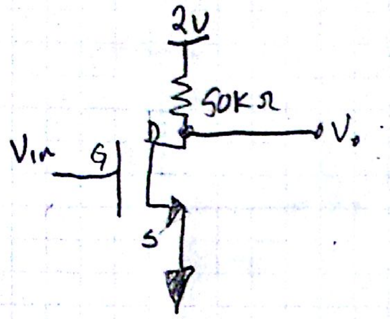
ECE 321 HW. #6 Mario Chaves

3) $k'_n = 75\mu A/V^2$, $W/L = 4$ if $V_o = 1.2V$, what is V_{in}?



$V_o = V_{DS} = 1.2V$

$V_{Tn} = 0.5V \leftarrow$ (in book not emailed)

$$I_{DS} = \frac{2-1.2}{50k} = 16\mu A$$

$$I_{DS} = \frac{k'_n}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{th})^2$$

$$\frac{I_{DS}(2)}{k'_n(4)} = (V_{GS} - V_{th})^2 \Rightarrow \sqrt{\frac{I_{DS}(2)}{k'_n(4)}} + V_{th} = \boxed{V_{GS} = 826.599mV}$$

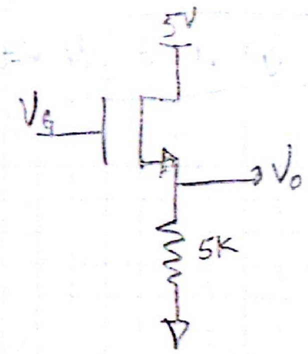
4) If $V_{in} = 0.8V$, $k_n = 100\mu A/V^2$ and $W/L = 4$, calculate V_G so that $I_D = 200\mu A$

$V_{GS} = V_G - V_o$

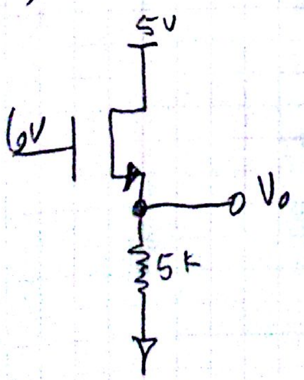
$V_{5K} = 200\mu A(5K) = 1V = V_o$

$$200\mu A = \frac{100\mu A}{2}(4)\left[(V_G - 1V) - 0.8V\right]^2$$

$$V_G = \sqrt{\frac{200\mu A(2)}{100\mu A(4)}} + 1.8V \Rightarrow \boxed{V_G = 2.8V}$$



6) Given $V_T = 0.8V$, $k'_n = 200\mu A/V^2$, $W/L = 4$ Calculate V_o



$V_{GS} = V_G - V_o$

$$I_{DS} = \frac{V_o}{5K}$$

$$I_{DS} = 200\mu A(4)\left[\left((6V - V_o) - 0.8V\right)(5 - V_o) - \frac{(5-V_o)^2}{2}\right]$$

$$\frac{V_o}{5K} = 200\mu A(4)\left[\left((6V - V_o) - 0.8V\right)(5 - V_o) - \frac{(5-V_o)^2}{2}\right]$$

