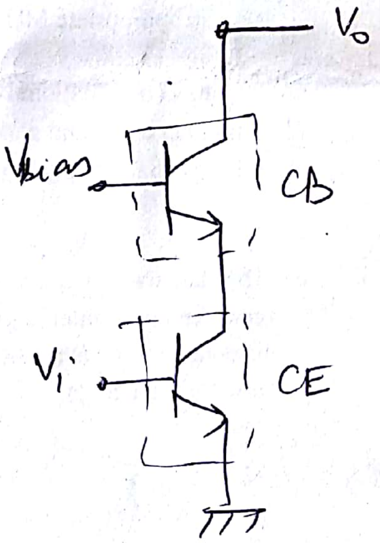
SOLUTION OF MID-SEM EXAM PAPER (NOV 2018)

SEM-V ; BRANCH - EE ; PAPER: ANALOG ELECTRONICS.

1(i) (d) Using current-shunt f/b means the sample is taken from o/p current and at the i/p, it is connected in shunt ~~with~~ through f/b n/w to the i/p current; Hence, such a feedback topology is used in a current amplifier which ideally has a zero i/p imp. and infinite o/p imp.

Hence, the feedback (since it tends the performance to the ideal one) will decrease i/p imp and increase o/p imp.

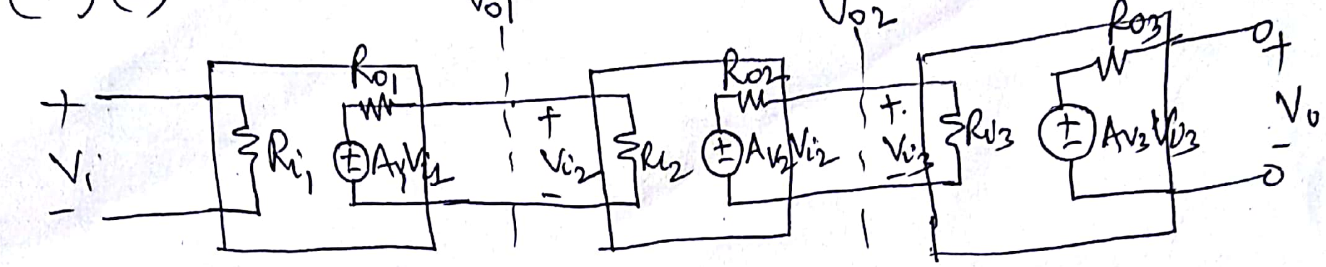
(ii) (b)



A cascode amp is a CE - CB configuration

P.T.O.

(iii) (C)



$R_{i_1} = R_{i_2} = R_{i_3} = 1\,k\Omega$

$A_{v_1} = A_{v_2} = A_{v_3} = 50$

$R_{o_1} = R_{o_2} = R_{o_3} = 250\,\Omega = 0.25\,k\Omega$

$$A_v = \frac{V_o}{V_i} = \frac{V_o}{V_{o2}} \times \frac{V_{o2}}{V_{o1}} \times \frac{V_{o1}}{V_i}$$

$V_{o2} = V_{i3}$ & $V_{o1} = V_{i2}$. & $V_{i_1} = V_i$.

$$\Rightarrow A_v = \frac{V_o}{V_{i3}} \times \frac{V_{o2}}{V_{i2}} \times \frac{V_{o1}}{V_{i1}} \quad \text{--- (1)}$$

~~Now~~, $$\Rightarrow A_v = \left(\frac{A_{v3}\cancel{V_{i3}}}{\cancel{V_{i3}}}\right) \times \left(\frac{A_{v2}\cancel{V_{i2}} \times R_{i3}}{(R_{o2}+R_{i3})\cancel{V_{i2}}}\right) \times \left(\frac{A_{v1}\cancel{V_{i1}} \times R_{i2}}{(R_{o1}+R_{i2})\cancel{V_{i1}}}\right)$$

$$= A_{v3} \cdot A_{v2} \cdot A_{v1} \cdot \frac{R_{i3}}{(R_{o2}+R_{i3})} \cdot \frac{R_{i2}}{(R_{o1}+R_{i2})}$$

