Slide No: 1

Biasing for a BJT Amplifier

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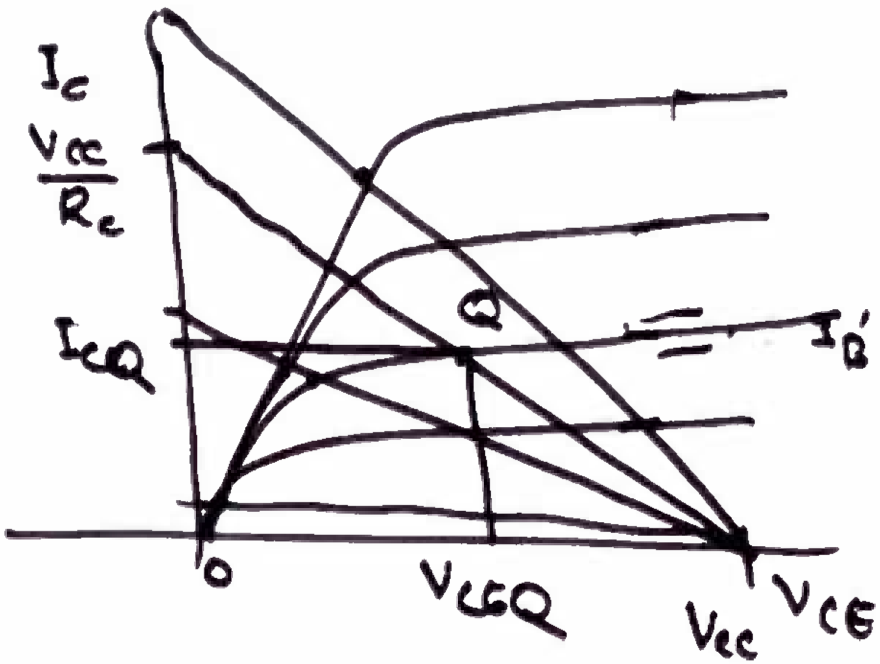
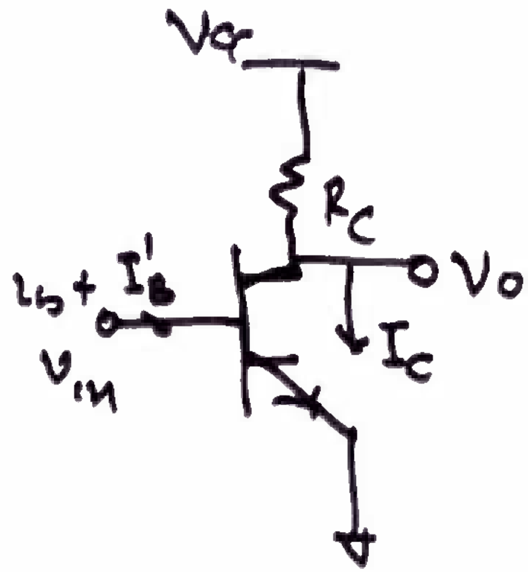
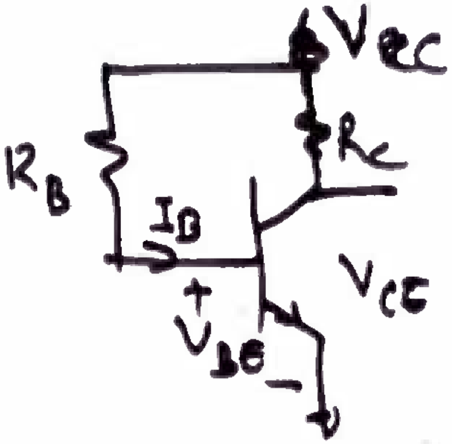




