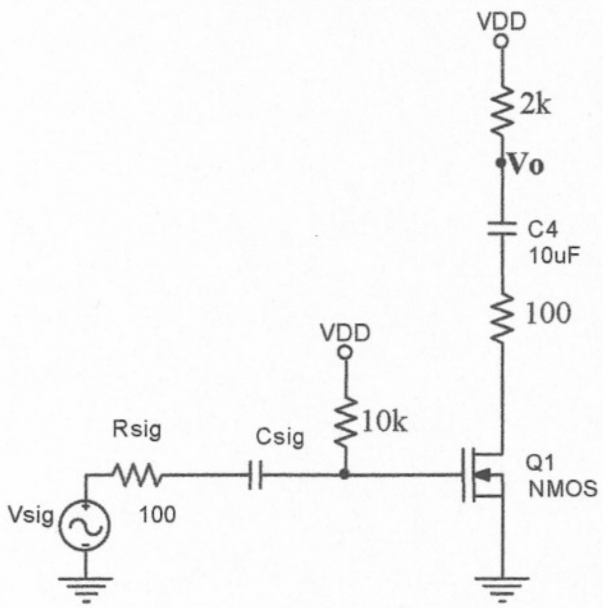
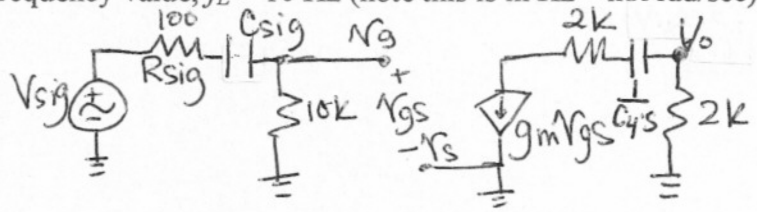
**ECE2280** **Homework #5** **Spring 2007**

1. Use: $g_m$=**100mA/V** for the circuit below. Vsig is an AC signal source.

(a) Derive the frequency response transfer function for Vo/Vsig in terms of Csig.
(b) Find the value of Csig where the low 3db frequency value, $f_L$ = 10 Hz (note this is in Hz – not rad/sec).




$$V_o = -g_m V_{gs}(2K)$$

$$V_{gs} = \left[\frac{V_{sig}(10K)}{10K + 100 + \frac{1}{C_{sig}\cdot S}}\right]\frac{C_{sig}\cdot S}{C_{sig}\cdot S}$$

$$V_{gs} = \frac{V_{sig}(10K)(C_{sig}\cdot S)}{C_{sig}\cdot S\,(10K+100)+1}$$

$$\frac{V_o}{V_{sig}} = \frac{-g_m(10K)(2K)(C_{sig}\cdot s)}{[C_{sig}\cdot s\,(10K+100)+1]} = \boxed{\frac{-2\,Meg\cdot s\cdot C_{sig}}{(10{,}100\cdot C_{sig}s+1)}}$$

$f_L = 10Hz \quad \therefore \quad \omega = 2\pi f \cong 63\,rad/sec.$

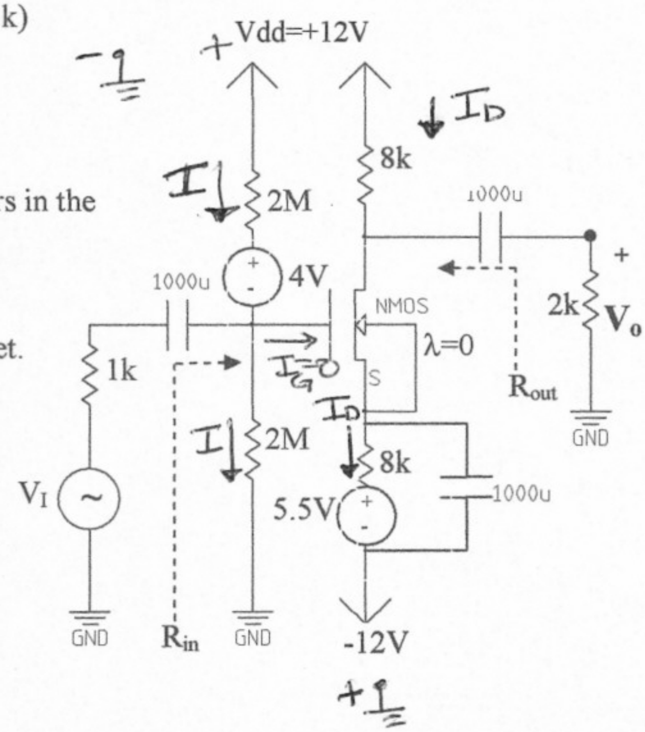
$$s = \frac{1}{10{,}100\cdot C_{sig}} = 63\,rad/sec. \Rightarrow \boxed{C_{sig} \cong 1.6\mu F}$$

