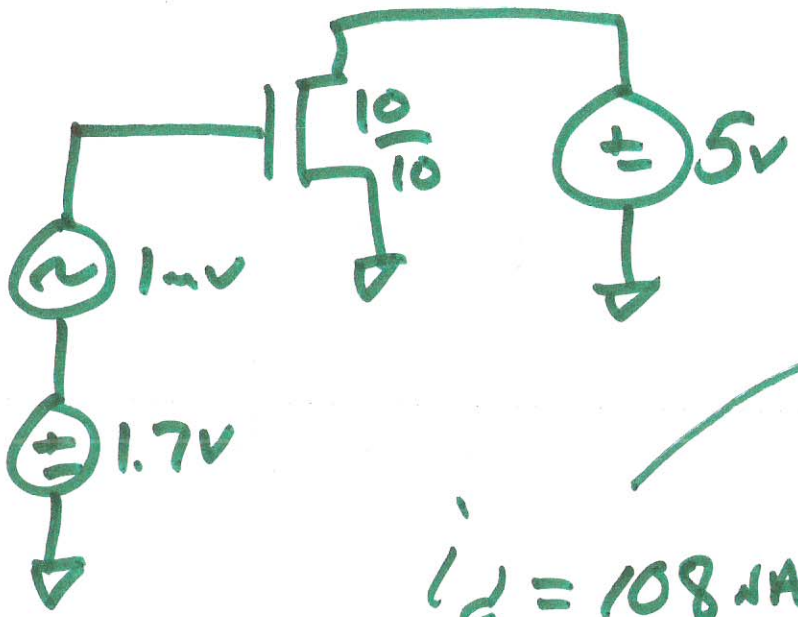
ECE 5/411 CMOS Analog IC Design

BOISE STATE UNIVERSITY

January 23, 2012

Lecture 2



$v_{gs} = 1mV$

$i_d = g_m v_{gs} = 108\mu A \cdot 1mV$

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

$= KR_N = 108\mu A/V$

$= 120\mu A/V (1.7 - .8)$

$= 108\mu A/V$

$i_d = 108\mu A$

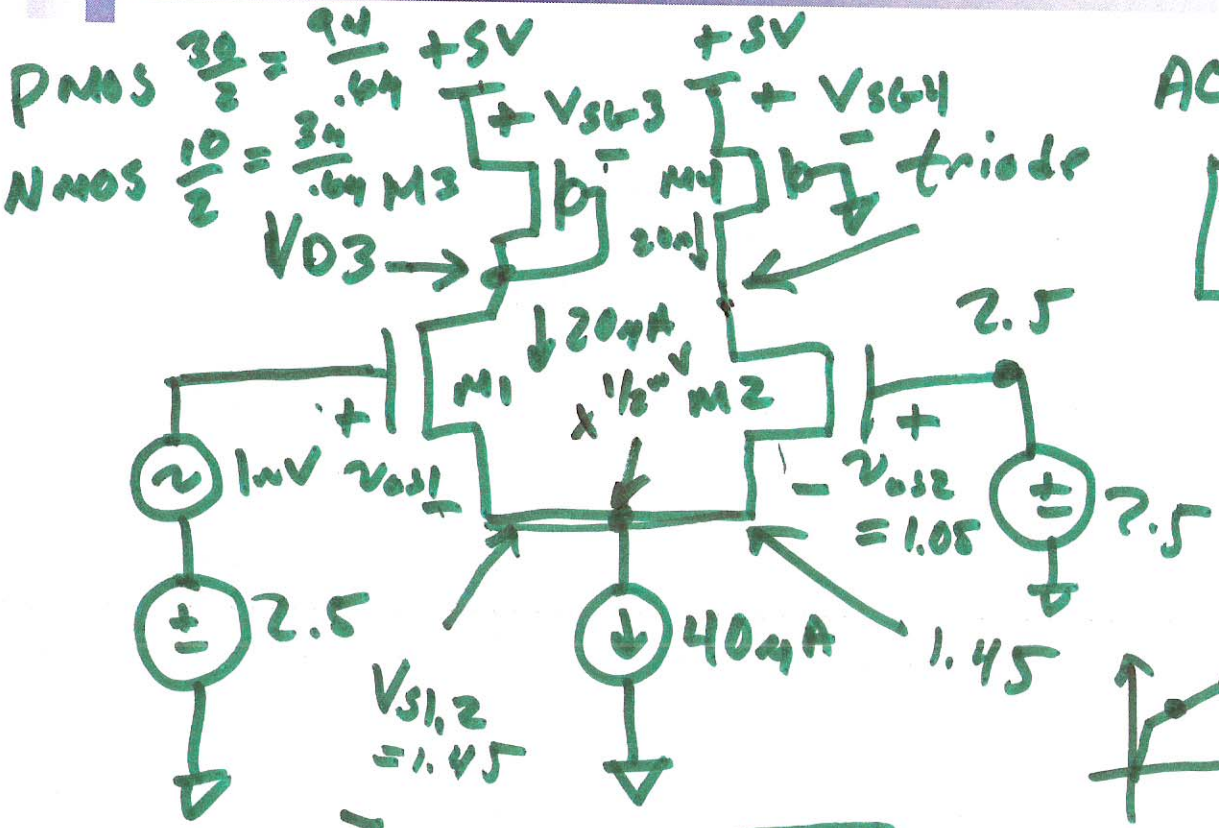
$I_D = \frac{KP}{2} \cdot \frac{W}{L}(1.7 - .8)^2$