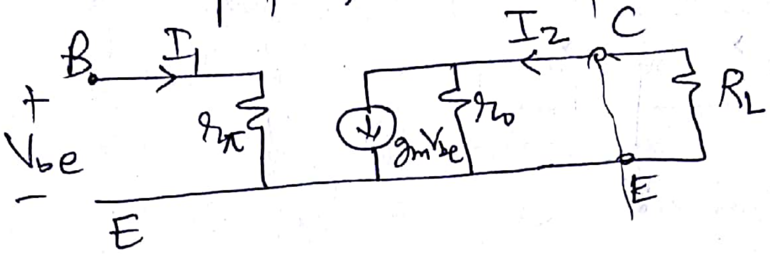
$$= 50 \times 50 \times 50 \times \frac{1}{1.25} \times \frac{1}{1.25}$$

$$= 80{,}000$$

in dB; $20\log_{10} A_v \simeq 98$ dB Ans

(iv) (b)

For a CE amplifier:



Current gain; $A_I = -\frac{I_2}{I_1}$

$I_1 = \frac{V_{be}}{r_\pi}$

& $-I_2 = -g_m V_{be} \cdot \frac{r_o}{r_o + R_L}$

$$\Rightarrow A_I = \left(-\frac{g_m V_{be} \cdot r_o}{r_o + R_L}\right)\left(\frac{1}{V_{be}/r_\pi}\right)$$

$$= -\frac{g_m r_o r_\pi}{r_o + R_L}$$

if $r_o >> R_L$,

$A_I \simeq -g_m r_\pi$

$\Rightarrow |A_I| = g_m r_\pi$ Ans.

(v)(b)

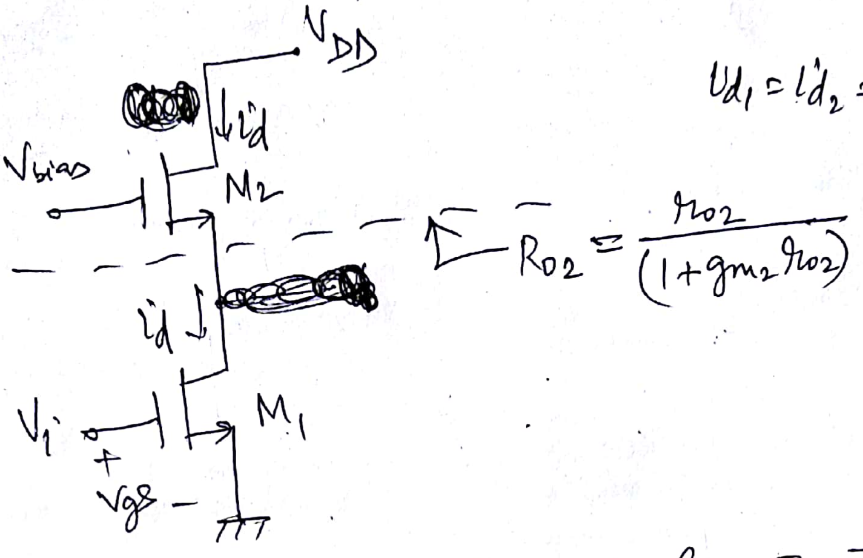
This is a Colpitt oscillator with $f_{osc} = \frac{1}{2\pi\sqrt{L C_{eq}}}$

where $C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{2 \times 2}{2+2} = 1\,pF$

$$\Rightarrow f_{osc} = \frac{1}{2\pi\sqrt{10 \times 10^{-6} \times 10^{-12}}} = \frac{1}{2\pi \times 3.16 \times 10^{-9}}$$

$= 50.39$ MHz.

