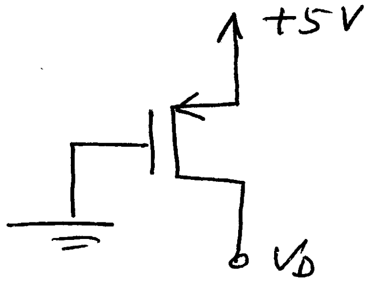
Homework #9

Ex 5.8



$V_{GS} = -5$ $k_p' \frac{W}{L} = 100 \frac{\mu A}{V^2} = \beta_p$

$V_t = -2V$

"Saturation edge" is when

$V_{DS} = V_{GS} - V_t$

$V_D - 5 = (0-5) - V_t$

$V_D = +2V$

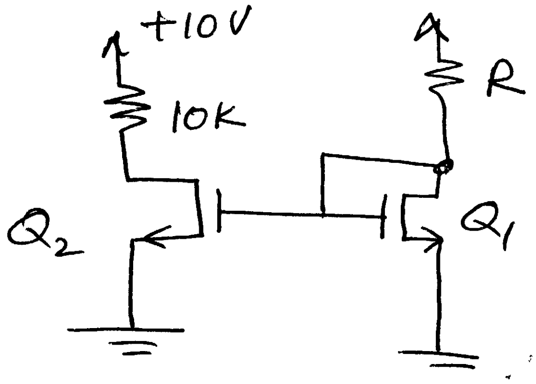
when $V_D = -5V$ $V_{DS} = -5-5 = -10\ V < V_{GS} - V_t$

$\therefore$ Transistor in saturation

$I_D = \frac{1}{2} \beta_p (V_{GS} - V_t)^2 = \frac{1}{2} \times 100 \frac{\mu A}{V^2} (-5-(-2))^2$

$= 50 \mu A \times 9 = 450 \mu A = 0.45 mA$

D5.35



$V_t = 2V$ $\mu_n C_{ox} = 20 \frac{\mu A}{V^2}$

$L_1 = L_2 = 10\mu$ $W = 100 \mu A$

Q_1 is in saturation since $V_{G_1} = V_{D_1}$

(a) $0.1 mA = 100 \mu A = \frac{1}{2} (\mu_n C_{ox}) \frac{W_1}{L_1} (V_{GS} - V_t)^2$

$= \frac{1}{2} * 20 \cdot \left(\frac{100}{10}\right) (V_{GS} - 2)^2$

$\therefore (V_{GS} - 2)^2 = 1 \Rightarrow V_{GS} = 3$ or $(+1) \leftarrow < V_t$ not possible

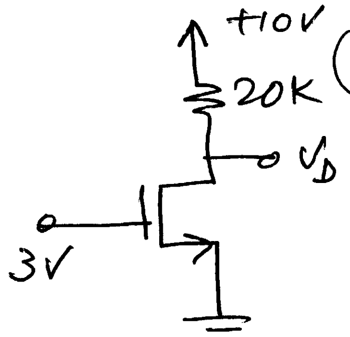
$\therefore V_{GS} = 3V$

$\therefore R = \frac{10-3}{0.1} = 70 k\Omega$

(b) $0.5 = \frac{1}{2}(20)\times10^{-3}\,\frac{W_2}{10}\,(3-2)^2$

$$W = \frac{2\times .5\times 10\times 10^{3}}{20 * 1} = 500\mu m$$

D 5.42 $\quad \beta_n = k_n'\frac{W}{L} = 200\,\frac{\mu A}{V^2} \quad V_t = 2V \quad V_A = 20V$



(a) Assume saturation

$$V_D = 10 - 20I_D \quad \text{or} \quad I_D = \frac{10 - V_D}{20K}$$

$$\frac{10 - V_D}{20K} = \frac{1}{2}(200\times10^{-6})(3-2)^2\left(1+\frac{V_D}{50}\right)$$

$$= 100\times10^{-6}\left(1+\frac{V_D}{50}\right)$$

$$\Rightarrow V_D = 7.27 > V_G - V_t = 1 \text{ (Sat)}$$

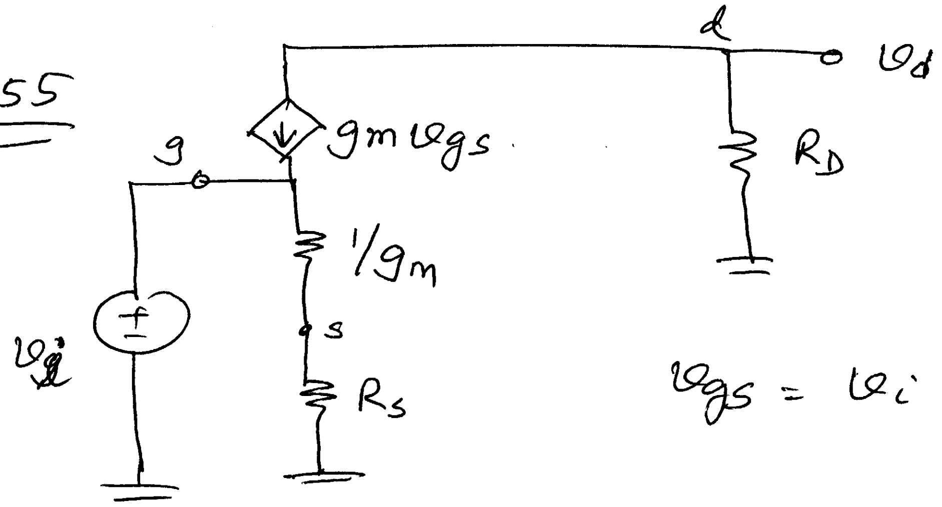
(b) Assume saturation

$$\frac{20 - V_D}{20\times K} = 100\times10^{-6}(1 + 0.05V_D) \Rightarrow V_D = 16.36 > V_{GS} - V_t \text{ (Sat)}$$

