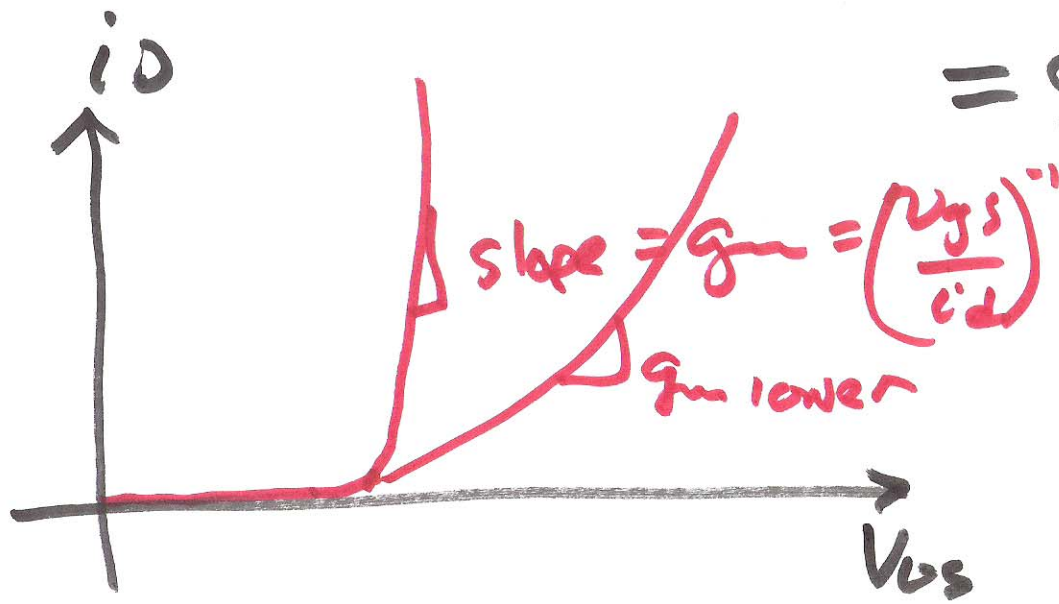
EE 422 and ECG 622

Analog IC Design

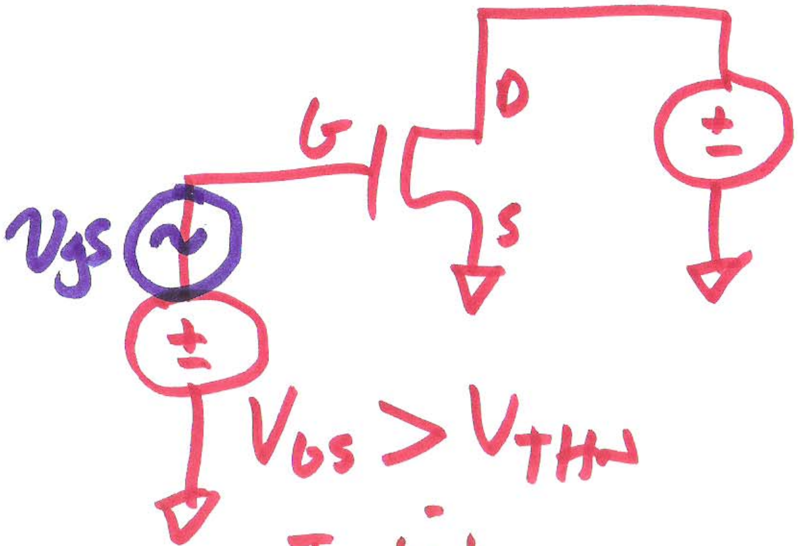
2/6/13 Lecture 5

transconductance, $g_m = \frac{\Delta i_D}{\Delta v_{GS}} = \frac{\partial i_D}{\partial v_{GS}}$, $\frac{1}{\Omega}$

