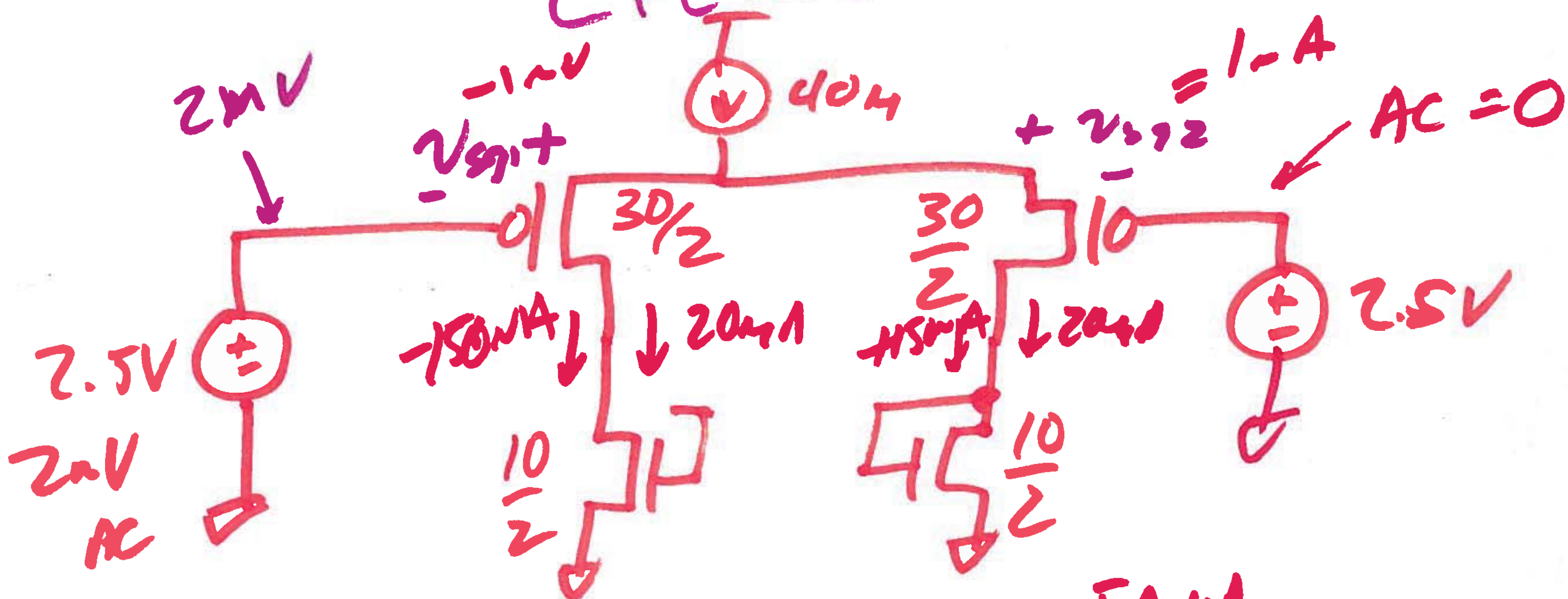
EE 420/ECG 620
Analog IC Design
Feb. 11, 2019
Lecture 6

