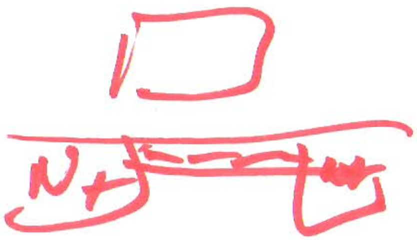
EE 420 / ECG 620

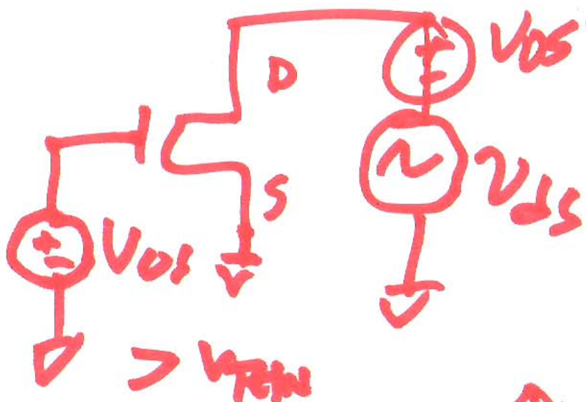
Analog IC Design

Lecture 3

January 26, 2015

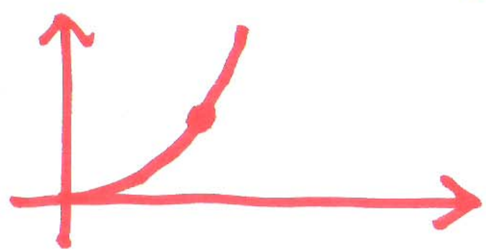


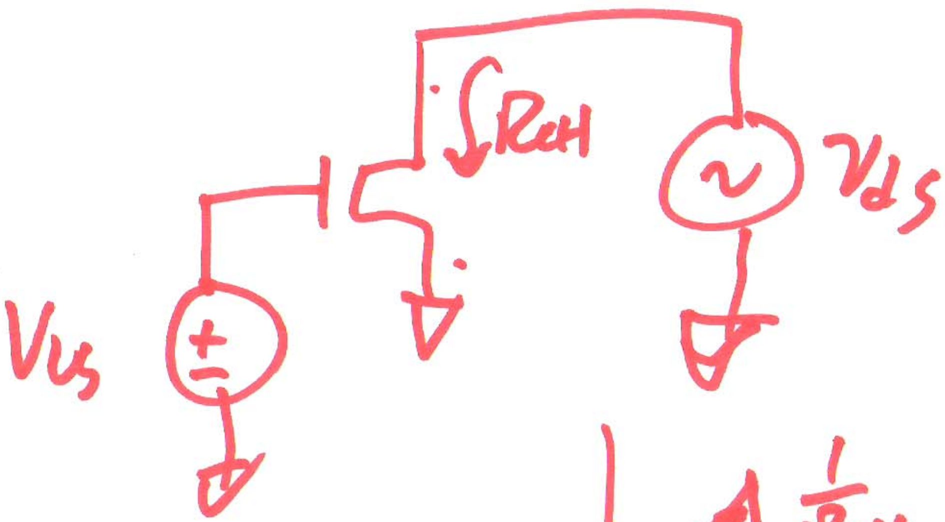
$V_{DS} < V_{GS} - V_{THN}$



$V_{DS} < V_{GS} - V_{THN}$

$V_{DS,sat} = V_{GS} - V_{THN}$





$$V_{DS} = 0$$

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

$$i_D = I_D + i_d = KP \frac{W}{L}\left((V_{GS} - V_{THN})(\cancel{V_{DS}}^{\,0} + v_{ds}) - \frac{(\cancel{V_{DS}}^{\,0} + v_{ds})^2}{2} \right)$$

