ENEE236
Solutions Homework on FET DC Analysis

1. $I_{DQ} = \frac{V_{DD} - V_D}{R_D} = \frac{14 - 9}{1.6\,K\Omega} = 3.125\,mA$

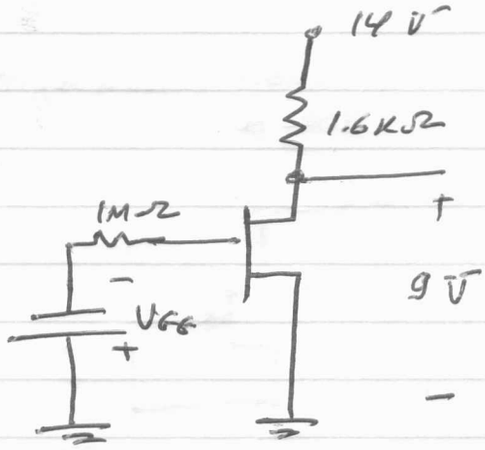
$V_{DS} = V_D - V_S = 9 - 0 = 9\,V$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2 \Rightarrow$

$V_{GS} = V_{GS(off)}\left[1 - \sqrt{\frac{I_D}{I_{DSS}}}\right]$

$= -4\left[1 - \sqrt{\frac{3.125\,mA}{8\,mA}}\right] = -1.5\,V$

$\therefore V_{GG} = 1.5\,V$



2. $I_{DQ} = I_S = \frac{V_S}{R_S} = \frac{1.7\,V}{0.51\,K\Omega} = 3.33\,mA$

$V_{GS(Q)} = -I_{DQ} R_S \quad (\text{since } V_G = 0)$

$= -3.33\,mA \cdot 0.51\,K\Omega = -1.7\,V$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2 = I_{DSS}\left(1 - \frac{-1.7}{-4}\right)^2 = 3.33\,mA$

$\Rightarrow I_{DSS} = 10.06\,mA$

$V_D = V_{DD} - I_{DQ} \cdot R_D = 18 - 3.33\,mA \cdot 2\,K\Omega$

$= 18 - 6.66\,V$

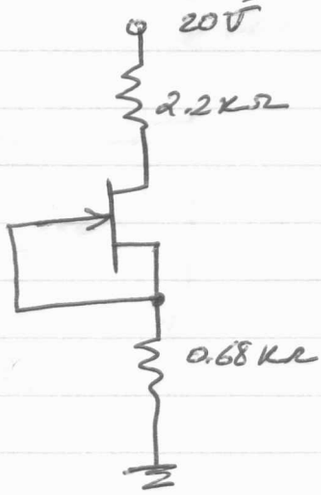
$= 11.34\,V$

$V_{DS} = V_D - V_S = 11.34 - 1.7 = 9.64\,V$

3. $-V_{GS} = V_G - V_S = 0$ (since $V_G = V_S$)

$-I_D = I_{DSS} = 4.5mA$

$-V_{DS} = V_{DD} - I_D(R_D + R_S) = 20 - 4.5mA(2.2k\Omega + 0.68k\Omega)$
$= 7.04V$



$-V_D = V_{DD} - I_D R_D$
$= 20 - 4.5mA \cdot 2.2k\Omega$
$= 10.1V$

$-V_S = I_S R_S = I_D R_S$
$= 4.5mA \cdot 0.68k\Omega$
$= 3.06V$

4. DMOSFET, n-channel

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

$$V_{GS} = V_G - V_S = 0 - (I_S R_S - 4) = 4 - I_S R_S$$
$$= 4 - (0.39k\Omega) \cdot I_D$$

$$I_D = 8mA\left(1 - \frac{4 - 0.39k \cdot I_D}{-8}\right)^2$$

solving the quadratic equation, yields

$$\begin{cases} I_{DQ} \approx 9mA \\ V_{GSQ} \approx 0.5V \end{cases}$$

$-V_{DS} = V_{DD} - I_D(R_D + R_S) + 4$
$= 18 - 9mA(1.2k + 0.39k\Omega) + 4V$
$= 22 - 14.31 = 7.69V$

$V_S = -V_{GSQ} = -0.5V$

5) n-channel EMOSFET

$$I_D = K_n \left(V_{GS} - V_{GS(th)}\right)^2$$

$$K_n = \frac{I_{D(ON)}}{\left(V_{GS(ON)} - V_{GS(th)}\right)^2} = \frac{5\,mA}{(7-4)^2} = 0.556 \cdot 10^{-3}\ A/V^2$$

$$V_{GS} = V_{DS} = V_{DD} - I_D (1.2K\Omega + 0.51K\Omega)$$
$$V_{GS} = 22 - I_D (1.71K\Omega)$$

$$I_D = 0.556 \cdot 10^{-3} \left((22 - I_D \cdot 1.7K\Omega) - 4\right)^2 \leftarrow \text{quadratic equation}$$

$$1605.7\, I_D^2 - 35\, I_D + 0.18 = 0$$

$I_{D1} = 8.31\ mA \rightarrow V_{GS1} = 22 - 8.31mA \cdot 1.7K\Omega$
$= 7.873\ V > V_{GS(th)}$ ✓

