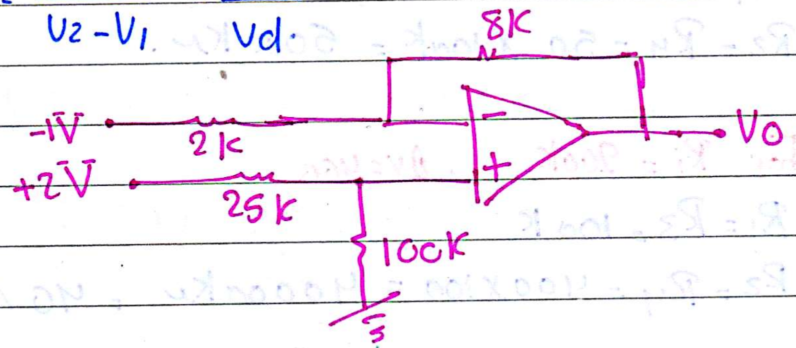
then : $V_o = \dfrac{R_2}{R_1}(V_2 - V_1)$

$V_o = A_{vd}(V_2 - V_1)$

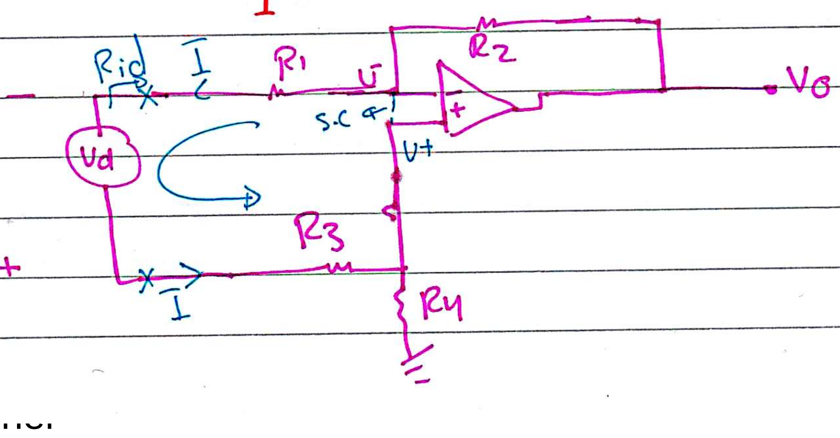
$A_{vd} = \dfrac{R_2}{R_1}$ (Differential gain of the Amp)

$A_{vd} = \dfrac{V_o}{V_2 - V_1} = \dfrac{V_o}{V_d}$.

i.g.



To find $R_{id} = \dfrac{V_d}{I}$ (input resistance)



$-V_d + I R_3 + I R_1 = 0$

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

Ex) Design a difference Amp to have:

1) $R_i = 20K$ and $A_{vd} = 50$

$R_i = R_3 + R_1$

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

$R_1 = R_3$, $R_2 = R_4$ so $R_i = 2R_1 = 2R_3$

For $R_i = 20\,K\Omega$

$R_1 = R_3 = 10\,K\Omega$.

$A_{vd} = \frac{R_2}{R_1} = \frac{R_4}{R_3} \rightarrow 50 = \frac{R_2}{10K} \rightarrow R_2 = 500\,K\Omega = R_4$

2) $R_i = 200K$, $A_V = 50$

$R_1 = R_3 = 100\,K\Omega$.

$R_2 = R_4 = 50 \times 100K = 5000\,K\Omega$.

3) For $R_i = 200K$, $A_V = 400$

$R_1 = R_3 = 100\,K$

$R_2 = R_4 = 400 \times 100 = 40000\,K\Omega = 40\,M\Omega$.

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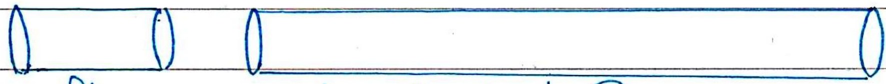
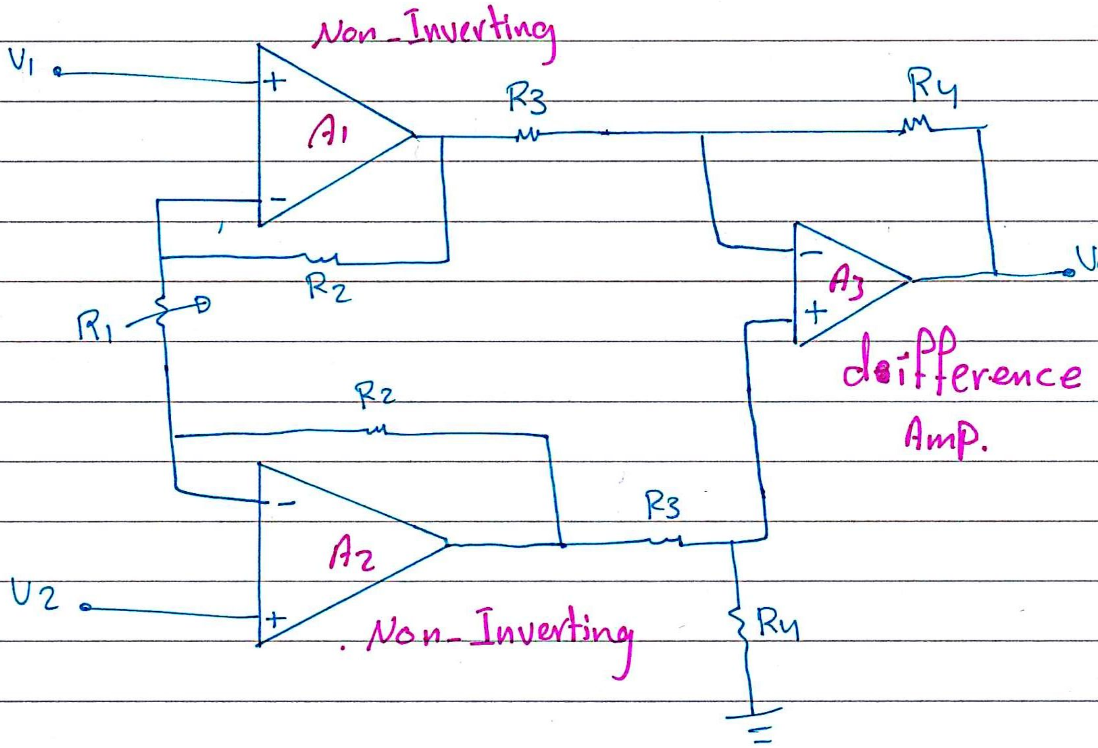


$R = \frac{\rho L}{A}$ → due to high R we need a very long cable.



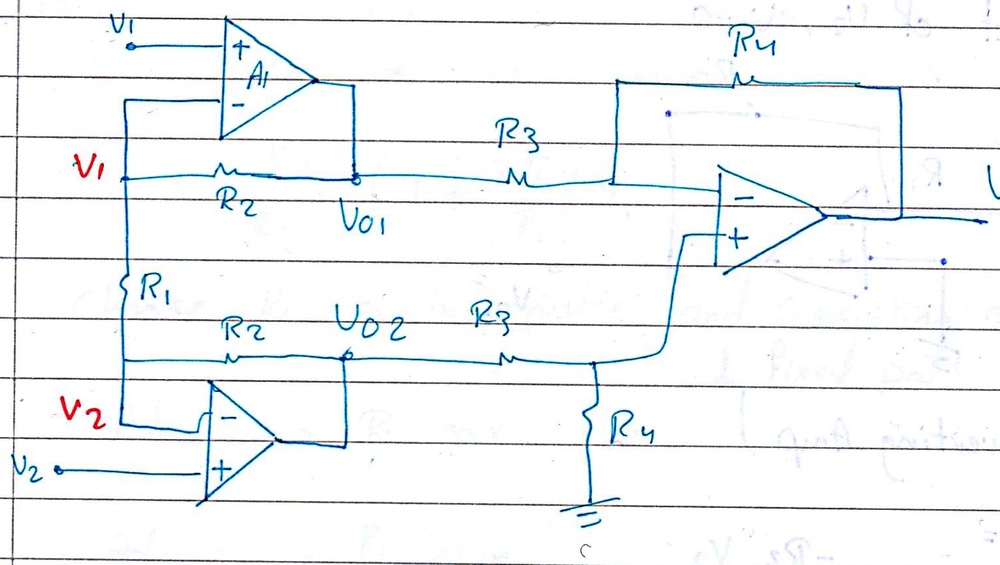
6) Instrumentation Amp

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

. Single element dependent device.

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

. Very high R_i, A_V



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

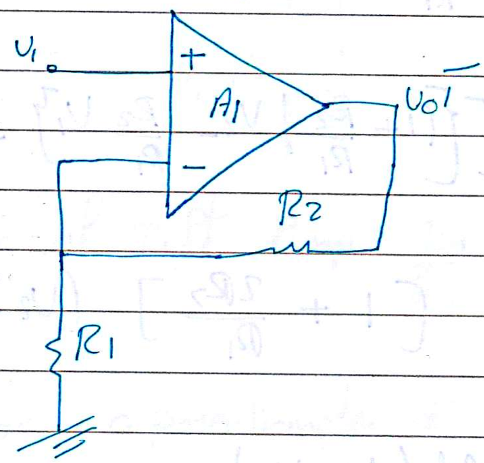
Instrumentation Amp.
very high I/p resistance.

high, adjustable and single-element dependent gain using resonable resistor values.

For Diff Amp A_3 & with balance condition.

$$V_o = \frac{R_4}{R_3}(V_{o2} - V_{o1})$$

1) For A_1 : Use superposition.
i) for V_1
(Non-Inverting)



$$V_{o1}' = \left(1 + \frac{R_2}{R_1}\right)V_1$$

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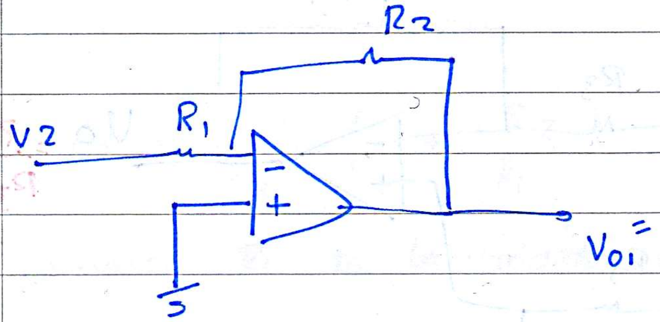
Effect of V_2, $V_1 = 0$

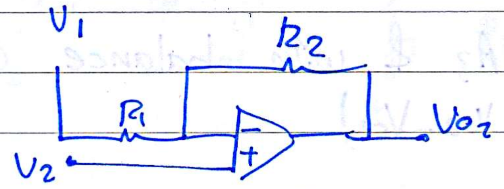


(Inverting Amp)

$$V_{o1}'' = \frac{-R_2}{R_1} V_2$$

$$V_{o1} = V_{o1}' + V_{o1}''$$
$$= \left(1 + \frac{R_2}{R_1}\right) V_1 - \frac{R_2}{R_1} V_2$$

2) For A_2:



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

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

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

$$V_o = A_d (V_2 - V_1)$$

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

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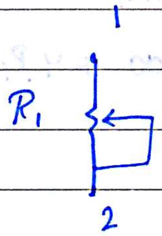
EXA: Design an I.A to have a gain ranging from (100 → 500) The max available resistor is ~~100~~ 220 kΩ.