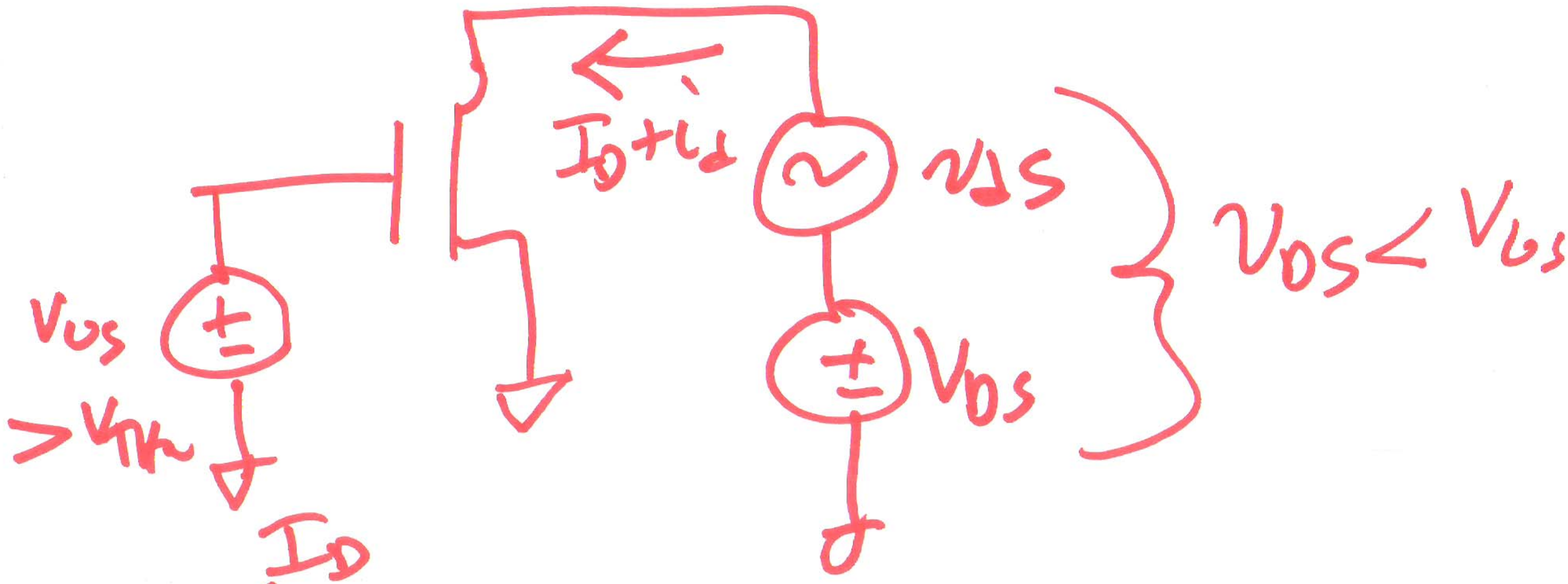
$$\frac{1}{R_{CH}} = \left.\frac{\delta i_D}{\delta v_{DS}}\right|_{\substack{V_{DS} = CONST \\ I_D = CONST}} = KP \frac{W}{L}\left[(V_{GS} - V_{THN}) - 2 \cdot \frac{v_{DS}}{2} \right]$$