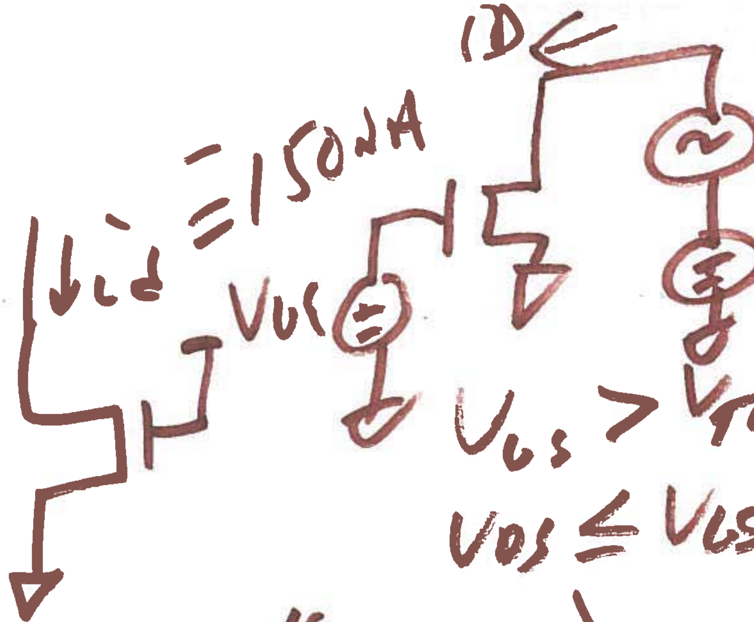
$$2mV + v_{sg1} - v_{sg2} = 0$$

$v_{sg1} = -1mV$, $v_{sg2} = +1mV$



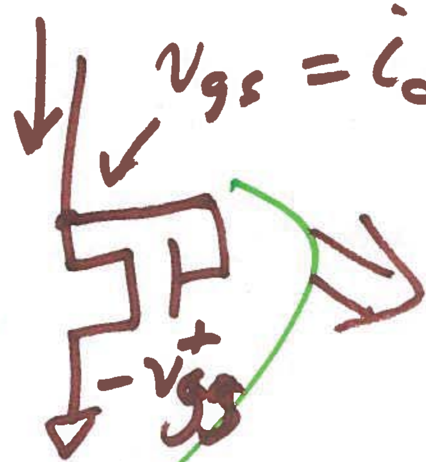
$$g_{mp,n} = 150 \frac{uA}{V}$$

$g_m v_{gs} = i_d$



$V_{GS} > V_{THN}$

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



$v_{gs} = i_d \cdot \frac{1}{g_m}$

$\approx \frac{1}{g_{mn}}$

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

$$\frac{1}{R_{CH}} = \frac{\delta i_d}{\delta V_{DS}}\Bigg|_{\substack{I_D = CONST \\ V_{GS} = CONST}} = KP_n \frac{W}{L}\left((V_{GS} - V_{THN}) - V_{DS}\right)$$

$\overset{DC}{V_{DS}} >> \overset{AC}{v_{ds}}$

$$v_{d24} = i_d \cdot \frac{1}{g_m} = 150nA \cdot \frac{1}{150 \frac{\mu A}{V}}$$

$$\boxed{= 1mV}$$

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

2)

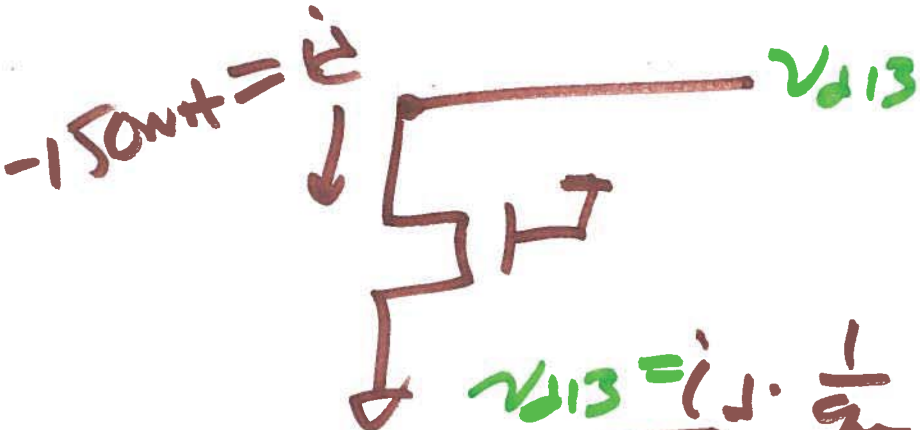
if $V_{DS} << V_{DS,SAT} = V_{GS} - V_{THN}$

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

5V

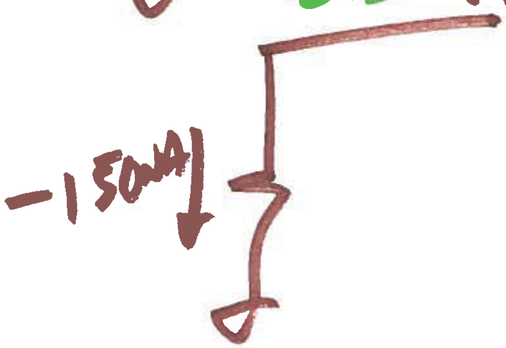
$$= \frac{1}{120\mu \cdot \frac{10}{2}(5 - .8)}$$