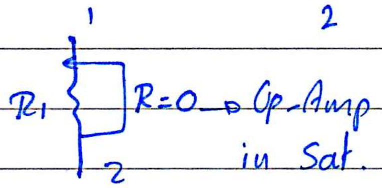
$$Ad = \frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)$$

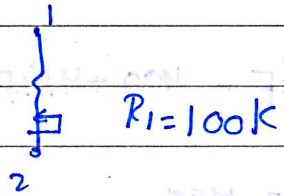
Choose R_1 to be variable. and consisting of variable & fixed part.

$Ad_{min} \rightarrow R_1 \, max$

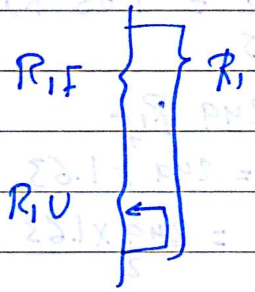
$Ad_{max} \rightarrow R_1 \, min$







$R_1 = R_{1V} + R_{1F}$



choose the gain of Diff Amp $\frac{R_4}{R_3}$ to be 2, $\frac{R_4}{R_3}$

Choose R_{1V} to be a potentiometer of 100 kΩ.

$R_1 \, min = 0 + R_{1F} = R_{1F}$

$R_1 \, max = 100 + R_{1F}$

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$Ad_{min} \Rightarrow R_1\ max \Rightarrow 100 + R_{1F}$

$Ad_{max} \rightarrow R_1\ min \Rightarrow R_{1F}$

$500 = 2\left(1+\frac{2R_2}{R_{1F}}\right) \Rightarrow 250 = 1+\frac{2R_2}{R_{1F}}$

$2R_2 = 249 R_{1F}$ -- (1)

$10 = 2\left(1+\frac{2R_2}{100+R_{1F}}\right)$

$4 = \frac{2R_2}{100+R_{1F}}$

$2R_2 = 400 + 4R_{1F}$

Equate (1) & (2)

$249 R_{1F} = 400 + 4R_{1F}$

$245 R_{1F} = 400$

$R_{1F} = \frac{400}{245} = 1.63\ k\Omega.$

from $2R_2 = 249 R_{1F}$

$2R_2 = 249 \times 1.63$

$= \frac{249 \times 1.63}{2} = 203\ k\Omega.$

$\frac{R_4}{R_3} = 2$

$R_4 = 2R_3$

Choose $R_3 = 1k\Omega$

$R_4 = 2k\Omega.$

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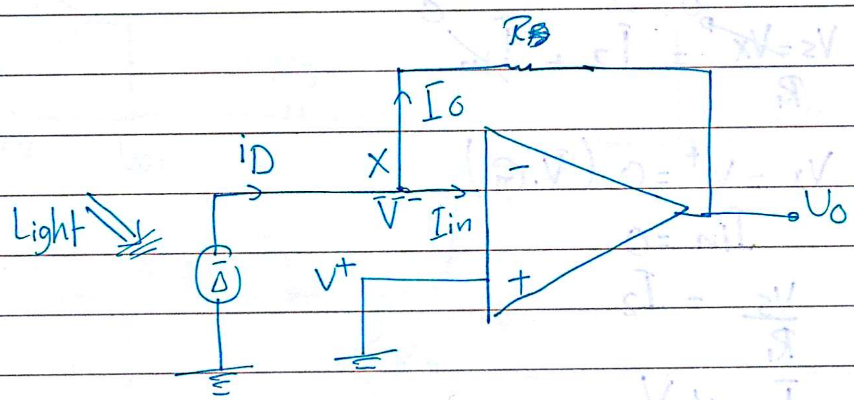
7) Current - to - Voltage Converter.



$V_o \propto i_D$

Kcl at Node X

$i_D = I_{in} + I_o$

$i_D = \cancel{I_{in}} = \frac{V_x - V_o}{R}$

For ideal Op-Amp

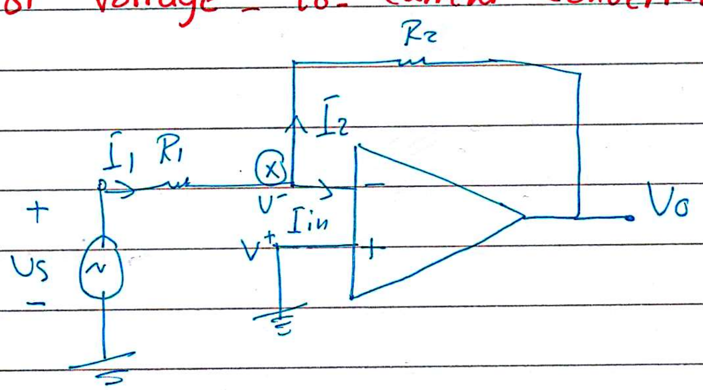
$I_{in} = 0$, $R_i = \infty$

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

$i_D = \frac{-V_o}{R}$ $\therefore V_o = -i_D R$

$V \propto i_D$

8) Voltage - to - Current Converter.



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$I_1 = I_2 + I_{in}$

$$\frac{V_s - \cancel{V_x}^{0}}{R_1} = I_2 + \cancel{I_{in}}^{0}$$

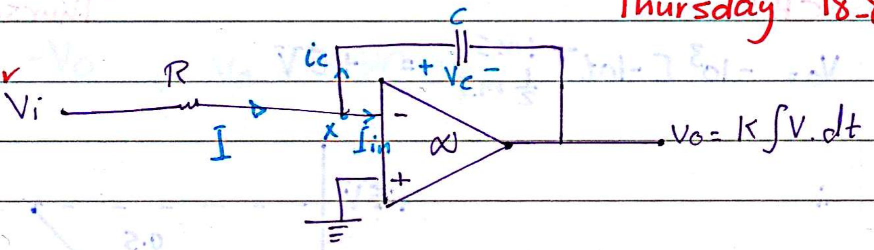
$V_x = V^+ = 0$ (V.G)

$I_{in} = 0$

$$\frac{V_s}{R_1} = I_2$$

$I_2 \propto V_s$

8) Integrator



KCL at node (x):

$I = I_{in} + i_c$

$\frac{V_i - \cancel{V_x}^{\,0}}{R} = I_{in} + \frac{c\,dV_c}{dt}$; $V_c = \cancel{V_x}^{\,0} - V_o = -V_o$

but for Ideal Op-Amp:

$I_{in} = 0$, $V^- = V^+ = V_x = 0$ (V.G)

$\frac{V_i}{R} = -c\frac{dV_o}{dt}$

$\int \frac{dV_o}{dt} = \frac{-1}{Rc}\int V_i\,dt + K$ but $K=0$ (initially uncharged)

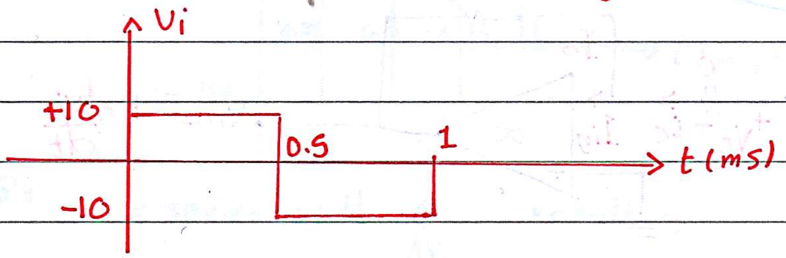
$\therefore V_o = \frac{-1}{Rc}\int V_i\,dt$

Exa: Draw $V_o(t)$ for the given V_i ; Given: $R = 1K$

$C = 1\mu F$

$T = \frac{1}{f} = 1ms$

$f = 1KHZ$.



1) For $0 < t < \frac{1}{2}ms$; $V_i = 10V$

$V_o = \frac{-1}{10^3 \times 10^{-6}}\int_0^{0.5ms} 10\,dt = -10^3\,[10t]_0^{0.5ms}$

$= -10^3 \times 10 \times 0.5 \times 10^{-3} - 0$

$= -5V$

2) For $(\frac{1}{2} < t < 1)ms$; $V_i = -10V$

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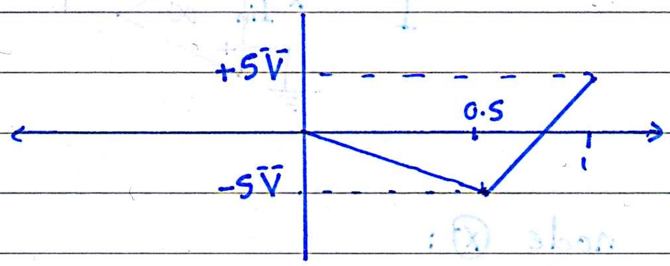
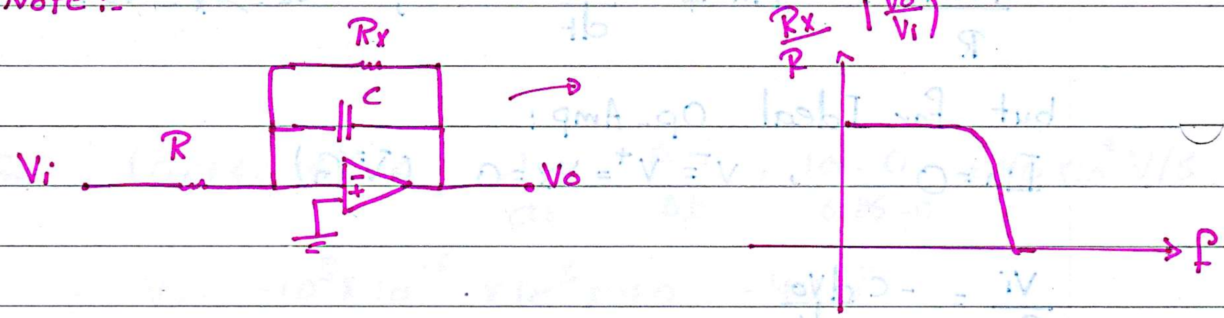
$V_o = -10^3 [-10t]_{\frac{1}{2}ms}^{1ms} = +5\bar{V}$

$\therefore$



Note :-

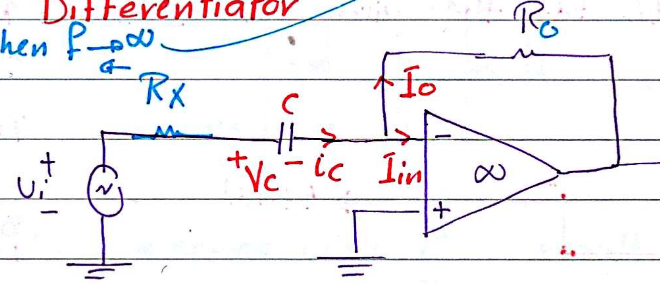


. we put Rx because at Low freq. C becomes an O.C So the Op_Amp becomes Open Loop and works is sat. Regn so to solve that we put Rx, it will make it works as an inverting Op_Amp at low freq.