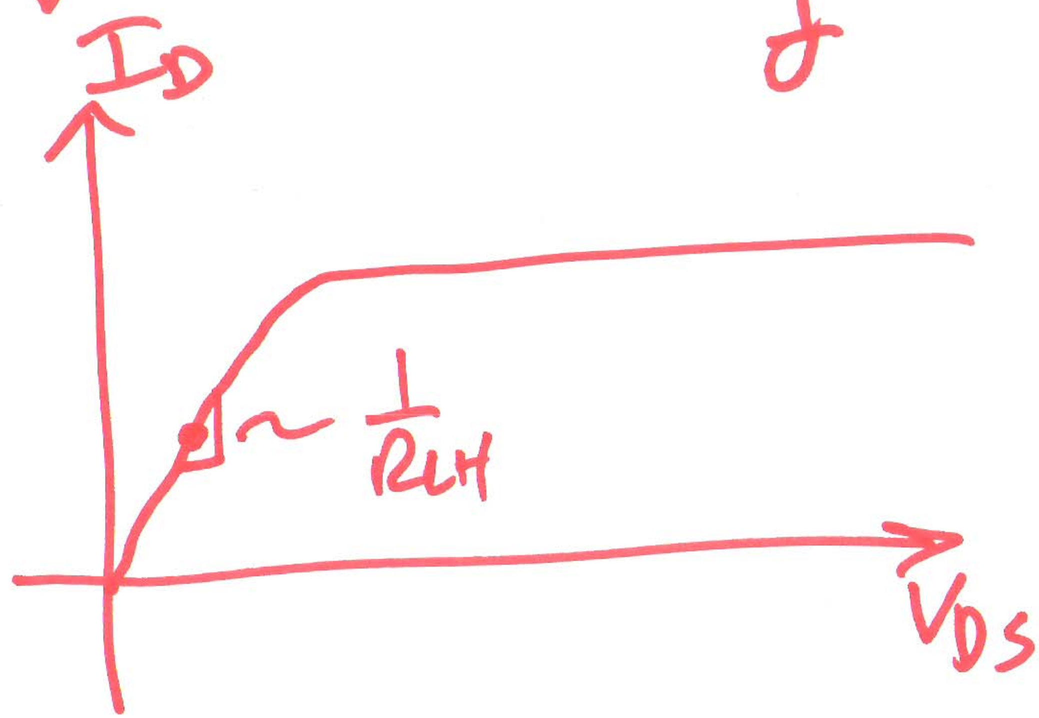
2)

$$\frac{1}{R_{CH}} = KP\frac{W}{L}\left[(V_{GS}-V_{THN}) - v_{DS}\right]$$

$$v_{DS} \ll V_{GS} - V_{THN}$$

$$R_{CH} \approx \frac{1}{KP\cdot\frac{W}{L}(V_{GS}-V_{THN})}$$


$I_D + i_d$
v_{ds}
V_{GS}
$> V_{THN}$
V_{DS}
$v_{DS} < V_{GS}$


I_D
$\sim \frac{1}{R_{CH}}$
V_{DS}

$$\frac{1}{R_{CH}} = \frac{\delta i_D}{\delta v_{DS}}\Bigg|_{\substack{I_D = \text{CONST} \\ V_{DS} = \text{CONST}}}$$

$$\frac{\delta\, KP \cdot \frac{W}{L}\left(\left(V_{GS} - V_{THN}\right)\underbrace{\left(V_{DS} + v_{ds}\right)}_{v_{ds}} - \frac{\left(v_{ds} + V_{DS}\right)^2}{2}\right)}{\delta v_{DS}}$$

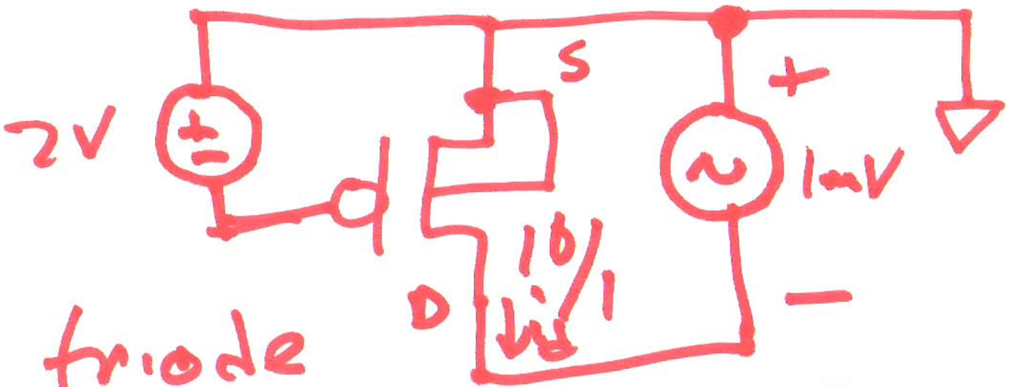
$$V_{DS} \gg v_{ds} \rightarrow = V_{DS}$$