$.81 \cdot 60\mu$

$I_D \approx 48\mu A$

~~48μA~~

1)



$$\approx$$

$$V_{GS1,2} = \sqrt{\frac{2I_N}{\beta_N}} + V_{THN}$$

$$= 1.05V$$

$$V_{S1,2} = 1.45V$$

AC & DC voltages

$$I_{D1} = I_{D2} = 20\mu A$$

$$V_{SG4} = 5V$$

$$I_D = \frac{K_P}{2}\frac{W_P}{L_P}(V_{SG} - V_{THP})^2$$

$$V_{SG3} = \sqrt{\frac{2I_D}{\beta_P}} + V_{THP}$$

$$= 1.15V$$

$$V_{OS} = VDD - V_{SG3}$$

$$= 3.85V$$

Sat.

$$V_{OS}^{SD} \geq V_{GS}^{SG} - V_{THP}$$

$$\geq 5 - .9 = 4.1$$

2)

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

$I_{D,} = \frac{\beta}{2}(V_{GS} - V_{THN})^2$ (saturation)

$I_D = \beta\left((V_{GS}-V_{THN})V_{DS} - \frac{V_{DS}^2}{2}\right)$ (triode)

$I_D = 20\mu A$, $V_{SG} = 5V$, $V_{THP} = .9V$

$20\mu A = 40\mu \cdot \frac{30}{2}\left((5-.9)V_{DS} - \frac{V_{DS}^2}{2}\right)$

$\frac{V_{DS}^2}{2} - 4.1V_{DS} + \frac{1}{30} = 0$

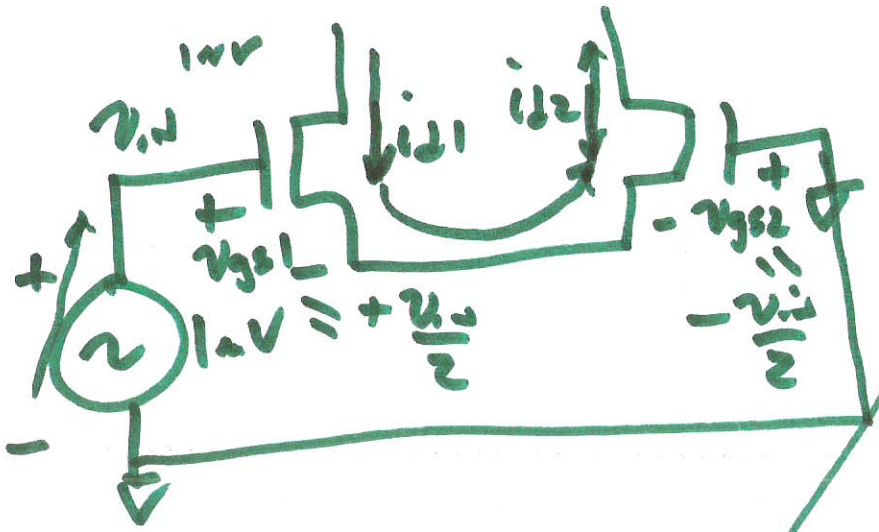
$V_{DS}^2 - 8.2V_{DS} + \frac{1}{15} = 0$

