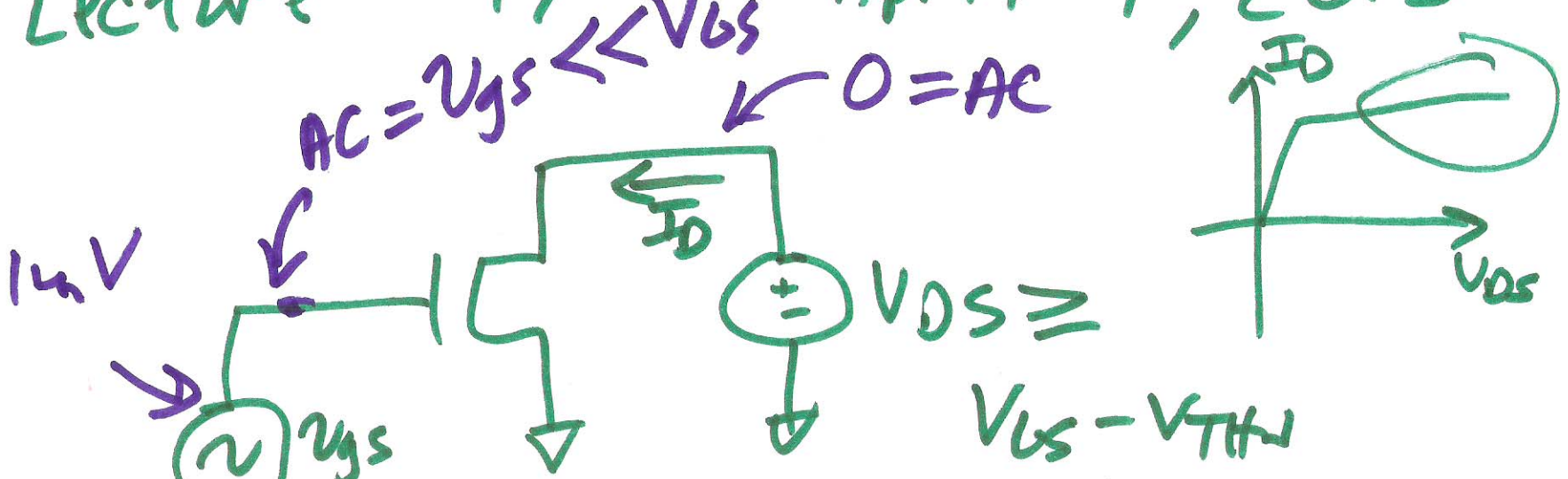
# Lecture 17 April 1, 2013







Calculate DC current

$$I_D = \frac{K_N'}{2} \cdot \frac{W}{L}(V_{GS} - V_{THN})^2$$

$V_{THP} = VTO$

$V_{THN} = \underbrace{VTO}_{SPICE}$

$K_N' = KP$

$K_P' = \underbrace{KP}_{SPICE}$

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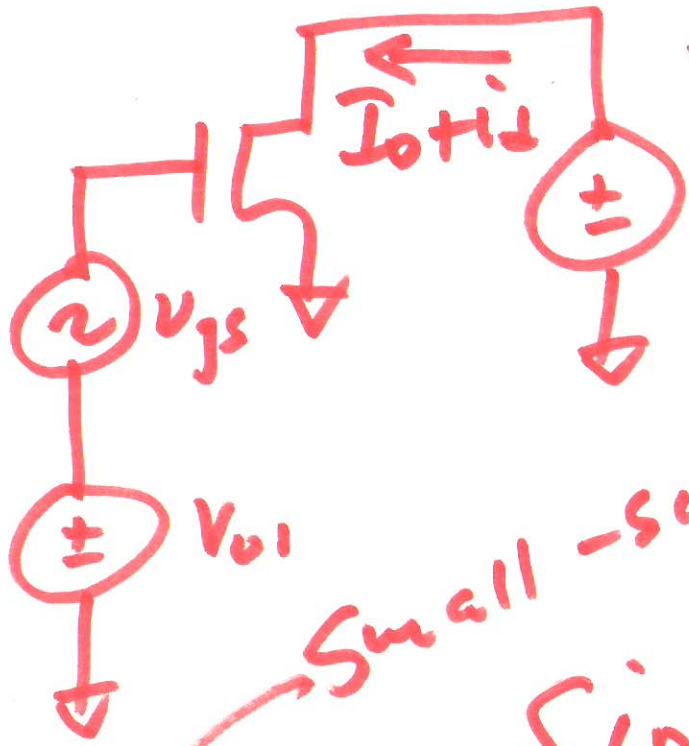
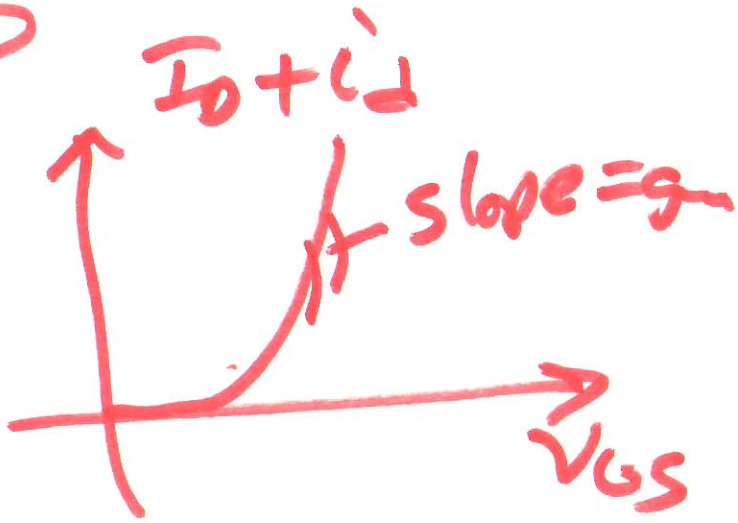
1)