The same Reason

9) Differentiator

when $f \to \infty$



$V_o = -K\frac{dv_i}{dt}$

$i_c = C\frac{dv_c}{dt}$; $V_c = V_i - V_x$

$I_c = I_{in} + I_o$

$c\frac{d(v_i - V_x)}{dt} = I_{in} + \frac{V_x - V_o}{R_o}$; but $I_{in} = 0$, $v^- = v^+ = V_x = 0$ $(\bar{V}.G)$

for ideal Op_Amp.

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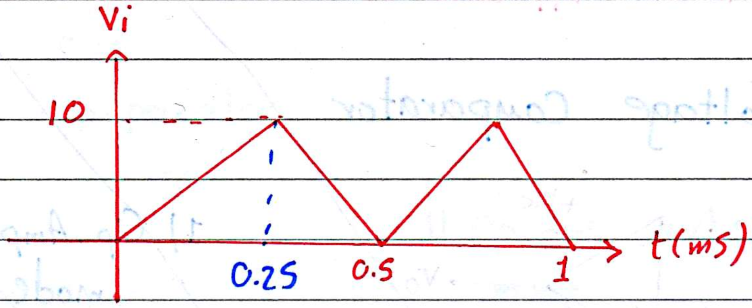
$$RC\frac{dv_i}{dt} = -V_o \rightarrow V_o = -RC\frac{dv_i}{dt}$$

Ex



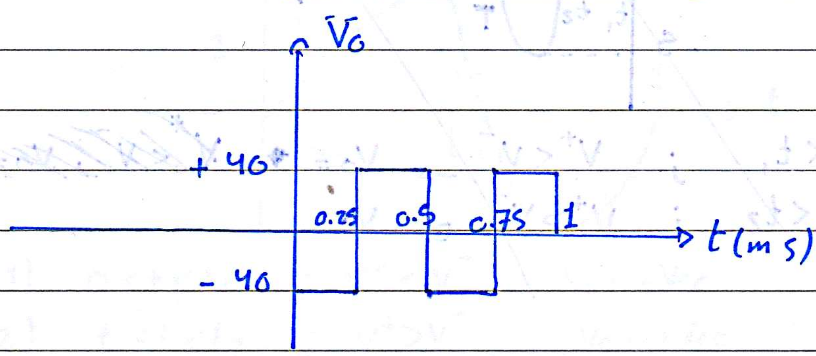
Given : $R = 1\,k\Omega$, $C = 1\mu F$.

For $(0<t<0.25)ms$; $\frac{dv_i}{dt} = \frac{\Delta V_i}{\Delta t} = \frac{10-0}{0.25-0} = 40\times10^3\ V/s$

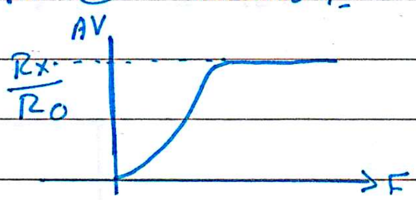
$\therefore V_o = -10^3 \times 10^{-6} \times 10^3 \times 40 = -40\ V$

For $(0.25<t<0.5)ms$, $\frac{\Delta v_i}{\Delta t} = \frac{(0-10)\ V}{(0.5-0.25)ms} = -40\times10^3\ V/s$

$\therefore V_o = -10^3 \times 10^{-6} \times -40\times10^3 = 40\ V$

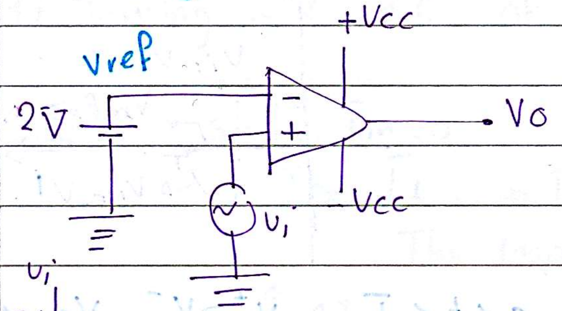


Rx series with C result :-

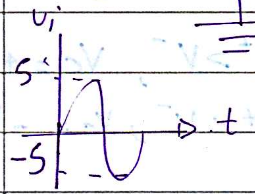


Non_Linear Applications

[1] Voltage comparator



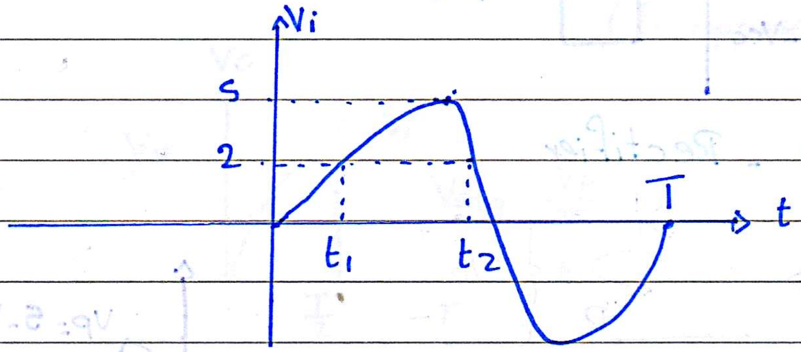
1) Op-Amp works in Open-loop mode
2) $V_o = \mp V_{cc}$



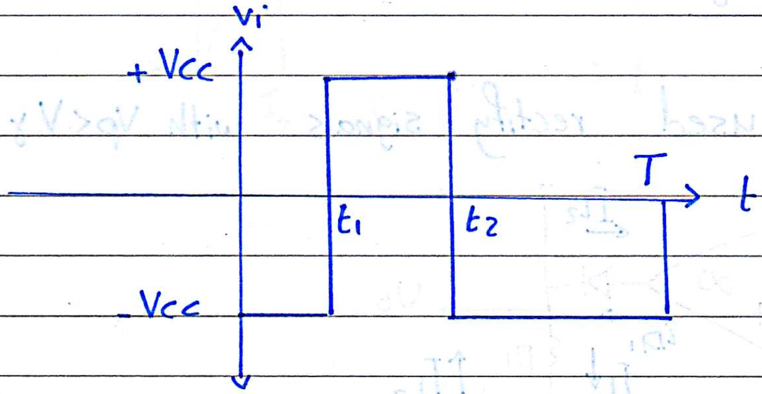
$V_o = A_{OL}(V^+ - V^-)$

For ideal op-Amp, $A_{OL} = \infty$

1] if $V^+ > V^-$ ∴ $V_o = +V_{cc}$
2] if $V^+ < V^-$ ∴ $V_o = -V_{cc}$

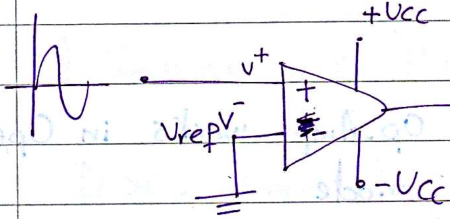


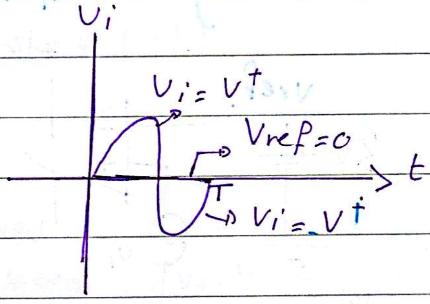
1). $0 < t < t_1$; $V^+ < V^- \rightarrow V_o = -V_{cc}$
2) $t_1 < t < t_2$; $V^+ > V^- \rightarrow V_o = +V_{cc}$
3) $t_2 < t < T$; $V^+ < V^- \rightarrow V_o = -V_{cc}$



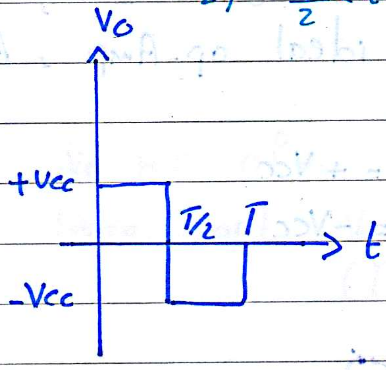
[2] Zero crossing detector.

