EMTR 1030 – Electronics

Assignment 4 Reference Solutions

Problem 5.14

5.14 $t_{ox} = 4$ nm, $\mu_n = 450$ cm^2/V·s, $V_t = 0.5$ V, and $W/L = 10$.

$$k_n = \mu_n C_{ox}\frac{W}{L} = 450 \times 10^{-4} \times \frac{3.45 \times 10^{-11}}{4 \times 10^{-9}} \times 10$$

$= 3.88$ mA/V^2

(a) $v_{GS} = 1.8$ V and $v_{DS} = 1$ V

$v_{OV} = v_{GS} - V_t = 1.3$ V

Thus $v_{DS} < v_{OV} \Rightarrow$ triode region,

$$i_D = k_n\left[v_{DS}v_{OV} - \frac{1}{2}v_{DS}^2\right]$$

$$= 3.88\left[1 \times 1.3 - \frac{1}{2} \times 1\right] = 3.1 \text{ mA}$$

(b) $v_{GS} = 0.7$ V and $v_{DS} = 1.5$ V

$v_{OV} = v_{GS} - V_t = 0.7 - 0.5 = 0.2$ V

Thus, $v_{DS} > v_{OV} \Rightarrow$ saturation region,

$$i_D = \frac{1}{2}k_n v_{OV}^2 = \frac{1}{2} \times 3.88 \times 0.2^2$$

$= 0.078$ mA $= 78$ µA

(c) $v_{GS} = 1.8$ V and $v_{DS} = 0.1$ V

$v_{OV} = 1.8 - 0.5 = 1.3$ V

Thus, $v_{DS} < v_{OV} \Rightarrow$ triode region,

$$i_D = k_n\left[v_{DS}v_{OV} - \frac{1}{2}v_{DS}^2\right]$$

$$= 3.88\left[0.1 \times 1.3 - \frac{1}{2}0.1^2\right] = 0.5 \text{ mA}$$

(d) $v_{GS} = v_{DS} = 1.8$ V

$v_{OV} = 1.8 - 0.5 = 1.3$ V

Thus, $v_{DS} > v_{OV} \Rightarrow$ saturation region,

$$i_D = \frac{1}{2}k_n v_{OV}^2$$

$$= \frac{1}{2} \times 3.88 \times 1.3^2 = 3.3 \text{ mA}$$

Problem 5.17

5.17 $V_{tn} = 0.4$ V, $k_n = 2$ mA/V^2

$$i_D = 0.05 = \frac{1}{2} \times 2 \times v_{OV}^2$$

$\Rightarrow v_{OV} = 0.22$ V and $v_{DS} \geq 0.22$ V

$v_{GS} = 0.4 + 0.22 = 0.62$ V

$$i_D = 0.2 = \frac{1}{2} \times 2 \times v_{OV}^2$$

$\Rightarrow v_{OV} = 0.45$ V and $v_{DS} \geq 0.45$ V

$v_{GS} = 0.45 + 0.4 = 0.85$ V

Problem 5.21

5.21 For the channel to remain continuous,

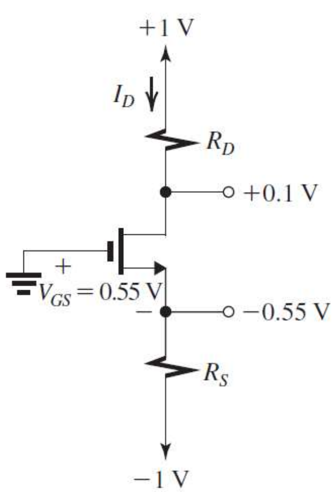
$v_{DS} \leq v_{GS} - V_t$

Thus for $v_{GS} = 1.0$ V to 1.8 V and $V_t = 0.5$,

$v_{DS} \leq 1 - 0.5$

That is, $v_{DS\max} = 0.5$ V.

Problem 5.44



Since $V_{DG} > 0$, the MOSFET is operating in saturation. Thus

$$I_D = \frac{1}{2} k_n (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \times 4 \times (0.55 - 0.4)^2$$

$$= 0.045 \text{ mA}$$

$$R_D = \frac{1 - V_D}{I_D} = \frac{1 - 0.1}{0.045} = \frac{0.9}{0.045} = 20 \text{ k}\Omega$$

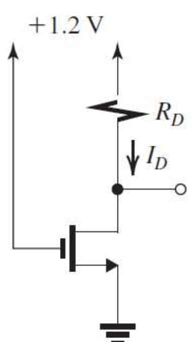
$$R_S = \frac{-0.55 - (-1)}{I_D} = \frac{-0.55 + 1}{0.045} = 10 \text{ k}\Omega$$

For I_D to remain unchanged from 0.045 mA, the MOSFET must remain in saturation. This in turn can be achieved by ensuring that V_D does not fall below V_G (which is zero) by more than V_t (0.4 V). Thus

$$1 - I_D \, R_{D\max} = -0.4$$

$$R_{D\max} = \frac{1.4}{0.045} = 31.1 \text{ k}\Omega$$

Problem 5.46



$$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \times 0.5 \times \frac{W}{L} (1.2 - 0.4)^2$$

$$= 0.16 \left(\frac{W}{L} \right)$$

$$V_D = 1.2 - I_D R_D = 1.2 - 0.16 \left(\frac{W}{L} \right) R_D$$

For the MOSFET to be at the edge of saturation, we must have

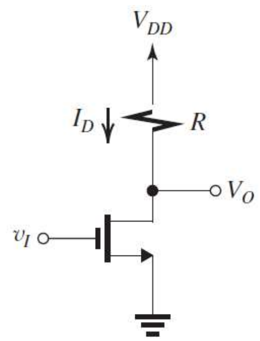
$$V_D = V_{OV} = 1.2 - 0.4 = 0.8$$

Thus

$$0.8 = 1.2 - 0.16 \left(\frac{W}{L} \right) R_D$$

$$\Rightarrow \left(\frac{W}{L} \right) R_D = 2.5 \text{ k}\Omega \qquad \text{Q.E.D}$$

<u>Problem 5.53</u>



Assuming linear operation in the triode region, we can write

$$I_D = \frac{V_O}{r_{DS}} = \frac{50\text{ mV}}{50\ \Omega} = 1\text{ mA}$$

$$I_D = k_n'\left(\frac{W}{L}\right)(V_{GS} - V_t)V_{DS}$$

$$1 = 0.5 \times \frac{W}{L} \times (1.3 - 0.4) \times 0.05$$

$$\Rightarrow \frac{W}{L} = 44.4$$

$$R = \frac{V_{DD} - V_O}{I_D} = \frac{1.3 - 0.05}{1}$$

$$= 1.25\text{ k}\Omega$$