$V_{DS} = 0$

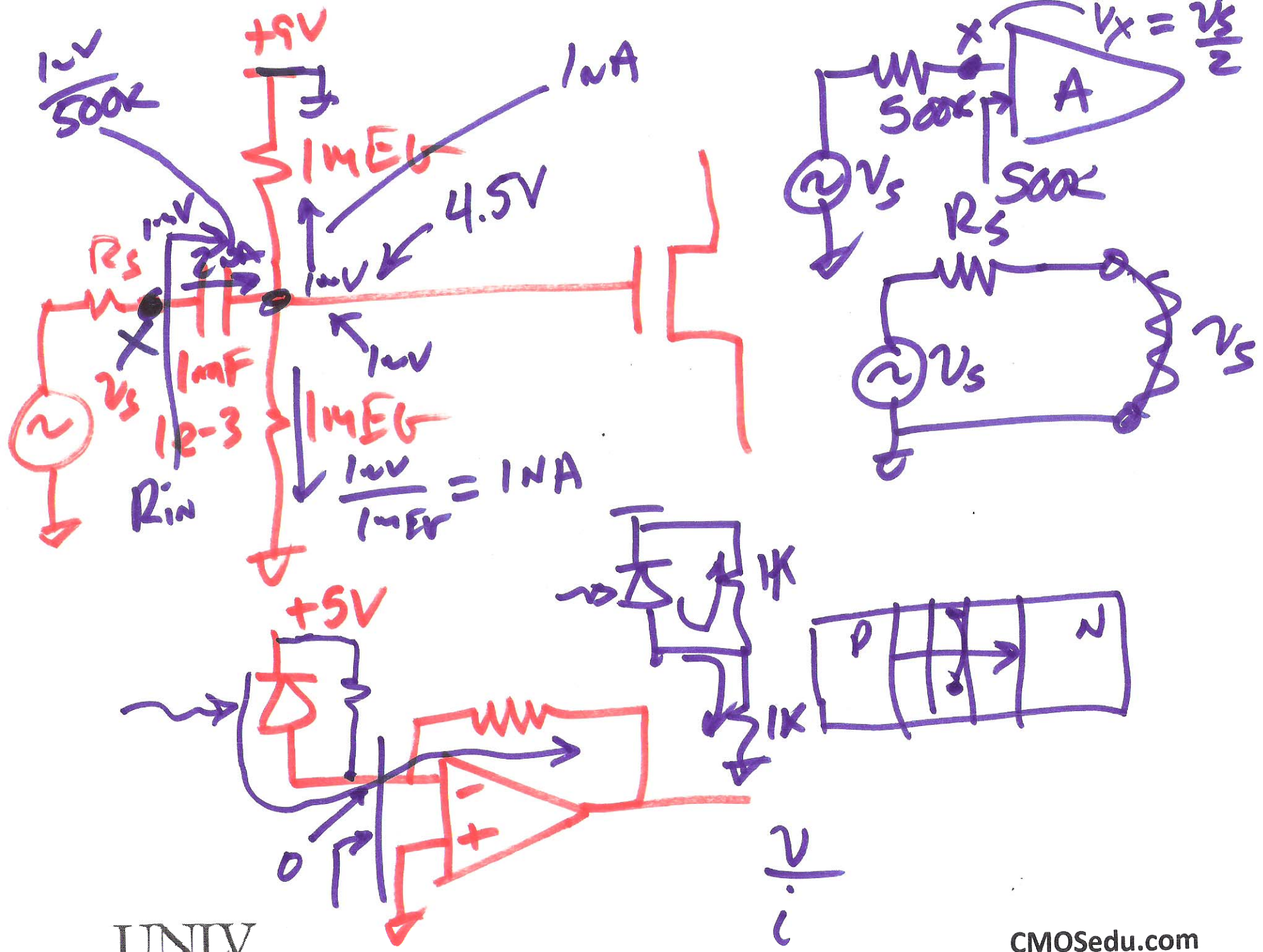



Small-signal approx.

$$g_m = \left.\frac{\delta i_D}{\delta V_{GS}}\right|_{\substack{I_D = \text{CONST} \\ V_{DS} = \text{CONST}}} = \frac{\delta}{\delta V_{GS}} \frac{K_n'}{2}\frac{W}{L}\left(V_{GS} + v_{gs} - V_{THN}\right)^2$$

$V_{GS} >> v_{gs}$