$$\frac{1}{R_{CH}} = \left(V_{GS} - V_{THN}\right)\frac{KP \cdot W}{L} - \frac{KPW}{L}\left(V_{DS} + v_{ds}\right)$$

$$R_{CH} = \frac{1}{KP \cdot \frac{W}{L}\left[(V_{GS} - V_{THN}) - (V_{DS} + V_{GS})\right]}$$

$$V_{GS} \gg V_{DS}$$

$$R_{CH} \approx \frac{1}{KP \cdot \frac{W}{L}(V_{GS} - V_{THN})}$$



$I_D = ?$ $\underline{\underline{0}}$

$i_d = ?$

for triode

$V_{SD} < V_{SG} - V_{THP}$

OR $V_{SG} > V_{SD} - V_{THP}$ (0, 900m)

$V_{SG} > V_{SD} + V_{THP}$

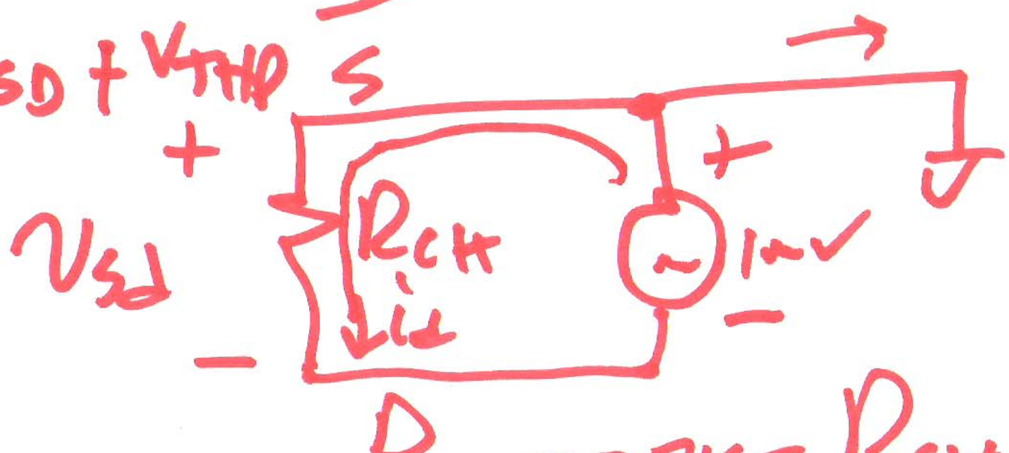
$2 > -.9V$

triode >

$V_{SG} \geq V_{SD} - V_{THP}$

$.2 \geq 2 - .9$

yes!



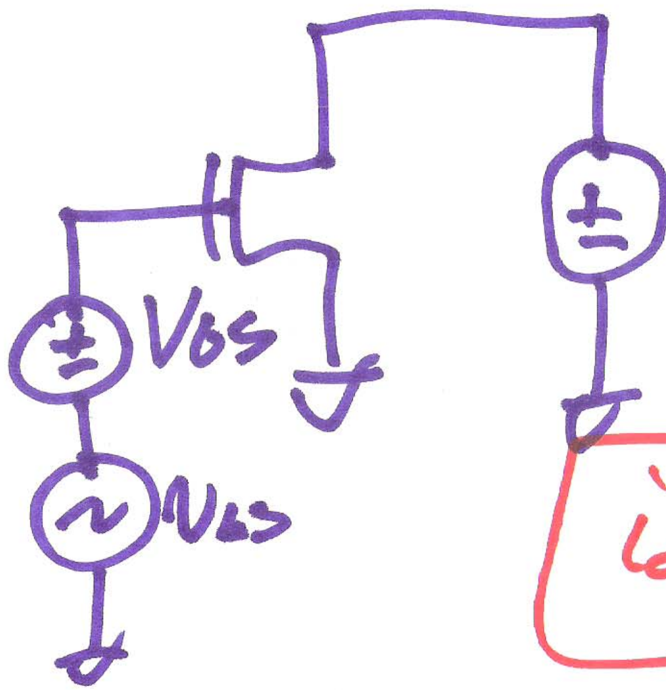
$$2.27K = R_{CH} = \frac{1}{KP \cdot \frac{10}{1}(2-.9)}$$

