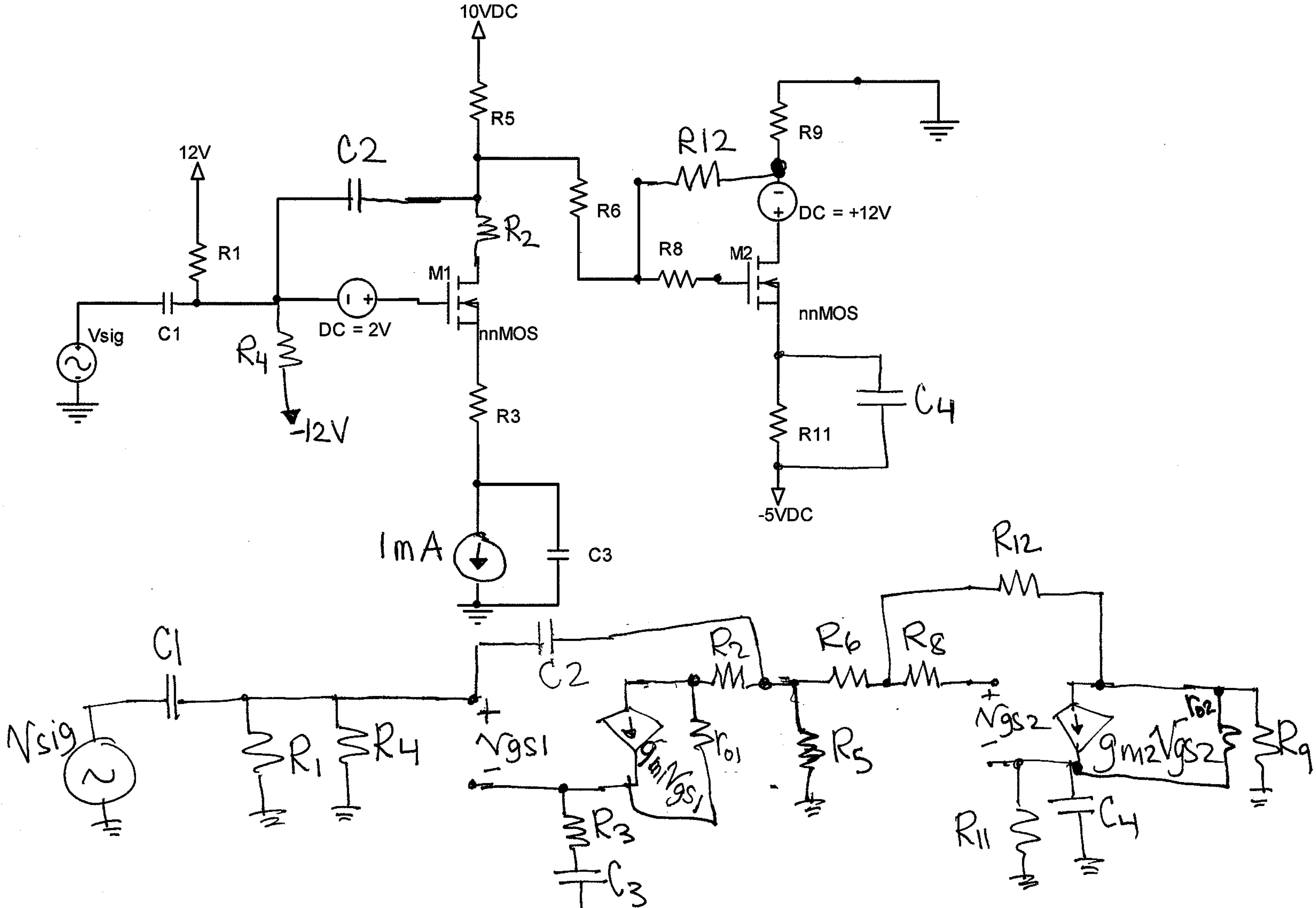
NAME: Solution

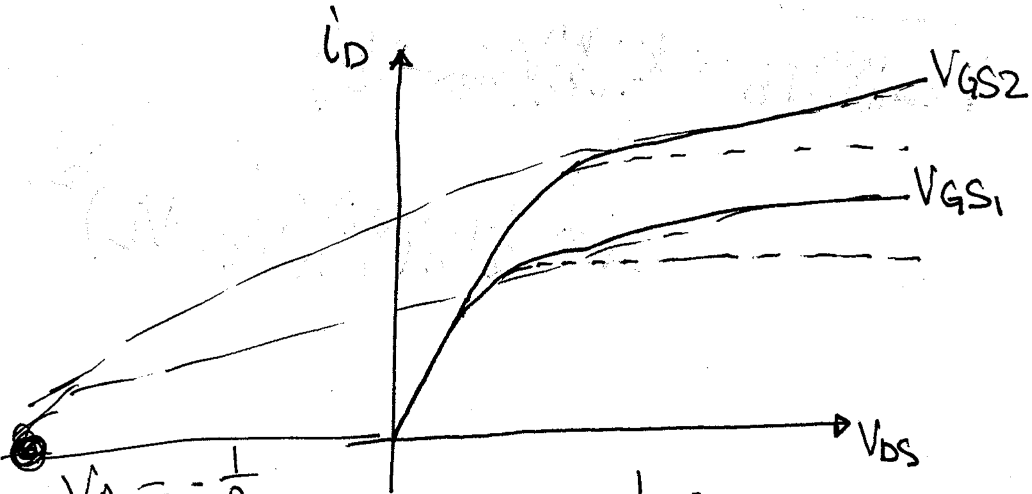
ECE2280
Quiz #4
(open book/notes)

I certify that the work below is my own.

Signature:____

For the circuit shown below, **draw** the AC small-signal equivalent circuit(use hybrid-π or model T). Make sure that everything is labeled in terms of the transistor number. (e.g. g_{m1}, v_{gs2}, r_{o1}, etc.). $\boldsymbol{\lambda \neq 0}$ for all transistors.(i.e. draw the small-signal with r_o included). v_{sig}=0.005sin(20t) AC. Draw the small-signal equivalent circuit **WITH** capacitors shown.