$$\sqrt{2 I_D \cdot K_n' \frac{W}{L}} = g_m = 2 \cdot \frac{K_n'}{2} \cdot \frac{W}{L}\left(V_{GS} + v_{gs} - V_{THN}\right) \cdot \frac{\delta V_{GS}'}{\delta V_{GS}}$$

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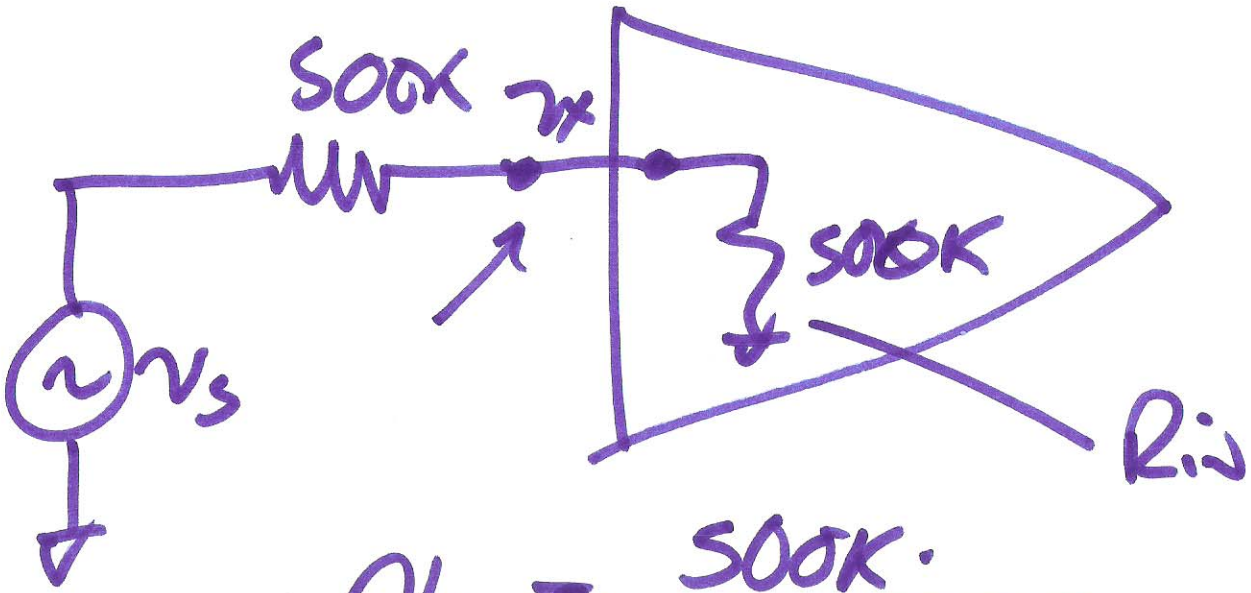
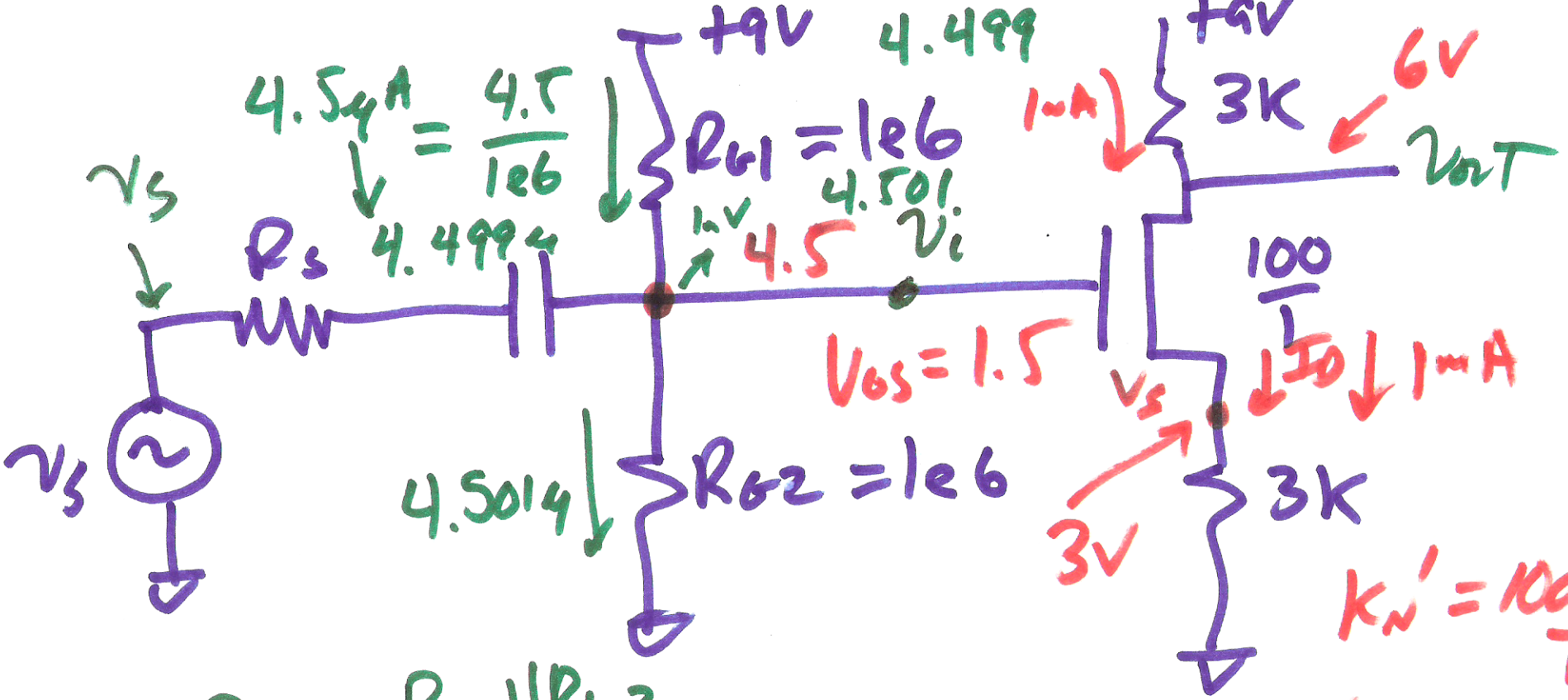
3)