$KP = 40\mu A / V^2$

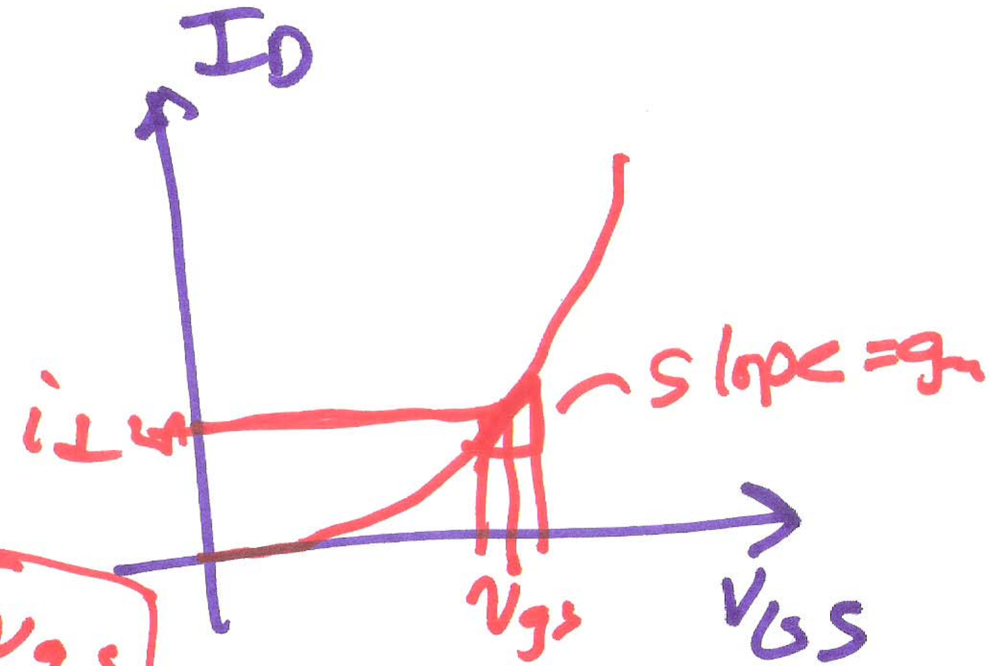
$$i_d = \frac{1mV}{2.2K} = 440nA = \underline{\underline{0.44\mu A}}$$

for saturation

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



$$\boxed{i_d = g_m v_{gs}}$$



$$g_m = \frac{i_d}{v_{gs}}$$

$$\frac{\delta\, i_d + I_D}{\delta V_{GS}} = \frac{\delta\, \frac{KP}{2}\frac{W}{L}\left(\underbrace{V_{GS} + v_{gs}}_{v_{GS}} - V_{THN}\right)^2}{V_{GS}} \qquad V_{GS} >> v_{gs}$$