2. (a) Solve the DC circuit(schematic below)to find $I_D$ and $V_{GS}$(assume caps open)
(b) Use Matlab to find the value that Vdd can be reduced and still keep the transistor in saturation.

3. Solve the AC circuit(schematic below):
(a) Draw the small-signal equivalent circuit (assume caps shorted)
(b) Find the midband gain $\frac{V_o}{V_I}$ ($V_I$ is an AC source)
(d) Find Rin (node to right of capacitor, remove $V_I$ and 1k)
(e) Find Rout (node to left of capacitor, remove 4k)
**Given:**
$V_t$=2.831V
$k_n'(W/L)$=3.1A/V$^2$

4. Solve the circuit(schematic below) by including the capacitors in the AC small-signal equivalent circuit. Solve thefrequency transfer function Vo/$V_I$.

5. Simulate the circuit using PSPICE and IRF150 for the MosFet.
(a) Find and compare the simulated AC bode plot with the theoretical function found in (4).
(b) Find and compare the DC values found in (2). If there are differences describe why.




2.(a)

$+12-I(2M)-4-I(2M)=0$

$I=\frac{8}{4M}=2\mu A$

$V_G=I(2M)=4V$

$+V_S-I_D(8K)-5.5+12=0 \Rightarrow V_S=I_D(8K)-6.5$

SAT:

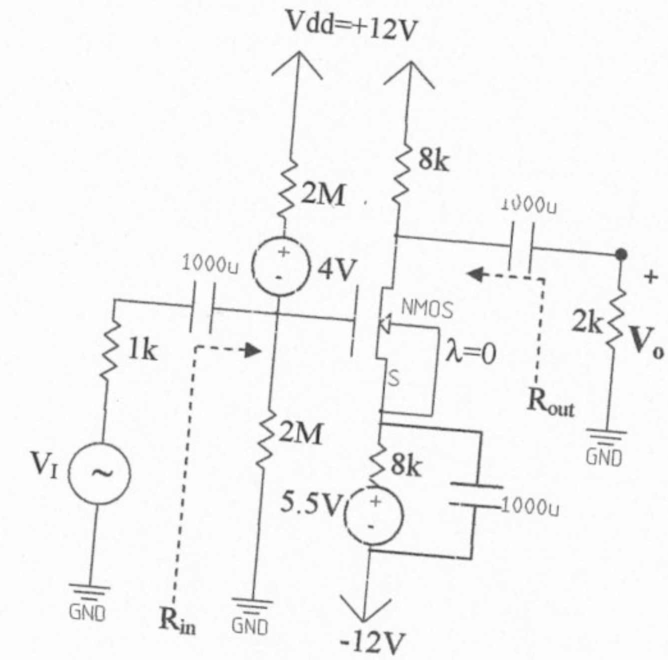
$I_D=\frac{1}{2}(3.1)(4-I_D(8K)+6.5-2.831)^2$

⇓ solving

$I_D=\boxed{.956m}, .962m \rightarrow$ $V_S=.962m(8K)-6.5=1.96$
$V_{GS}=4-1.96=2.804<V_t$ ∴ off