$$v_x = v_s = \frac{500K \cdot}{500K + 500K}$$

$$v_x = \frac{v_s}{2}$$




$$v_i = v_s \cdot \frac{R_{G1} \| R_{G2}}{R_{G1} \| R_{G2} + R_S}$$

$$v_i = v_s \cdot \frac{500K}{500K + R_S}$$

$V_S = I_D \cdot 3k$

$K_N' = 100\mu A/V$

$V_{THN} = .75$

$$I_D = \frac{K_N'}{2} \cdot \frac{W}{L} \left( V_{GS} - V_{THN} \right)^2$$

$$I_D = \frac{100\mu A}{V^2 \cdot 2} \cdot \frac{100}{1} \left( \underbrace{4.5 - I_D \cdot 3k}_{V_{GS}} - .75 \right)^2$$

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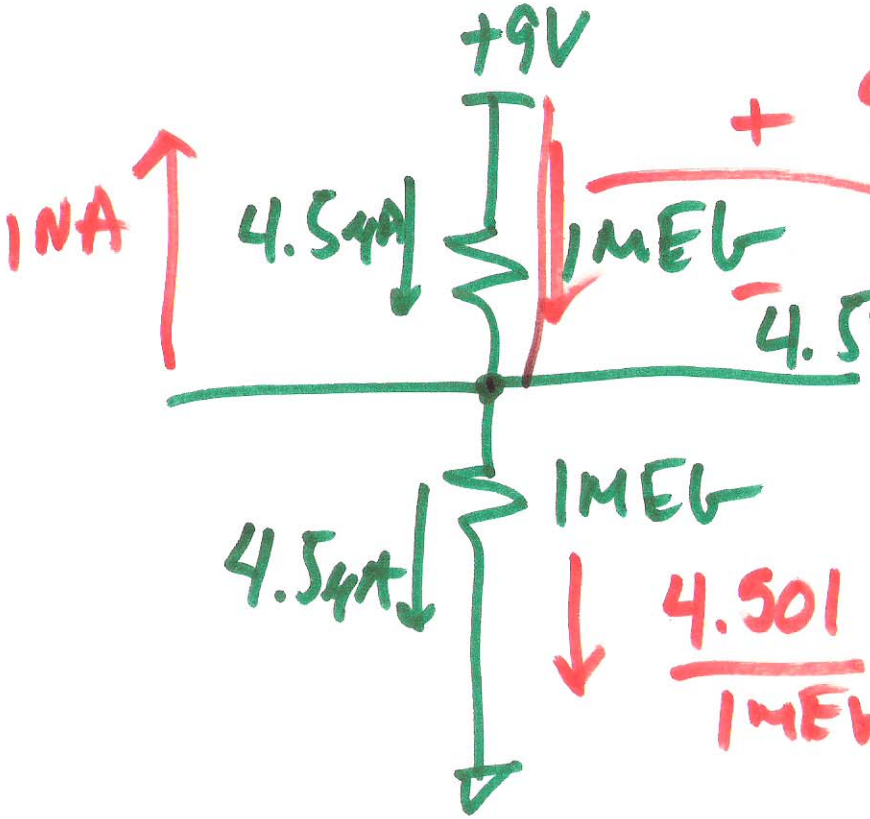
5)