Voltage comparator with $V_{ref} = 0$
and V_o is symmetrical square wave (sin $\rightarrow$ square)

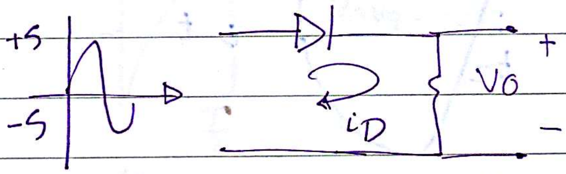


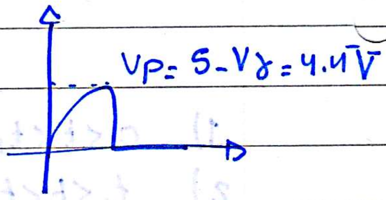


1) $0 < t < \frac{T}{2}$, $V^+ > V^-$, $V_o = +V_{cc}$
2) $\frac{T}{2} < t < T$, $V^+ < V^-$, $V_o = -V_{cc}$



[3] Precision Rectifier

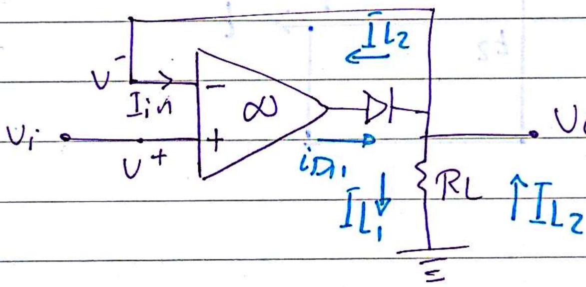




$$V_o = i_D R = \frac{V_i - V_\gamma}{R} \cdot R$$

$$i_D = \frac{V_i - V_\gamma}{R}$$

. Rectifiers used rectify signals with $V_p < V_\gamma$



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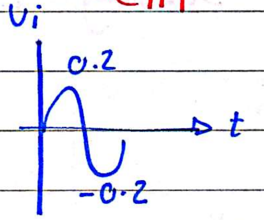
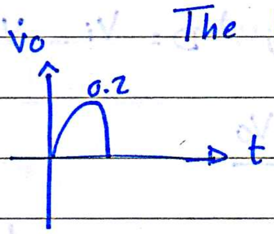


1) During +ve H.C of v_i, $V_o = V_i$ (V.F)

$I_L > 0$, since $I_{in} = 0$

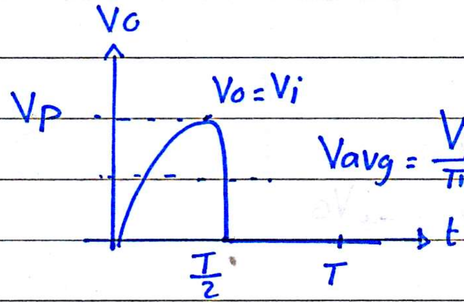
$I_D = I_L \rightarrow$ D is On.

The Loop is closed $\rightarrow V_o = V_i$

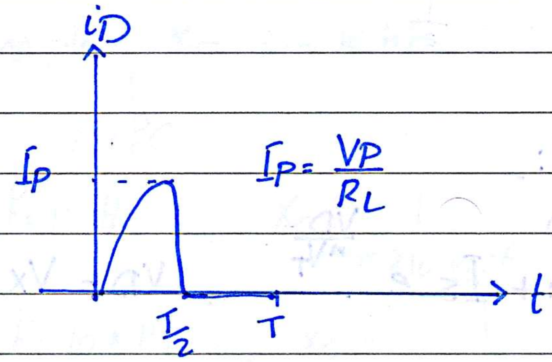


2) During -ve H.C of v_i $\xleftarrow{I_L}$ so diode is off (open loop) V_o = zero

(I_L opposes I_D)

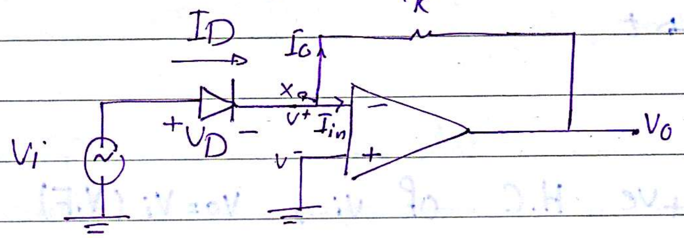


$V_{avg} = \frac{V_P}{\pi}$



$I_P = \frac{V_P}{R_L}$

$\boxed{4}$ exponential Amp.



$i_D = I_{in} + I_o$

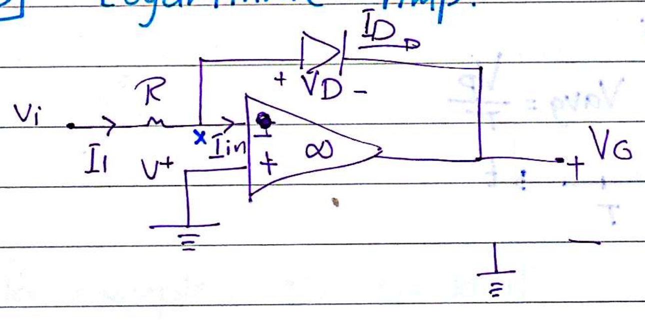
$I_s e^{\frac{V_D}{nV_T}} = I_{in} + I_o \quad , \quad V_D = V_i - V_x$

$I_s e^{\frac{V_i - \cancel{V_x}^{0}}{nV_T}} = \cancel{I_{in}}^{0} + \frac{\cancel{V_x}^{0} - V_o}{R}$

but $V_x = V^- = V^+ = \text{zero}$ (Virtual ground) "ideal op-Amp"

$V_o = -I_s R e^{\frac{V_i}{0.026}}$

$\boxed{5}$ Logarithmic Amp.



KCl at node X:

$I_1 = I_{in} + I_D$

$\frac{V_i - V_x}{R} = I_{in} + I_s e^{\frac{V_D}{nV_T}} \quad , \quad V_D = V_x - V_o$

but for ideal op-Amp : $I_{in} = \text{zero}$, $V_x = V^- = V^+ = \text{zero}$ (V.G)

$\frac{V_i}{R} = I_s e^{-V_o/nV_T} \quad ; \quad \frac{V_i}{RI_s} = e^{\frac{-V_o}{nV_T}}$

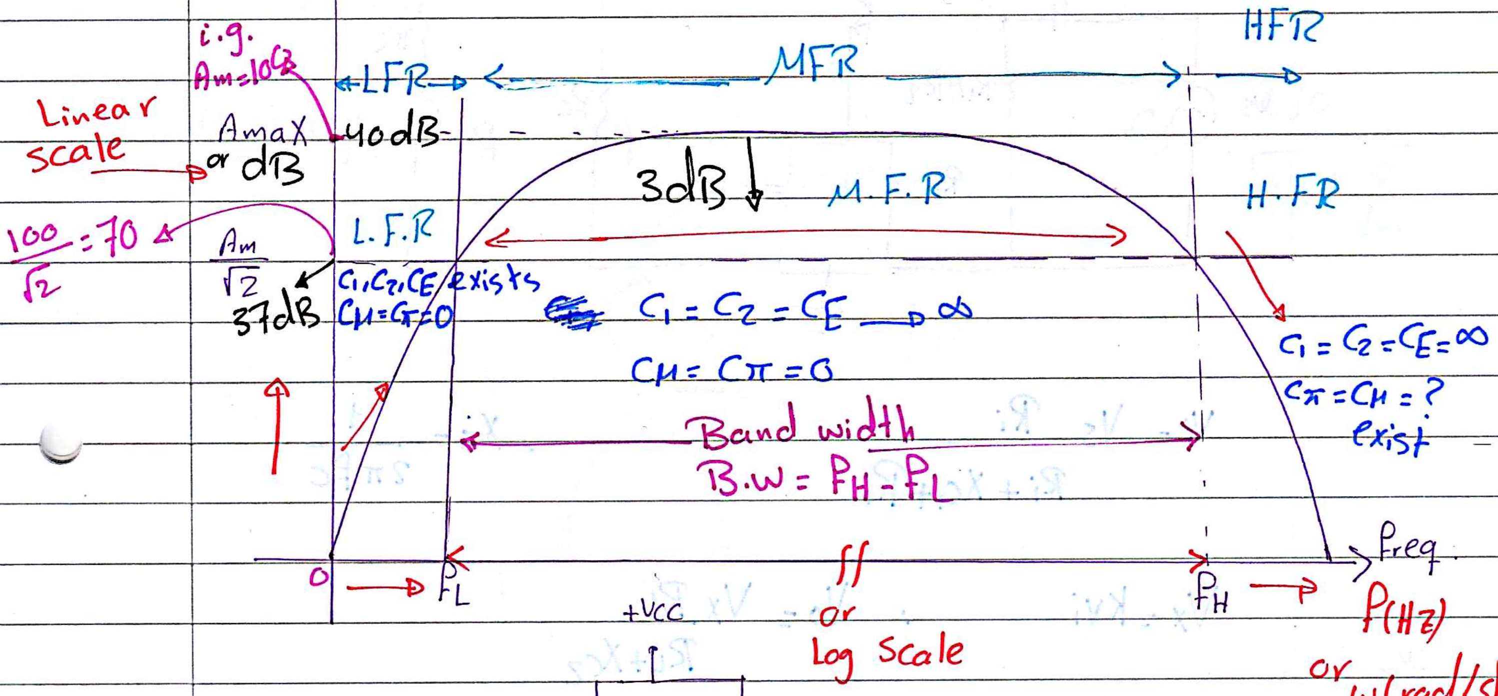
$V_o = -nV_T \ln \frac{V_i}{RI_s} = -0.026 \ln \frac{V_i}{RI_s}$

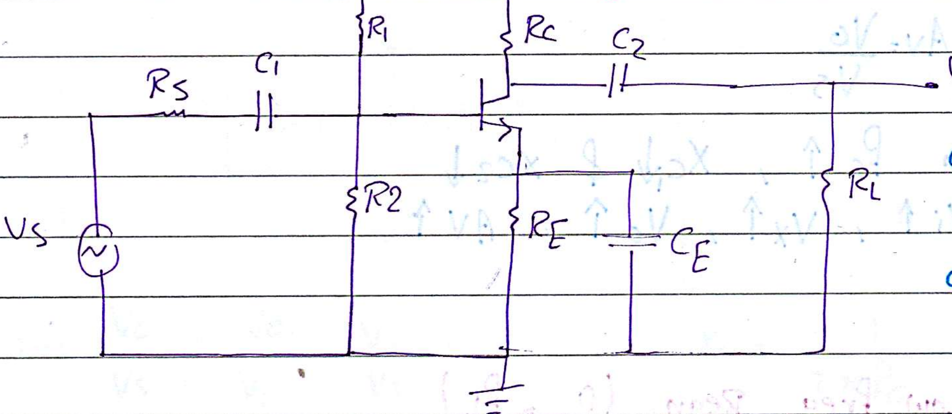
CH7

Frequency Response of Amp. Monday 22-8-2016

Av or AI → Unitless or in dB → $A_V(dB) = 20 \log \frac{V_o}{V_s}$

$A_I(dB) = 20 \log \frac{I_o}{I_s}$





C_1, C_2 → Coupling Cap

C_E → bypass Cap.