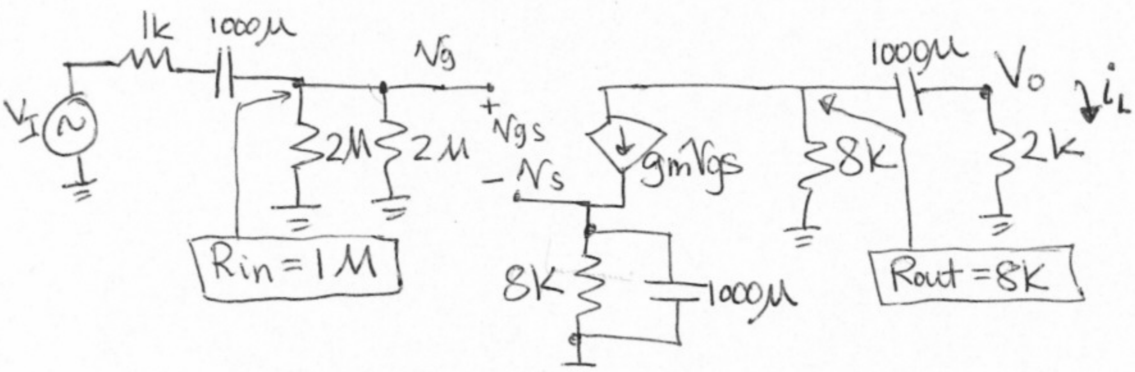
$V_S=.956m(8K)-6.5=1.148$

$V_{GS}=4-1.148=\boxed{2.852V}>V_t$




$$g_m = \sqrt{2(3.1)(.956m)} \cong .077\ \tfrac{A}{V^2}$$

4. $$\boxed{\frac{V_o}{V_I} = \frac{-1997 \cdot s^2 (8s+1)}{(10s+1)(1{,}001s+1)\left(\frac{8s}{617}+1\right)}}$$




3. when caps shorted: $V_o = -g_m V_{gs}(8k \| 2k) = -g_m V_{gs}(1600)$

$$V_g = \frac{V_I(1M)}{1M+1k} \approx V_I \quad \therefore V_{gs} \approx V_I$$

$$\Rightarrow \frac{V_o}{V_I} \cong \boxed{-123.2\ V/V} \approx 41.8\text{dB}$$

4. with caps: $$i_L = \frac{-g_m V_{gs}(8k)}{8k+2k+\frac{1}{1000\mu \cdot s}} = \frac{-g_m(8k)V_{gs}(1000\mu \cdot s)}{10k(1000\mu \cdot s)+1} = \frac{-.616 V_{gs} \cdot s}{(10s+1)}$$

$$V_o = i_L \cdot 2k = \frac{-1232 \cdot V_{gs} \cdot s}{(10s+1)}$$

$$V_g = \frac{V_I(1M)}{1M+1k+\frac{1}{1000\mu \cdot s}} = \frac{V_I(1M)1000\mu \cdot s}{(1M+1k)(1000\mu \cdot s)+1} = \frac{1000 \cdot V_I \cdot s}{(1001 \cdot s+1)}$$

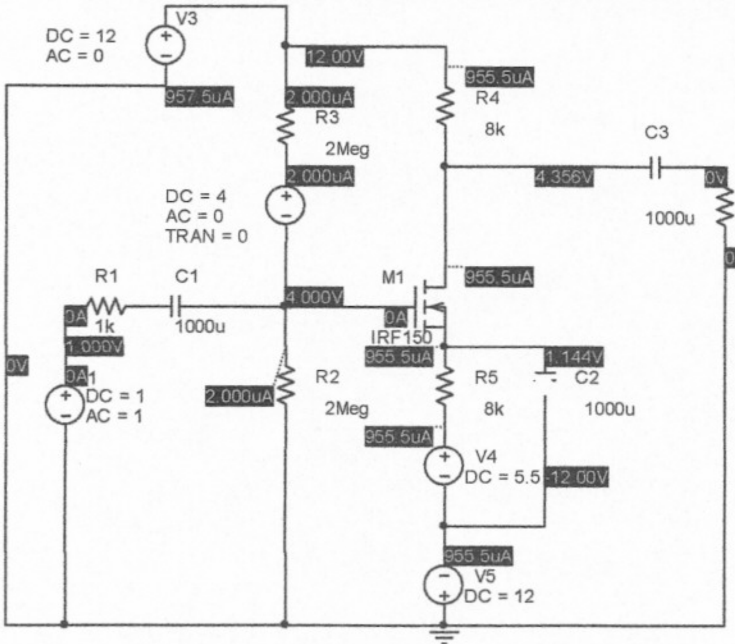
$$V_s = g_m V_{gs}\left(8k \| \tfrac{1}{1000\mu s}\right) = \frac{g_m V_{gs}(8k)}{(8s+1)} \Rightarrow V_{gs} = \frac{1{,}000 V_I \cdot s}{(1001 \cdot s+1)} - \frac{616\ V_{gs}}{(8s+1)}$$