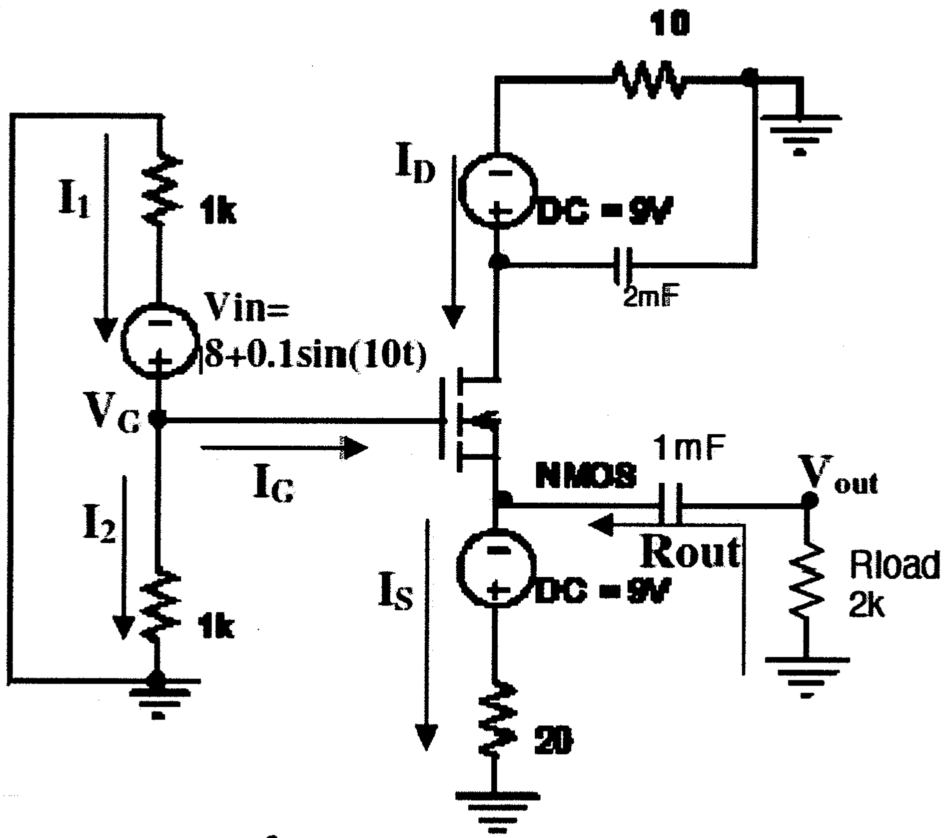


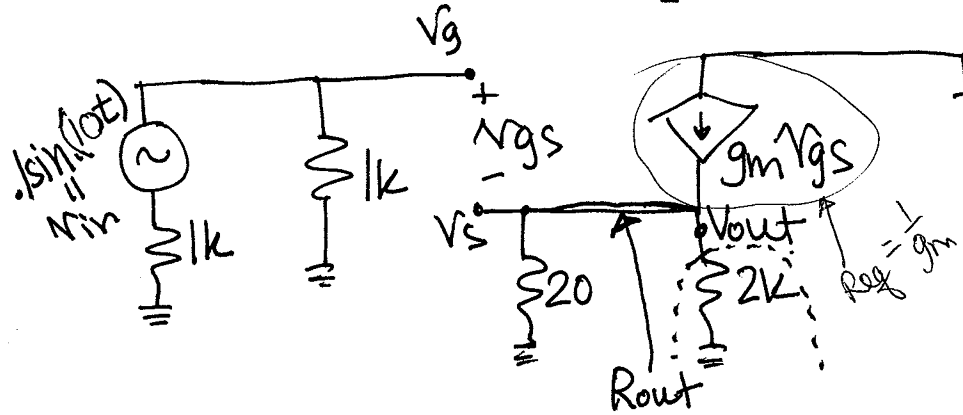
$-V_A = -\frac{1}{\lambda}$

$r_o = \frac{1}{\lambda I_D}$ BIG

DC ONLY!!!

Let V_t=2V, $k_n'(W/L)$=180µA/V^2, I_D=10.5mA, and V_{GS}=12.8V. Find the ideal gain Vout/Vin and Rout(do not include the 2k load resistor).





$g_m = \sqrt{2(180\mu)(10.5m)}$

OR

$g_m = K_n'\left(\frac{W}{L}\right)(V_{GS} - V_t)$