$$= KP\frac{W}{L}\left(V_{GS} - V_{THN}\right)$$

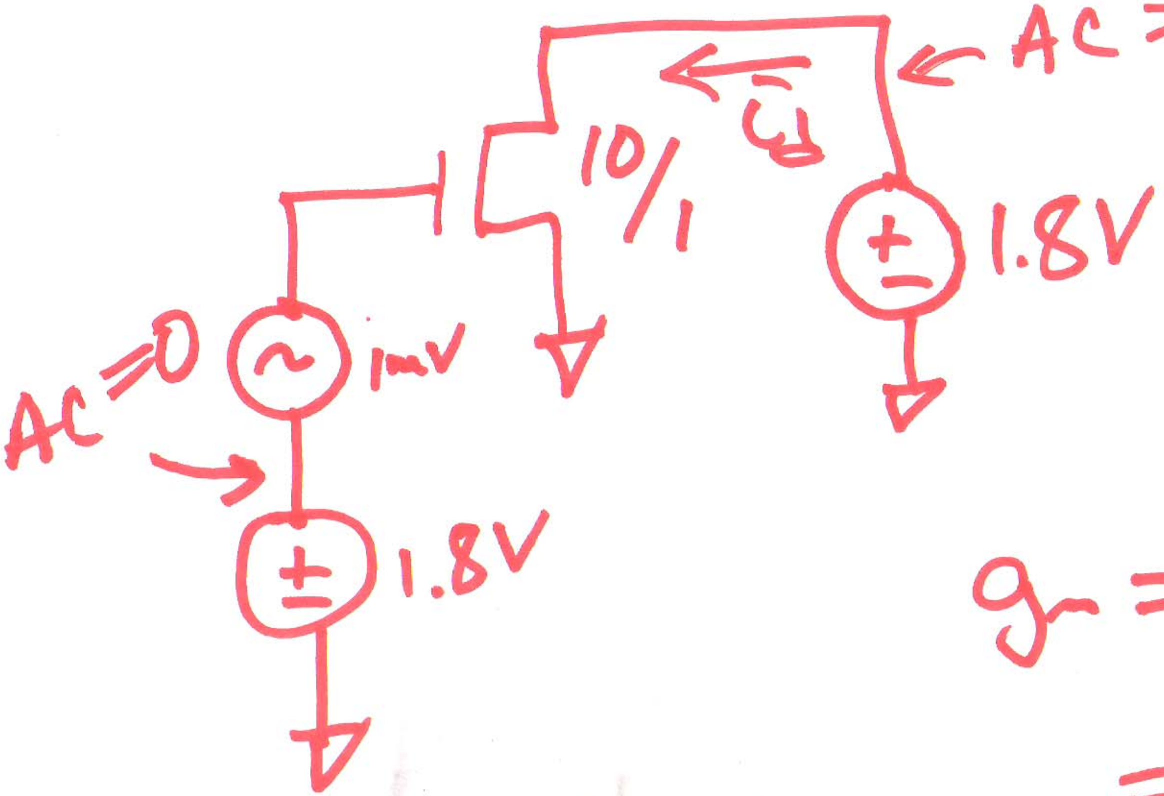
$$g_m = KP \cdot \frac{W}{L}(V_{GS} - V_{THN})$$

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

$$V_{GS} - V_{THN} = \sqrt{\frac{I_D 2}{KP \cdot \frac{W}{L}}}$$

$$g_m = \sqrt{2 \cdot KP \cdot \frac{W}{L} I_D}$$

$$= \sqrt{2 \beta I_D}, \quad \beta = KP \cdot \frac{W}{L}$$



IN SAT?

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

$$1.8 \geq 1.8 - .8$$

yes!