$$V_{gs} = \frac{1{,}000 V_I \cdot s}{(1001 \cdot s+1)} \cdot \frac{(8s+1)}{(8s+617)}$$

$$\therefore \frac{V_o}{V_I} = \frac{-1232 \cdot s\ 1{,}000 \cdot s\,(8s+1)}{617(10s+1)(1{,}001 \cdot s+1)\left(\frac{8s}{617}+1\right)}$$ → see top of page

**PSpice Simulation:**

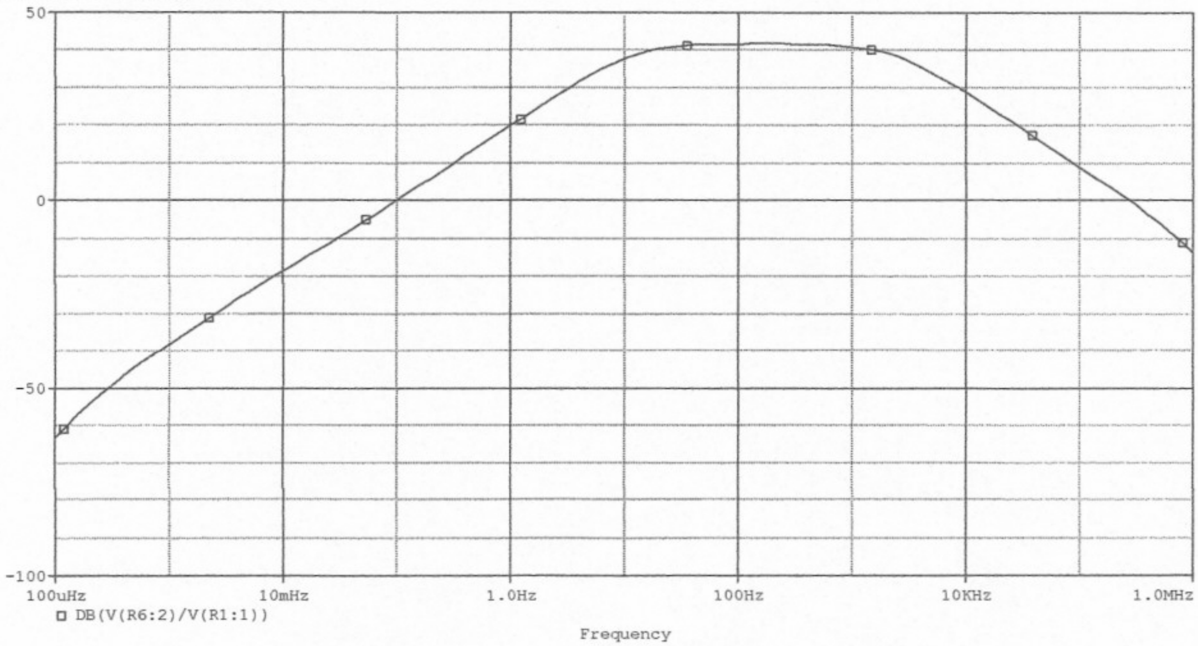
**DC values are similar to analysis in (2). Difference is due to rounding $I_D$.**