$g_m = 180\mu(12.8 - 2)$

$g_m \approx 1.9m$

$V_{out} = g_m V_{gs}(20 \| 2k)$

$V_{gs} = V_g - \underset{V_{out}}{V_s}$

$V_{gs} = \frac{V_{in}(1k)}{2k} \Rightarrow V_{gs} = V_{in}\left(\frac{1}{2}\right) - g_m V_{gs}(20 \| 2k)$

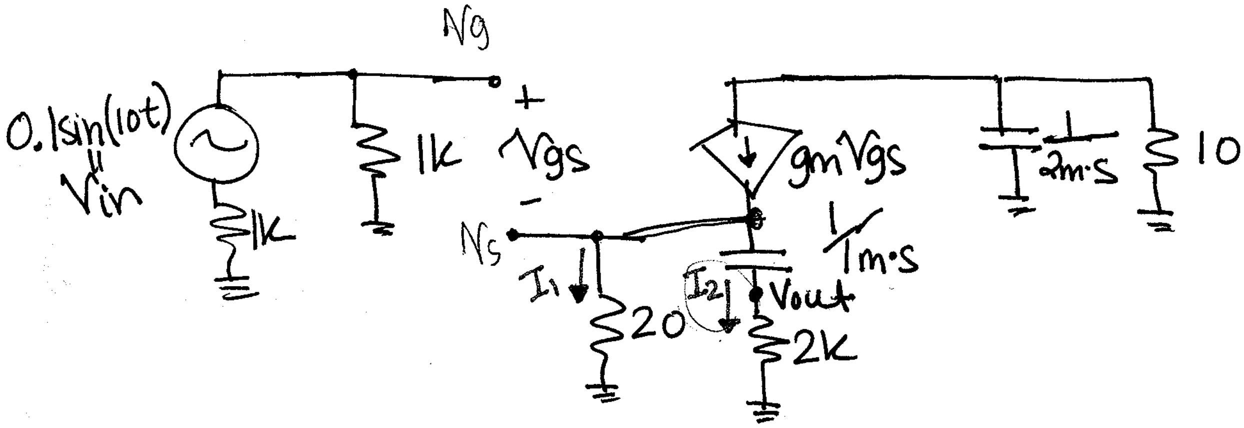
$V_{gs}\left(\cancel{1 + g_m(20 \| 2k)}\right) = \frac{V_{in}\left(\frac{1}{2}\right)}{1 + g_m(20 \| 2k)}$

