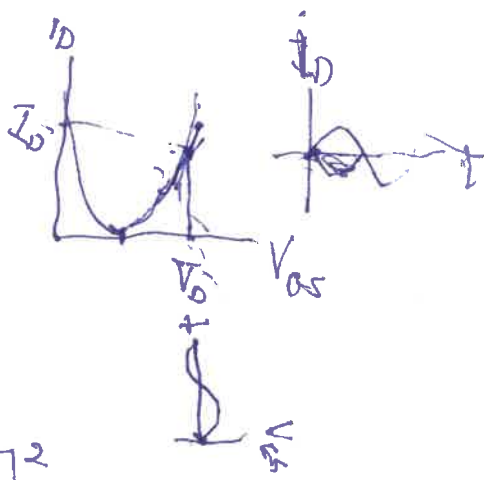
total DC (Q) AC

$$i_D(t) = I_D + i_d(t)$$

$$v_{GS}(t) = V_{GS} + v_{gs}(t)$$



$$i_D(t) = K\left[V_{GS} + v_{gs}(t) - V_{TO}\right]^2$$

$$= \underbrace{K\left(V_{GS} - V_{TO}\right)^2}_{I_D} + \underbrace{2K(V_{GS} - V_{TO})\, v_{gs}(t)}_{i_d(t)} + \underbrace{K\left(v_{gs}(t)\right)^2}_{0}$$

$$i_d(t) = g_m v_{gs}(t)$$

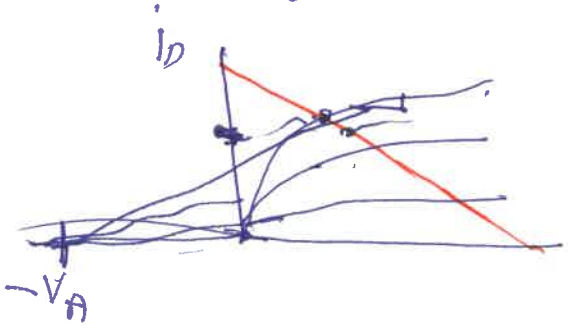
$$g_m = \frac{2I_D}{(V_{GS} - V_{TO})} \quad \text{or} \quad g_m = 2\sqrt{K I_D}$$

$$g_m = 2K(V_{GS} - V_{TO})$$

Small signal.

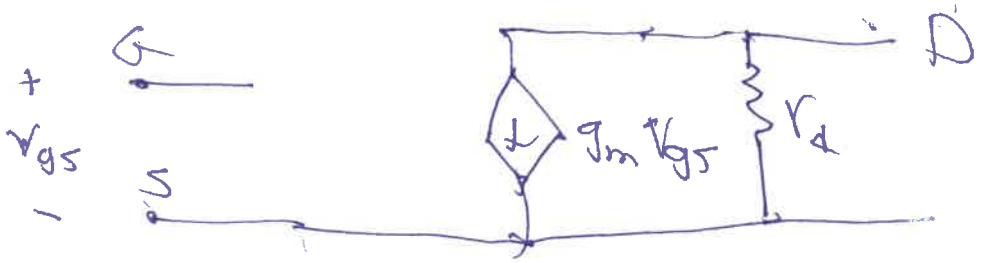
Pi model.

Early Voltage + Drain Resistance

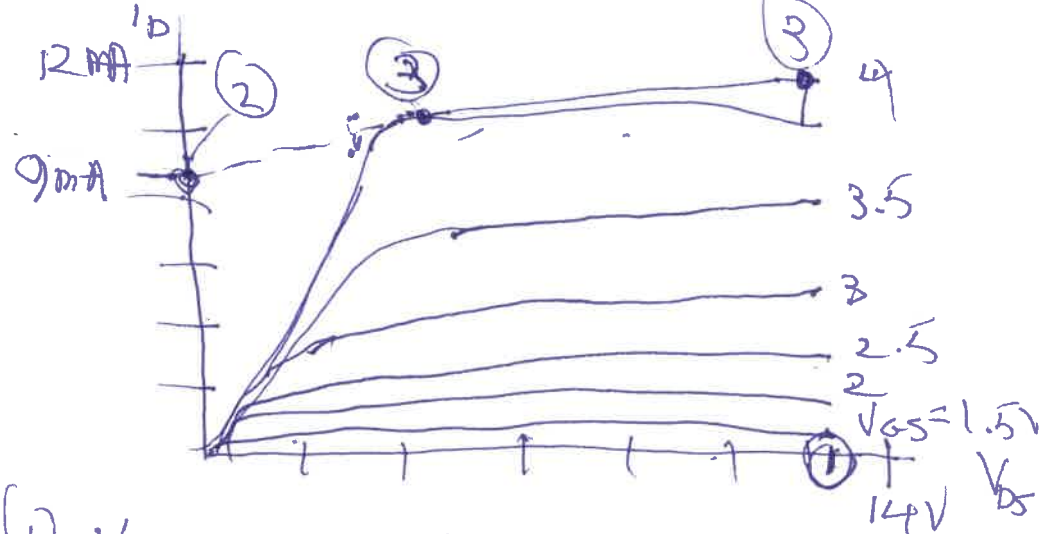


slope is $\frac{1}{r_d}$ ← drain Resistance

$$I_D = K(V_{GS} - V_{TO})^2$$



Reading The Curves.

