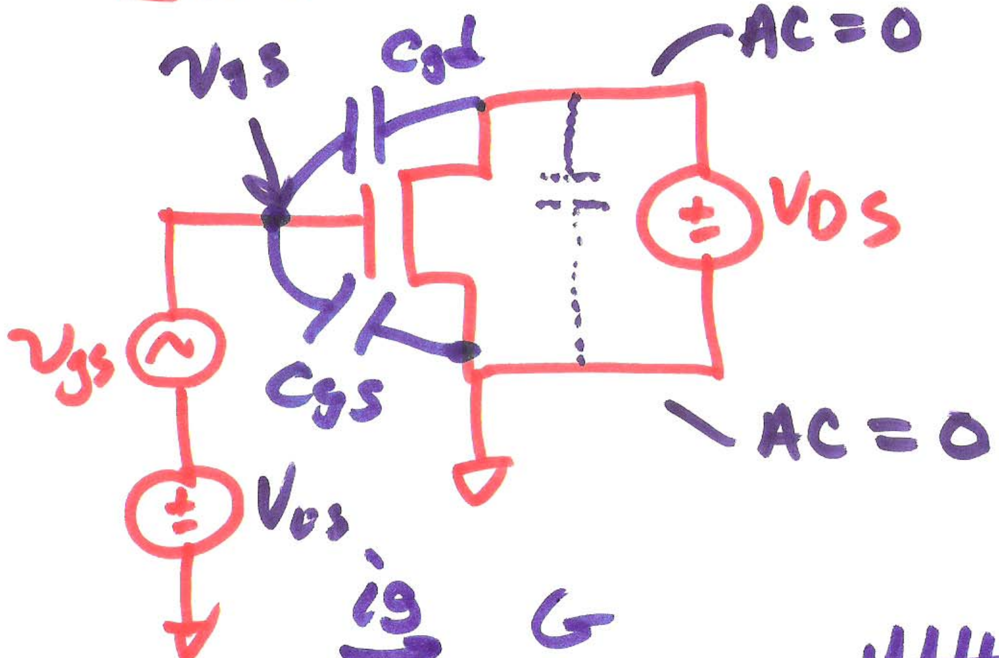
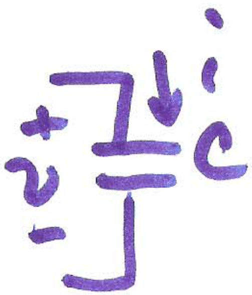
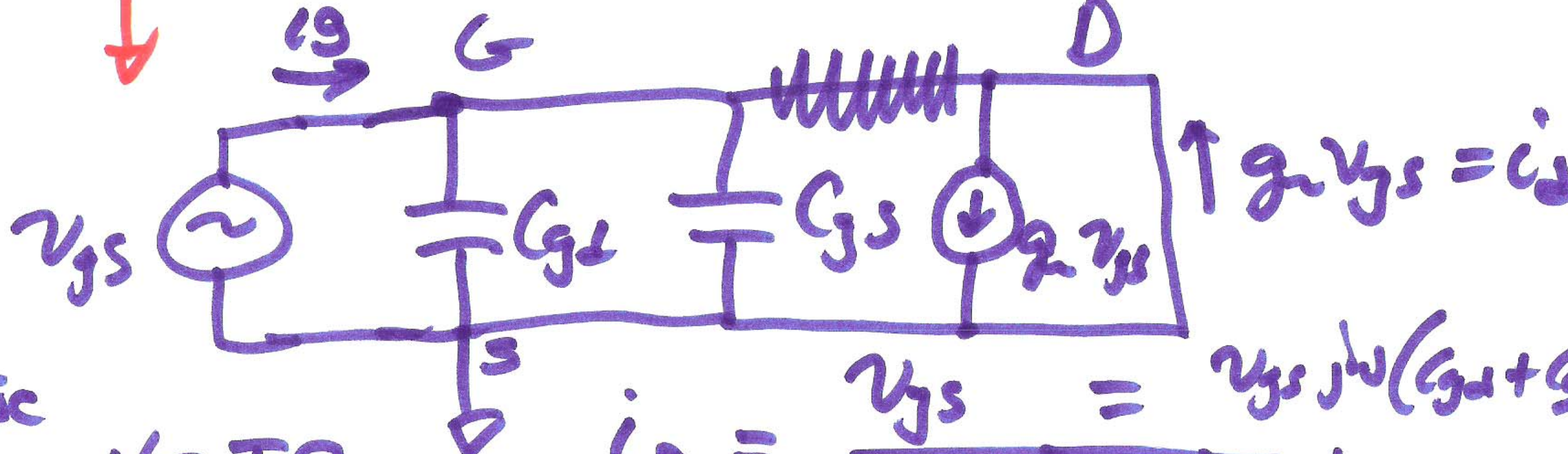
EE 422 ECG 622
Analog IC Design
Lecture 7 2/13/13