$$\frac{V_{out}}{V_{in}} = g_m(20\|20k)\frac{\cancel{V_{in}}\left(\frac{1}{2}\right)}{(1+g_m(20\|2k))}$$

$$g_m \approx 1.9m$$

$$\frac{V_{out}}{V_{in}} \approx \boxed{18m\,V/V}$$

$$R_{out} = 20 \,\|\, \frac{1}{g_m} \approx \boxed{19\,\Omega}$$



$$V_{out} = I_2(2K)$$

$$I_2 = \frac{g_m V_{gs}(20)}{20 + 2K + \frac{1}{1ms}} \cdot \frac{1m\cdot s}{1m\cdot s} = \frac{g_m\, 20\, 1m\cdot s \cdot V_{gs}}{\left((2K+20)1ms + 1\right)}$$

$$V_{gs} = V_g - V_s = \tfrac{1}{2}V_{in} - V_s$$

$$V_s = I_2\left(\frac{1}{1ms} + 2K\right) = \Bigg[\underbrace{\frac{g_m(20)1m\cdot s \cdot V_{gs}}{\left((20+2K)1ms + 1\right)}}_{I_2}\Bigg] \cdot \left(\frac{1}{1ms} + 2K\right)$$

$$\left(\frac{1}{1ms} + 2K\right) \downarrow \frac{1}{1ms}\left(1 + 2K\cdot 1m\cdot s\right)$$

$$V_s = \frac{g_m(20)\cancel{1ms}\cdot V_{gs}(1 + 2K\cdot 1m\cdot s)}{\cancel{1ms}\left((20+2K)1ms + 1\right)}$$

$$V_{gs} = \tfrac{1}{2}V_{in} - \frac{g_m\, 20\, V_{gs}(1 + 2K1ms)}{(20+2K)1ms + 1}$$

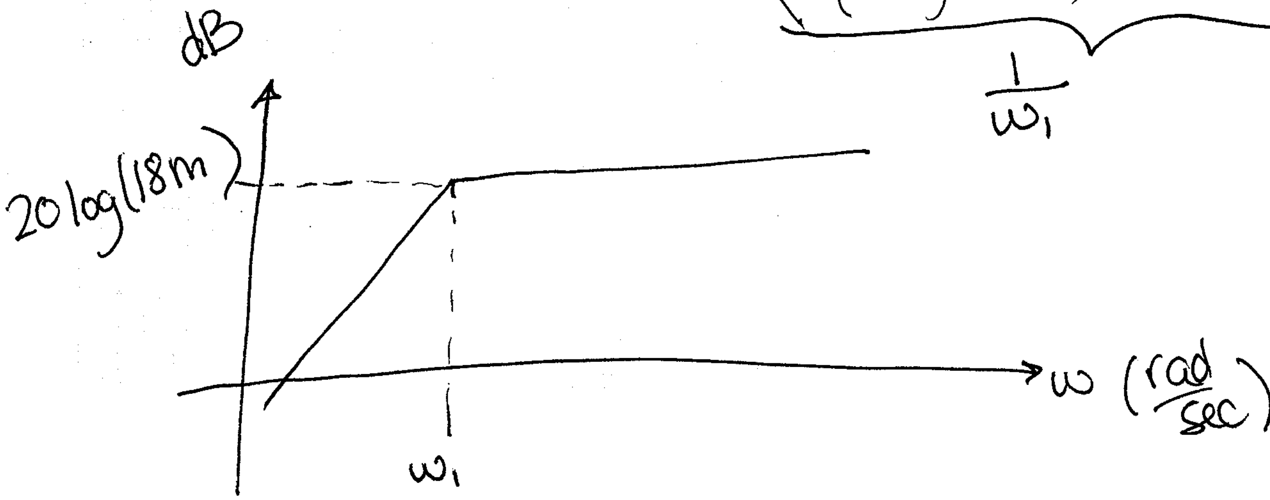
$$V_{gs} = \frac{\tfrac{1}{2}V_{in}}{1 + \dfrac{g_m 20(1+2K1ms)}{(20+2K)1ms+1}}$$