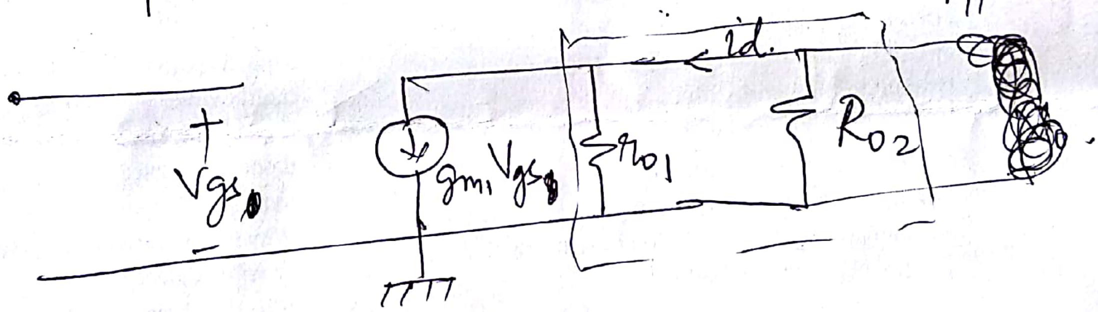
(2)



$i_{d_1} = i_{d_2} = i_d$

M_2 acts as a load for M_1 with $R_{o2} = \frac{r_{o2}}{1+g_{m2} r_{o2}}$

Considering small signal model:



(i) Calculation of overall g_m: $\left(g_m = \frac{\partial i_d}{\partial V_{gs}} \right)$

Now, $i_d = g_{m1} V_{gs} \cdot \frac{r_{o1}}{R_{o2} + r_{o1}}$

$$\Rightarrow \frac{\partial i_d}{\partial V_{gs}} = g_m = \frac{g_{m1} r_{o1}}{r_{o1} + R_{o2}}$$

$$= \frac{g_{m1} r_{o1}}{r_{o1} + \frac{r_{o2}}{1+g_{m2} r_{o2}}}$$

if $g_{m2} r_{o2} >> 1$, then

$$\boxed{g_m \simeq \frac{g_{m1} r_{o1}}{r_{o1} + 1/g_{m2}}}$$ Ans.

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NOTE: This expression can be further simplified as follows:

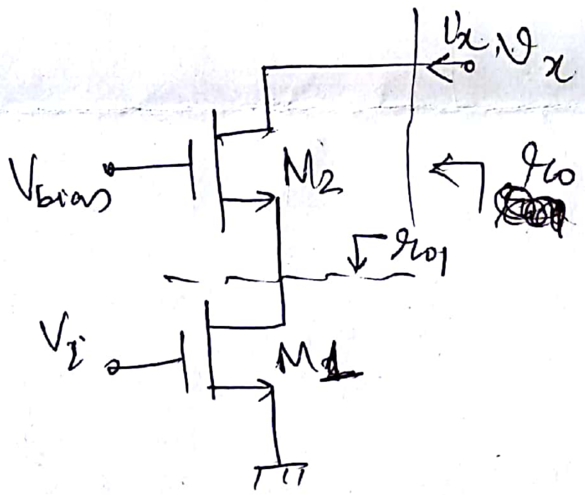
$$g_m \simeq \frac{g_{m1} r_{o1} \cdot g_{m2}}{r_{o1} g_{m2} + 1}$$