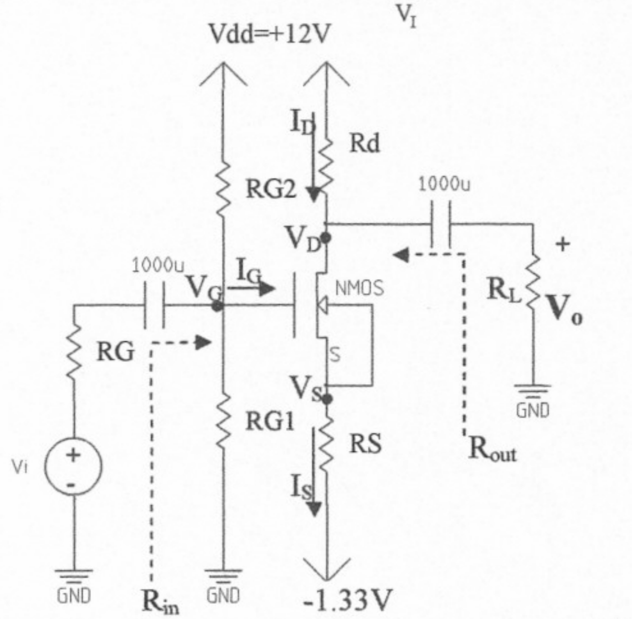

Graph below is has dB for the y-axis. Comparing to (3) =>

- Midband gain = 123.2V/V which is 41.8dB. Graph below shows midband gain at 41.7dB.
- 3dB value from calculation is the highest pole value which is 617/8=77rad/sec = 12Hz. The graph below had a measurement of the 3dB at 12.6Hz.
    - *Differences are very slight between the hand calculations and the simulation*

PSPICE Simulation:



6. $V_I$ is an AC voltage source. Use $\lambda=0$, $g_m=1mA/V^2$
$R_G=10\Omega$, $R_{G1}=2M\Omega$, $R_{G2}=10M\Omega$, $Rd=10k\Omega$, $RS=1k\Omega$, $R_L=10k\Omega$.
(a) Find the midband gain $A_v=\frac{V_o}{V_I}$ (use small-signal model), $R_{in}$ (remove $R_G$) and $R_{out}$(remove $R_L$)




• Common-Source Configuration with emitter resistance.

$R_{in} = 2M \| 10M$

$\boxed{R_{in} \doteq 1.7M}$

$\boxed{R_{out} = 10k}$

Note: Amplifier part without input ($V_I$ & $R_G$) and output load $R_L = 10K$

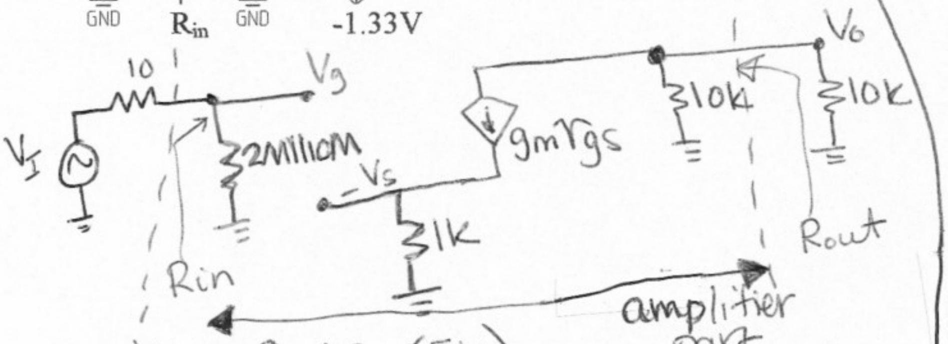
$\Rightarrow A_{vo} = \frac{V_o}{V_g}$

$V_o = -g_m V_{gs}(10k)$

$V_{gs} = V_g - g_m V_{gs}(1k)$

$V_{gs} = \frac{V_g}{1+1} = \frac{V_g}{2}$

$\frac{V_o}{V_g} = \frac{-10}{2} = \boxed{-5 V/V}$




$V_o = -g_m V_{gs}(5k)$

$V_g \approx V_I$

$V_s = g_m V_{gs}(1k)$

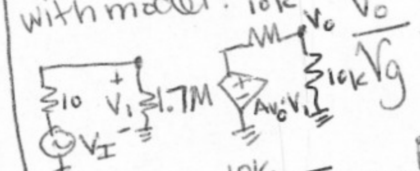
$\therefore V_{gs} = V_I - g_m V_{gs}(1k)$

