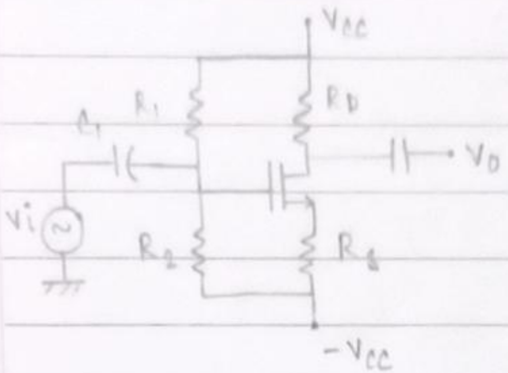
DA-3 Part-2 MOSFET.

5.



$V_{CC} = 10V$

$R_1 = 100\ k\Omega$

$R_2 = 50\ k\Omega$

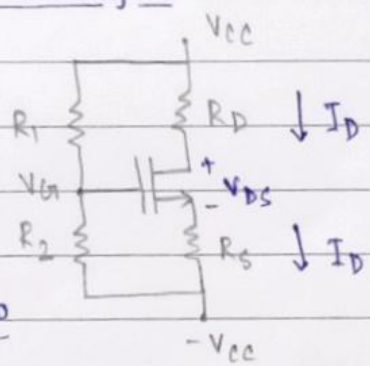
$R_D = 5k\Omega$

$R_S = 1k\Omega$

$V_T = 1V$

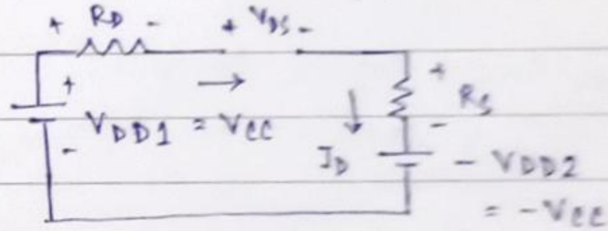
$K_n = 0.5\ mA/V^2$.

(a) DC analysis:



$I_G = 0$

KVL at D-S loop,



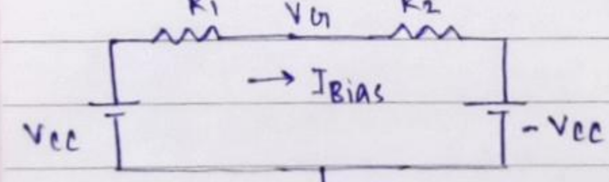
$$-V_{CC} + I_D R_D + V_{DS} + I_D R_S - V_{CC} = 0$$

$$\Rightarrow V_{DS} = 2V_{CC} - I_D (R_D + R_S)$$

When $I_D = 0$, $V_{DS} = 2V_{CC}$.

When $V_{DS} = 0$, $I_D = \dfrac{2V_{CC}}{R_D + R_S}$

KVL at input side,



$$-V_{CC} + I_{Bias}(R_1 + R_2) - V_{CC} = 0$$

$$\Rightarrow I_{Bias} = \frac{2V_{CC}}{R_1 + R_2}$$

$$-V_{CC} + I_{Bias} R_1 + I_{Bias} R_2 - V_{CC} = 0$$

Now, $I_{Bias} R_2 - V_{CC} = V_G$.

$$\therefore V_G = \left(\frac{2V_{CC}}{R_1 + R_2}\right) R_2 - V_{CC}$$

$$-V_S + I_D R_S - V_{CC} = 0$$

$$\therefore V_S = I_D R_S - V_{CC}.$$

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Now, $V_{GSQ} = V_G - V_S$

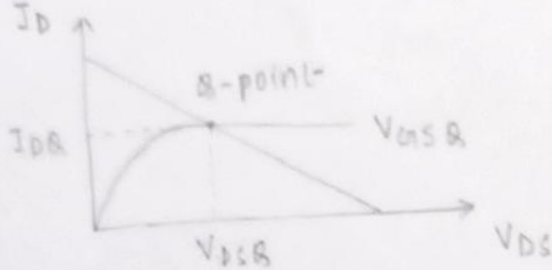
$$= \left(\frac{2V_{cc}}{R_1+R_2}\right)R_2 - \cancel{V_{cc}} - I_D R_S + \cancel{V_{cc}}$$

$$= \left(\frac{2V_{cc}}{R_1+R_2}\right)R_2 - I_D R_S.$$

$$\therefore I_{DQ} = K(V_{GSQ} - V_T)^2$$

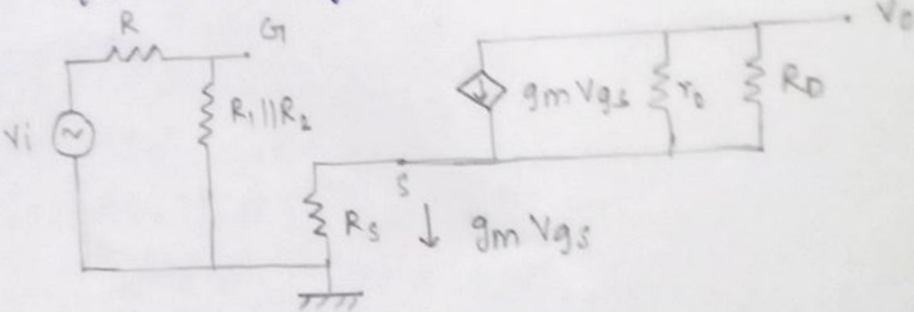
$$V_{DSQ} = 2V_{cc} - I_{DQ}(R_S + R_D)$$

Load line:



(b) Small signal Analysis:

Equivalent diagram:



$$v_o = -g_m v_{gs}(r_o \| R_D)$$

$$v_i = v_{gs} + g_m v_{gs} R_S$$

$$= v_{gs}(1 + g_m R_S)$$

$\therefore$ small signal voltage gain,

$$A_v = \frac{-g_m(r_o \| R_D)}{(1 + g_m R_S)}.$$

$$|A_v| = \frac{g_m(r_o \| R_D)}{1 + g_m R_S}.$$

If $r_o = \infty$, then $|A_v| = \dfrac{g_m R_D}{1 + g_m R_S}$.

