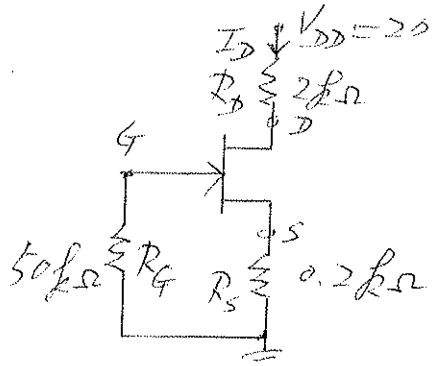
EECE 315 Exercise #5

3.63



$I_{DSS} = 10$ mA

$V_p = -5V$

Assume saturation region.

$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_p}\right)^2 = 10\left(1+\frac{V_{GS}}{5}\right)^2 \quad \cdots (1)$$

$$20 = I_D \times 2 + V_{DS} + I_D \times 0.2 \quad \cdots (2)$$

$$V_{GS} = V_G - V_S = 0 - I_D \times 0.2 = -0.2 I_D \quad \cdots (3)$$

$$\text{or} \quad I_D = \frac{V_{GS}}{-0.2} = -5V_{GS} \quad \cdots (4)$$

Sub. (4) into (1),

$$-5V_{GS} = 10\left(1+0.4V_{GS}+0.04V_{GS}^2\right)$$

$$\therefore 0.04V_{GS}^2 + 0.9V_{GS} + 1 = 0$$

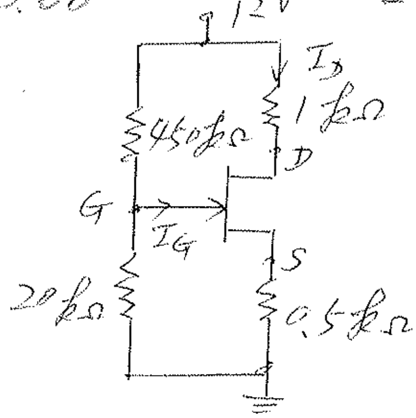
$$V_{GS} = \frac{-0.9 \pm \sqrt{(0.9)^2 - 4 \times 0.04}}{2 \times 0.04} = -1.172V \text{ or } -21.328V$$

Choose $V_{GS} > V_p$ $\therefore$ $\underline{V_{GSQ} = -1.172V}$, $\underline{I_{DQ} = 5.86 mA}$

From (2), $V_{DSQ} = 20 - 2.2 I_{DQ} = \underline{7.11 V}$

$$\underline{V_{GD} = V_{GS} - V_{DS} = -8.28V < V_p}$$

3.68 EE315 Exercise # 5



$V_{DSQ} = 5\,V$

$I_{DSS} = 10\,mA$

$I_G = 0$

Assume saturation.

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 \quad \cdots \text{①}$$

$$V_{GS} = V_G - V_S = 12 \times \frac{20}{20+450} - I_D \times 0.5$$

$$V_{GS} = 0.511 - 0.5\,I_D \quad \cdots \text{②}$$

$$12 = I_D \times 1 + V_{DS} + I_D \times 0.5 = 1.5\,I_D + 5 \quad \cdots \text{③}$$

$$\therefore \quad I_D = \frac{12-5}{1.5} = \underline{4.67\,mA}$$

From ②, $V_{GS} = 0.511 - 0.5\,I_D = \underline{-1.824\,V}$

Sub. I_D and V_{GS} into ①,

$$4.67 = 10\left(1 - \frac{-1.824}{V_p}\right)^2 = 10\left(1 + \frac{1.824}{V_p}\right)^2$$

$$\left(1 + \frac{1.824}{V_p}\right)^2 = 0.467$$

$$\therefore \quad 1 + \frac{1.824}{V_p} = \pm\sqrt{0.467} = \pm 0.683$$

$V_p = -1.084\,V$ or $-5.754\,V$. $\underline{V_p = -5.754\,V}$

$(V_{GS} > V_p)$

$\left[V_{GD} = V_{GS} - V_{DS} = -6.824\,V < V_p \right]$

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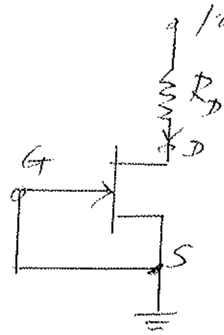


$I_{DSS} = 4\ mA$

$V_p = -3\ V$

$V_{GS} = 0\ V > V_p$

Assume saturation.