$V_{gs} + g_m V_{gs}(1k) = V_I$

$V_{gs} = \frac{V_I}{1+1} = \frac{V_I}{2}$

$V_o = -5\frac{V_I}{2} = -2.5V_I \Rightarrow \boxed{\frac{V_o}{V_I} = -2.5 V/V}$

with model:

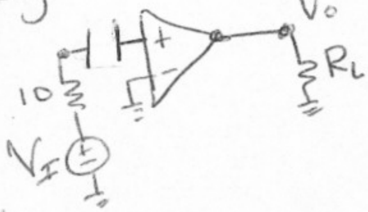



$\Rightarrow V_o = A_{vo} V_1 \cdot \frac{10k}{10k+10k}$

$V_1 \approx V_I$

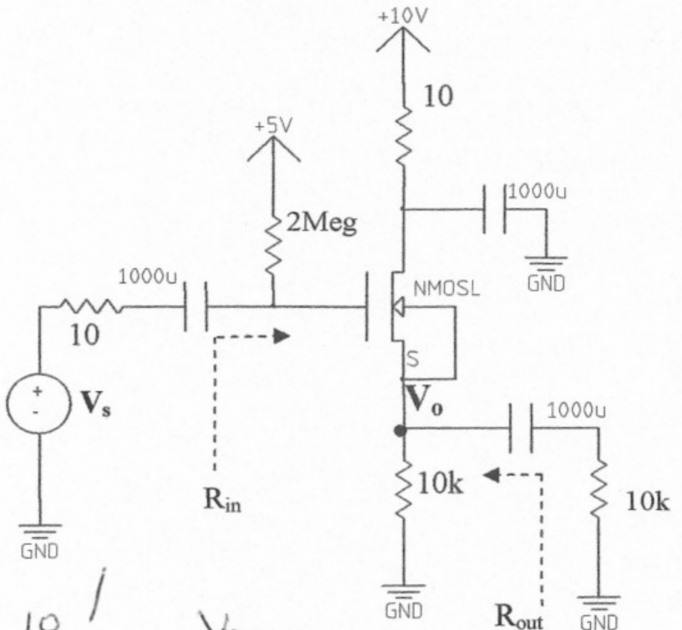
$\therefore \frac{V_o}{V_I} = \frac{-5}{2} = -2.5 V/V$

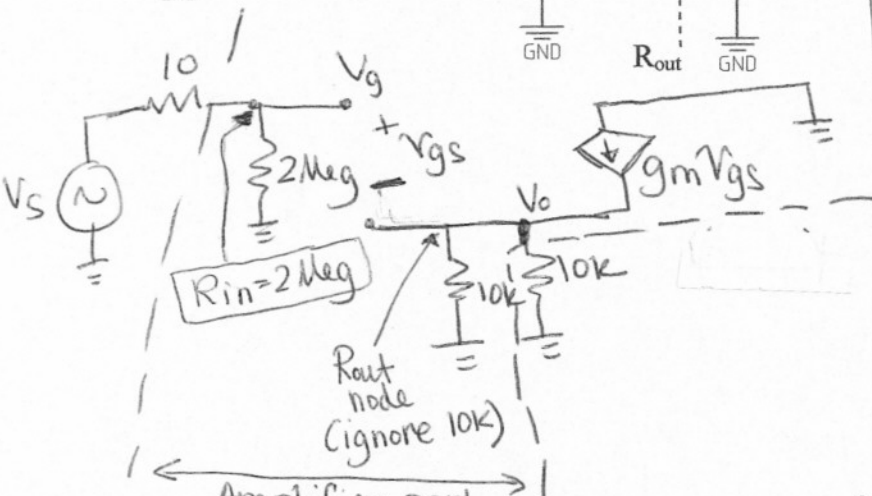
(same)