$+ \quad 9 - 4.501 = 4.499$

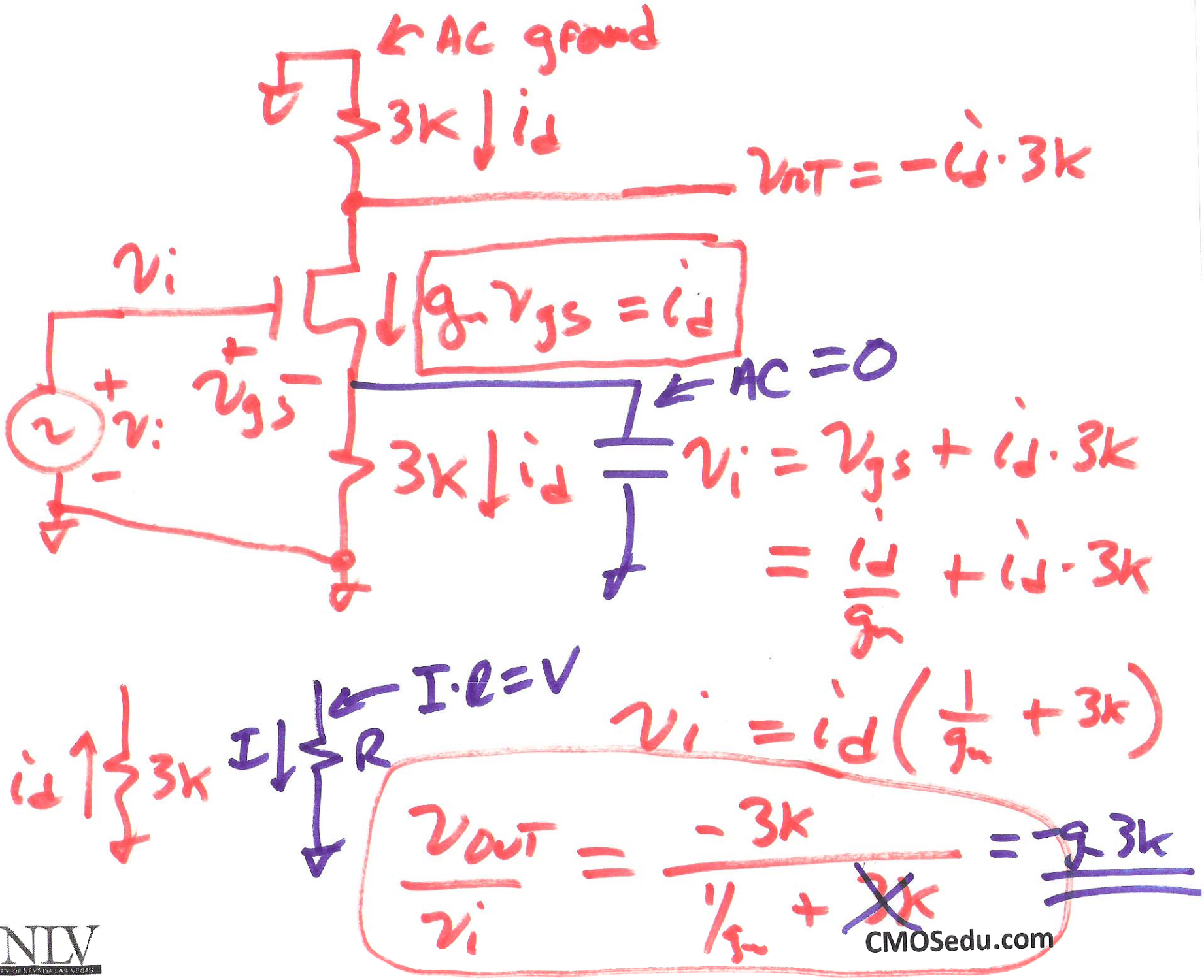
$4.499_{4} = 4.5_{4} - 1NA$

$4.501\,V$

$AC = 1mV$

$\frac{4.501}{1MEG} = 4.5014A$

$AC = 1NA = 0.0014A$


AC ground
3k
$i_d$
$v_{out} = -i_d \cdot 3k$
$v_i$
$g_m v_{gs} = i_d$
AC = 0
$v_{gs}$
$v_i$
3k
$i_d$
$v_i = v_{gs} + i_d \cdot 3k$
$= \frac{i_d}{g_m} + i_d \cdot 3k$
$i_d$
3k
I
R
I·R = V