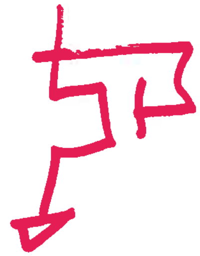
396



$$v_{d13} = i_d \cdot \frac{1}{g_m} = i_d \cdot R_{CH} = \boxed{\cancel{-1mV}}$$

$$= 150n \cdot 396 = \boxed{59\mu V}$$





$\Rightarrow$ $\frac{1}{g_m} \| r_o \approx \frac{1}{g_m}$

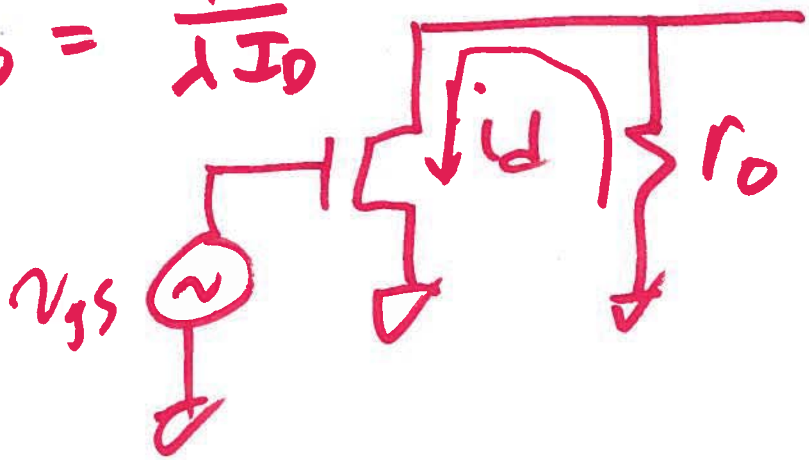
$r_o \gg \frac{1}{g_m}$

open-ckt gain (AC)

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

$r_o = \frac{1}{\lambda I_D}$

$v_{out} = -i_d \cdot r_o = -g_m v_{gs} \cdot r_o$



open-ckt gain $= -g_m r_o$

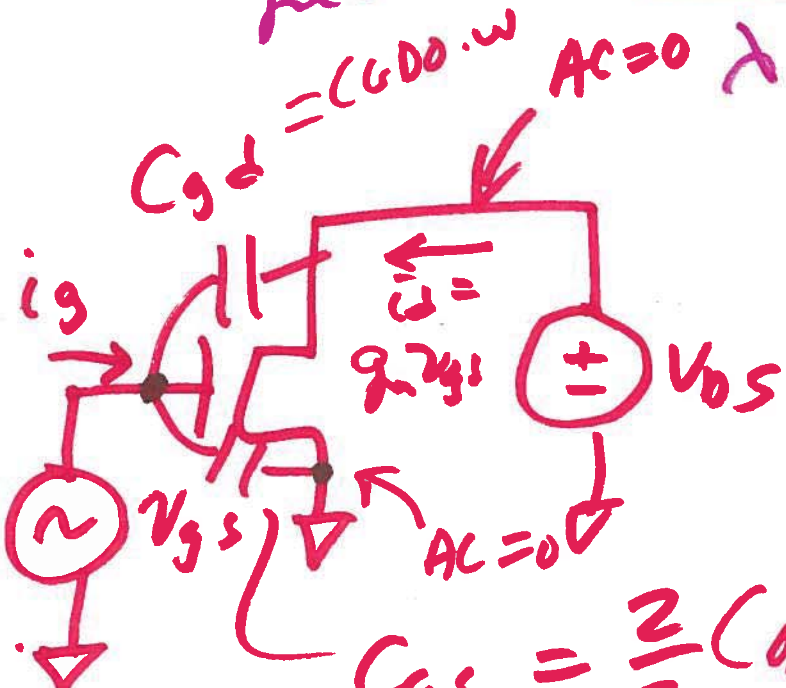
$|\downarrow| = g_m r_o = \frac{r_o}{1/g_m}$

open-ckt gain $= \frac{\sqrt{2KP \frac{W}{L} I_D}}{\lambda I_D} \propto \frac{1}{\sqrt{I_D}}$

$$g_m = KP_N(V_{GS} - V_{THN}) = KP_N V_{DS,sat} = KP_N \cdot V_{ovn}$$

$$I_D = \frac{KP_N}{2} \cdot \frac{W}{L}(V_{GS} - V_{THN})^2, \quad r_o = \frac{1}{\lambda I_D}$$