7. Use $V_t$=2V, $k_n'(W/L)$=3mA/V$^2$, $\lambda$=0, Vs is an AC voltage source. $g_m$=10mA/V$^2$

(a) Find the midband gain $A_v = \frac{V_o}{V_s}$ (use small-signal model), $R_{in}$(remove 10) and $R_{out}$(remove 10k)




$(V_{gs} = V_g - V_o)$

$V_o = g_m V_{gs}(10K \| 10K)$

$V_g = \frac{V_s(2Meg)}{2Meg + 10} \approx V_s$

$V_o = g_m V_{gs}(5K)$

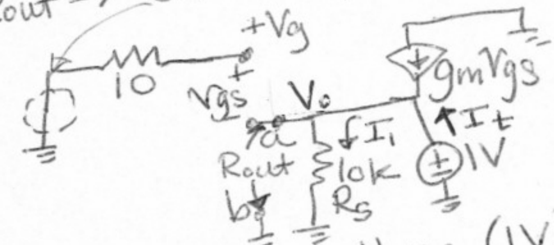
$V_{gs} = V_s - g_m V_{gs}(5K)$

$V_{gs} = \frac{V_s}{1+50} = \frac{V_s}{51}$

$\frac{V_o}{V_s} = \frac{50}{51} \approx \boxed{.98 V/V}$

·Common-Drain

Rout ⇒ ① short input ⇒




② Apply test voltage (1V)

③ Measure $I_t$ ⇒

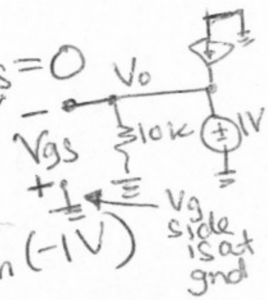
④ $R_{th} = \frac{1V}{I_t}$

$-I_1 + I_t + g_m V_{gs} = 0$

$V_{gs} = -1V$

$I_1 = \frac{1}{10K}$

$I_t = I_1 - g_m(-1V)$

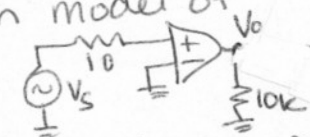



$I_t = \frac{1}{10K} + g_m$

$R_{th} = \frac{1}{\frac{1}{10K} + g_m}$ (Note → This is $R_{th} = R_S \| \frac{1}{g_m}$)

$R_{th} = \boxed{R_{out} \cong 99\,\Omega}$

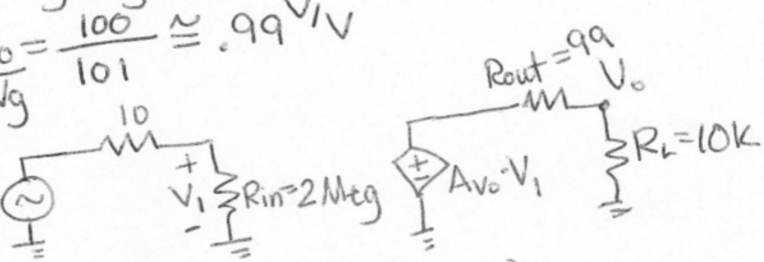
Note: with model of opamp ⇒




$A_{vo} = \frac{V_o}{V_g}$

$V_o = g_m V_{gs}(10K) = g_m(10K)\left(\frac{V_g}{1 + g_m(10K)}\right)$

$A_{vo} = \frac{V_o}{V_g} = \frac{100}{101} \cong .99 V/V$




$V_o = \frac{A_{vo} \cdot V_1 \cdot 10K}{10K + 99} = \frac{.99 V_s(10K)}{10K+99}$

$V_1 \approx V_s \Rightarrow \frac{V_o}{V_s} \cong .98 V/V$ (same)