$$\boxed{V_o = 3.81V}$$

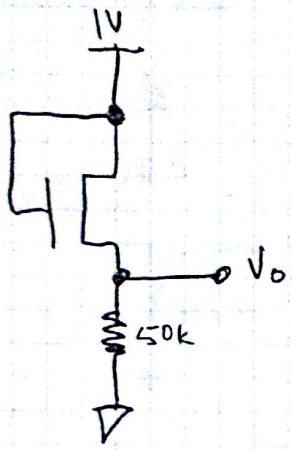
$V_{DS} = 5 - 3.81 = 1.19$

$6 - 3.81 - 0.8 = 1.39$

$V_{DS} \boxed{<} V_{GS} - V_T$

$1.19V < 1.39V$ Linear ✓

8) Given that $W/L = 5$ $V_T = 0.25$ and $k_n = 110\,\mu A/V^2$, find V_o & I_D

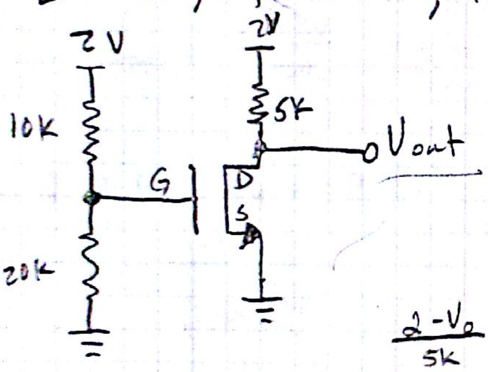


$I_{DS} = \frac{V_o}{50K}$ $V_G = 1V$

$$\frac{V_o}{50k} = \frac{110\,\mu A/V^2}{2}(5)\left((1 - V_o) - 0.25\right)^2$$

$$\boxed{V_o = 550\,mV}$$

9) $\frac{W}{L} = 20$, $V_T = 0.5V$, $k_n = 120\,\mu A/V^2$, find v_o and I_D



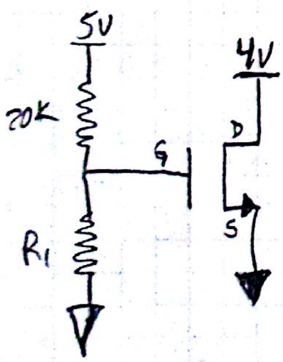
$$V_G = 2V\left(\frac{20k}{10k+20k}\right) = 1.333V = V_{GS}$$

$$I_{DS} = \frac{2 - V_o}{5K}$$

$$\frac{2 - V_o}{5k} = 120\,\mu A/V^2(20)\left((1.333 - 0.5)V_o - \frac{V_o^2}{2}\right)$$

$$\boxed{\begin{aligned} V_o &= 205.63\,mV \\ I_{DS} &= 358.874\,\mu A \end{aligned}}$$

13) Adjust R_1 so that M1 is on the saturated/non saturated border when $V_T = 0.5V$

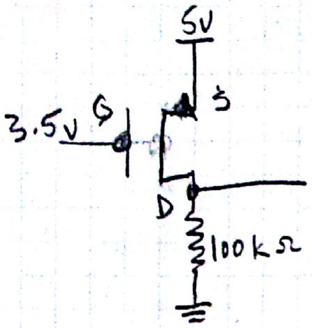


$$V_{DS} = V_{GS} - V_T$$

$$4V = 5\left(\frac{R_1}{20K+R_1}\right) - 0.5V$$

$$\frac{4V + 0.5V}{5} = \frac{R_1}{20K+R_1} \Rightarrow \boxed{R_1 = 180K\Omega}$$

16) Calculate I_D and V_o for the circuit where $V_T = -0.8V$, $K_p = 30\mu A/V^2$ where $\frac{W}{L} = 2$.



$$|V_{DS}| \; \square \; |V_{GS}| - |V_T|$$

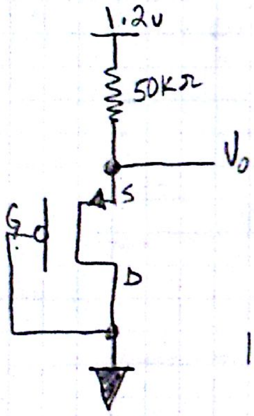
$$|V_o - 5V| \; \square \; |3.5 - 5V| - |-0.8V|$$

$$\underbrace{|V_o - 5V|}_{3.53V} \; \boxed{>} \; 700mV = \text{Saturated}$$

$$\frac{V_o}{100K} = \frac{30\mu A/V^2}{2}(2)\left(|-1.5| - |-0.8|\right)^2 \Rightarrow \boxed{V_o = 1.47V}$$

$$I_{DS} = \frac{1.47V}{100k} = \boxed{14.7\mu A = I_{DS}}$$

21) $\frac{W}{L} = 6$, $V_T = -0.3V$, $K_p = 40\mu A/V^2$ Calculate V_o and I_D



$|V_{GS}| = |0 - V_o|$ $|V_{DS}| = |0 - V_o|$

$$I_{DS} = k'n\left(\frac{W}{L}\right)\left[(V_{GS} - V_{Tn})V_{DS} - \frac{V_{DS}^2}{2}\right]$$

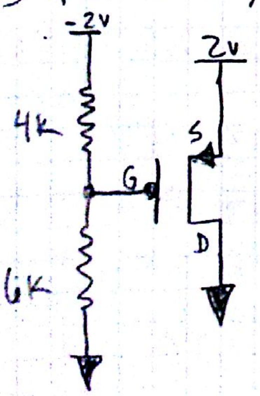
$$I_{DS} = \frac{1.2V - V_o}{50K} = (40\mu A/V^2)(6)\left[(|-V_o| - |-0.3V|)|-V_o| - \frac{(|-V_o|)^2}{2}\right]$$

$$\boxed{V_o = 713.602mV}$$

$$|V_{DS}| \; \square \; |V_{GS}| - |V_T|$$

$$V_o \; \boxed{>} \; V_o - |-0.3V| \quad \text{sat}$$

22) $V_T = -0.4V$, $W/L = 4$, $K_p = 100\mu A/V^2$



$V_G = -2V\left(\frac{6k}{4K+6K}\right) \Rightarrow V_G = -1.2V$, $|V_{GS}| = |-1.2V - 2V|$, $|V_{DS}| = |0 - 2|$