For example ~~X_I~~ $C_1 = 10\,\mu F$

$X_C = \frac{1}{2\pi f C}$

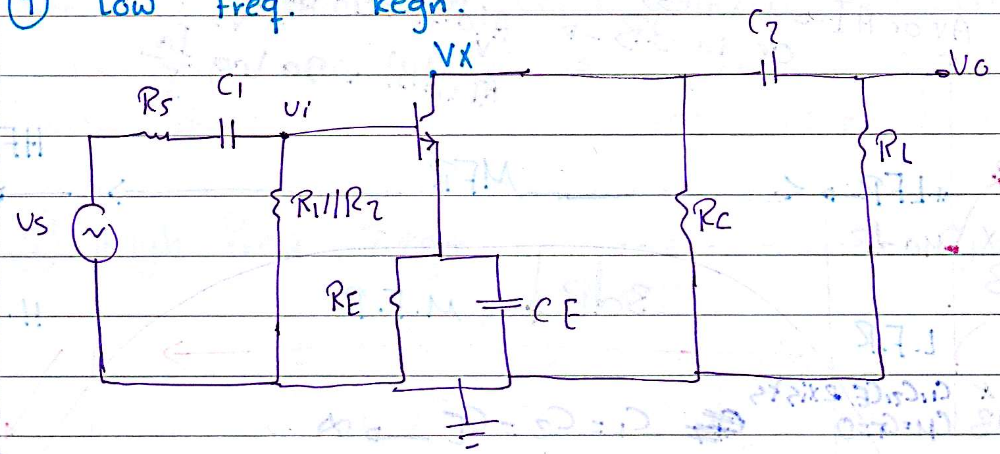
For $f = 10\,Hz$ → $X_C = \frac{1}{2\pi \times 10 \times 10^{-6}} = 1.7\,K\Omega$.

For $f = 10\,KHz$ → $X_C = \frac{1}{2\pi \times 10^4 \times 10^{-6}} = 1.7\,\Omega$.

For $f = 100\,KHz$ → $X_C = 0.17\,\Omega$.

CH7 Monday 22-8-2016

① Low Freq. Regn.



$$V_i = V_s \frac{R_i}{R_i + X_{C_1} + R_i}, \quad X_C = \frac{1}{2\pi f_C}$$

$$V_x = K V_i, \quad V_o = V_x \frac{R_L}{R_L + X_{C_2}}$$

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

when $f_C \uparrow$, $X_{C_1} \downarrow$ & $X_{C_2} \downarrow$
& $V_i \uparrow$, $V_x \uparrow$, $V_o \uparrow$, $AV \uparrow$

So:

in Low Freq. Regn ($0 \to f_L$)

In this Regn, the gain is Freq. dependant, such that as $f \uparrow$, $A \uparrow$, Due to effect of coupling (C_1, C_2) and bypass C_E capacitor, where as $f \uparrow$, $X_C \downarrow$ and since they are in series path of signal so $V_o \uparrow$, $AV \uparrow$

$V_s = 5 \sin(2\pi f t)$

② Medium Freq. Regn ($f_L \to f_H$)

$$A_v = -\frac{R_i}{R_i + R_s} \left[g_m (R_C // R_L) \right]$$

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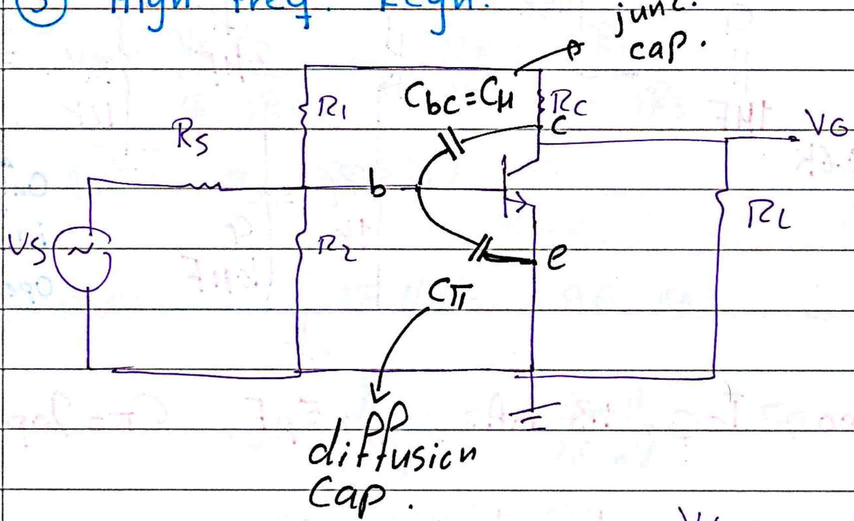
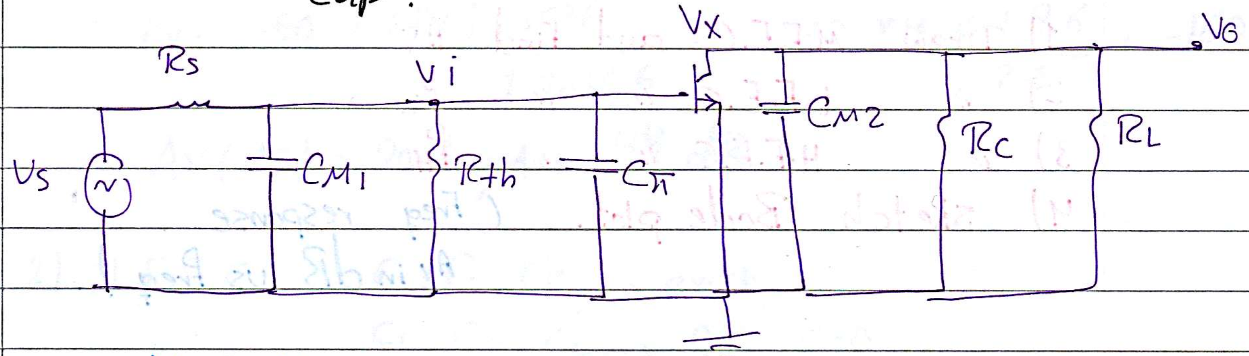
- In this Regn; All capacitors are considered (short cct)
- The Amp will behave as a pure resistance Amp and the gain will be freq. independant.

③ High freq. Regn.

$$C_j = \frac{C_{j0}}{\sqrt{1 + \frac{V_R}{V_{bi}}}}$$





$$A_V = \frac{V_o}{V_s} = \frac{V_o}{V_i} \cdot \frac{V_i}{V_s} \quad , \quad X_C = \frac{1}{2\pi f_C}$$

$$V_i = \frac{Z_i \cdot V_s}{Z_i + R_s} \quad , \quad V_o = K V_i = -g_m V_\pi (R_C \,//\, R_L \,//\, X_{CM2})$$

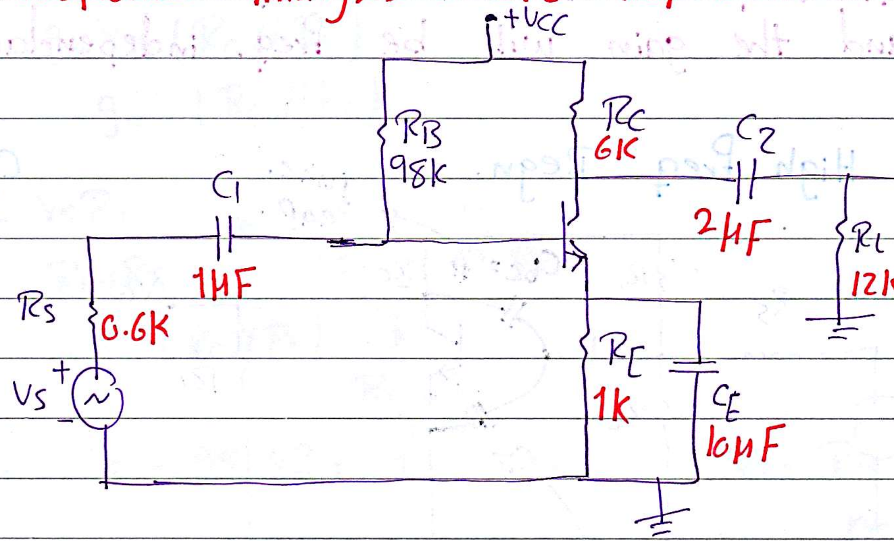
- In this Regn all Coupling cap and bypass cap are s.c but new stray capacitance appear effectivily (No physical existance)

($C_\mu \to$ junction cap. , $C_\pi \to$ diff cap.)

They appear in parallel for i/p and O/p side as $f\uparrow$, $X_C\downarrow$, $V_o\downarrow$, $A_V\downarrow$

- The Value of C_π and C_μ at low and Medium Rgn. is = Zero

Freq. response Analysis : C.E Amplifier

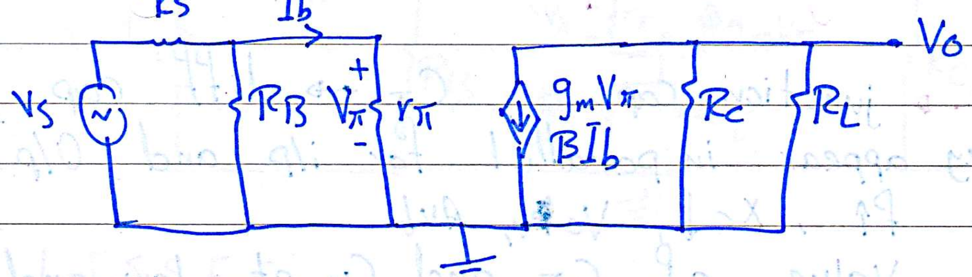


Only in H.F in M, L it's Open cct

Given $\beta = 100$, $I_{CQ} = 1.3$ mA., $C_\mu = 5pF$, $C_\pi = 20pF$

1) Draw M.F.E.C and find A_V
2) " L.F.E.C " " f_L
3) " H.F.E.C " " f_H
4) sketch Bode plot. (Freq response A_V in dB vs Freq).

