HW 9 Electronics I EE 20242

5.9 $V_{DS,sat} = V_{GS} - V_t = 2.5V - 1V = 1.5V$

$I_{D,sat} = \frac{1}{2} k_n (V_{GS} - V_t)^2 = \frac{1}{2} \times \frac{1mA}{V^2} \times (1.5V)^2 = 1.125 mA.$

5.17 $r_{DS} = \left[k_n' \frac{W}{L}(V_{GS} - V_t)\right]^{-1} \Rightarrow \frac{r_{DS1}}{r_{DS2}} = \frac{V_{GS2} - V_t}{V_{GS1} - V_t} \Rightarrow V_{GS2} = 3.5V.$

For a device with twice the width:

$$\frac{r_{DS1}}{r_{DS2}} = \frac{W_2 (V_{GS2} - V_t)}{W_1 (V_{GS2} - V_t)}$$

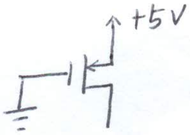
For $V_{GS} = 1.5V$

$\frac{r_{DS1}}{r_{DS2}} = 2 \Rightarrow r_{DS2} = \frac{1000}{2} = 500\Omega$

For $V_{GS} = 3.5V$

$r_{DS2} = \frac{200}{2} = 100\Omega.$

5.38



$V_{DS} \le V_{GS} - V_t = -5V - (-1.5V) = -3.5V$

For $V_D = 4V$, $V_{DS} = -1V > -3.5V \Rightarrow$ triode region

$i_D = k_p' \frac{W}{L}\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right] = 80\left[(-5-(-1.5)) \times (-1) - \frac{1}{2} \times 1\right] = 0.24mA$

For $V_D = 1.5V$, $V_{DS} = -3.5V = -3.5V \Rightarrow$ edge of saturation

$i_D = \frac{1}{2} k_p' \frac{W}{L}(V_{GS} - V_t)^2 (1 + \lambda V_{DS}) = \frac{80}{2}(3.5)^2(1 + 0.02 \times 3.5) = 0.52mA$

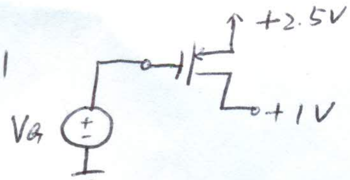
For $V_D = 0$, $V_{DS} = -5V < -3.5V \Rightarrow$ saturation region

$i_D = \frac{1}{2} k_p' \frac{W}{L}(V_{GS} - V_t)^2 (1 + \lambda V_{DS}) = \frac{80}{2}(3.5)^2(1 + 0.02 \times 5) = 0.54mA$

For $V_D = -5V$, $V_{DS} = -10V < -3.5V \Rightarrow$ saturation region

$i_D = \frac{1}{2} k_p' \frac{W}{L}(V_{GS} - V_t)^2 (1 + \lambda V_{DS}) = \frac{80}{2} \times (3.5)^2(1 + 0.02 \times 10) = 0.59mA$

5.41



$V_{SD} = 1.5V.$

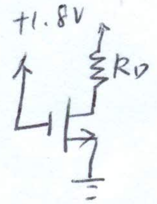
$V_{tp} = -0.5V$

when $V_{GS} \ge V_{tp} \Rightarrow V_G \ge 2V$ cutoff

when $V_{GD} \le V_{tp} \Rightarrow V_G \le 0.5V$ triode

when $0.5V \le V_G \le 2V$ saturation

5.48



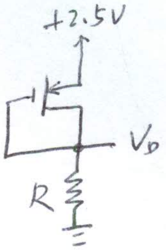
$V_{GS} = 1.8V$

$V_t = 0.5V$

$V_{DS,sat} = V_{GS} - V_t = 1.3V \Rightarrow V_D = 1.3V$

$$R_D = \frac{1.8V - V_D}{I_D} = \frac{(1.8 - 1.3)V}{1mA} = 500\Omega$$

5.49



make $i_D = 0.8mA$ @ $V_D = 1.5V$.