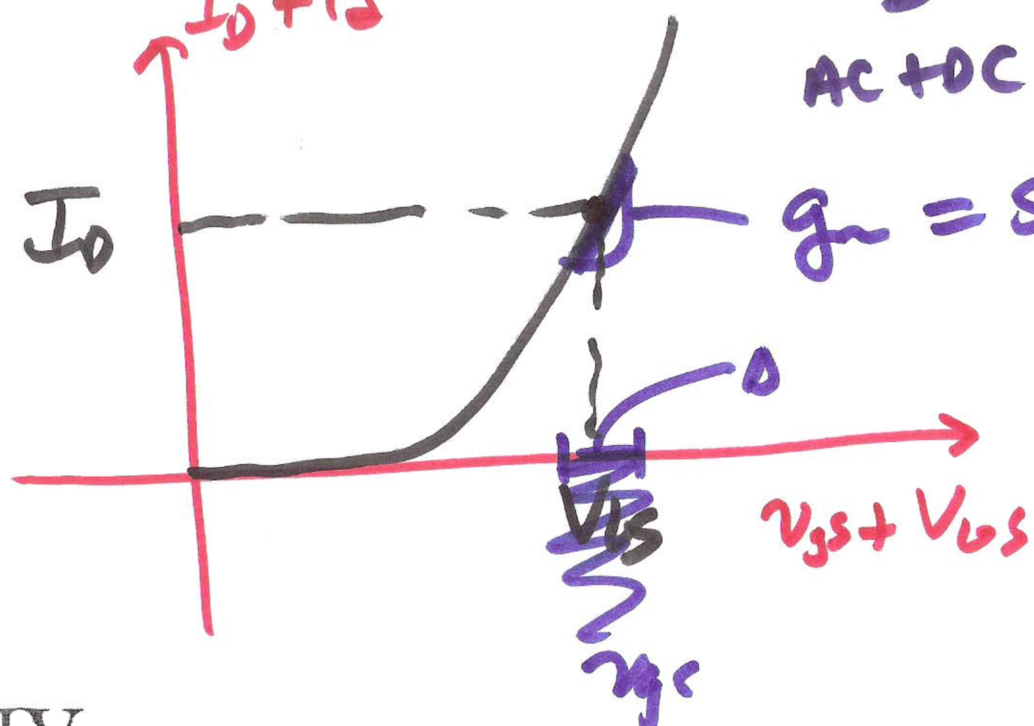


MHOS
siemens

$$\beta_N = KP_N \cdot \frac{W}{L}$$

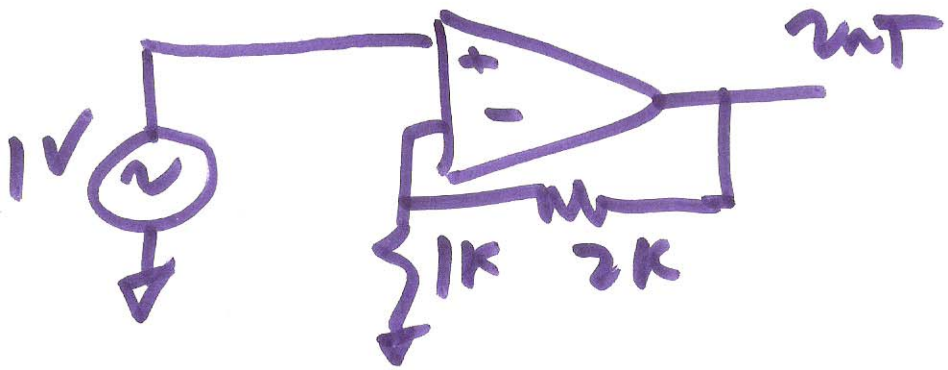


$$\underbrace{I_D + i_d}_{\substack{i_D \\ AC+DC}} = \frac{KP_N}{2}\cdot\frac{W}{L}\Big(\underbrace{V_{GS} + v_{gs}}_{\substack{v_{GS} \\ AC+DC}} - V_{THN}\Big)^2$$



$$\left.\frac{\delta i_D}{\delta v_{GS}}\right|_{\substack{I_D = CONST \\ V_{GS} = CONST}} = g_m$$

$$g_m = \frac{\partial i_D}{\partial v_{GS}}\Bigg|_{\substack{I_D = CONST \\ V_{DS} = CONST}} = \frac{\partial \frac{\beta_N}{2}(v_{GS} - V_{THN})^2}{\partial v_{GS}}$$



$$= 2 \cdot \frac{\beta_N}{2}(v_{GS} - V_{THN})^{\cancel{2}} \frac{\partial \overset{1}{\cancel{(v_{GS} - V_{THN})}}}{\partial v_{GS}}$$

$$r_o = \frac{1}{\lambda I_{DSAT}}$$

$$g_m = \beta_N (v_{GS} - V_{THN})$$

$$= \beta_N (V_{GS} + v_{gs} - V_{THN})$$

$V_{GS} \gg v_{gs} \Rightarrow$ small-signal approx.