$$g_m = KP \cdot \frac{W}{L}\left(V_{GS} - V_{THN}\right)$$

$$= \frac{120\mu}{V^2} \cdot \frac{10}{1}\left(1.8 - .8\right)$$

$$g_m = \frac{1.2mA}{V}$$

$$v_{gs} = 1mV$$

$$i_d = g_m v_{gs}$$

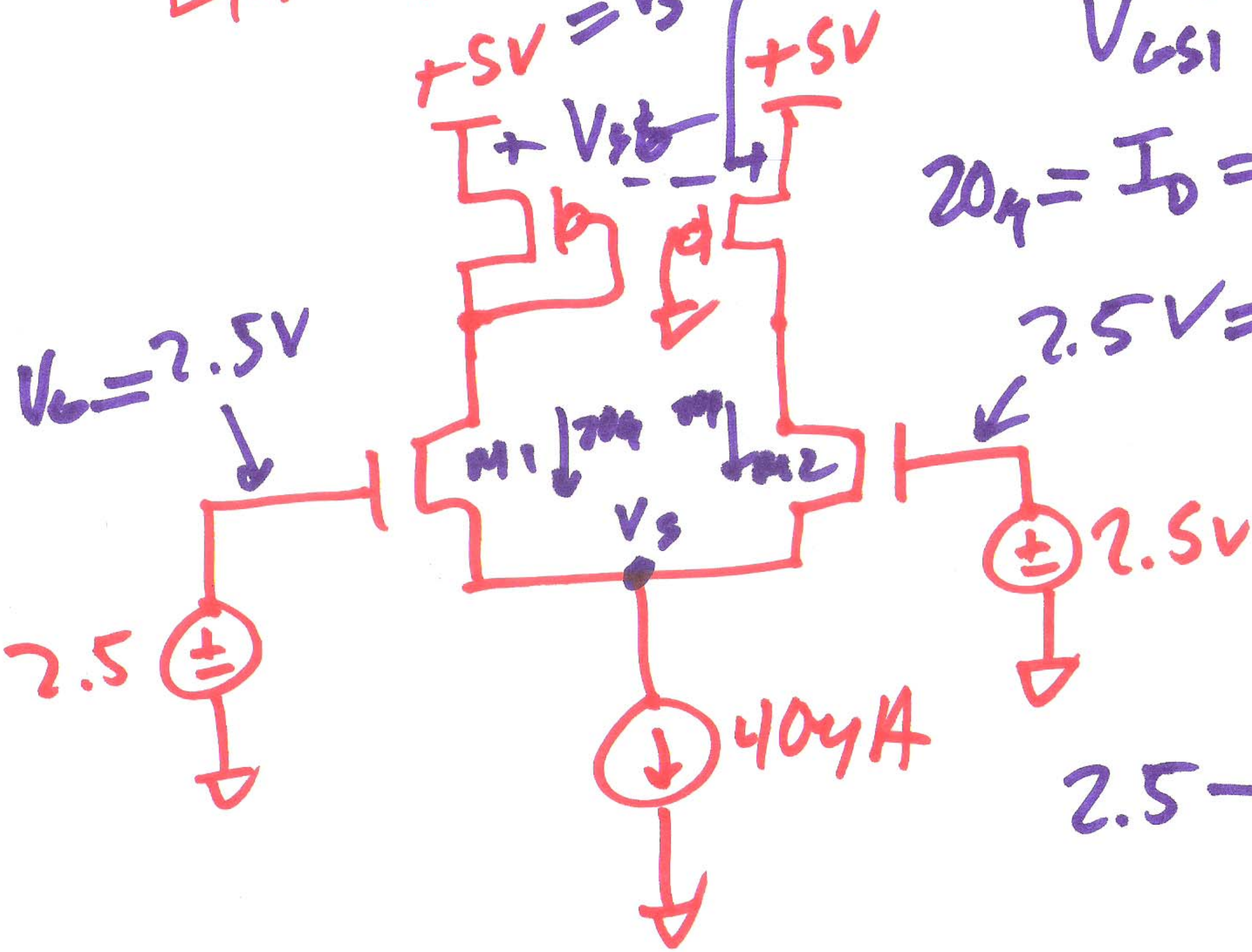
$$i_d = 1.2\mu A = \frac{1.2mA}{V} \cdot 1mV$$

Ex. 9.5

$V_{SG} = 5$

$2.5 - V_S$

$V_{GS1} = V_{GS2}$



$$20\mu = I_D = \frac{KP}{2}\frac{W}{L}\left(V_{GS} - V_{THN}\right)^2$$

$$V_{GS} = \sqrt{\frac{2I_D}{KP\cdot\frac{W}{L}}} + V_{THN}$$

$$2.5 - V_S = \sqrt{\frac{20\mu\cdot 2}{120\mu\cdot\frac{10}{2}}} + .8$$