$v = i \cdot \frac{1}{j\omega C}$

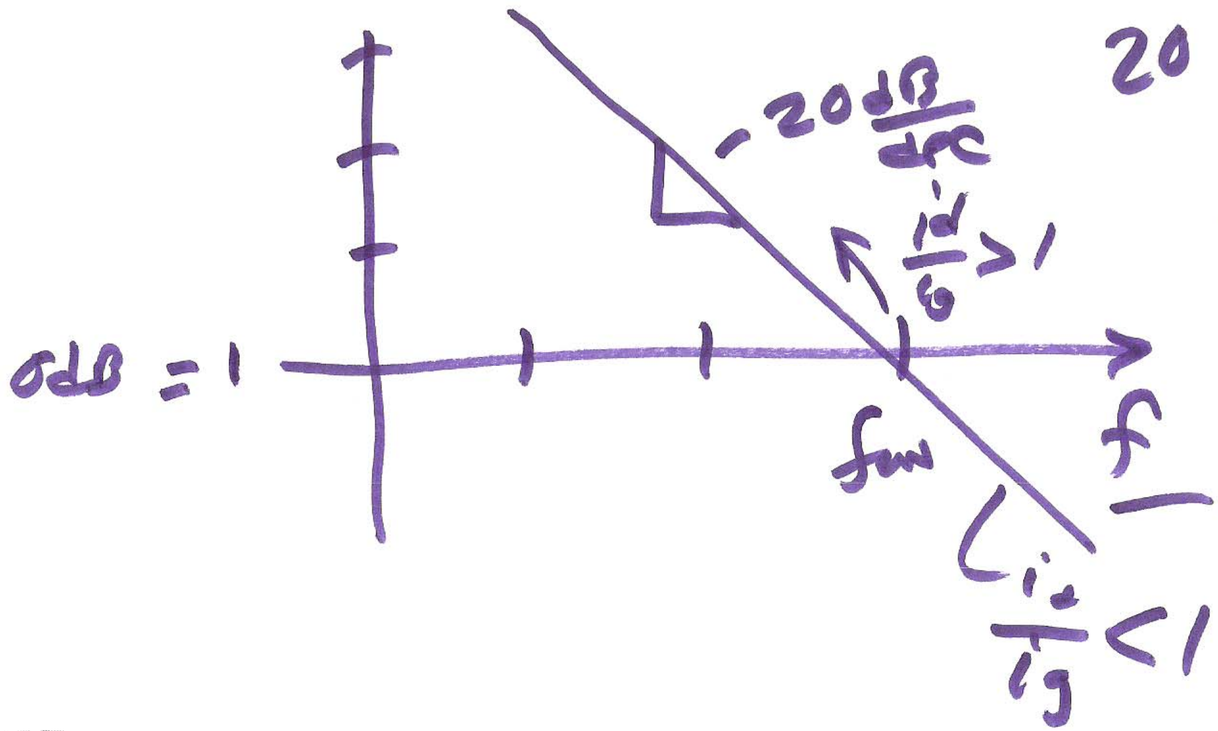
$V = IR$

$i = j\omega C \cdot v$

$$i_g = \frac{v_{gs}}{\left(j\omega(C_{gs}+C_{gd})\right)^{-1}} = v_{gs}\, j\omega(C_{gd}+C_{gs})$$

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

$$\frac{i_d}{i_g} = \frac{g_m}{j \cdot 2\pi \underline{f} \left(C_{gd} + C_{gs}\right)}$$



$$20 \log \frac{1}{f}$$

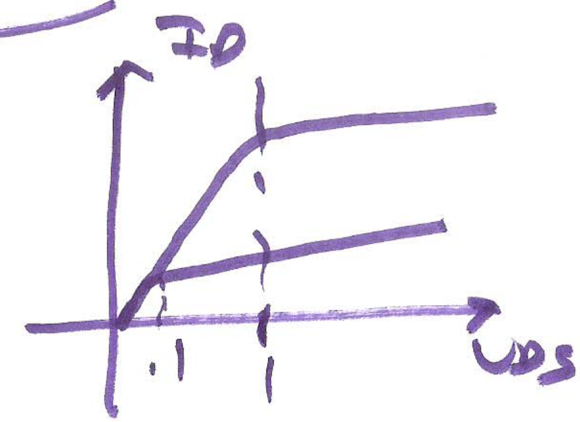
$$= -20 \cdot f$$

$$\left|\frac{i_d}{i_g}\right| = \frac{KP_n \cdot \frac{W}{L} \cdot (V_{GS} - V_{THN})}{2\pi \cdot f \cdot (C_{gs} + C_{gd})}$$