$$g_m \approx \beta_N (V_{GS} - V_{THN})$$

$$r_o = \frac{1}{\lambda I_{D,SAT}}$$

$$g_m = \beta_N (V_{GS} - V_{THN}) = \left(\sqrt{\beta_N^2}\right)\sqrt{\frac{2I_D}{\beta_N}}$$

$$I_D = \frac{\beta_N}{2}(V_{GS} - V_{THN})^2 = \sqrt{\frac{2 I_D \beta_N^2}{\beta_N}}$$

$$\frac{A(B+C)}{D \cdot E} = \frac{F}{G}$$

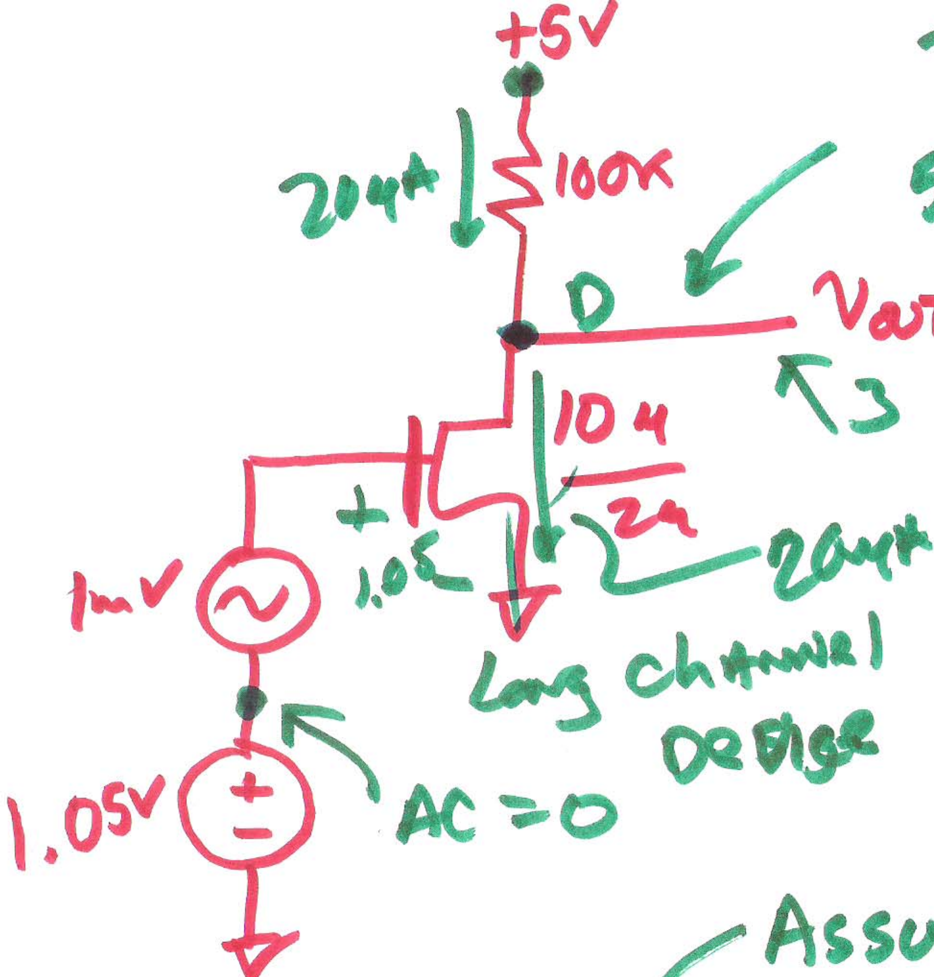
$$V_{GS} - V_{THN} = \sqrt{\frac{2I_D}{\beta_N}}$$