$v_i = i_d\left(\frac{1}{g_m} + 3k\right)$
$\frac{v_{out}}{v_i} = \frac{-3k}{1/g_m + 3k} = -3k$
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7)

$$g_m = \frac{K_N'}{100\mu A/V^2} \cdot \frac{W}{L} (V_{GS} - V_{THN})$$
$4.5 - 3.2$

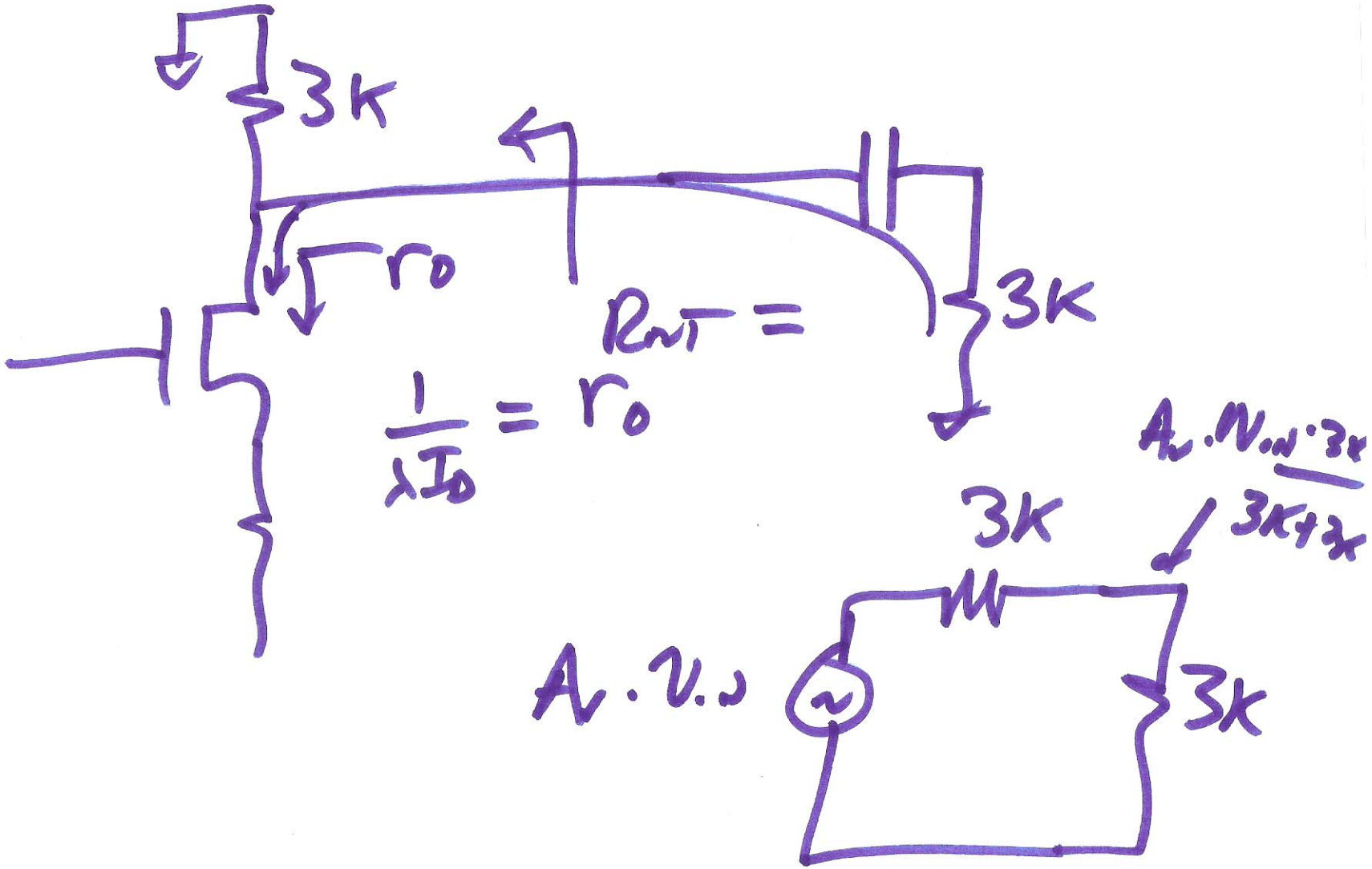
$$= \frac{100\mu A}{V^2} \cdot \frac{100}{1} (1.8 - .75)$$
$3 \quad .55 \quad 5.5$