$V_{DS} = \frac{8.2 \pm \sqrt{(8.2)^2 - 4/15}}{2} = 8V$

$\approx \frac{4}{30} = \frac{2}{15} V$

3)

AC CKT



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

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

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

+.1m ⇒ 20.1 i_d = .1mA

20mA

-.1m ⇒ 19.9

$i_d = -.1mA$

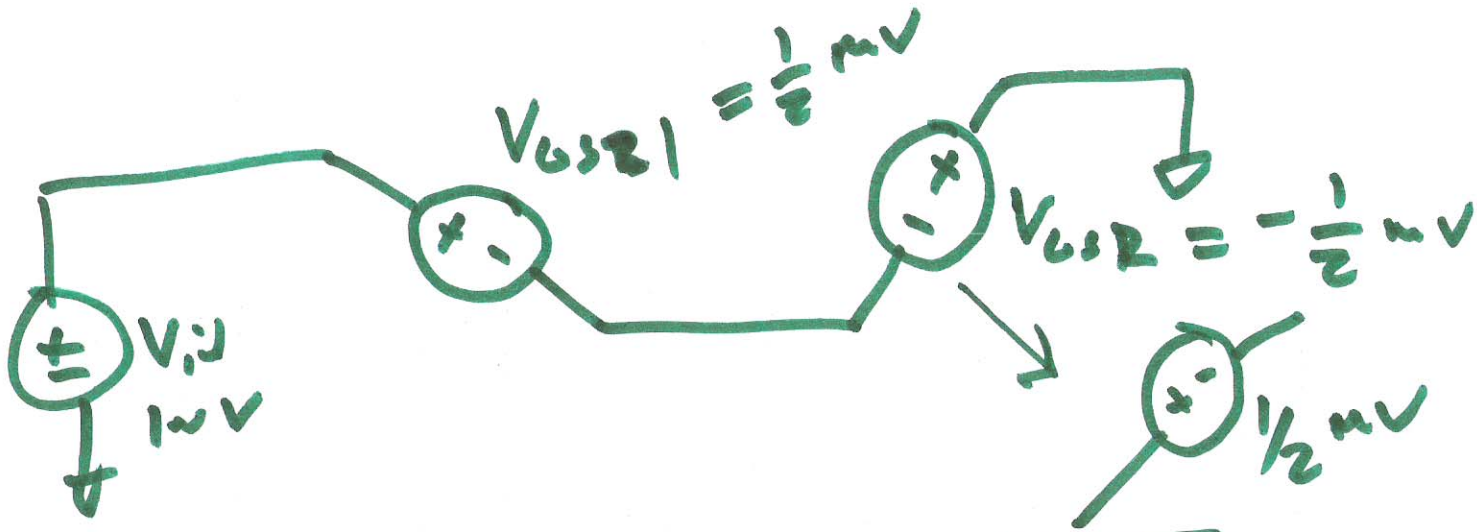
$v_{gs1} = \frac{v_{in}}{2}$

$v_{gs2} = -\frac{v_{in}}{2}$

$v_{in} = \frac{i_{d1}}{g_m} - \frac{i_{d2}}{g_m} = \frac{2i_d}{g_m}$

$v_{id} = \frac{v_{in}}{2} - \left(-\frac{v_{in}}{2}\right)$ $\quad i_d = g_m \frac{v_{gs}}{2}$