$$V_{cc} = I_C R_c + V_{CE}$$

Slide No: 2

BJT Biasing



$V_{CC} = 12V$

$\beta = 100$

$V_{BE_{on}} = 0.7V$

$V_{CEQ} = 6V$

$I_{CQ} = 1mA$

$I_{CQ} = 1mA$

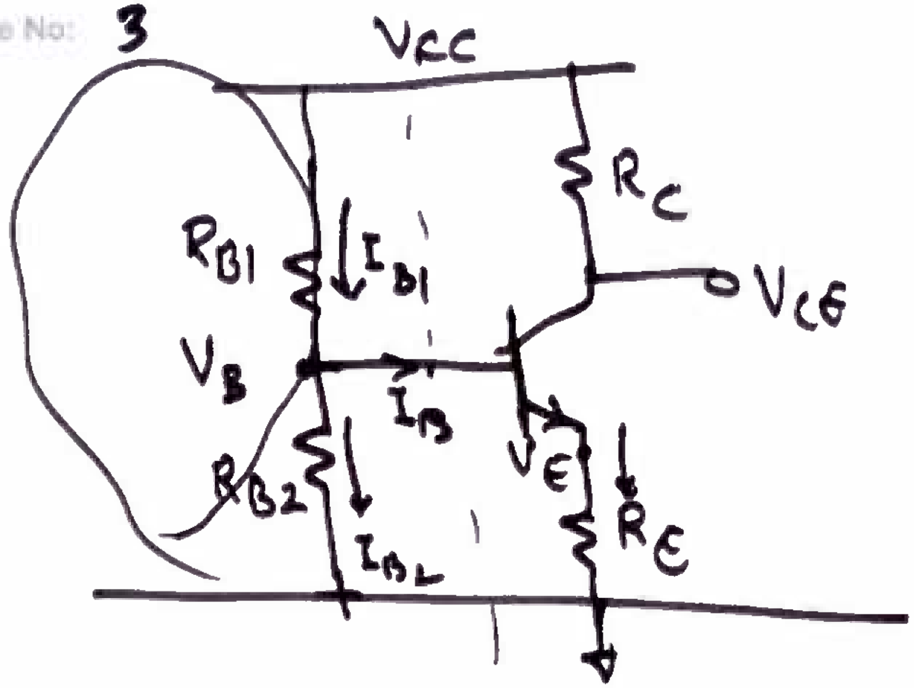
$$V_{CE} = V_{CC} - I_C R_C \quad -(1)$$

$$I_{BQ} = \frac{1mA}{100} = 10\,\mu A$$

$$V_{CC} = I_B \cdot R_B + V_{BE_{on}} \quad -(2)$$

$R_C = 6\,K\Omega$. $\quad R_B \cong 1.1\,M\Omega$

Slide No: 3



$$I_{B1} = I_{B2} + I_B$$

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

$$I_E = I_B + I_C$$

$$I_E = (\beta + 1) I_B$$

$$I_C = \beta I_B$$

$$I_E R_E + V_{BEO} = V_B$$

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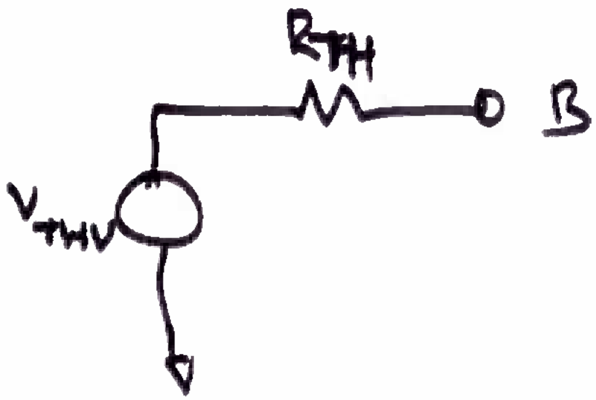
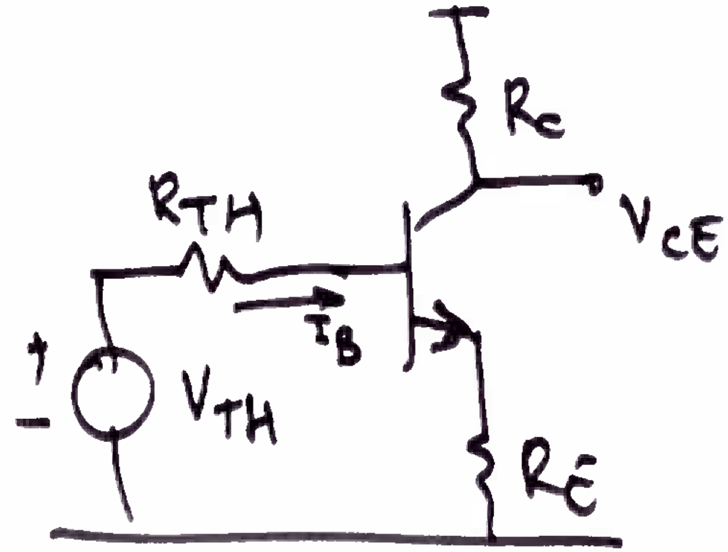