If $g_{m2} r_{o1} >> 1$

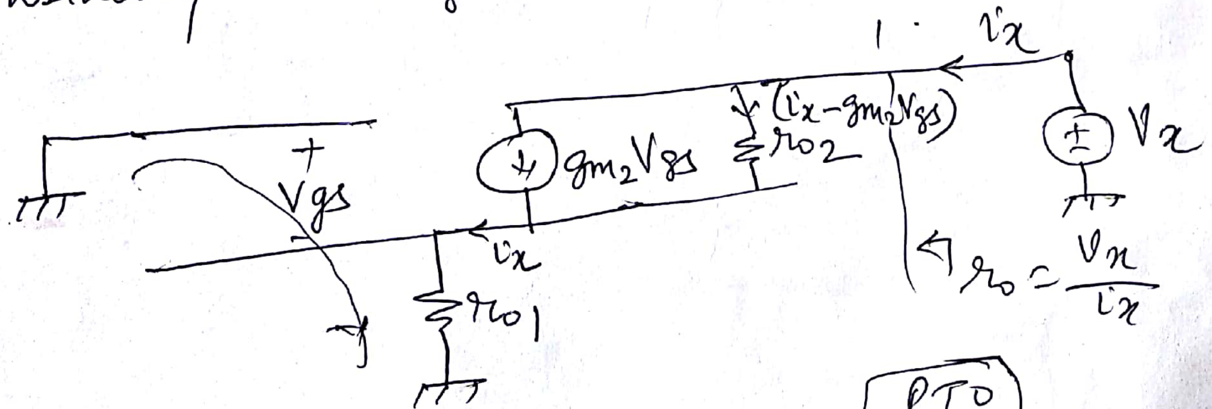
$$\Rightarrow \quad g_m \simeq \frac{g_{m1} r_{o1} \cdot g_{m2}}{r_{o1} g_{m2}}$$

$$\Rightarrow \quad g_m \simeq g_{m1} \quad \underline{\text{Ans.}}$$

(ii) Calculation of $r_o = \dfrac{\partial V_{ds}}{\partial i_d} = \dfrac{V_x}{i_x}$



For calculation of r_o; i/p voltage source must be short-ckted. M1 will appear as a load r_{o1} for M2. Considering small signal model.



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Now, applying KVL in i/p loop:

$$V_{gs} + i_x r_{o1} = 0 \Rightarrow V_{gs} = -i_x r_{o1} \quad \text{—(1)}$$

Applying KVL in o/p loop:

$$V_x = (i_x - g_{m2} V_{gs}) r_{o2} + i_x r_{o1}$$

$$= (i_x + i_x g_{m2} r_{o1}) r_{o2} + i_x r_{o1}$$

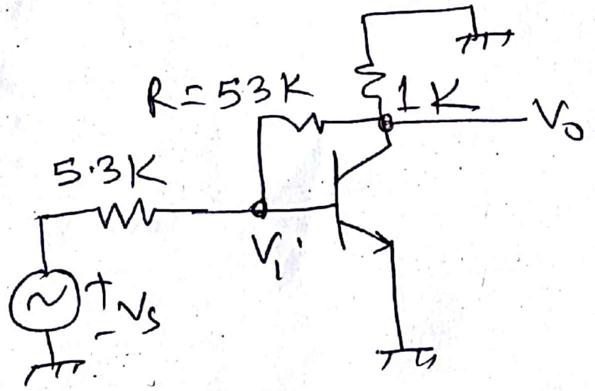
$$\Rightarrow \frac{V_x}{i_x} = (1 + g_{m2} r_{o1}) r_{o2} + r_{o1}$$

$$\Rightarrow \boxed{r_o = r_{o1} + r_{o2} + g_{m2} r_{o1} r_{o2}} \text{ Ans.}$$

(3) Since $h_{ie} = \infty \Rightarrow I_b = 0$

but since $h_{fe} \to \infty \Rightarrow I_c$ is finite

For small signal analysis, let us redraw the ckt as follows:



Using Miller's Theorem:

$$R_1 = \frac{R}{1+K} \quad \text{and} \quad R_2 = \frac{R}{1-K} \quad \because R = 53K.$$

where ~~$K = A_v \left(= \frac{V_o}{V_b} \right)$~~ $K = \frac{V_o}{V_i}$

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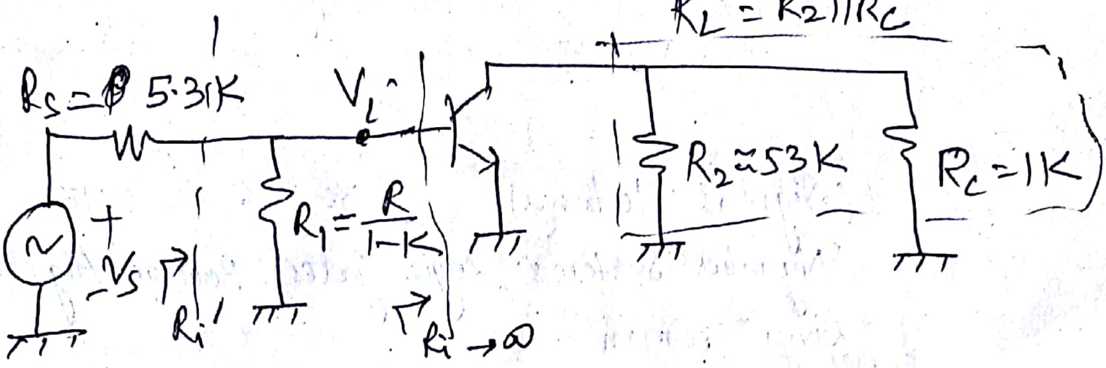


$$R_L = R_2 || R_C = 53 || 1 = 0.981\, K\Omega.$$

Voltage gain; $K = \frac{V_o}{V_i} = \frac{-h_{fe} R_L}{R_i} \simeq -R_L = -981$

$[\because h_{fe} \to \infty$ and $R_i = h_{ie} \to \infty]$

$$\Rightarrow R_1 = \frac{R}{1-K} = \frac{53}{1+981} = 54\,\Omega$$

$$V_i = \frac{R_1}{R_s + R_1} V_s = \frac{54}{54+5300} V_s$$

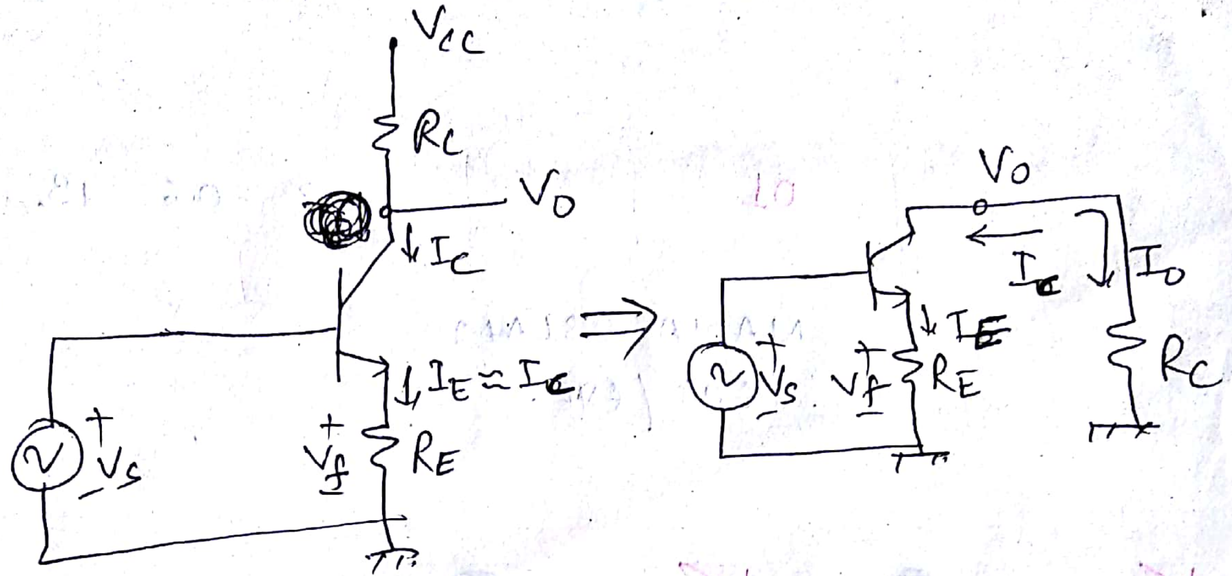
$$\Rightarrow \frac{V_i}{V_s} \simeq 0.01$$

$\Rightarrow$ Voltage gain, $A_{vs} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \times \frac{V_i}{V_s} = K \frac{V_i}{V_s}$

or, $A_{vs} = -981 \times 0.01$

or, $\boxed{A_{vs} = -9.81}$ Ans.