overdrive voltage $= V_{GS} - V_{THN} = V_{DS,SAT} = V_{ovn}$

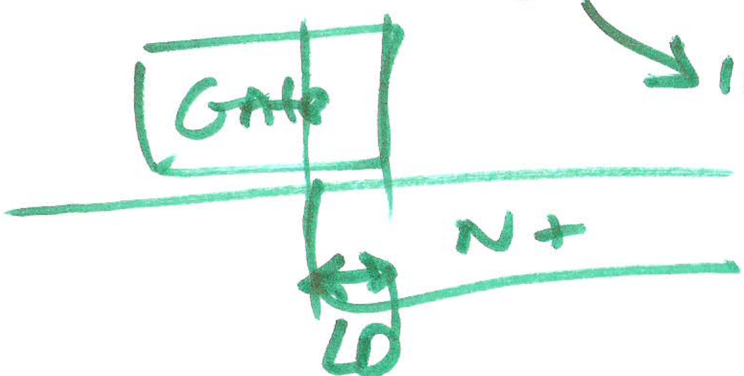
excess gate voltage

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



$$C_{gd} = C'_{ox} \cdot W \cdot LD$$

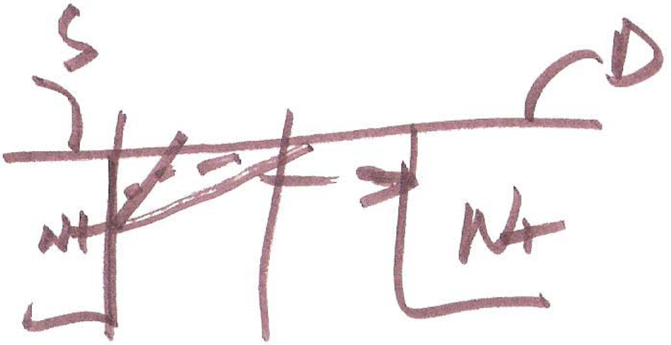
→ in saturation



$$C_{gs} >> C_{gd}$$

$r_o \propto \frac{[illegible]}{L}$

$$\left|\frac{i_d}{i_g}\right| = \frac{KP\cdot\frac{W}{L}(V_{GS}-V_{THN})}{2\pi\cdot f\cdot\left(\frac{2}{3}C'_{ox}\cdot W\cdot L + C'_{ox}\cdot LD\cdot W\right)}$$



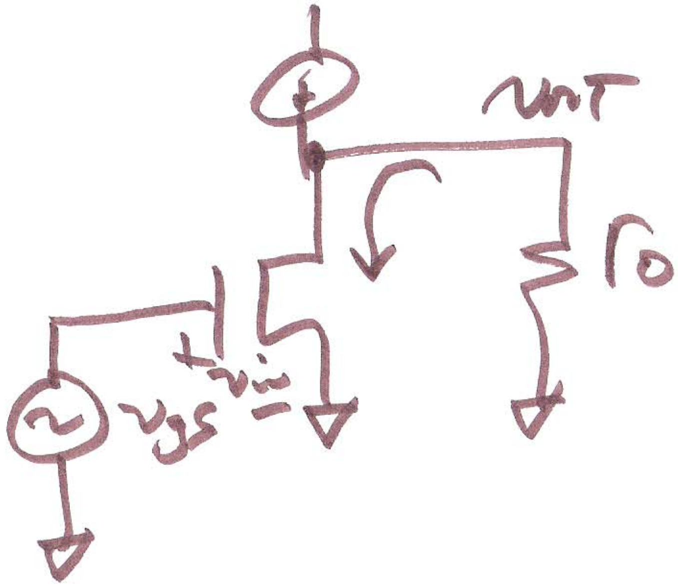
$$= \frac{KP\cdot(V_{GS}-V_{THN})}{2\pi f\left(\frac{2}{3}C'_{ox}\cdot L^2 + L\cdot C'_{ox}\cdot LD\right)}$$

L_{eff}

$\frac{W}{L_{eff}}\cdot(V_{GS}-V_{THN})^2$ $\quad C_{gs} >> C_{gd}$

$$1 = \left|\frac{i_d}{i_g}\right| \approx \left|\frac{\mu_n\cdot C'_{ox}(V_{GS}-V_{THN})}{2\pi f_T\cdot\frac{2}{3}C'_{ox}\cdot L^2}\right|$$

Small L gives small gain!