$$V_{TH} = \frac{R_{B2}}{R_{B1}+R_{B2}} \cdot V_{CC}$$

$$R_{TH} = R_{B1} \parallel R_{B2}$$



$$V_{THQ} = 1.79 = I_{BQ} R_{TH} + V_{BEon} + I_{EQ} \cdot R_E$$

$$I_{EQ} = (\beta_0 + 1) I_{BQ}$$

$$I_{BQ} = 21.6 \ \mu A$$

$$I_{CQ} = 100 \times 21.6 \ \mu A = 2.16 \ mA$$

$$I_{EQ} = 101 \times 21.6 \ \mu A = 2.18 \ mA$$

$$V_{CEQ} = V_{CC} - (I_{CEQ} R_C + I_{EQ} R_E) = 4.8 V$$

$$\boxed{\begin{matrix} I_{CQ} = 2.16 \ mA \\ V_{CEQ} = 4.8 V \end{matrix}}$$

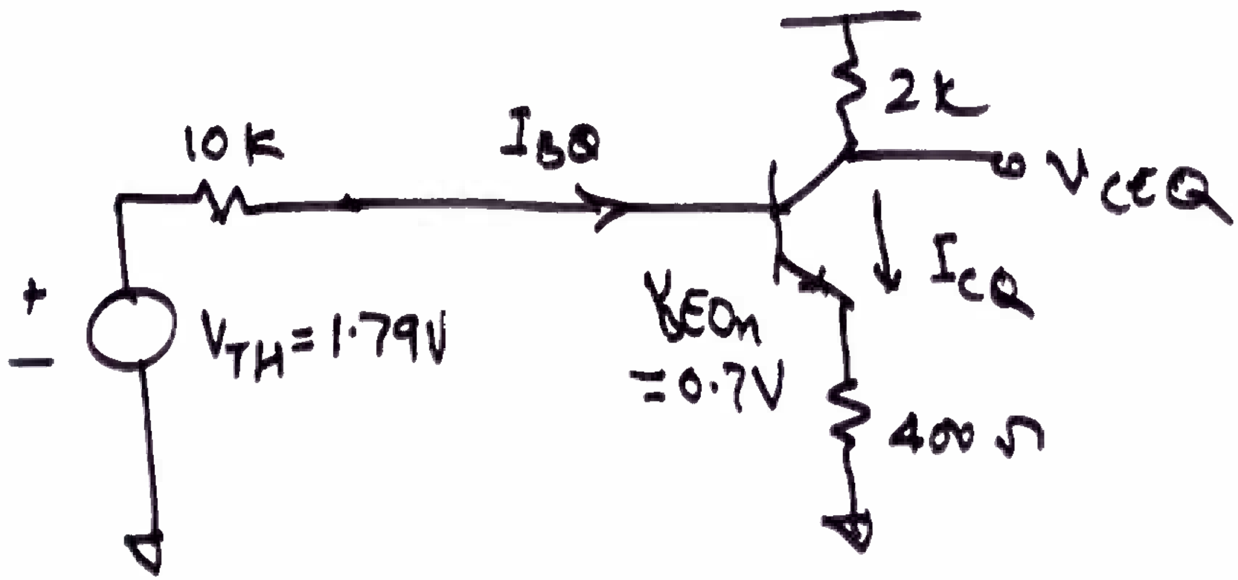
Slide No: 6

$R_{B1} = 56K \quad R_{B2} = 12.2k$

$R_C = 2K \quad R_E = 400\ \Omega \quad \beta = 100$

$V_{CC} = 10V \quad V_{BEon} = 0.7V$

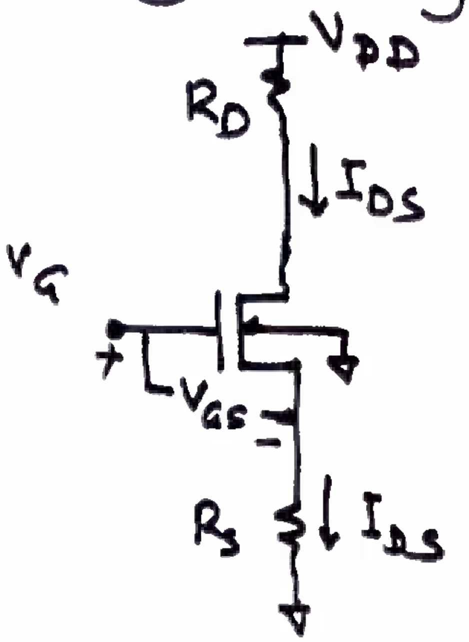
$V_{TH} = 1.79V \quad R_{TH} = 10K$



Slide No: 7

MOSFET Amplifiers.