1) M.F.E.C , $C_1, C_2, C_E \to$ S.C.
C_μ, C_π and $C_L \to$ O.C



$$A_V = \frac{V_o}{V_s} = \frac{V_o}{V_\pi} \cdot \frac{V_\pi}{V_s}$$

$$V_o = -g_m V_\pi (R_c // R_L)$$

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

$$V_\pi = \frac{V_s R_i}{R_i + R_s} \Rightarrow \frac{V_\pi}{V_s} = \frac{R_i}{R_i + R_s}$$

$$A_V = -g_m (R_c // R_L) \cdot \frac{R_i}{R_i + R_s}$$

~~A_V~~ $R_i = 98 // 2 = 1.96\ K\Omega$. ; $R_i = R_B // r_\pi$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = 2K\Omega.$$

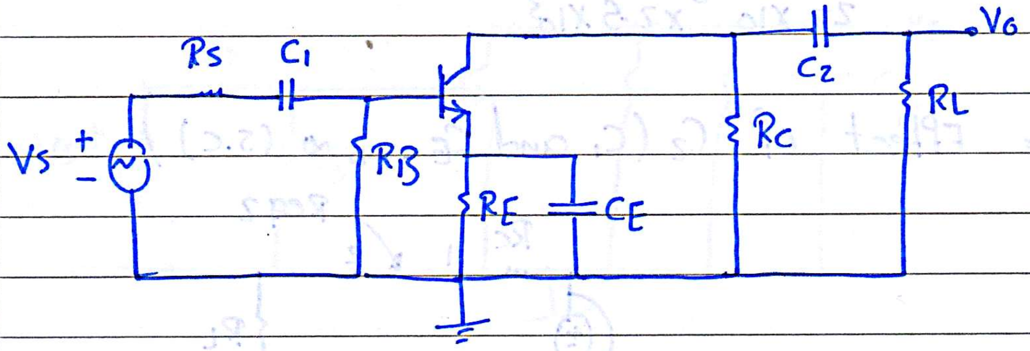
$$g_m = \frac{I_{CQ}}{V_T} = \frac{1.3\,mA}{26\,mV} = 50\ mA/V$$

$$A_V = -50\ (6 // 12)\ \frac{1.96}{1.96 + 0.6} = -50 \times 4 \times \frac{1.96}{2.5} = -160$$

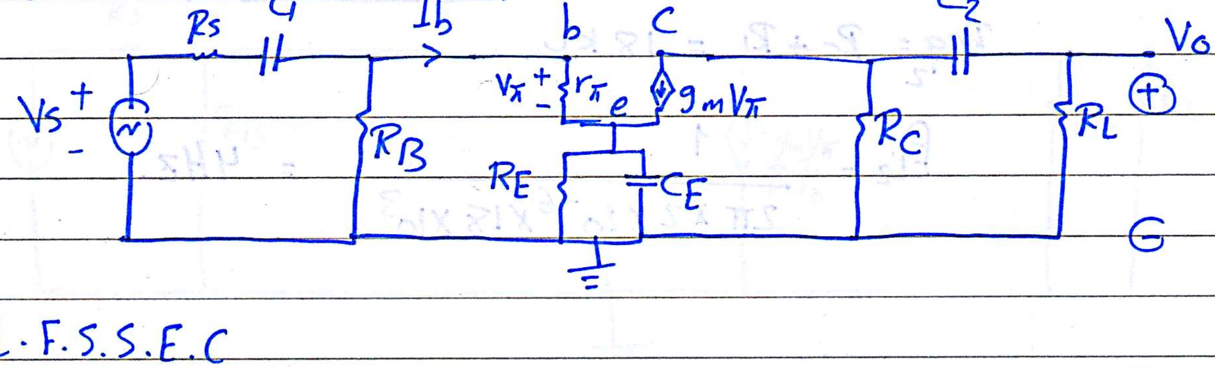
$$A_V(dB) = 20 \log A_V = 44\ dB$$

2) L.F.E.C $\quad C_1, C_2, C_E \rightarrow$ exist

$C_L, C_\pi, C_\mu \rightarrow$ O.C $\quad C = 0$



L.F.E.C :



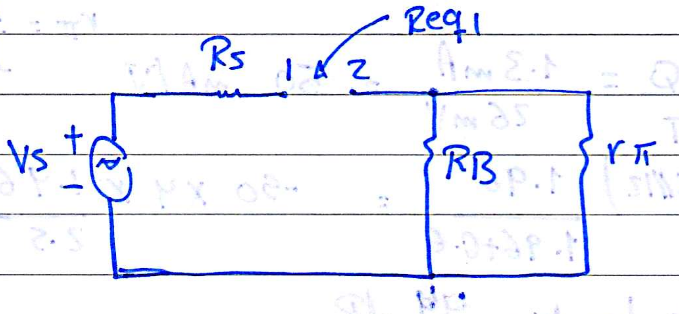
L.F.S.S.E.C

$$f_{L1} = \frac{1}{2\pi C_1 R_{eq1}} \quad , \ R_{eq1} : R_{th} \text{ seen by } C_1$$

$$f_{L2} = \frac{1}{2\pi C_2 R_{eq2}} \quad , \ R_{eq2} : R_{th} \text{ seen by } C_2$$

$$f_{LE} = \frac{1}{2\pi C_E R_{eqE}} \quad , \ R_{eqE} : R_{th} \text{ seen by } C_E$$

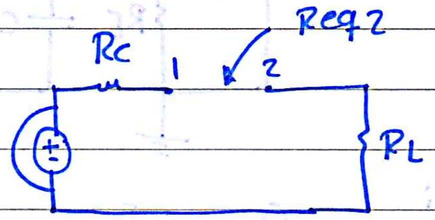
1) Effect of $C_1 \rightarrow [C_2$ and $C_E \rightarrow \infty]$



$$R_{eq1} = R_{12} = R_s + R_i = 0.6 + 1.96 = 2.56 \ K\Omega .$$

$$f_{L1} = \frac{1}{2\pi \times 10^{-6} \times 2.5 \times 10^3} = 62 \ Hz.$$

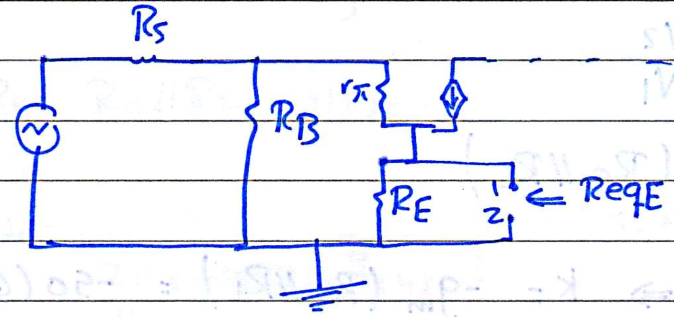
2) Effect of C_2 (C_1 and $C_E \rightarrow \infty$ (s.c))



$$R_{eq_2} = R_C + R_L = 18 \ K\Omega .$$

$$f_{L2} = \frac{1}{2\pi \times 2 \times 10^{-6} \times 18 \times 10^3} = 4 Hz.$$

2) Effect of C_E (C_1 and $C_2 \rightarrow$ S.C.)



$$R_{EqE} = \left[\frac{(R_S // R_B) + r_\pi}{\beta+1}\right] // R_E = 24\ \Omega.$$

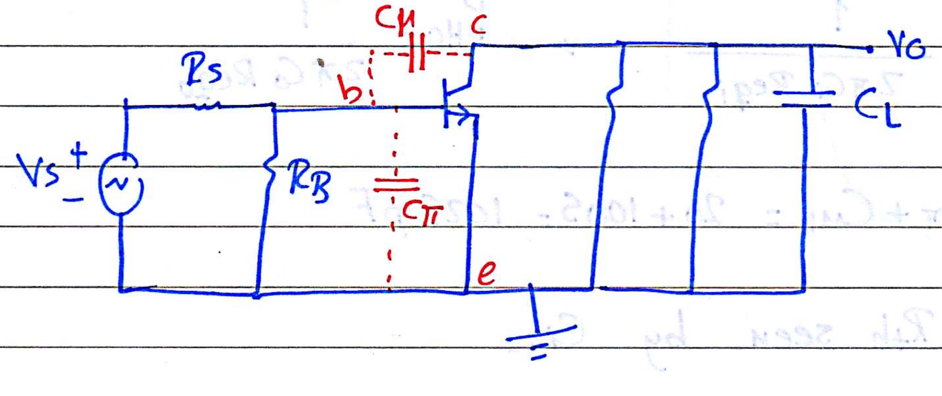
$$f_{LE} = \frac{1}{2\pi \times 10 \times 10^{-6} \times 24} = \frac{10^5}{48\pi} = 660\ \text{HZ}$$

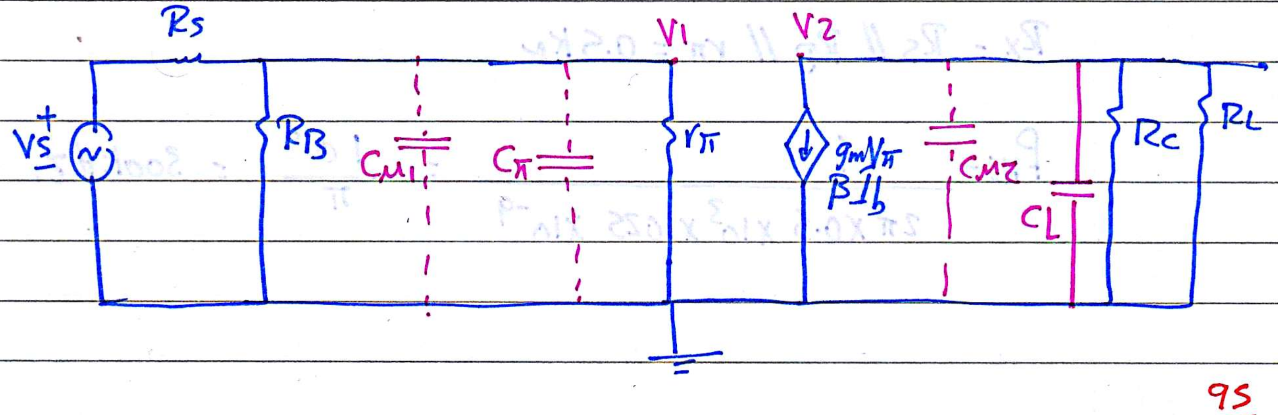
$\therefore$ F_{L} (effective) = 660 Hz (الأكبر)

$\therefore$ C_E determine F_L of the Amp.

3) H.F.R $C_1, C_2, C_E \longrightarrow$ S.C.

$C_\mu, C_\pi, C_L \rightarrow$ Exist.