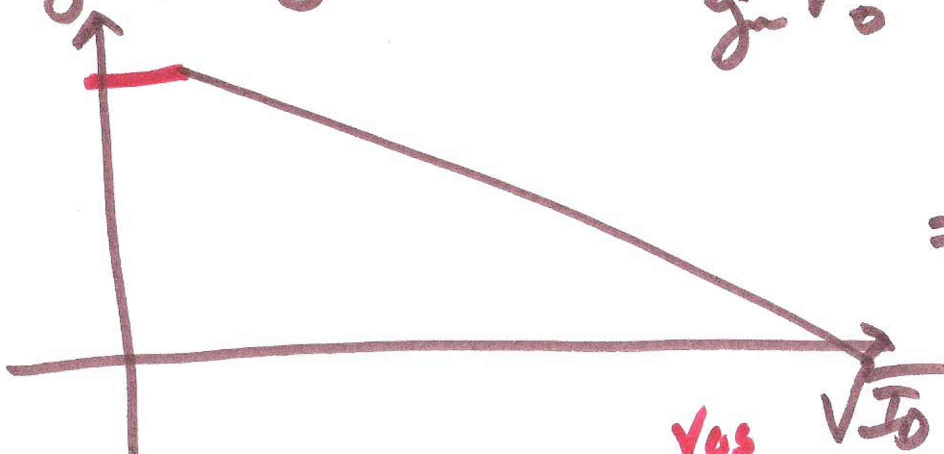


$$\left|\frac{v_{out}}{v_{in}}\right| = \frac{g_m v_{gs} r_o}{v_{gs}}$$

$$\text{open-ckt gain} = g_m r_o = \frac{\sqrt{2KP \cdot \frac{W}{L} I_D}}{\lambda I_D}$$

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

$g_m r_o = \text{gain}$



$$g_m r_o = \frac{\sqrt{2KP \cdot W/L}}{\lambda \cdot \sqrt{I_D}} = \frac{\sqrt{2KP_n \cdot W/L}}{\lambda \cdot \sqrt{\frac{KP_n}{2} \cdot \frac{W}{L}}\,(V_{GS} - V_{THN})}$$

$I_D = I_{D0} e^{\frac{V_{GS}}{nV_T}}$ for subthreshold

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

$$g_m r_o = \frac{2}{\lambda \cdot (V_{GS} - V_{THN})}$$

Figure of Merit

$$GFT = g_m r_o \cdot f_T = \frac{\mu_n \cdot 3 (V_{GS} - V_{THN}) \cdot 2}{4\pi \cdot L^2 \, (V_{GS} - V_{THN})}$$