(c) Assume saturation

$$\frac{20 - V_D}{20K} = (100\mu A)(4)(1 + 0.05V_D) \Rightarrow V_D = 8.57 > V_{GS} - V_t \text{ (Sat)}$$

5-55



$$v_{gs} = v_i \frac{1/g_m}{1/g_m + R_s} = \frac{v_i}{1 + g_m R_s}$$

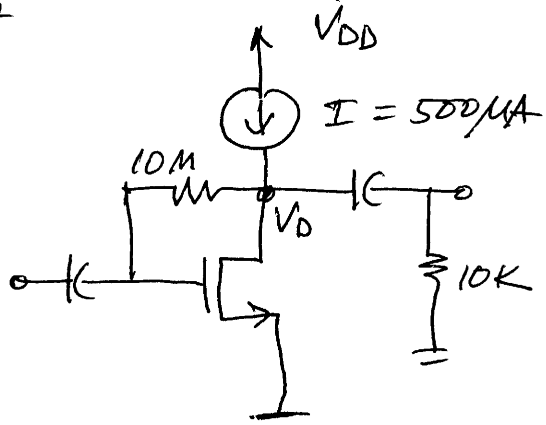
$$v_s = v_i \frac{R_s}{1/g_m + R_s} = v_i \frac{g_m R_s}{1 + g_m R_s}$$

$$\therefore \frac{v_s}{v_i} = \left[\frac{g_m R_s}{1 + g_m R_s}\right]$$

$$v_d = -g_m v_{gs} R_D = -g_m \left(\frac{v_i}{1 + g_m R_s}\right) R_D$$

$$\therefore \frac{v_d}{v_i} = -\left(\frac{g_m R_D}{1 + g_m R_s}\right)$$

5-57



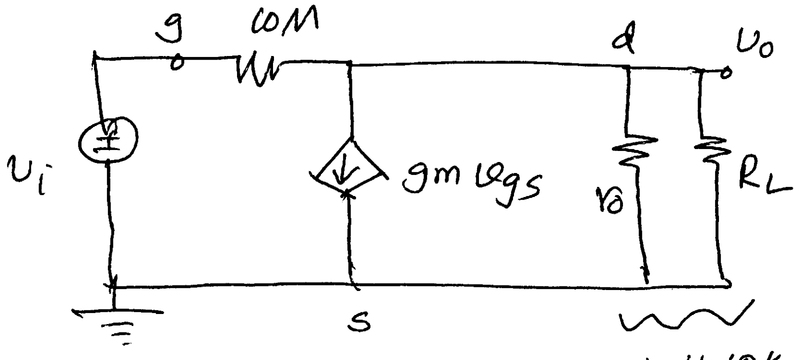
$|V_t| = 0.9V$ $V_A = 50V$

$V_D = 2V$

$$r_o = \frac{50V}{0.5m} = 100K$$

$$g_m = \frac{2I_D}{V_{GS} - V_t} = \frac{2(0.5mA)}{2 - 0.9} = 0.91\frac{mA}{V}$$

Small signal equivalent ckt



$100K \parallel 10K$
$= 9.09K$

$v_{gs} = v_i$

$v_o = -g_m v_i (r_o \parallel R_L)$

$\therefore \frac{v_o}{v_i} = -0.91\frac{mA}{V} \cdot 9.09K$

$= -8.27 \frac{V}{V}$

This transistor is always in saturation

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

[Note $V_{GS} = V_{DS} = V_D$]

$0.5mA = \frac{1}{2}\left(k_n' \frac{W}{L}\right)(2 - 0.9)^2\left(1 + \frac{2}{50}\right)$

$\Rightarrow \frac{1}{2}\left(k_n' \frac{W}{L}\right) = 3.97 \times 10^{-4} \frac{A}{V^2}$

Now when I is increases to 1mA

$10^{-3} = 3.97 \times 10^{-4} (V_D - 0.9)^2\left(1 + \frac{V_D}{50}\right) = 0$

Assume $\left(1 + \frac{V_D}{50}\right) \simeq 1$ (for the time being)

$(V_D - 0.9)^2 = \frac{10}{3.97} = 2.51 \Rightarrow V_D = 2.48$ or $= 0.687$ ← discard.

Second iteration

$(V_D - 0.9)^2 = \frac{10}{3.97}\left(\frac{1}{1 + \frac{2.48}{50}}\right) \Rightarrow V_D = 2.446V$

when $I_D = 1mA$ $\quad g_m = \frac{2 \times 1mA}{2.45 - 0.9} = 1.29 \frac{mA}{V}$

$$r_o = \frac{V_A}{I_D} = 50K$$

$$\therefore \frac{v_o}{v_i} = -g_m (r_o \| 10K) = -10.75 \, \frac{V}{V}$$