(1) Biasing (DC operation)



Clearly $V_G = V_{GS} + I_{DS} R_S$

However $I_{DS} = \frac{\beta}{2}(V_{GS} - V_T)^2$

$= \frac{\beta}{2} V_{ov}^2$

Assume $[\lambda = 0]$

But $V_{GS} = V_G - I_{DS} R_S = V_G - \frac{\beta}{2} V_{ov}^2 \cdot R_S$

Hence fixing V_G, we can fix V_{GS}.

R_S is called Degeneration resistance

Slide No: 8

Example from (SMC)

Let $\beta_n = 1 mA/V^2$ $\quad I_{DS} = \frac{1}{2} mA$

$\lambda = 0$ $\quad V_{DD} = 15 V$ $\quad V_T = 1.0 V$

$R_D = 10 K\Omega$ $\quad R_s = 10 K\Omega = 10K$

$$\therefore V_{DS} = V_{DD} - I_{DS}(R_D + R_s)$$

$$= 15 - 0.5(20 \times 10^3)10^{-3} = 15 - 10 = 5V$$

For Saturation $V_{DS} > V_{GS} - V_T$

or $5 + 1 > V_{GS}$ or $V_{GS} < 6V$

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But $V_G = V_{GS} + I_{DS} R_S$

$= V_{GS} + 0.5 \times 10^{-3} \times 10 \times 10^{3}$

$= V_{GS} + 5$

We have $I_{DS} = 0.5 \times 10^{-3} = \frac{\beta_n}{2} (V_{GS} - V_T)^2$

or $\sqrt{\frac{2 \times 0.5 \times 10^{-3}}{1 \times 10^{-3}}} + 1V = V_{GS}$

or $V_{GS} = 2\ V$

$\therefore\ V_G = 2 + 5 = 7\ V$

Amplifier (Common Source)

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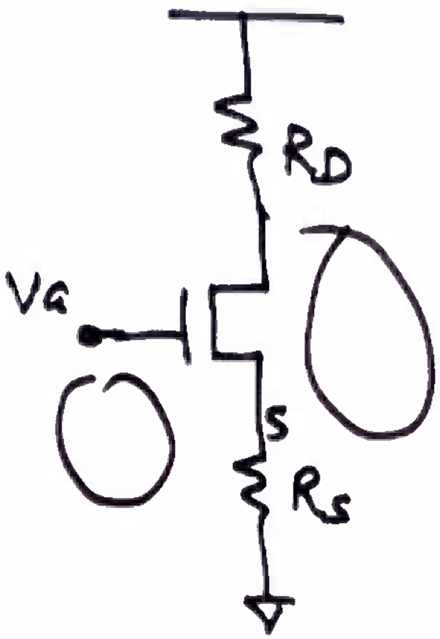

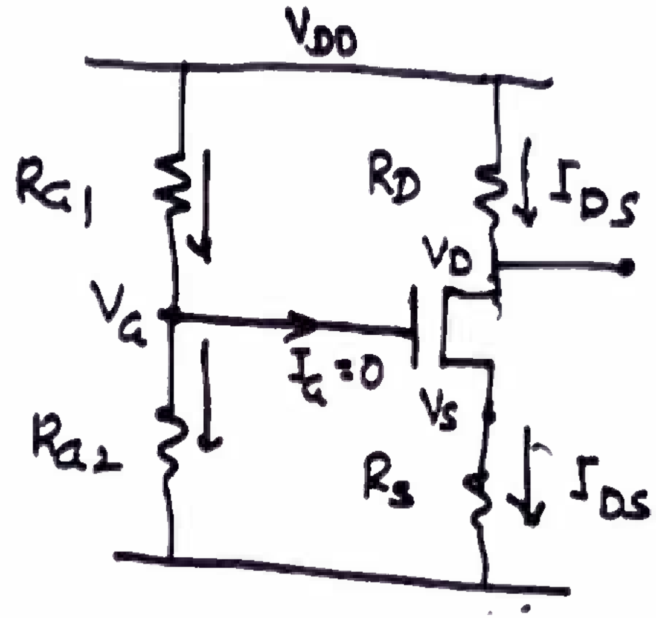

$$R_D = \frac{V_{DD} - V_D}{I_{DS}} \quad ; \quad R_S = \frac{V_S}{I_{DS}}$$

$$I_{DS} = \frac{\beta_n}{2}\left[V_{GS} - V_T\right]^2 = \frac{\beta_n}{2} V_{OV}^2$$