$$V_{out} = \frac{g_m 20(1ms)\cdot \cancel{V_{gs}}}{\left((2k+20)\,1ms+1\right)} \left[\frac{\frac{1}{2}V_{in}}{1+\frac{g_m 20(1+2k1ms)}{(20+2k)1ms+1}} \right]$$

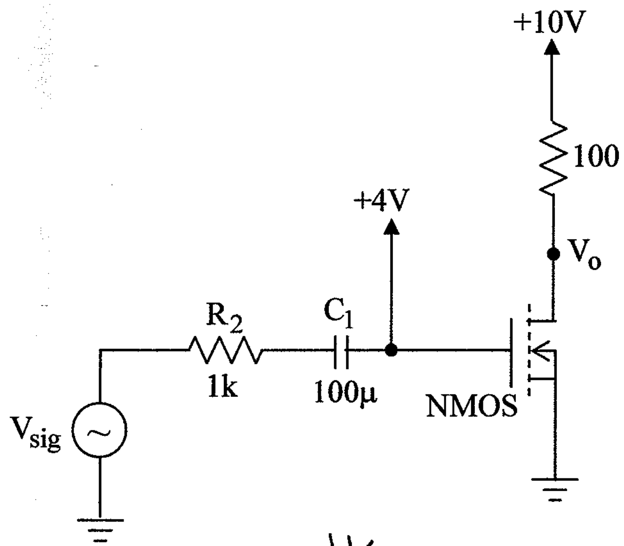
$$\frac{V_{out}}{V_{in}} = \frac{g_m 20(1ms)}{2\left((2k+20)1ms+1\right)+g_m 20+g_m 20 2k 1ms}$$

$$\frac{V_{out}}{V_{in}} = \frac{g_m 20(1m)s}{2\left[\left[(2k+20)1m+g_m(20)(2k)(1m)\right]s+\left(1+g_m 20\right)\right]}$$

$$= \frac{g_m 20(1m)s}{2(1+g_m 20)\left[\underbrace{\left(\frac{(2k+20)1m+g_m(20)(2k)(1m)}{(1+g_m 20)}\right)}_{\frac{1}{\omega_1}}s+1\right]}$$



Let V_t=2V, $k_n'(W/L)$=4mA/V^2, v_{sig} ={9+0.001sin(ωt)}Volts. Assume that the capacitor acts as an open for DC operation and a short for AC operation. Does this circuit operate as a **linear** AC amplifier? If so, what is the gain, $\frac{Vo}{Vsig}$, of the following circuit? If not, explain why.



SAT, ON

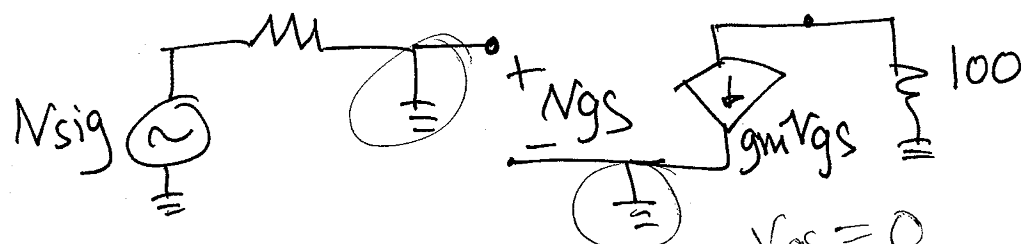
$V_{GS} = 4 > V_t = 2$ ✓ ON

$I_D = \frac{1}{2}(4m)(4-2)^2 = 8m$

$V_D = 10 - 8m(100) = 9.2$

$9.2 > \underbrace{(V_{GS}-V_t)}_{2}$ ✓ SAT

$V_o = 0$!



$V_{gs} = 0$

NO