$I_{D2} = 13.48\ mA \rightarrow V_{GS2} = 22 - 13.48m \cdot 1.7K\Omega$
$= 0.916 < V_{GS(th)}$ ✗ wrong

Solution

$I_D = I_{D1} = 8.31\ mA$
$V_{GS} = V_{DS} = 7.873\ V$

$V_D = V_{DD} - I_D R_D = 22 - 8.31mA \cdot 1.2K\Omega = 12.028\ V$
$V_S = V_{DD} - I_D R_D - V_{DS} = 12.028 - 7.873$
$= 4.155\ V$

6. $V_G = \frac{6.8M\Omega}{10M\Omega + 6.8M\Omega} \cdot 24\,V = 9.71\,V$

$V_{GS} = V_G - I_D R_S$

$V_{GS} = 9.71 - I_D(0.75k\Omega)$

$I_D = K_n \left(V_{GS} - V_{GS(th)}\right)^2$

$K_n = \frac{5mA}{(6-3)^2 V^2} = 0.556 \cdot 10^{-3}\ A/V^2$

$I_D = 0.556 \cdot 10^{-3} \left(9.71 - I_D(0.75k\Omega) - 3\right)^2$

$= 0.556 \cdot 10^{-3} \left(6.71 - 750 I_D\right)^2$

$= 0.556 \cdot 10^{-3} \left(45.03 - 10065 I_D - 562500 I_D^2\right)$

$I_D = 312.52 I_D^2 - I_D\, 5.592 + 0.02502$

$0 = 312.52 I_D^2 - 6.592 I_D + 0.02502$

$I_{D1} = 16.129\ mA \rightarrow V_{GS1} = 9.71 - 16.129mA \cdot 0.75k\Omega = -2.38$ X

$I_{D2} = 4.96\ mA \rightarrow V_{GS2} = 9.71 - 4.96mA \cdot 0.75k\Omega = 6\,V$ ✓

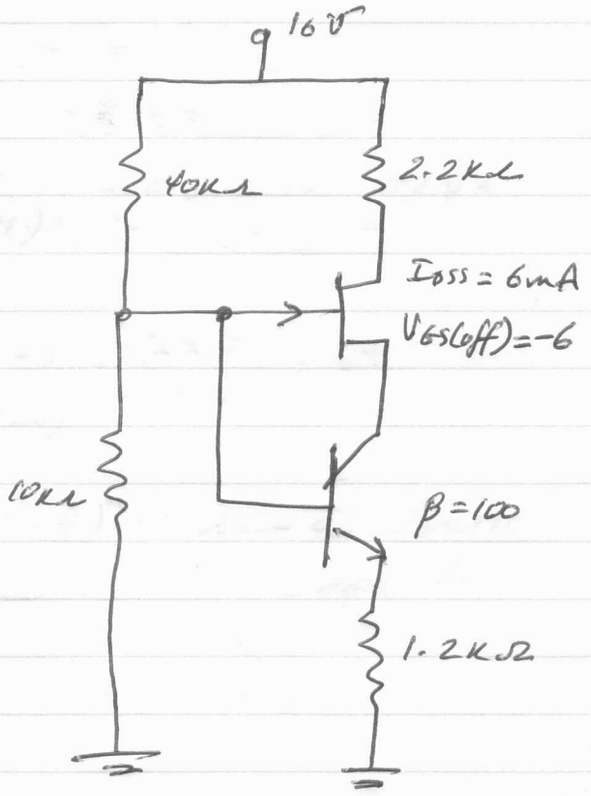
$V_D = 24 - I_D \cdot 2.2k\Omega$

$= 24 - 4.96mA \cdot 2.2k\Omega$

$= 13.09\,V$

$V_S = I_D \cdot 0.75k\Omega = 3.72\,V$

7. - $V_B = V_G = \frac{10k\Omega}{40k\Omega + 10k\Omega} \cdot 16V = 3.2V$



- $V_E = V_B - V_{BE} = 3.2 - 0.7 = 2.5V$

- $I_E = \frac{V_E}{R_E} = \frac{2.5}{1.2k} = 2.08\,mA$

$I_C \cong I_E = 2.08\,mA$

$I_D = I_C = 2.08\,mA$

- $I_B = \frac{I_C}{\beta} = \frac{2.08\,mA}{100} = 20.8\,\mu A$

- $V_C = V_S = V_G - V_{GS}$

- $V_{GS} = V_{GS(off)}\left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right)$

$= -6\left(1 - \sqrt{\frac{2.08mA}{6mA}}\right) = -2.47V$

- $V_C = 3.2 - (-2.47) = 5.67V$

- $V_D = V_{DD} - I_D R_D = 16 - 2.08mA \cdot 2.2k\Omega = 11.42V$

- $V_{CE} = V_C - V_E = 5.67 - 2.5 = 3.17V$

- $V_{DS} = V_D - V_S = 11.42 - 5.67 = 5.75V$