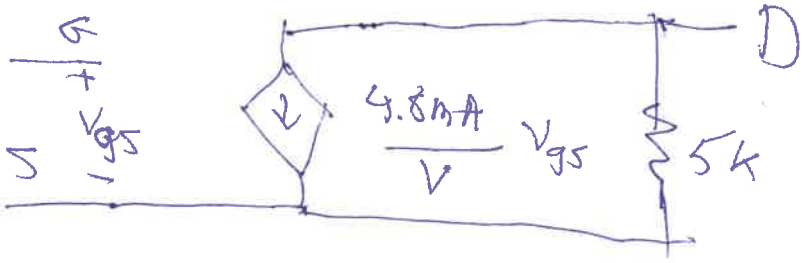


(1) $V_{TO} \approx 1$ VOLT

(2) $K = \frac{9\,mA}{(4V-1V)^2} = 1\ mA/V^2$

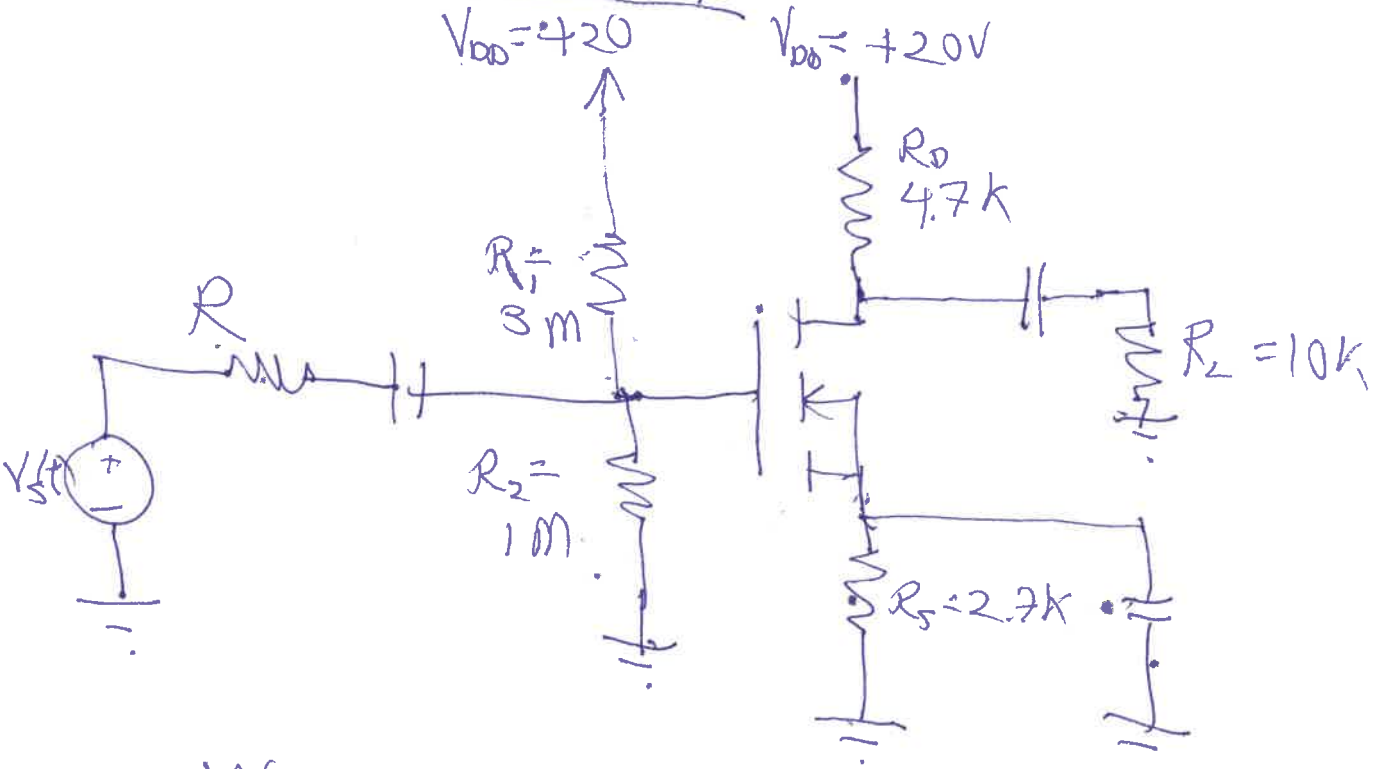
$\frac{W}{L} = \frac{2K}{KP} = \frac{2 \times 1000\mu A/V^2}{50\mu A/V^2} = 40$