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = I_{DSS} = 4\ mA$

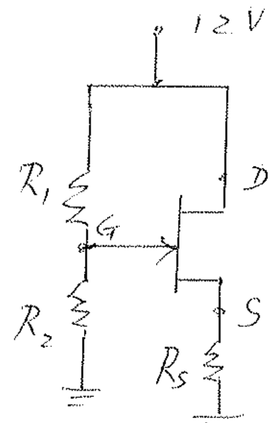
$10 = I_D R_D + V_{DS} = I_D R_D + 3$

$R_D = \frac{10-3}{I_D} = \underline{1.75\ k\Omega}$

$\underline{V_{GD} = V_{GS} - V_{DS} = 0 - 3 = -3 = V_p}$

D4.77

(a) <u>dc bias analysis</u>



$I_{DSS} = 10\ mA$, $V_p = -5\ V$

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

$I_{DQ} = \frac{I_{DSS}}{2} = 5\ mA$

$V_{DSQ} = \frac{V_{DD}}{2} = 6\ V$, $R_{in} = R_1 \| R_2 = 100\ k\Omega$

$I_{DQ} = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$

$1 - \frac{V_{GS}}{(-5)} = \pm\sqrt{\frac{I_{DQ}}{I_{DSS}}} = \pm\sqrt{0.5} = \pm 0.707$

$V_{GS} = -1.465\ V$ or $-8.535\ V$ Choose $\underline{V_{GS} = -1.465\ V} > V_p$

$V_{SQ} = I_{DQ} \times R_S = 12 - V_{DSQ} = 6\ V$, $\underline{R_S = \frac{6}{I_{DQ}} = 1.2\ k\Omega}$

D 4.77

$$V_{GS} = V_G - V_S = 12 \times \frac{R_2}{R_1+R_2} - 6 = -1.465$$

$$\therefore \frac{R_2}{R_1+R_2} = \frac{4.535}{12}, \text{ but } R_1 /\!/ R_2 = \frac{R_1R_2}{R_1+R_2} = R_{in} = 100\,k\Omega$$

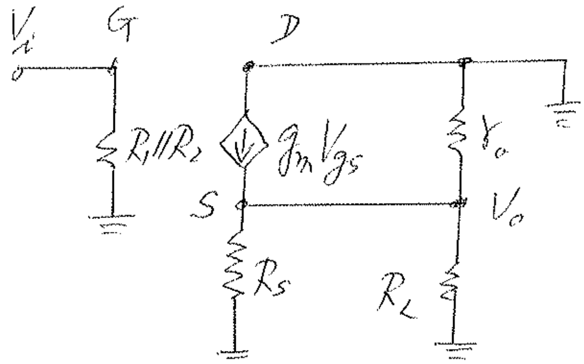
$$\frac{R_1R_2}{R_1+R_2} = \frac{4.535\,R_1}{12} = 100, \quad \underline{R_1 = 264.6\,k\Omega}$$

$$R_2 = \frac{4.535\,R_1}{12 - 4.535} = \underline{160.8\,k\Omega}$$

(b) $g_m = \frac{2}{|V_p|}\sqrt{I_{DQ}\,I_{DSS}} = 2.83\ mA/V$, $R_L = 0.5\,k\Omega$