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$$V_G = \frac{R_{G2}}{R_{G1}+R_{G2}} \cdot V_{DD}$$

$$\text{or} \quad 7 = \frac{R_{G2}}{R_{G1}+R_{G2}} \cdot 15$$

$$\text{or} \quad 7(R_{G1}+R_{G2}) = 15 R_{G2}$$

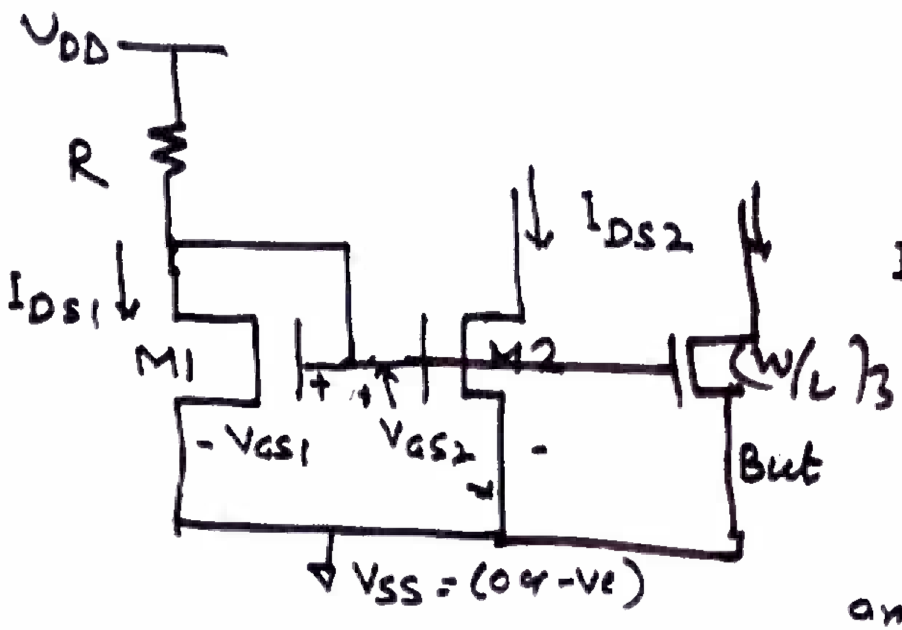
$$\text{or} \quad 8 R_{G2} = 7 R_{G1}$$

Assume $R_{G1} = 7\ M\Omega$

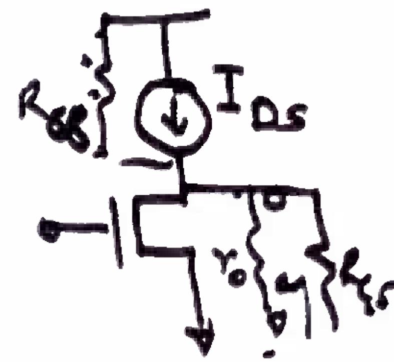
Then $R_{G2} = \frac{49}{8}\ M\Omega$

Current Source Biasing

Current Mirrors



$$I_{DS1} = \frac{V_{DD} - V_{GS1} - V_{SS}}{R}$$



$$V_{GS1} = V_{GS2}$$

and $V_{DS1} = V_{GS1}$

Since $V_{DS1} > V_{GS1} - V_T$ M1 is in saturation

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From Transistor I-V

$$I_{DS1} = \beta'_{n1} \left(\frac{W}{L}\right)_1 (V_{GS_1} - V_{Tn})^2 \qquad [\lambda = 0]$$