$C_{M1} = C_M(1-K)$, $C_{M2} = C_M\left(1-\frac{1}{K}\right)$

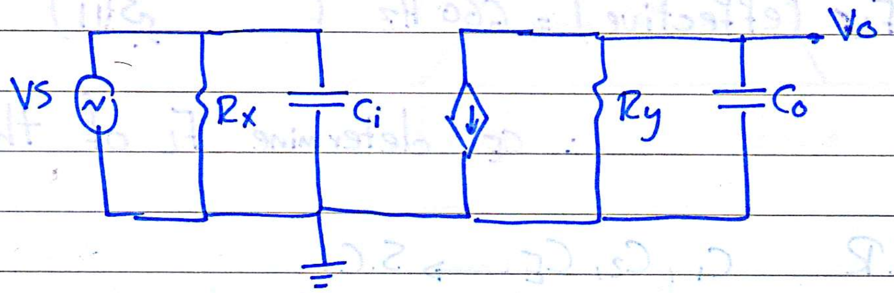
where $K = \frac{V_2}{V_1}$

$V_2 = -g_m V_\pi (R_C // R_L)$

$V_1 = V_\pi \Rightarrow K = -g_m (R_C // R_L) = -50(6//12) = -200$

$\therefore C_{M1} = 5(1+200) = 1005\,pF$

$C_{M2} = 5\left(1-\frac{1}{200}\right) \simeq 5\,pF$



$f_{Hi} = \frac{1}{2\pi C_i R_{eqi}}$, $f_{Ho} = \frac{1}{2\pi C_o R_{eqo}}$

$C_i = C_\pi + C_{M1} = 20 + 1005 = 1025\,pF$

R_X = R_{th} seen by C_i :-

$R_X = R_S // R_B // r_\pi = 0.5\,K\Omega$.

$f_{Hi} = \frac{1}{2\pi \times 0.5 \times 10^3 \times 1025 \times 10^{-9}} = \frac{10^6}{\pi} = 300\,KHZ$.

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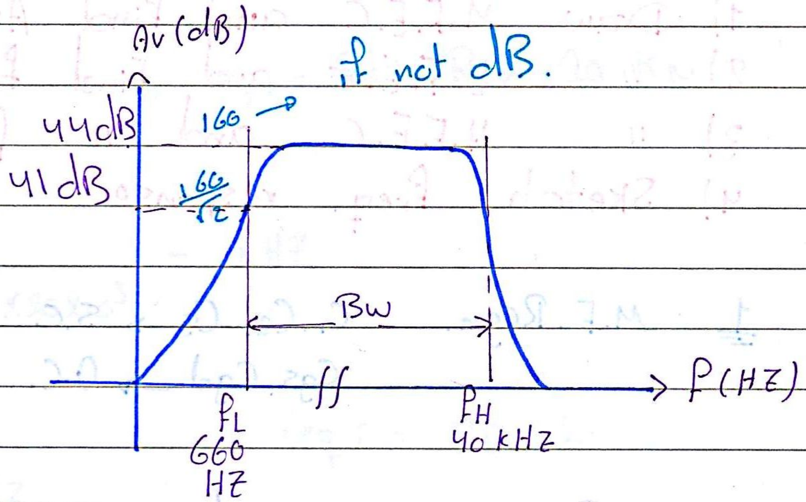
$C_o = C_{m2} + C_L = 5pF + 1nF = 1005\,pF.$

R_y = R_{th} seen by C_o

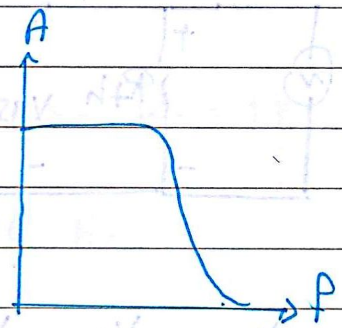
$R_y = R_c // R_L = 4k\Omega.$

$$f_{Ho} = \frac{1}{2\pi \times 1.005\times10^{-9} \times 4\times10^{3}} = 40\,kHz.$$

$\therefore$ f_H eff. $= 40\,kHz.$



. if all $C \to \infty$



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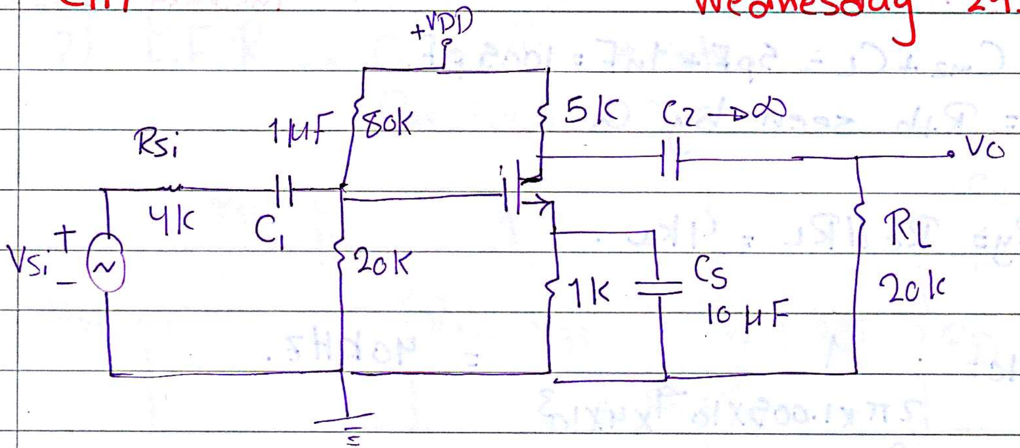


$K_n = 2mA/V^2$

$V_{TN} = 1V$

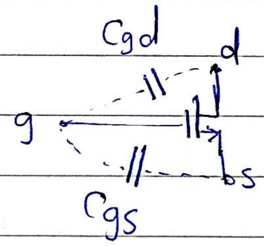
$I_{DQ} = 2mA$

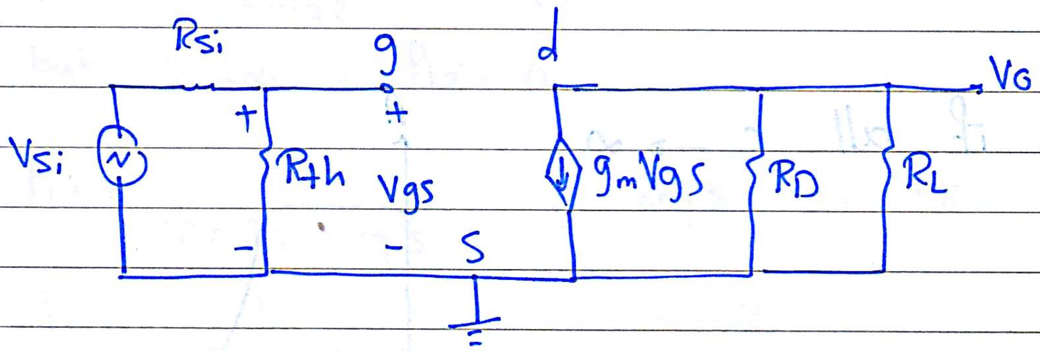
$C_{gs} = 2pF$

$C_{gd} = 100fF$

1) Draw M.F.E.C and find Avm.
2) " L.F.E.C and find f_L
3) " H.F.E.C and " f_H.
4) Sketch freq. response.

1. M.F. Regn. $C_1, C_2, C_s \to$ S.C.
$C_{gs}, C_{gd} \to$ O.C.





$$A_V = \frac{V_o}{V_{si}} = \frac{V_o}{V_{gs}} \cdot \frac{V_{gs}}{V_{si}} = -g_m (R_D // R_L) \cdot \frac{R_{th}}{R_{th}+R_{si}}$$

$$g_m = 2\sqrt{K_n I_D} = 2\sqrt{2\times2} = 4\ mA/V$$

$$A_V = -4 \times (5//20) \left(\frac{16}{16+4}\right) = -16 \times 0.8 = -12.8 \to A_{VM} = 12.8$$

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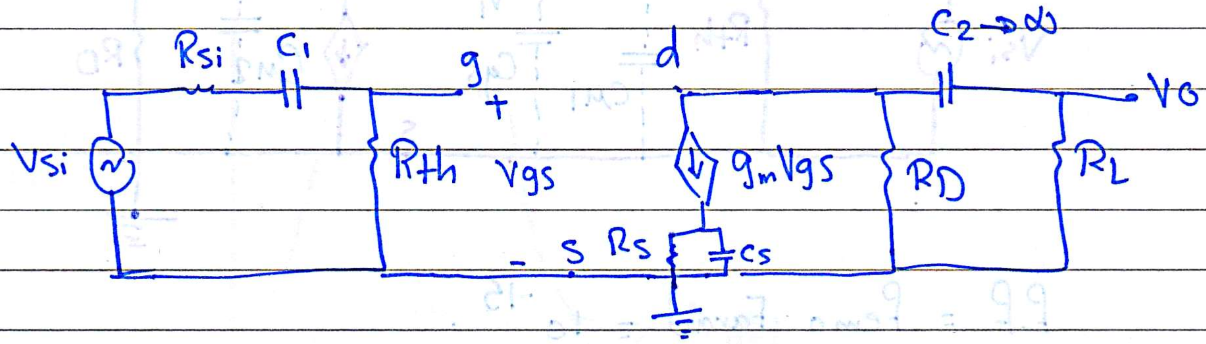
2) L.F.R $\rightarrow C_1, C_2, C_S$ exists.

$C_{gs}, C_{gd} \rightarrow$ O.C.



$$f_{L_1} = \frac{1}{2\pi C_1 R_{eq_1}} \quad , \quad R_{eq_1} = R_{si} + R_{th} = 20\ K\Omega.$$

$$f_{L_1} = \frac{1}{2\pi \times 1 \times 10^{-6} \times 20 \times 10^3} = 8\ HZ.$$

$$f_{L_2} = \frac{1}{2\pi C_2 R_{eq2}} \quad , \quad R_{eq\,2} = R_D + R_L$$

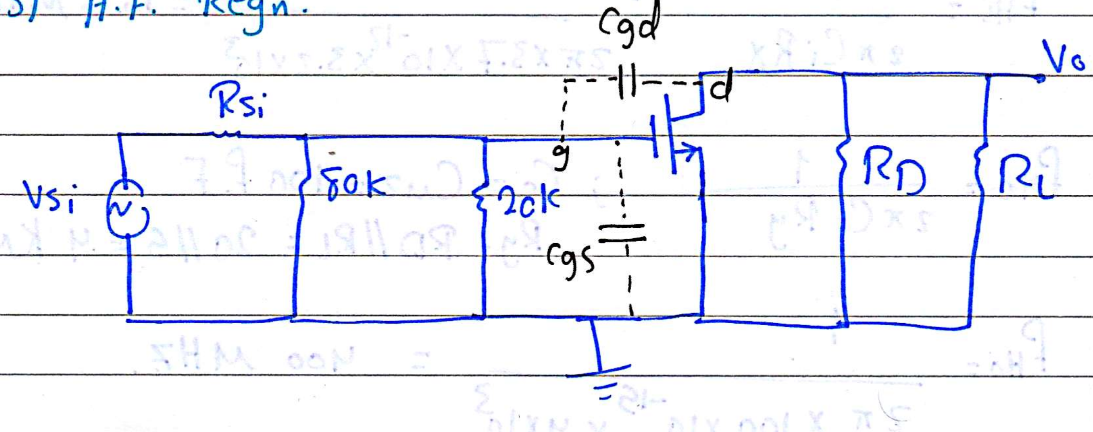
but $C_2 \rightarrow \infty \quad \therefore \quad f_{L2} = 0$

$$f_{L3} = \frac{1}{2\pi C_S \cdot R_{eq\,S}} \quad , \quad R_{eq\,S} = R_S = 1K$$

$$f_{L3} = \frac{1}{2\pi \times 10 \times 10^{-6} \times 1 \times 10^3} = 16\ Hz$$

$\therefore f_L = 16\ Hz.$

3) H.F. Regn.