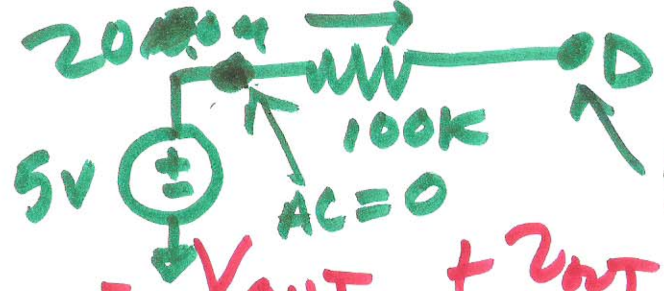
$$A = \frac{F \cdot D \cdot E}{G \cdot (B+C)}$$

$$g_m = \sqrt{2 I_D \cdot \beta_N}$$

$$\frac{1}{1} = \frac{1}{\frac{1}{A}} \qquad A = 1$$

$$= \beta_N (V_{GS} - V_{TN})$$





$5 - 100K \cdot 20\mu$

$V_{OUT} = V_{OUT} + v_{out} = 3V$

↖ 3

Calculate DC operating point & AC gain

Assume saturation region

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

$3 > 1.05 - .8$

in sat? yes!

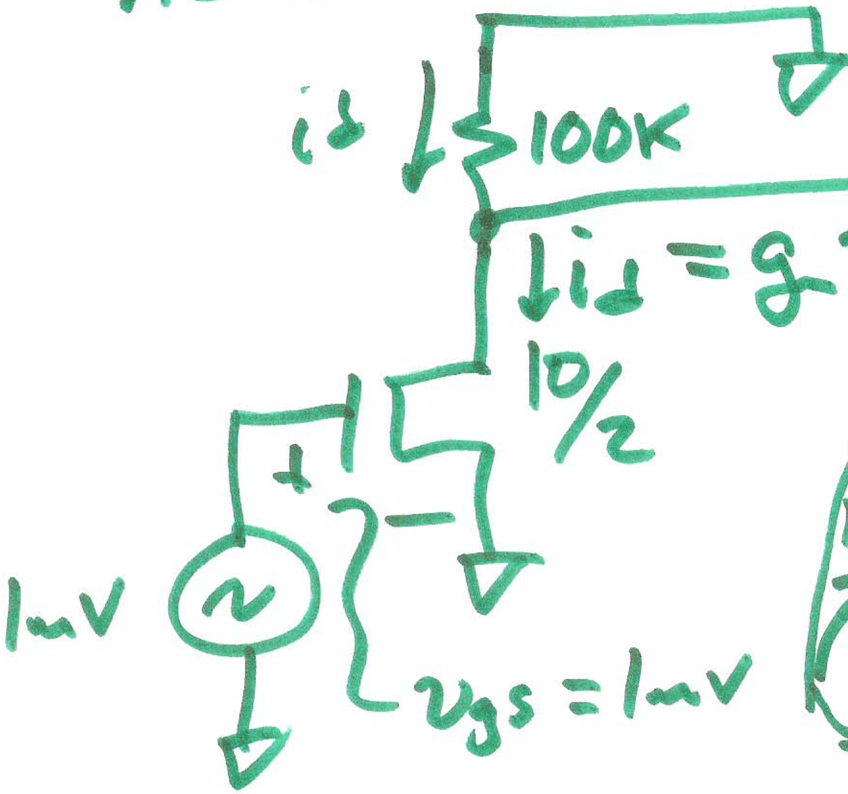
$$I_D = \frac{120\mu A/V^2}{2} \cdot \frac{10}{2}(1.05 - .8)^2$$

$$= 300\frac{\mu A}{V^2}(.0625)$$

$$= 20\mu A$$

5)

AC CKT



$v_{out} = -i_d \cdot 100K$

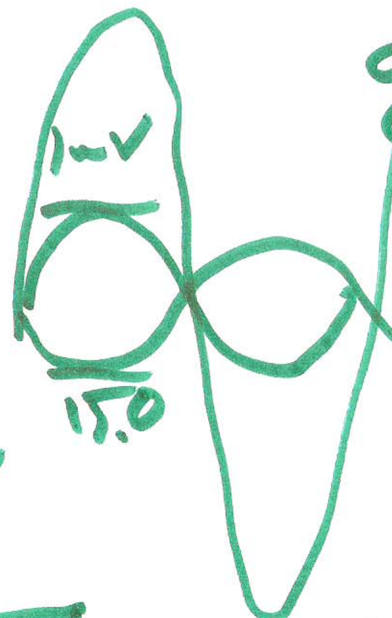
$= -150\,nA \cdot 100K = 150 \cdot 10^{-4} = 15\,mV$