$r_d = r_o = \frac{1}{\lambda I_{DQ}} = 20\,k\Omega$

$V_g = V_i$, $V_s = V_o$



$$\frac{V_o}{R_S} + \frac{V_o}{R_L} + \frac{V_o}{r_o} - g_m V_{gs} = 0$$

$$\frac{V_o}{(R_S /\!/ R_L /\!/ r_o)} - g_m(V_i - V_o) = 0$$

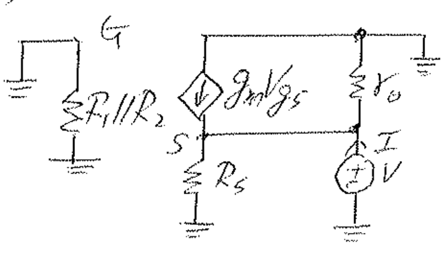
$R_S /\!/ R_L /\!/ r_o = 0.347\,k\Omega$

$$\left(\frac{1}{0.347} + 2.83\right)V_o = 2.83\,V_i, \quad \underline{A_V = \frac{V_o}{V_i} = 0.495}$$

<u>Output resistance</u>

$V_g = 0$, $V_s = V$

$$I + g_m V_{gs} = \frac{V}{R_S} + \frac{V}{r_o} = \frac{V}{R_S /\!/ r_o} = \frac{V}{1.132}$$

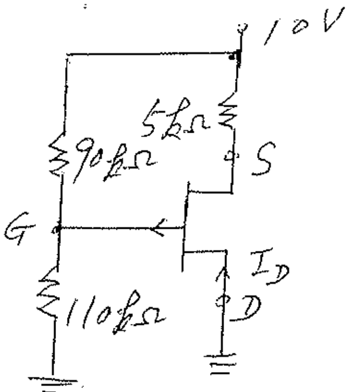


$$I + 2.83 \times (0 - V) = \frac{V}{1.132}$$

$$\underline{R_o = \frac{V}{I} = 0.269\,k\Omega}$$

4.78

(a)



$I_{DSS} = -2$ mA , $V_p = 1.75$V

$\lambda = 0 \quad (r_o = \infty)$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2 = -2\left(1 - \frac{V_{GS}}{1.75}\right)^2 < 0 \quad \cdots (1)$$

$$V_{GS} = V_G - V_S = 10 \times \frac{110}{110+90} - (10 + I_D \times 5)$$

$$V_{GS} = 5.5 - 10 - 5 I_D \quad \text{or} \quad I_D = \frac{-4.5 - V_{GS}}{5} \quad \cdots (2)$$

Sub. (2) into (1),

$$\frac{-4.5 - V_{GS}}{5} = -2\left(1 - \frac{V_{GS}}{1.75}\right)^2$$

$$0.3265\, V_{GS}^2 - 1.243\, V_{GS} + 0.55 = 0$$

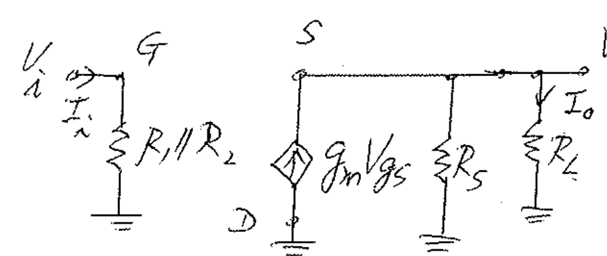
$$V_{GS} = 3.296 \text{ V} \quad \text{or} \quad 0.511 \text{ V}$$

Choose $\underline{\underline{V_{GS} = 0.511 \text{ V}}} < 1.75$V

$$I_{DQ} = \frac{-4.5 - V_{GS}}{5} = \underline{\underline{-1 \text{ mA}}}$$

$$V_{SDQ} = 10 + 5 \times I_{DQ} = \underline{\underline{5 \text{ V}}}$$

(b)



$$V_o = g_m V_{gs} (R_S // R_L)$$

$$g_m = \frac{2}{|V_p|}\sqrt{I_{DQ} I_{DSS}} = 1.616 \text{ mA/V}$$

$$V_{gs} = V_g - V_s = V_i - V_o$$

$$A_v = \frac{V_o}{V_i} = \frac{g_m (R_S // R_L)}{1 + g_m (R_S // R_L)} = \underline{\underline{0.843}}$$