$$I_{DS2} = \beta'_{n2} \left(\frac{W}{L}\right)_2 (V_{GS_2} - V_{Tn})^2$$

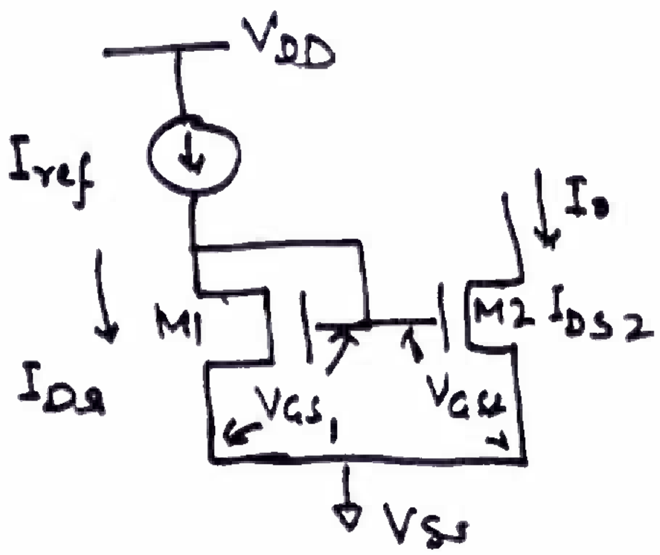
Since $\beta'_n = \mu_n C_{ox}$, common for both M1 & M2

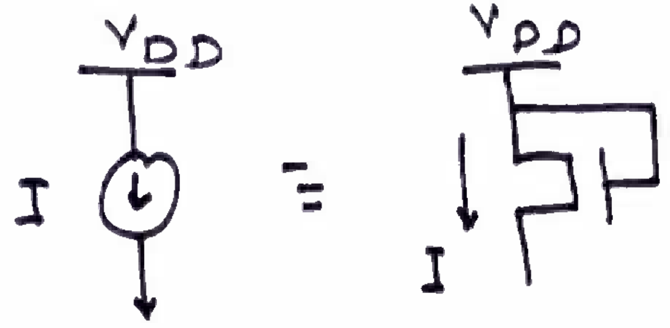
and that $V_{GS1} = V_{GS2}$

$$\therefore \quad \frac{I_{DS2}}{I_{DS1}} = \frac{(W/L)_2}{(W/L)_1}$$

where $I_{DS1} = I_{Ref} = \dfrac{V_{DD} - V_{GS1} - V_{SS}}{R} = \beta_n \left(\frac{W}{L}\right)_1 (V_{GS1} - V_{Tn})^2$

Other Current Sources & Mirrors





Design current source

for $I_{ref} = 0.25\,mA$ & $I_o = 0.10\,mA$

Given $V_{DD} = 5\,V$ $V_{SS} = 0$ $V_{Th} = 1\,V$ $V_{OV} = 200\,mV$

$\beta_n' = 40\ \mu A/V^2$

$(W/L)_1$ & $(W/L)_2$ are the ones we need to evaluate

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$$I_{DS1} = I_{Ref} = \frac{1}{2}\beta_n'\left(\frac{W}{L}\right)_1 (V_{GS_1} - V_T)^2$$

$$0.25 \times 10^{-3} = \frac{1}{2} \times 20 (W/L)_1 (200 \times 10^{-3})^2$$

$$\therefore (W/L)_1 \text{ is known}$$

since $$\frac{I_{DS2}}{I_{DS1}} = \frac{I_0}{I_{Ref}} = \frac{0.1}{0.25} = \frac{(W/L)_2}{(W/L)_1}$$