4)



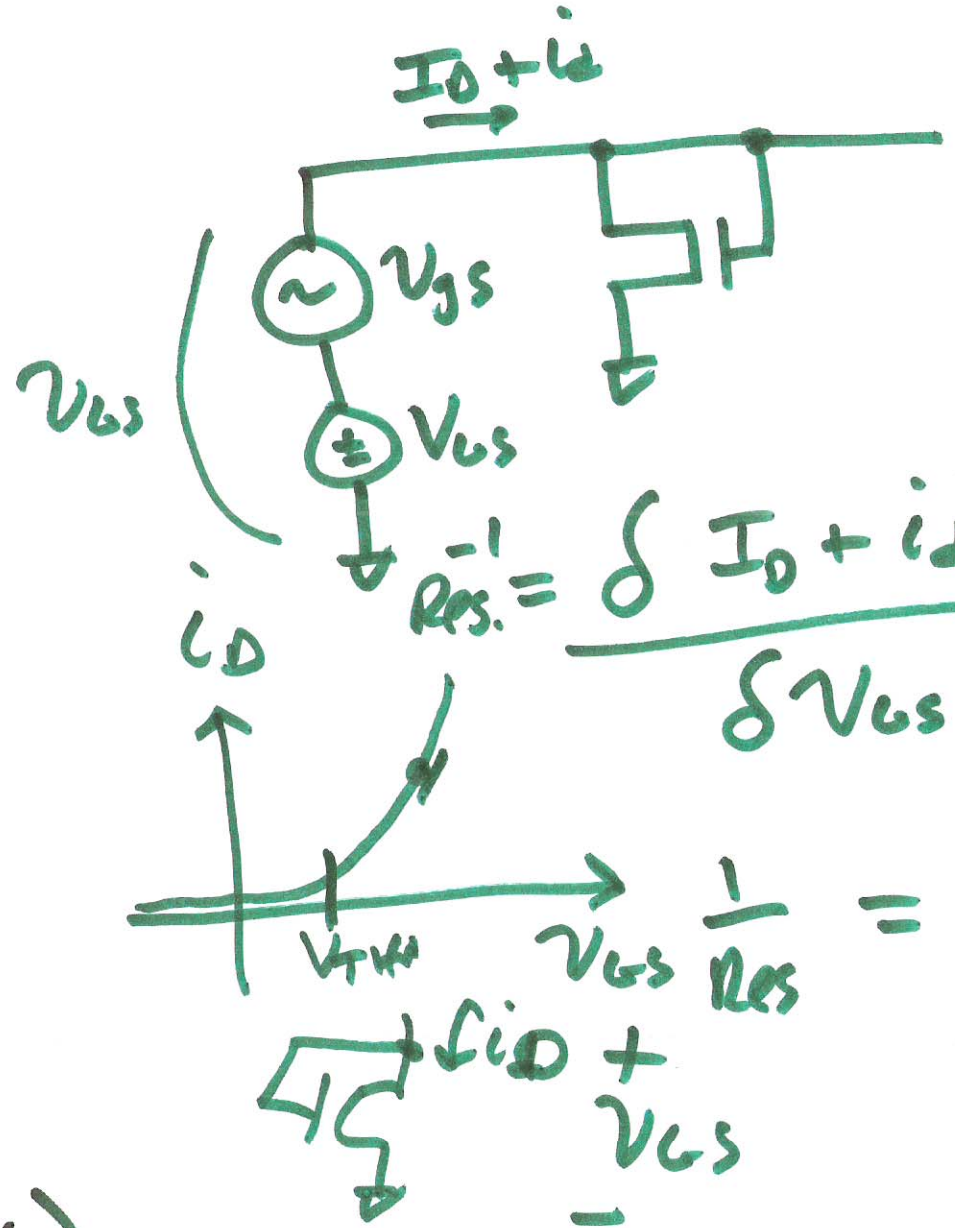
$$g_m = \sqrt{2\beta I_D} = \sqrt{2 \cdot 120\mu \cdot \frac{10}{2} 20\mu A} = 150\,\mu\frac{A}{V}$$