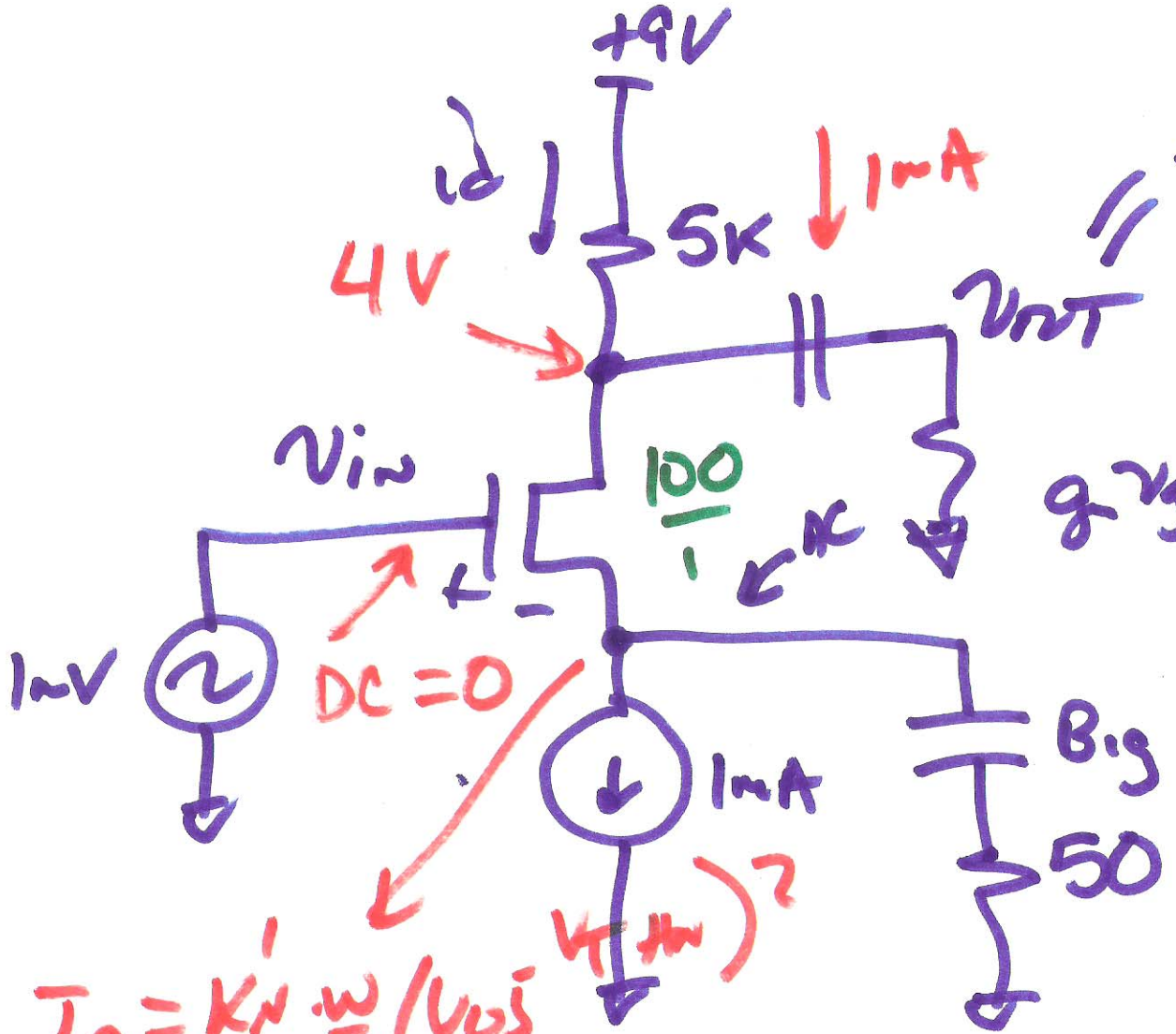
$$g_m = K_N' \cdot \frac{W}{L} (V_{GS} - V_{THN}) = \frac{10mA}{V} \cdot 7.5 = 7.5\frac{mA}{V}$$

