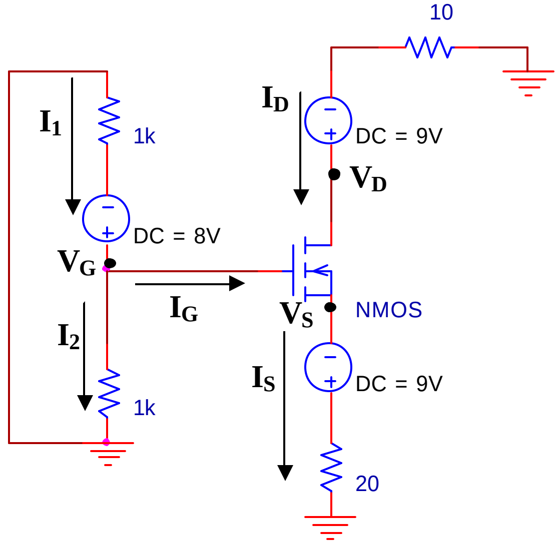
ECE2280 Homework #5 Spring 2008

1. Analyze the circuit shown below to determine the voltages (V_D, V_G, V_S) at all nodes and the currents through all branches (I_1, I_2, I_G, I_D, I_S). Let V_t=2V and $k_n'(W/L)=180\mu A/V^2$. Neglect the channel length modulation effect (i.e. λ=0).
2. If an AC source is applied at node V_G, state the condition that needs to be satisfied for the ac input amplitude. (what is the small-signal condition?)



$\boxed{I_D = I_S \quad I_G = 0}$ $\boxed{I_1 = I_2}$

$-I_1(1k) + 8 - I_1(1k) = 0$

$I_1 = \frac{8}{2K} = \boxed{4mA}$

$V_G = I_2(1k) = 4m(1k) = \boxed{4V}$

$+V_S + 9 - I_S(20) = 0$

$V_S = I_S(20) - 9$

$I_S = I_D = \frac{1}{2}(180\mu)(\underbrace{4 - I_S(20) + 9 - 2}_{11 - I_S(20)})^2$

$I_S(11,111) = (121 - 440 I_S + 400 I_S^2)$

$0 = 400 I_S^2 - 11,551 I_S + 121$

$I_S = \frac{11,551 \pm \sqrt{(11551)^2 - 4(121)(400)}}{2(400)} = 28.9, \boxed{0.0105 A} \rightarrow \boxed{V_S = -8.79} \quad V_{GS} = 12.79V$

$V_S = 569$

$V_{GS} = -565$

$+I_D(10) - 9 + V_D = 0$

$V_D = -I_D(10) + 9 = (-.0105)(10) + 9 \cong \boxed{8.9V}$

$V_{DS} \geq V_{GS} - V_t$

$8.9 = V_D \geq (V_G - V_t) = 2V$ ✓

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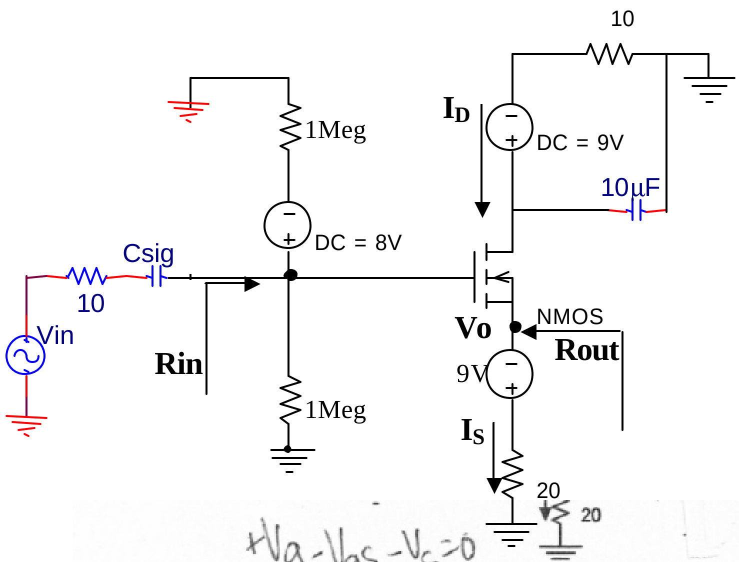
2. Vac << 2(VGS-Vt)
Vac << 2*(12.8-2)
Vac << 2*(10.8)

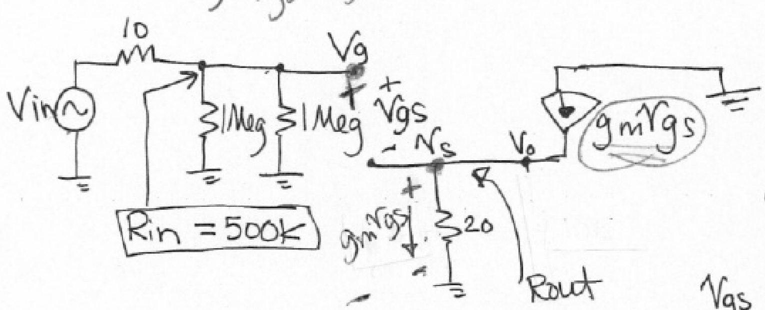
Let V_t=2V, $k_n'(W/L)=180\mu A/V^2$, $I_D=I_S$=10mA, and λ=0.

2. Draw the small-signal equivalent circuit by assuming all capacitors become shorts.
3. Analyze the circuit to find $A_v=V_o/V_{in}$, R_{in}(remove 10Ω) and R_{out}
4. Explain how to make the input resistance, R_{in} more ideal. State exact resistors that could be changed and how they could be changed. If this resistors were changed, how does this effect the gain?
5. How could the overall gain be increased. By making that change, what is the tradeoff or what do you have to be careful about?
6. Derive the frequency response transfer function for Vo/Vin in terms of Csig.
7. Find the value of Csig where the low 3db frequency value, f_L = 10 Hz (note this is in Hz – not rad/sec).



$$g_m = \sqrt{2k_n'\left(\tfrac{W}{L}\right)I_D} = \sqrt{2(180\mu)(\ldots}$$
$$g_m = \sqrt{3.6\mu A/V^2} \approx 1.9m$$

$+V_g - V_{gs} - V_s = 0$



$$V_o = g_m V_{gs}(20)$$
$$(V_{gs} = V_g + V_s)$$
$$V_{gs} = \frac{V_{in}(500k)}{500k+10} - g_m V_{gs}(20)$$
$$V_{gs} + g_m V_{gs}(20) \cong V_{in}$$
$$V_{gs} = \frac{V_{in}}{1+g_m(20)}$$

$$R_{out} = 20 \parallel \frac{1}{g_m}$$
$$R_{out} = \frac{20(527)}{527+20}$$
$$\boxed{R_{out} \cong 19\Omega}$$

$$\therefore V_o = \frac{g_m(20)V_{in}}{1+g_m(20)}$$
$$\frac{V_o}{V_{in}} = \frac{g_m(20)}{1+g_m(20)} \cong \boxed{37 mV/V}$$

4. Rin can be increased to become more ideal => Change into Mega Ohms. No effect on gain.
5. Increase gm which means to increase ID. This will put the circuit at risk of moving out of the saturation region. Increasing the 20ohm will increase gain.