$$v_{gs} = \frac{1}{2}\,mV$$

$$i_d = \frac{1}{2}\,mV \cdot 150\,\mu A$$

$$= \underline{\underline{75\,nA}}$$

5 Ex)



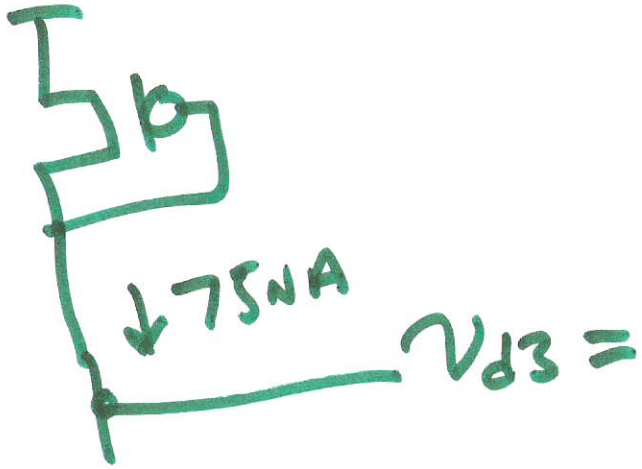
S.S. Resistance $= \frac{v_{gs}}{i_d} = \frac{1}{g_m}$

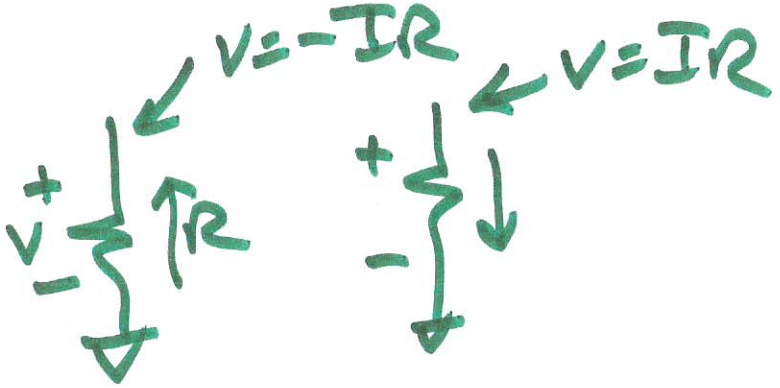
$$\frac{1}{R_{eq}} = \frac{\delta\, I_D + i_d}{\delta V_{GS}} = \frac{\delta \frac{\beta_N}{2}(v_{gs} + V_{GS} - V_{THN})^2}{\delta V_{GS}}$$

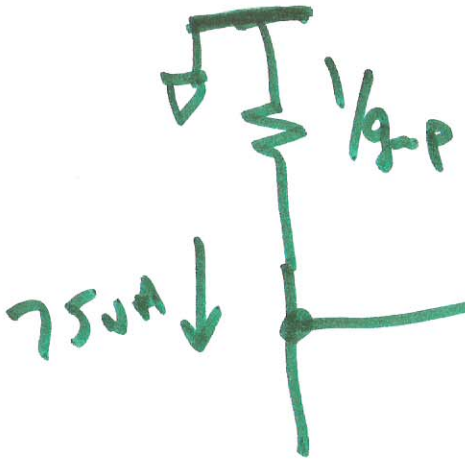
$$\frac{1}{R_{eq}} = \beta_N (\underbrace{v_{gs} - V_{GS}} - V_{THN}) = g_m$$

$\simeq V_{GS}$ since $V_{GS} >> v_{gs}$

6)


75μA
v_{d3} =


V=-IR
V=IR
+
v
−
IR
+
−


$1/g_m = \frac{1}{150\mu A} = 6.5K$
75μA
$v_{d3} = -75\mu A \cdot 6.5K = -\frac{1}{2}mV$

7)