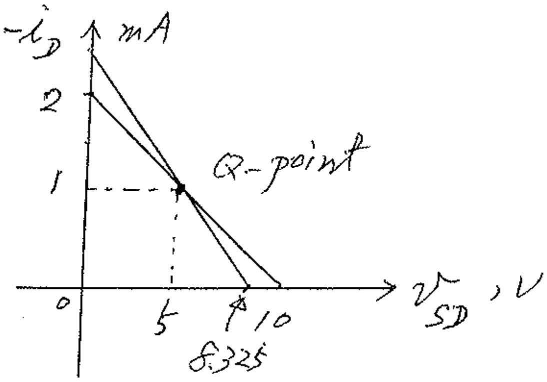
4.78

(b) $I_o = \frac{V_o}{R_L}$, $I_i = \frac{V_i}{(R_1 // R_2)}$

$\therefore A_i = \frac{I_o}{I_i} = \frac{V_o}{V_i} \times \frac{R_1 // R_2}{R_L} = 0.843 \times \frac{49.5}{10}$

$A_i = \underline{\underline{4.17}}$

(c)



dc load line eq.

$10 = -5 I_D + V_{SD}$

$R_{ac} = R_S // R_L = 3.33\ k\Omega$

ac load line eq.

$-i_D = -\frac{1}{R_{ac}} v_{SD} + b$

@ the Q-point , $i_D = -1$ mA , $v_{SD} = 5$V

$\therefore b = 2.5$ mA

$\therefore -i_D = -\frac{1}{R_{ac}} v_{SD} + 2.5$

Let $i_D = 0$, $v_{SD} = 8.325$V

4.78 (c)

Since $v_{SD}(ac) = v_o$, then $v_{o,max} = 8.325$ V.

$v_{o,min} = v_{SD,min} = V_p - V_{GS}$ (Triode region $V_{GD} = V_p = V_{GS} - V_{DS}$)

where $V_{GS} \neq V_{GSQ}$

$$\begin{cases} v_{SD,min} = 10 - i_{SD,max} \times 5 = V_p - V_{GS} \\ i_{SD,max} = |I_{DSS}|\left(1 - \frac{V_{GS}}{V_p}\right)^2 . \end{cases}$$

$$i_{SD,max} = \frac{10 - V_p + V_{GS}}{5} = \frac{10 - 1.75 + V_{GS}}{5} = \frac{8.25 + V_{GS}}{5}$$

$$\therefore \frac{8.25 + V_{GS}}{5} = |I_{DSS}|\left(1 - \frac{V_{GS}}{V_p}\right)^2 = 2\left(1 - \frac{V_{GS}}{1.75}\right)^2$$

$$8.25 + V_{GS} = 10\left(1 - \frac{2V_{GS}}{1.75} + \frac{V_{GS}^2}{(1.75)^2}\right)$$

$$3.265 V_{GS}^2 - 12.43 V_{GS} + 1.75 = 0$$

$$V_{GS} = \begin{cases} 3.65 \text{ V} \\ \underline{\underline{0.148 \text{ V}}} \quad (V_{GS} < V_p) \end{cases}$$

$$\therefore v_{o,min} = V_p - 0.148 = 1.602 \text{ V}$$

$$\Delta v_{o,up} = 8.325 - 5 = 3.325 \text{ V}$$

$$\Delta v_{o,down} = 5 - 1.602 = 3.398 \text{ V}$$

$$\therefore V_{o,p.p.max} = 2 \times 3.325 = \underline{\underline{6.65 \text{ V}}}$$