$|V_{GS}| = |-3.2|$ $|V_{DS}| = |-2V|$

a) bias state

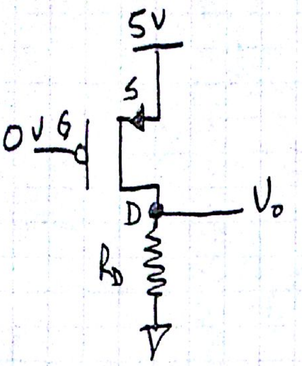
$$|V_{DS}| \; \square \; |V_{GS}| - |V_T| \Rightarrow 2 \; \boxed{<} \; 3.2 - 0.4 \quad \boxed{\text{linear}}$$

b) calculate I_D

$$I_D = (100\mu A/V^2)(4)\left[(|-3.2V| - |-0.4|)|-2| - \frac{|-2|^2}{2}\right]$$

$$\boxed{I_D = 1.44mA}$$

23) $V_T = -0.8V$, $K_p = 75\,\mu A/V^2$, what is the required $\left(\frac{W}{L}\right)$ ratio and what is R_D if M_1 is to pass $0.25A$ and keep $V_{SD} < 0.2V$



$|V_{DS}| \square |V_{GS}| - |V_T| \Rightarrow$

$0.2 \square |0-5| - |-.8|$

$0.2 \boxed{<} 5 - .8$ linear

$$0.25A = (75\mu)\left(\frac{W}{L}\right)\left[(|0-5| - |-0.8|)\,0.2 - \frac{0.2^2}{2}\right]$$

$$\boxed{\frac{W}{L} = 4065.04}$$

$\overset{0.2}{\downarrow}$

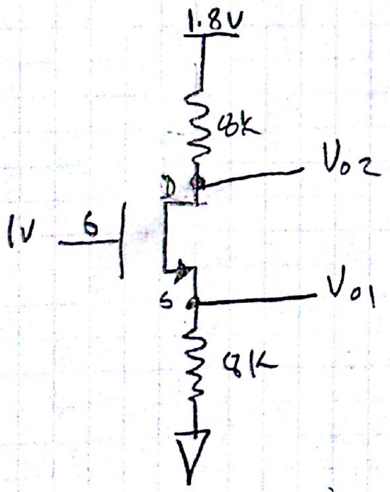
$V_{SD} = 5 - V_o$

$V_o = 5 - 0.2v$

$V_o = 4.8v$

$$\frac{V_o}{R_D} = I_{DS} = \frac{4.8}{0.25} = \boxed{19.2\Omega = R_D}$$

27) $\frac{W}{L} = 4$, $V_T = 0.4$, $K'_n = 95\,\mu A/V^2$, Calc V_{o1}, V_{o2} and I_D



$V_{DS} \square V_{GS} - V_T$

$V_{GS} = 1 - V_{o1}$

$V_{DS} = V_{o2} - V_{o1}$

$$I_{DS} = \frac{1.8v - V_{o2}}{8K} = \frac{V_{o1} - 0}{8K}$$

$V_{o1} = 1.8 - V_{o2}$

$V_{o2} = 1.8 - 219.762mV$

$V_{o2} = 1.58v$

assume saturation

$$I_{DS} = \frac{K'_n}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{Tn})^2$$

$$\frac{V_{o1}}{8K} = \frac{95\mu A}{2}(4)\left((1 - V_{o1}) - 0.4\right)^2$$

$$\boxed{V_{o1} = 219.762mV}$$

$V_{o2} = 1.8 - 219.762mV \Rightarrow \boxed{V_{o2} = 1.58v}$

$$I_D = \frac{V_{o1}}{8K} = \frac{219.762mV}{8K} = \boxed{27.47\mu A = I_D}$$

$|V_{DS}| \square |V_{GS}| - |V_T|$

$|1.58 - 219.762| = |V_{DS}|$

$|1 - 219.762mV| = |V_{GS}|$

$1.36 \boxed{>} 0.380$

✓ = Saturation