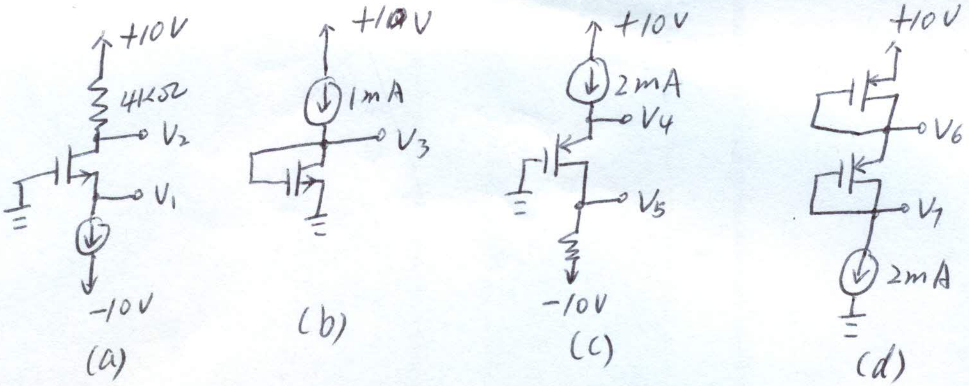
$$R = \frac{V_D}{i_D} = \frac{1.5V}{0.8mA} = 1.875k\Omega$$

$V_{SG} = 2.5V - 1.5V = 1V$

$$i_D = \frac{1}{2}k_n' \frac{W}{L}(V_{GS} - V_t)^2 \Rightarrow 0.8mA = \frac{1}{2} \times 100\mu A/V^2 \times \frac{W}{L}(1 - 0.6)^2 \Rightarrow \frac{W}{L} = 100$$

$\Rightarrow W = 25um$

5.55.



In (a), $V_2 = 10 - 4 \times 2 = 2V$

Assume Saturation. $I_D = 2 = \frac{1}{2} \times 1 \times (V_{GS} - 2)^2 \Rightarrow V_{GS} = 4V$. $V_1 = -4V$.

$V_{DS} = 6V > V_{GS} - V_t$, so our assumption was correct.

In (b),

$I_D = 1 = \frac{1}{2} \times 1 \times (V_{GS} - 2)^2 \Rightarrow V_{GS} = 3.41V$ $V_3 = 3.41V$.

In (c),

$I_D = 2mA \Rightarrow V_{GS} = -4V \Rightarrow V_S = 4V = V_4$ $V_5 = -10 \times 2.5 \times 2 = -5V$

In (d)

$I_D = 2mA \Rightarrow V_{GS} = -4V \Rightarrow V_6 = 6V. \Rightarrow V_7 = V_6 - 4 = 2V.$

If we replace the current source with a resistor in each of those circuits:

In circuit (a): $R = \frac{-4-(-10)}{2} \cong 3.01K\Omega$ (From the table for 1% resistors)

$I_D = \frac{1}{2} \times 1 \times (V_{GS} - V_t)^2$ $V_{GS} - V_t = 0 - (-10 + 3.01 I_D) - 2 = 8 - 3.01 I_D \Rightarrow I_D = 1.99mA$

$\Rightarrow V_2 = 2.04V.$ $V_1 = -4.01V$

In (b): $R = \frac{10-3.41}{1} = 6.59k \cong 6.65k\Omega$

$V_{GS} = 10 - 6.65I = \frac{1}{2} \times 1 \times (10 - 6.65I - 2)^2 \Rightarrow I = 0.99mA$

$V_3 = 10 - 6.65 \times 0.99 = 3.41V$

In (c): $R = \frac{10-4}{2} \cong 3.01K\Omega$, $V_{GS} = -(10 + 3.01I)$

$I = \frac{1}{2} \times 1 \times (-10 + 3.01I + 2)^2$ $I_D = 1.99mA.$

$V_4 = 10 - 3.01 \times 1.99 = 4.01V.$ $V_5 = -10 + 2.5K \times 1.99 = -5.03V.$

In (d): $R = \frac{2}{2} = 1K$ $V_7 = 2V.$ $V_6 = 6V$