4(i)



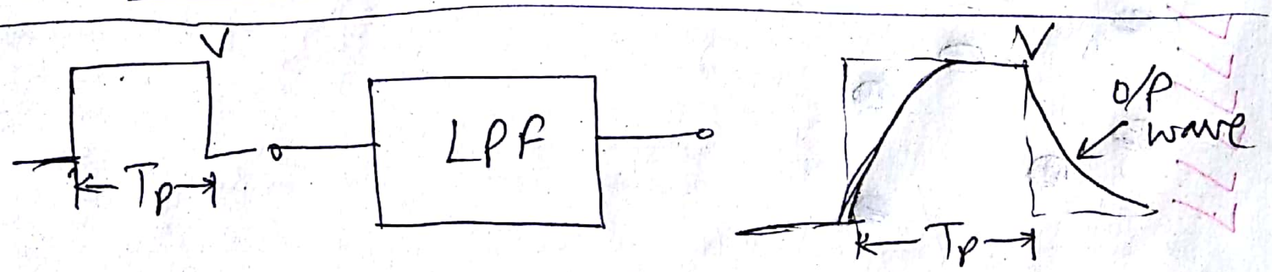
feedback topology: Current-series
The sampled signal is the load current 'I_o' and the feedback signal is voltage 'V_f' across 'R_E'.

$$\beta = \frac{V_f}{I_o} = \frac{I_E R_E}{I_o}$$

but $I_E \simeq I_C = -I_o$

$$\Rightarrow \boxed{\beta \simeq -\frac{I_o R_E}{I_o} = -R_E}$$ Ans.

(ii)



Let us consider a simple RC n/w as a first order LPF.

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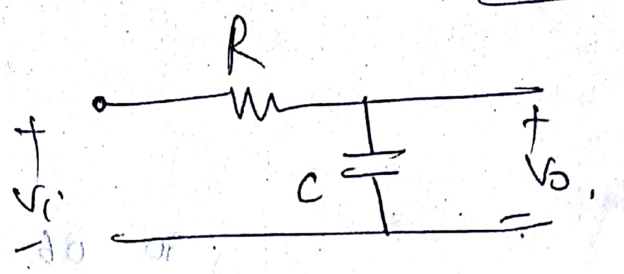

Since the ~~o/p~~ capacitor voltage cannot change instantaneously, the o/p starts from zero and rises towards the steady state value 'V'.

The o/p is given as:

$$V_o = V\left(1 - e^{-t/RC}\right) \quad \text{--- (1)}$$

where RC is the charging time constant, 'τ'.
Now 'τ' also decides the high 3dB freq. ~~for~~ of the amplifier used to amplify ~~this~~ signal without excessive distortion.

Let us consider rise time, t_r be the time required for 10% rise in O/p voltage. Then from eqn (1),

$$\Rightarrow \quad 0.1\,V = V\left(1 - e^{-t_r/RC}\right)$$

$$\Rightarrow \quad t_r = 2.2RC = \frac{0.2}{2\pi f_H} = \frac{0.35}{f_H}$$

where $2\pi f_H = \frac{1}{\tau}$ or; $f_H = \frac{1}{2\pi RC}$

Choosing f_H equal to the reciprocal of pulse width, $\left(f_H = \frac{1}{T_P}\right)$, we have $\boxed{t_r = 0.35\,T_P}$

Q.5(i) & (ii) are Q.6 are derivations or theoretical questions which are present in class notes.