(c) For the mentioned values,

$$V_{DS} = 2\times10 = 20V$$

$$I_D = \frac{(2\times10)V}{(5+1)K\Omega} = 3.33 \text{ mA}.$$

and, $V_{GSQ} = \left[\frac{2\times10}{(100+50)K}\right] \times 50K - (3.33mA \times 1K\Omega)$

$$= 3.33 \text{ V}.$$

$$I_{DQ} = 0.5 mA/V^2 (3.33-1)^2$$
$$= 1.165 \text{ mA}.$$

$$V_{DSQ} = 2\times10 - [1.165m \times (1+5)K]$$
$$= 13.01 \text{ V}.$$

∴ Q-point,

$$V_{GSQ} = 3.33V$$
$$I_{DQ} = 1.165 mA$$
$$V_{DSQ} = 13.01V$$

Now, small signal voltage gain,

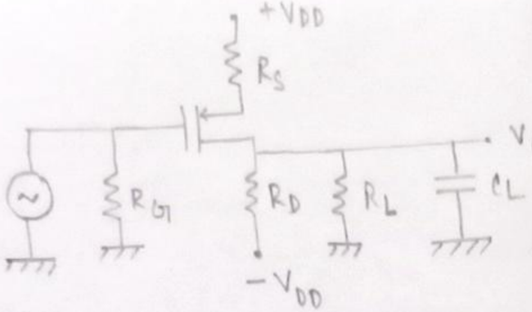
$$A_V = \frac{-g_m R_D}{1+g_m R_S} \quad [\text{considering } r_o = \infty].$$

$$g_m = \frac{I_{DQ}}{V_T} = 3.33 \text{ mA/V}$$

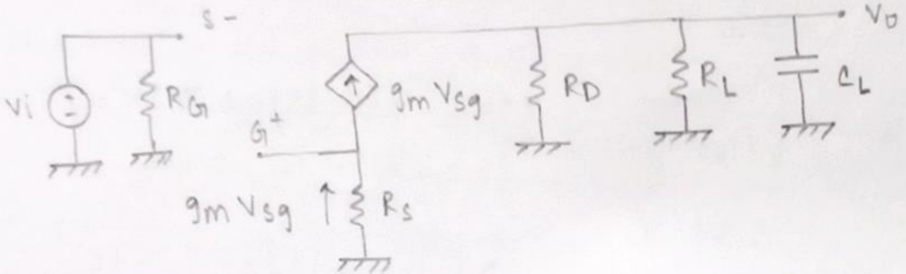
$$A_V = \frac{-3.33m \times 5K}{1+(3.33m\times1K)} = -3.845.$$

$$\therefore |A_V| = 3.845.$$

6.



(a) small signal Eq. circuit :



To find τ, we set $v_i = 0$, $g_m V_{sg} = 0$

Eq. resistance seen by C_L is $R_D \| R_L$.

$$\tau_p = (R_D \| R_L)\, C_L .$$

To find $A_{v\,max}$, we open circuit C_L.

$$v_o = +g_m V_{sg} (R_D \| R_L)$$

Applying KVL,

$$v_i = V_{sg}(1 + g_m R_S)$$

$$\therefore |A_v|_{max} = \frac{v_o}{v_i} = \frac{g_m (R_D \| R_L)}{1 + g_m R_S} .$$

(b) Given, $R_D = 10\,K\Omega$

$R_L = 100\,K\Omega$

$R_G = 1\,K\Omega$

$V_{DD} = 20\,V$

$C_L = 1\,\mu F$

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

$$\cancel{V_{GSQ} = \left(\frac{V_{DD} + V_{DD}}{R_D + R_G}\right) R_G - I_D R_D}$$

$$\tau_p = (10K \| 100K) \times 1\,\mu F$$

$$= \frac{10 \times 100 \times 10^3}{(10 + 100)} \times 1 \times 10^{-6}$$

$$= 9.09\ ms.$$

8. Given, $K_n = 0.2\ mA/V^2$, $V_T = 1V$, $\lambda = 0$, $C_{gd} = 0.02\ pF$,

$C_{gs} = 0.25\ pF$, $I_{DQ} = 0.4\ mA$.

$I_{DQ} = K_n (V_{GS} - V_T)^2$

$\Rightarrow V_{GS} = \sqrt{\frac{I_{DQ}}{K_n}} + V_T = 2.41\ A.$

Now, $g_m = 2K_n (V_{GS} - V_{TN})$

$= 2 \times 0.2\ m\ (2.41 - 1)$

$= 0.4 \times 1.41 \times 10^{-3}\ A/V$

$= 0.56\ mA/V.$

$\therefore$ Unity gain frequency, $f_T = \frac{g_m}{2\pi (C_{gs} + C_{gd})}$

$= \frac{0.56m}{2\pi (0.02p + 0.25p)}$

$= 330.09\ MHz.$

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