↑ gain·f_T product = GFT $\propto \frac{\mu_n}{L^2}$

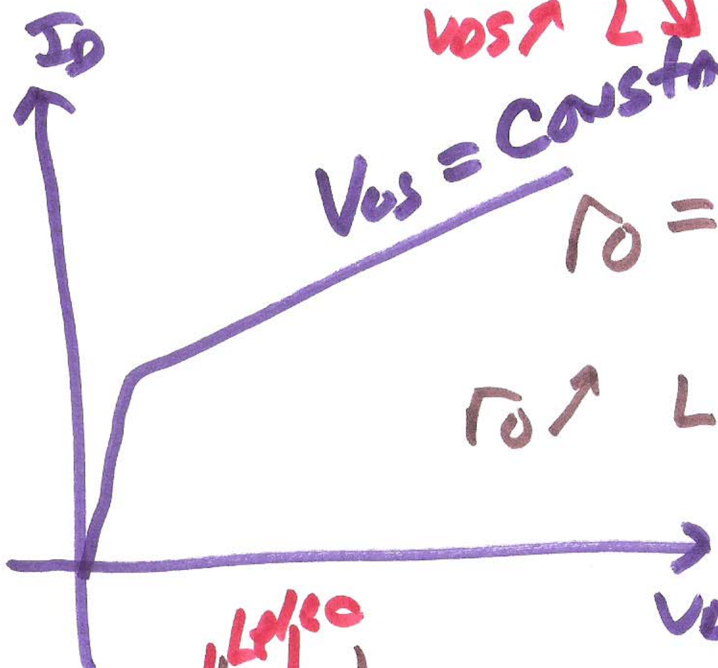
General design

set L → 2 to 5 minimum

$V_{ovn} = V_{GS} - V_{THN} = 5\%$ of VDD

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

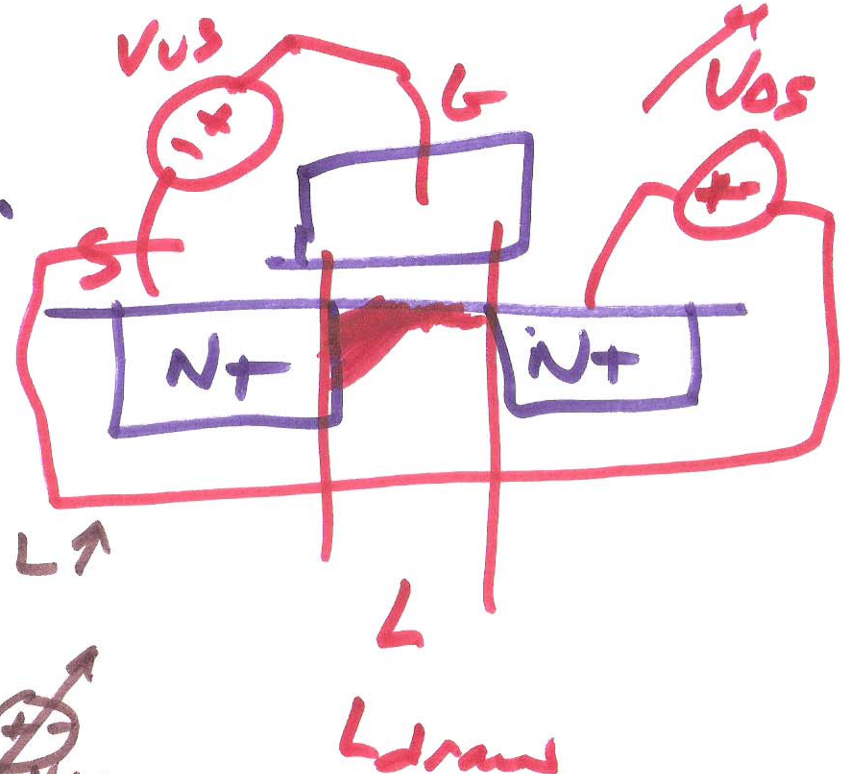
$V_{DS}\uparrow$ $L\downarrow$

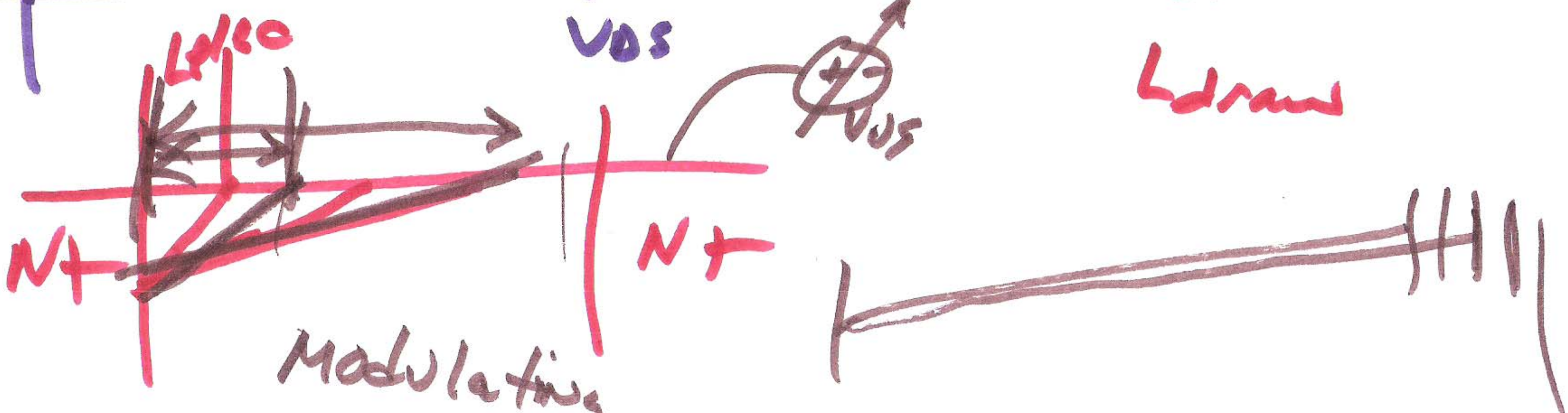


$$r_o = \frac{1}{\lambda I_D}$$

$r_o \uparrow$ $L \uparrow$

$\lambda \downarrow$ $L \uparrow$





Modulating the channel length