$$r_d = \frac{14V - 4V}{(11.5 - 9.5)mA} = 5K$$



$$g_m = 2\frac{I_D}{V_{GS} - V_{TO}}$$

Common Source Amp



W = 400um L = 10um

V_{TO} = 2V V_A = 70V

DC solution (P 112) I_D = 784uA

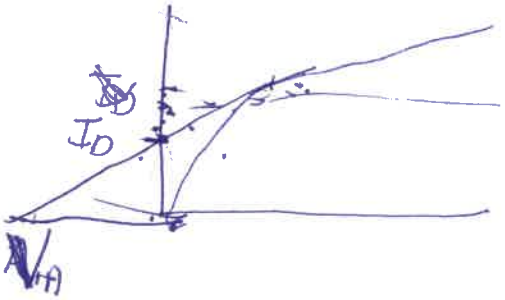
Small Signal

$$K = 2\frac{W}{L} KP = 4\,mA/V^2$$

Transconductance $g_m = \sqrt{K I_D} = \sqrt{4\frac{mA}{V^2} \times 0{,}784\,mA}$

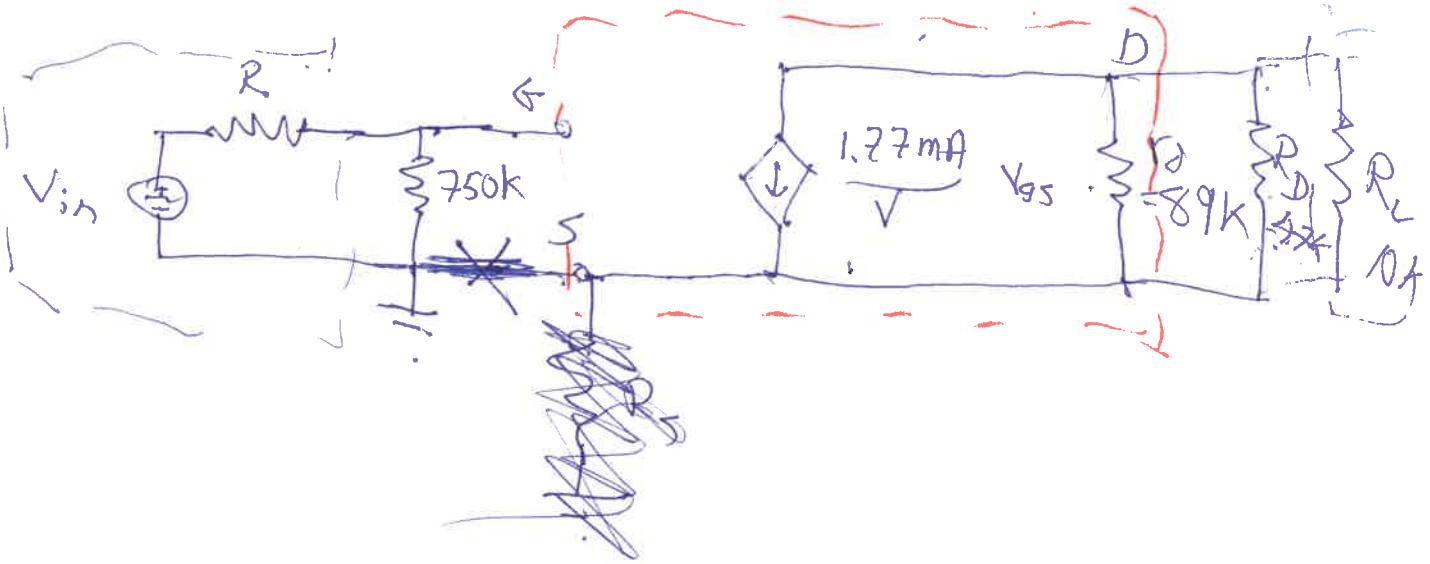
$$\boxed{g_m = 1.77\,mA/V}$$

$V_A = 70V$ $\quad \frac{1}{r_d} = \frac{I_D}{V_A}$



$$\frac{1}{r_d} = \frac{0.784\,mA}{70\,V}$$

$$\boxed{r_d = 89k\Omega}$$



Voltage Gain

$$v_{out} = -g_m (R_L \| R_D \| r_d) v_{in}$$

$$A_v = \frac{v_{out}}{v_{in}} = -1.77 \frac{mA}{V} * 3.2k = -5.66$$

Input Resistance

$$R_{in} = 750k$$

output Resistance

$$R_{out} = r_d \| R_D \approx 4.7k$$

Amplifier