$$\therefore (W/L)_2 = \frac{2}{5}(W/L)_1$$

Slide No: 16

Common Source Amplifier with Source Degeneration

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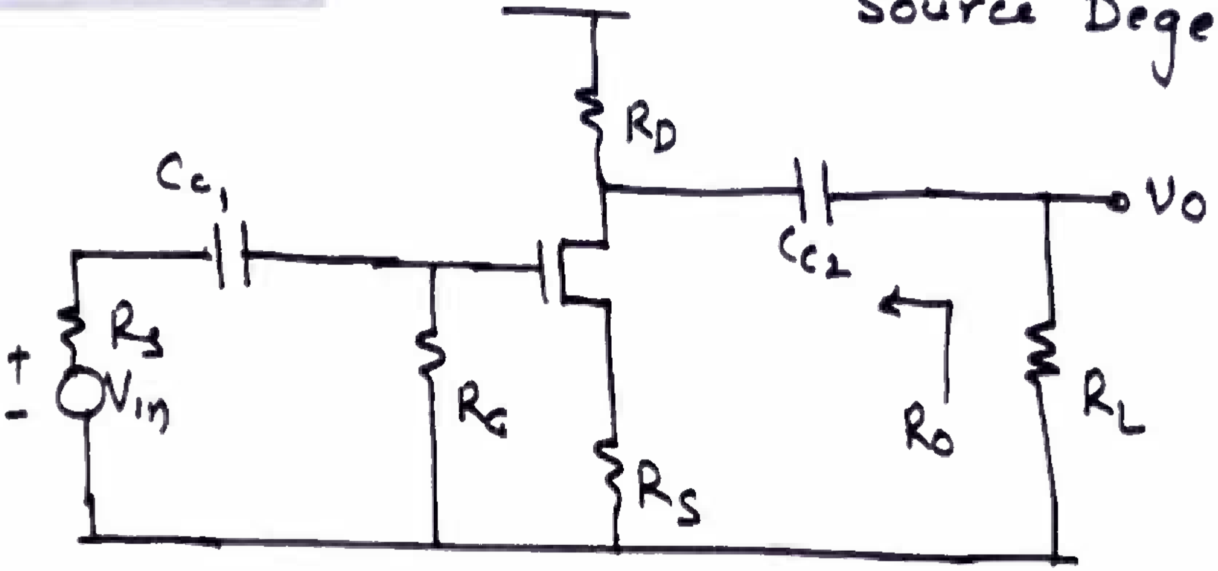
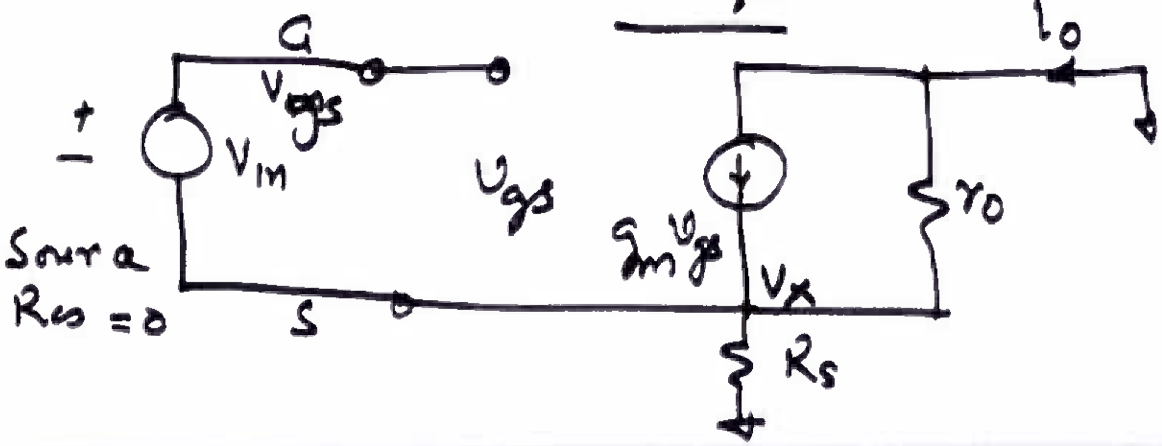


$$G_m = \frac{\partial I_{DS}}{\partial V_{gs}} = \frac{i_o}{v_{gs}}$$

G_{mequ}



$$i_o = g_m v_{gs} - \frac{V_x}{r_o}$$

& $V_x = i_o R_s$

$$\therefore \quad i_o = g_m v_{gs} - \frac{i_o R_s}{R_o}$$

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$$\therefore\ i_o = g_m(v_{in} - i_o R_s) - \frac{i_o R_s}{r_o}$$

$$\text{or } i_o\left[1 + g_m R_s + \frac{R_s}{r_o}\right] = g_m v_{in}$$

$$\therefore\ G_m = \frac{i_o}{v_{in}} = \frac{g_m r_o}{(1 + g_m R_s) r_o + R_s}$$

Then Voltage Gain $A_v = -G_m(R_D \| R_L)$

$$= -\frac{g_m(R_D \| R_L)}{(1 + g_m R_s) + R_s/r_o}$$

As $r_o \gg R_s$

$$A_v = -\frac{g_m(R_D \| R_L)}{1 + g_m R_s} = \frac{-(R_D \| R_L)}{\frac{1}{g_m} + R_s}$$

If $R_s > \frac{1}{g_m}$

Then $\boxed{A_v = \frac{-(R_D \| R_L)}{R_s}}$