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

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

$= \frac{120\,\mu A}{V^2} \cdot \frac{10}{2} \cdot (1.05 - .8)$

$= \frac{600\,\mu A}{V^2} \cdot .25\,V$



$i_d = \frac{150\,\mu A}{V} \cdot 1\,mV$

$\boxed{i_d = 150\,nA}$ AC 15mV

$\boxed{g_m = \frac{150\,\mu A}{V}}$

$A_v = \frac{15}{1} = 15$

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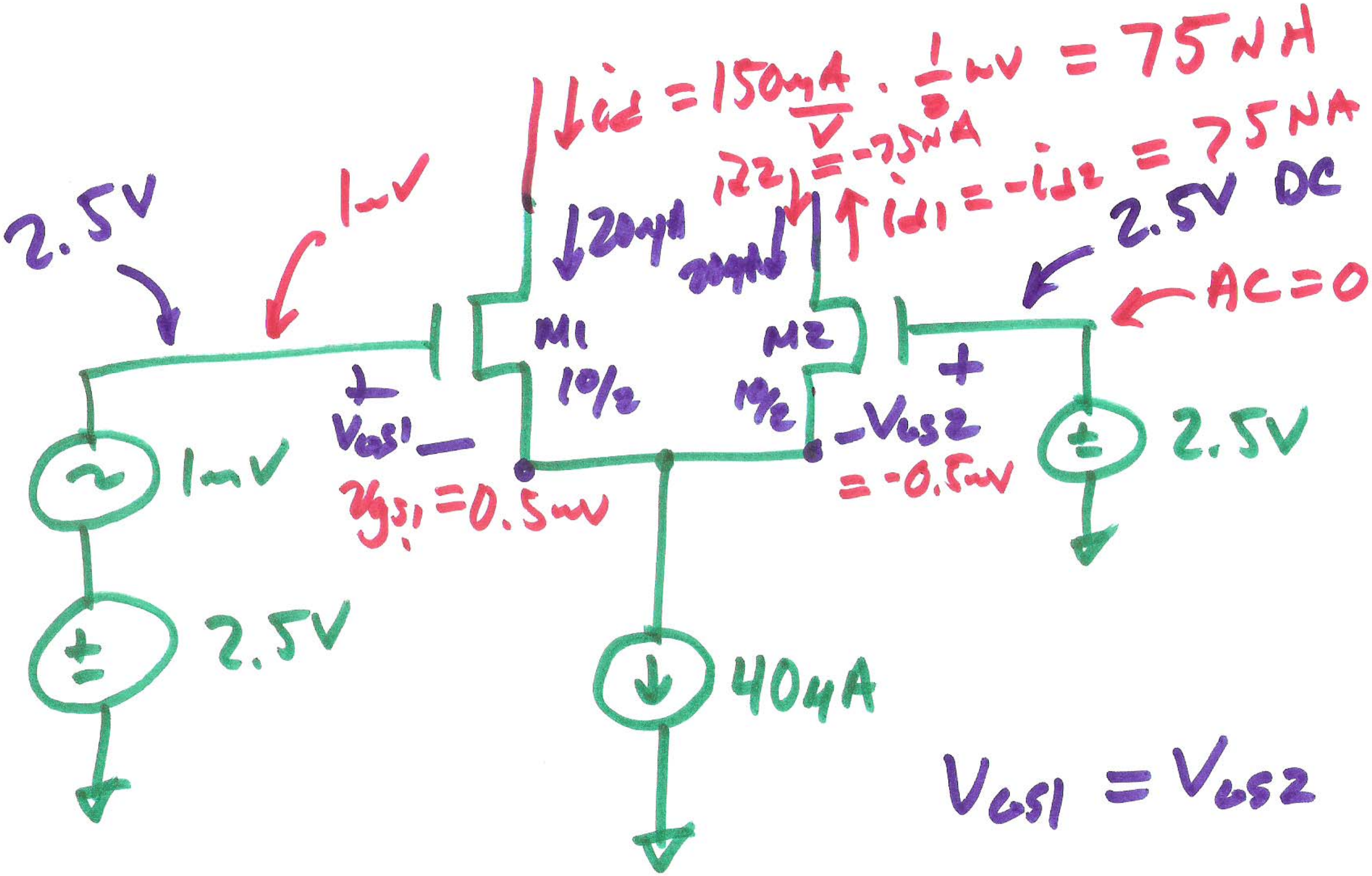
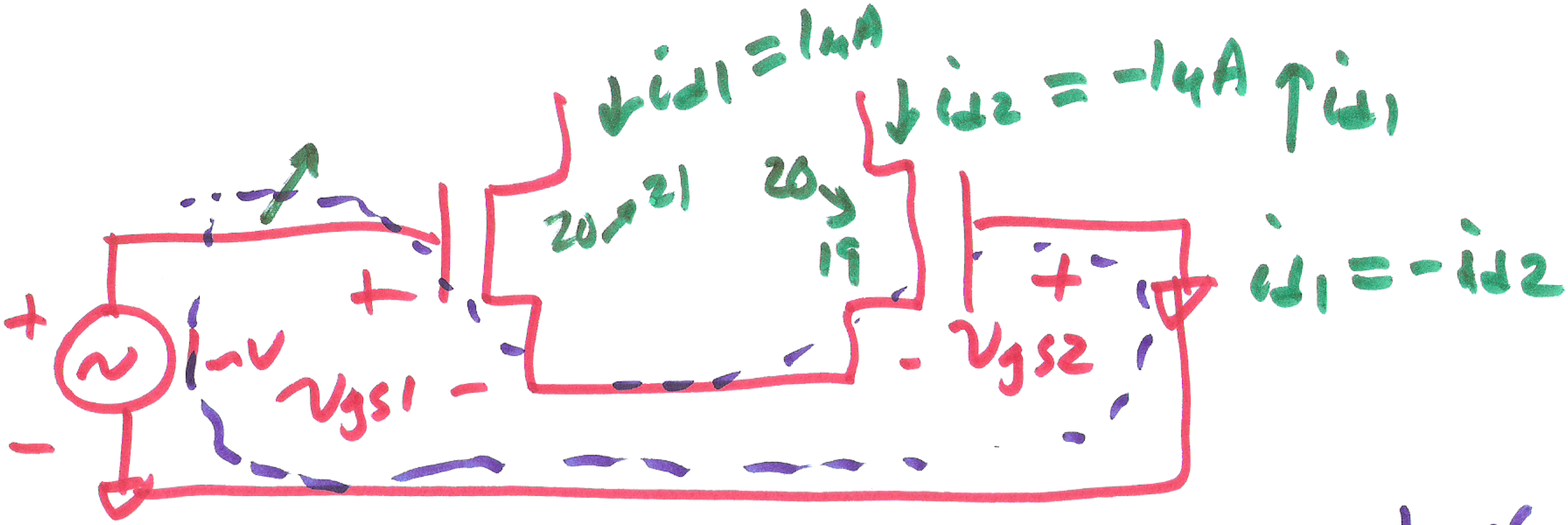


$V_{GS1} = V_{GS2}$

$$g_{m1} = g_{m2} = \sqrt{2\beta_n \cdot I_D} = \sqrt{2 \cdot \frac{120\mu A}{V^2} \cdot \frac{10}{2} \cdot 20\mu A} = 150\frac{\mu A}{V}$$



$$1mV - v_{gs1} + v_{gs2} = 0, \quad v_{gs1} = \frac{1}{2} mV$$

$$v_{gs1} - v_{gs2} = 1mV \quad v_{gs2} = -\frac{1}{2} mV$$

$$i_{d1} = g_{m1} \cdot v_{gs1}$$

$$i_{d2} = g_{m2} \cdot v_{gs2}$$

$$g_{m1} = g_{m2}$$

$$i_{d1} = -i_{d2}$$

$$v_{gs1} = -v_{gs2}$$

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