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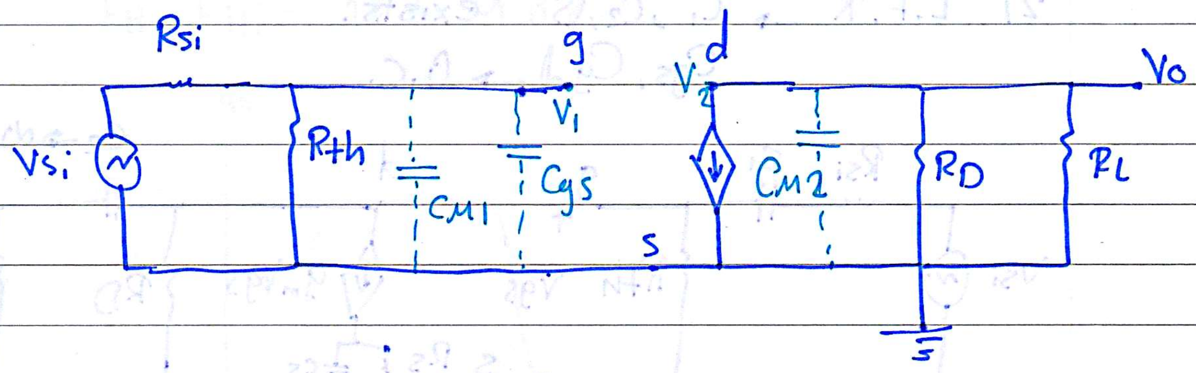


f.F = femo Farad = 10^{-15}.

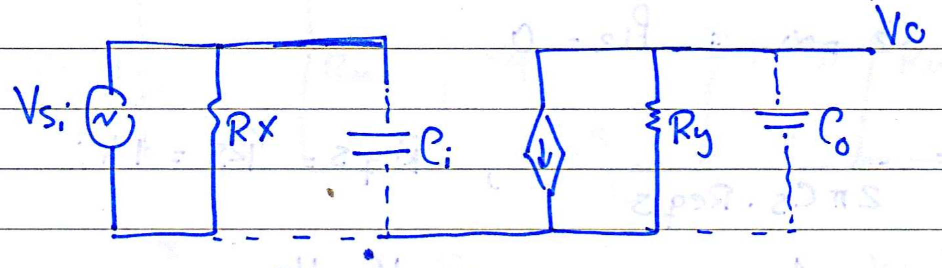
$C_{M1} = C_{gd}(1-K)$; $K = \frac{V_2}{V_1} = \frac{-g_m \cancel{V_{gs}}(R_D // R_L)}{\cancel{V_{gs}}}$

$C_{M2} = C_{gd}\left(1 - \frac{1}{k}\right)$ $= -g_m (R_D // R_L)$

$= -4 \times 4 = -16$

$C_{M1} = 100 \times 10^{-15} (1+16) = 1.7 pF.$

$C_{M2} = 100 \times 10^{-15}\left(1 + \frac{1}{16}\right) \simeq 100 \text{ f.F.}$



$C_i = C_{M1} + C_{gs} = (1.7 + 2) = 3.7 pF.$

$R_X = R_{th} // R_{si} = 4 // 16 = 3.2 K\Omega.$

$f_{Hi} = \frac{1}{2\pi C_i R_X} = \frac{1}{2\pi \times 3.7 \times 10^{-12} \times 3.2 \times 10^{3}} = 16.6 MHz$

$f_{Ho} = \frac{1}{2\pi C_o R_y}$; $C_o = C_{M2} = 100 \text{ f.F}$

$R_y = R_D // R_L = 20 // 5 = 4 K\Omega.$

$f_{Ho} = \frac{1}{2\pi \times 100 \times 10^{-15} \times 4 \times 10^{3}} = 400 MHz.$

100

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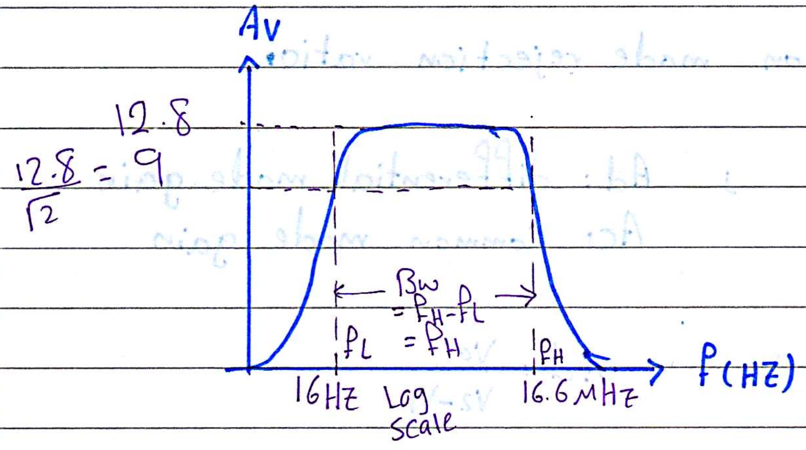
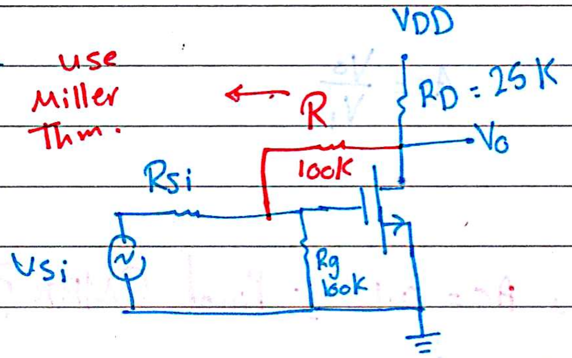
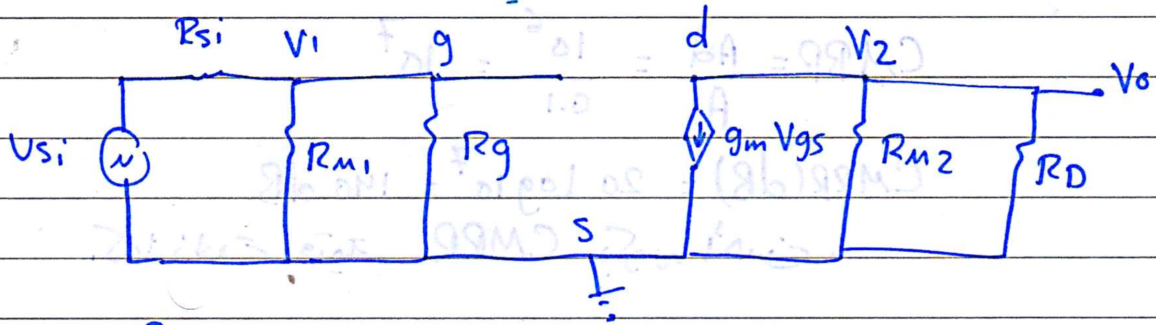
$\therefore f_H = f_{Hi} = 16.6\ MHZ$



. Note. use Miller Thm.

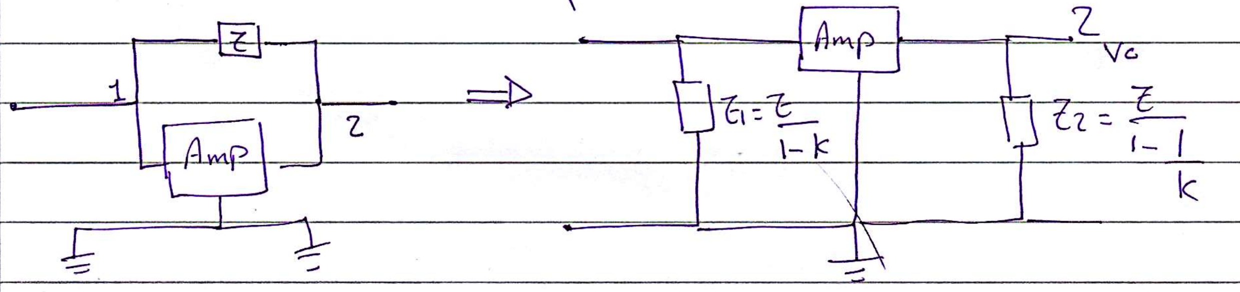


Find Av, Ro, Ri



$R_{M1} = \frac{R}{1-K}$, $R_{M2} = \frac{R}{1-\frac{1}{K}}$; $K = \frac{V_2}{V_1}$

Miller Thm:

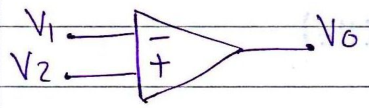


. Note — Wednesday 24-8-2016

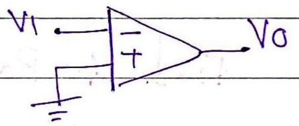
Op-Amp

CMRR : Common mode rejection ratio.

$$CMRR = \frac{A_d}{A_c}$$; A_d: differential mode gain
A_c: Common mode gain



$$A_d = \frac{V_o}{V_2 - V_1}$$



$$A_c = \frac{V_o}{V_1}$$

Ex $A_d = 10^6$, $A_c = 0.1$; find CMRR?

$$CMRR = \frac{A_d}{A_c} = \frac{10^6}{0.1} = 10^7$$

$$CMRR(dB) = 20 \log 10^7 = 140\ dB$$

كلما زادت قيمة CMRR يكون أحسن.