$$\frac{v_{out}}{v_i} = -g_m 3k = -7.5\frac{mA}{V} \cdot 3k$$
$5.5mA$

$$= -22.5\frac{V}{V}$$
$16.5$

8)


3k
$r_o$
$R_{out}$ =
3k
$\frac{1}{\lambda I_D} = r_o$
$A_v \cdot V_{in} \cdot 3k$
3k
$3k \| 3k$
$A_v \cdot V_{in}$
3k




$-i_d \cdot 5K$

$\left.\frac{v_{out}}{v_{in}}\right|_{\text{no load}} =$

$g_m r_{ds} = 2$ with 5k load

$I_D = \frac{K_N'}{2}\frac{W}{L}(V_{OS} - V_{th})^2$

$g_m = \sqrt{2 \cdot K_N' \frac{W}{L} \cdot 1mA}$

$= \sqrt{2 \cdot 100\mu \cdot 100 \cdot 1m}$

$= \sqrt{20mA/V^2 \cdot 1mA}$

$\sqrt{20e\text{-}3 \cdot 1mA}$

$3.4\,mA/V$

$v_{in} = v_{gs} + i_d \cdot 50$

$= i_d\left(\frac{1}{g_m} + 50\right)$

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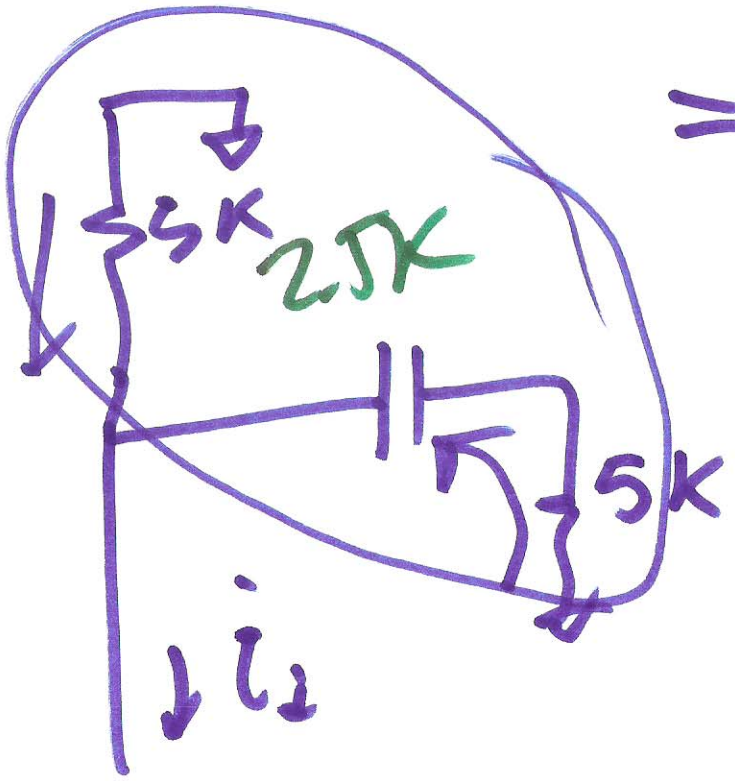
10)

$$\frac{v_{out}}{v_{in}} = \frac{-i_d \cdot 5K}{-i_d\left(\frac{1}{g_m} + 50\right)}$$




$$= \frac{-5K \rightarrow 2.5K}{\frac{1}{3.4mA} + 50}$$

$$\frac{2.5K}{294} = \frac{-5K}{344}$$

$$= -14.5$$

$$-7.25$$