$$g_m r_o = \frac{\cancel{KP_N} \cdot \cancel{\frac{W}{L}}(V_{GS} - V_{THN})}{\lambda \frac{\cancel{KP_N}}{2} \cdot \cancel{\frac{W}{L}}(V_{GS} - V_{THN})^2} \propto \frac{1}{V_{GS} - V_{THN}} \propto \frac{1}{V_{ovn}}$$



$$i_g = \frac{v_{gs}}{1/j\omega(C_{gd} + C_{gs})}$$

$$i_d = g_m v_{gs}$$

$$C_{gs} = \frac{2}{3} C_{ox} = \frac{2}{3} C'_{ox} \cdot W \cdot L$$

$$C'_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$

$$\frac{i_d}{i_g} = \frac{g_m \cancel{v_{gs}}}{\cancel{v_{gs}} \cdot j\omega (C_{gs} + C_{gd})}$$

define

$$\left|\frac{i_d}{i_g}\right| = 1 \ @ \ f = f_T = \text{transition}$$

$$\frac{i_d}{i_g} > 1 \text{ to } \frac{i_d}{i_g} < 1$$

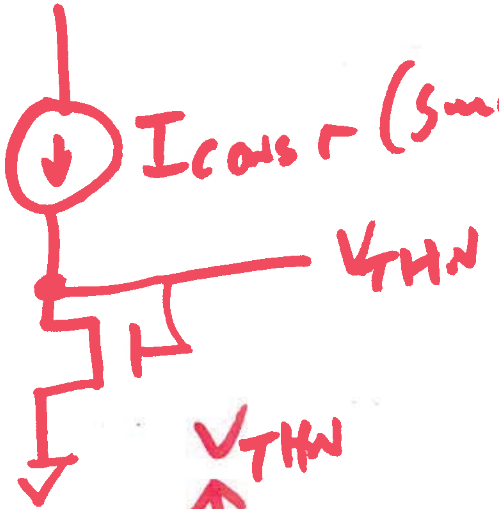
$$1 = \left|\frac{i_d}{i_g}\right| = \frac{g_m}{2\pi f_T \cdot (C_{gs} + C_{gd})} \approx \frac{\cancel{KP} \cdot \frac{W}{L} \cdot (V_{GS} - V_{THN})}{2\pi f_T \left(\frac{2}{3} W \cdot L \, C_{ox}'\right)}$$

$C_{gs} >> C_{gd}$, $KP = \mu_n \cdot C_{ox}'$

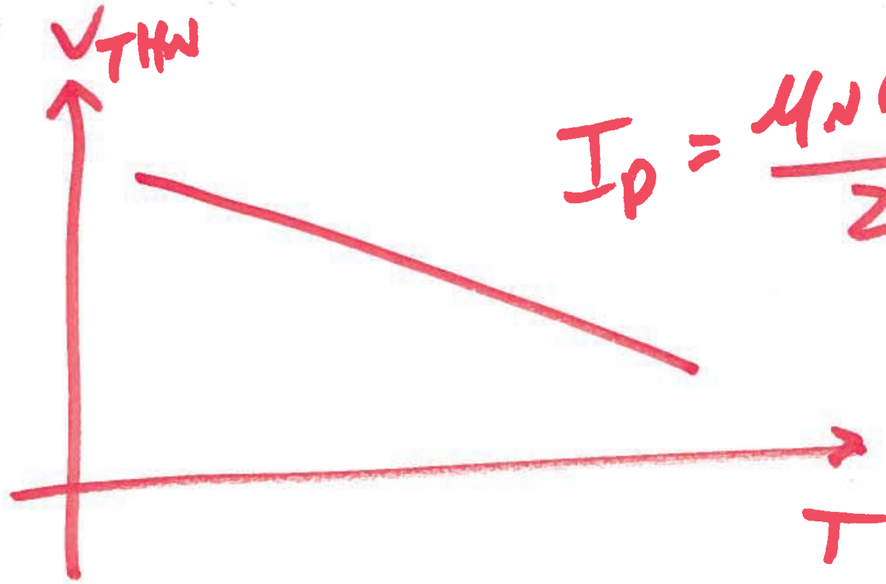
$$\boxed{f_T = \frac{\mu_n \cdot (V_{GS} - V_{THN})}{2\pi \cdot L^2 \cdot \frac{2}{3}}}$$

$$f_T \propto \frac{V_{ovn}}{L^2}$$

b)



T ↑ V_{THN} ↓



$$I_D = \frac{\mu_n C'_{ox}}{2} \frac{W}{L} (V_{GS} - V_{THN})^2$$

Mobility μ

T ↑ μ ↓