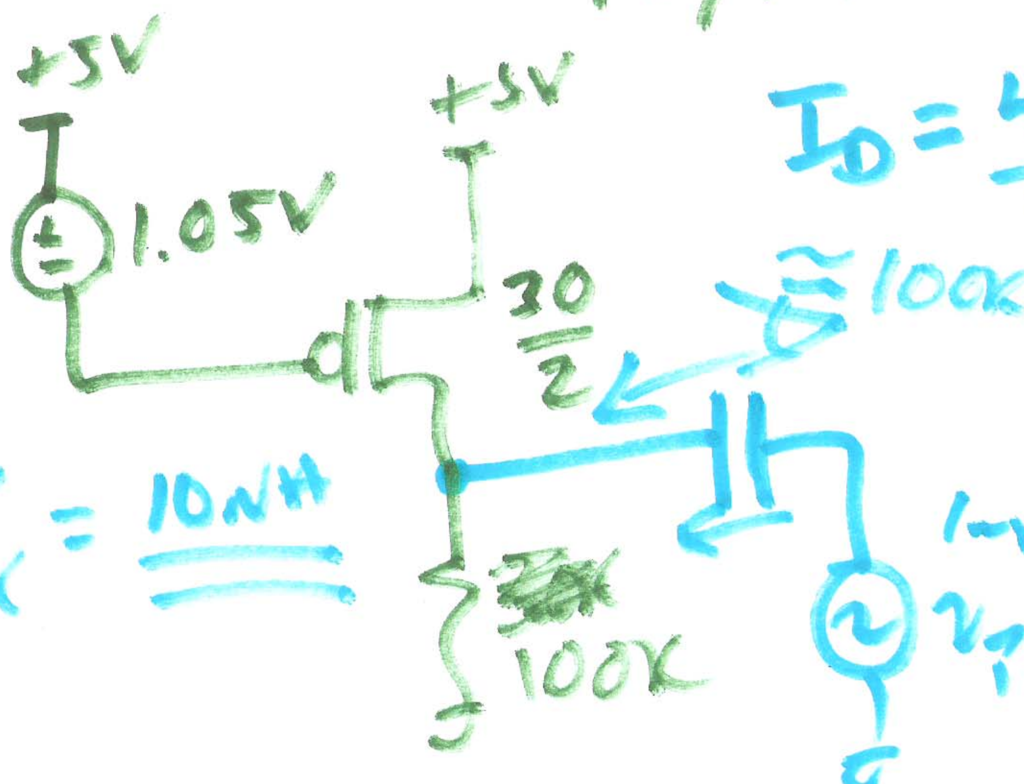
EE 420 / ECG 620

Electronics II
Analog IC Design

2/3/14 Lecture 4



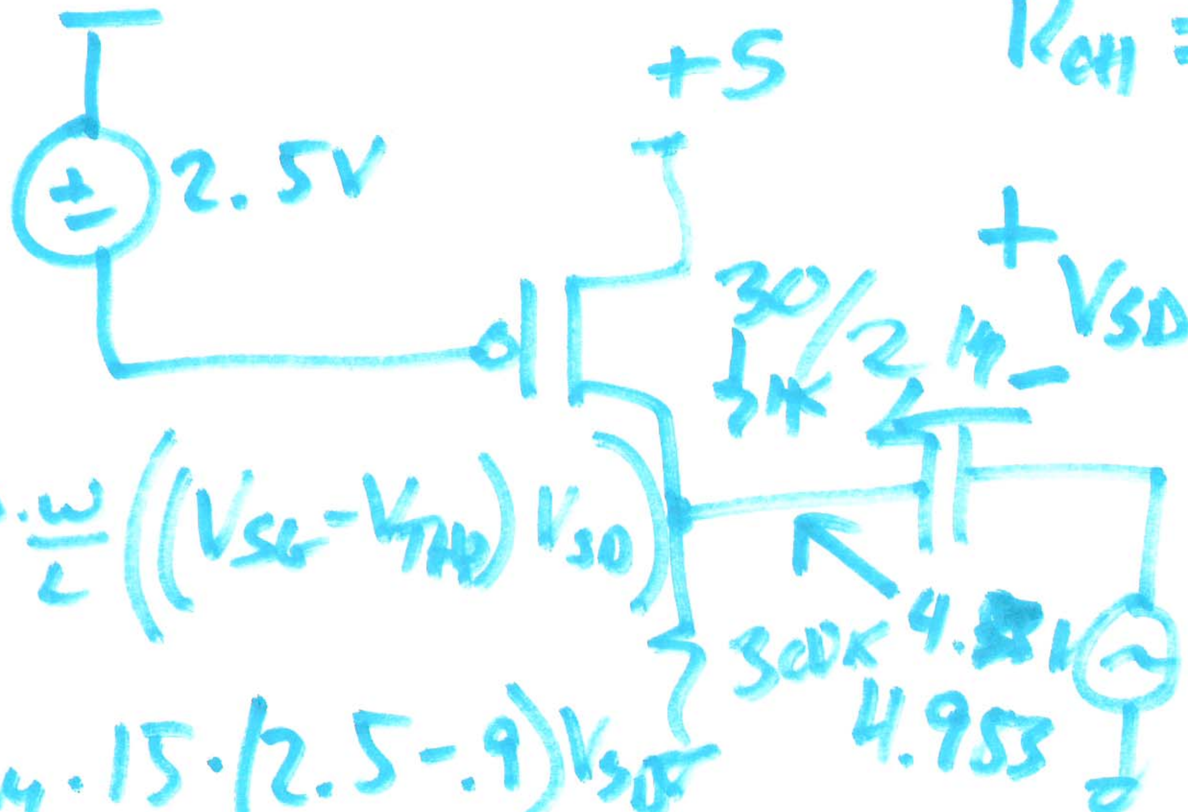
$$\frac{1mV}{100K} = 10nA$$

$$I_D = \frac{40\mu}{2}\cdot\frac{30}{2}(1.05 - .9)^2$$

$$I_D = 6.75\mu A$$

$$g_m = 40\mu\cdot\frac{30}{2}(.15) = 90\frac{\mu A}{V}$$

$$r_o = \frac{1}{6.75\mu\cdot 0.0125} \approx 11.5 M\Omega$$



$$R_{CH} = \frac{1}{KP\frac{W}{L}(2.5-.9)} = \frac{1}{40\mu\cdot 15\cdot 1.6} = \frac{1}{960\mu} \approx 1K$$

$$I_D = KP\cdot\frac{W}{L}\left((V_{SG}-V_{THP})V_{SD}\right)$$

$$= 40\mu\cdot 15\cdot(2.5-.9)V_{SD}$$

$$= \frac{5-V_{SD}}{300K}$$

$$300K\cdot 600\mu\ 1.6\cdot V_{SD} = 5 - V_{SD}$$

$$180\cdot 1.6\ V_{SD} = 5 - V_{SD}$$

$$288\ V_{SD}$$

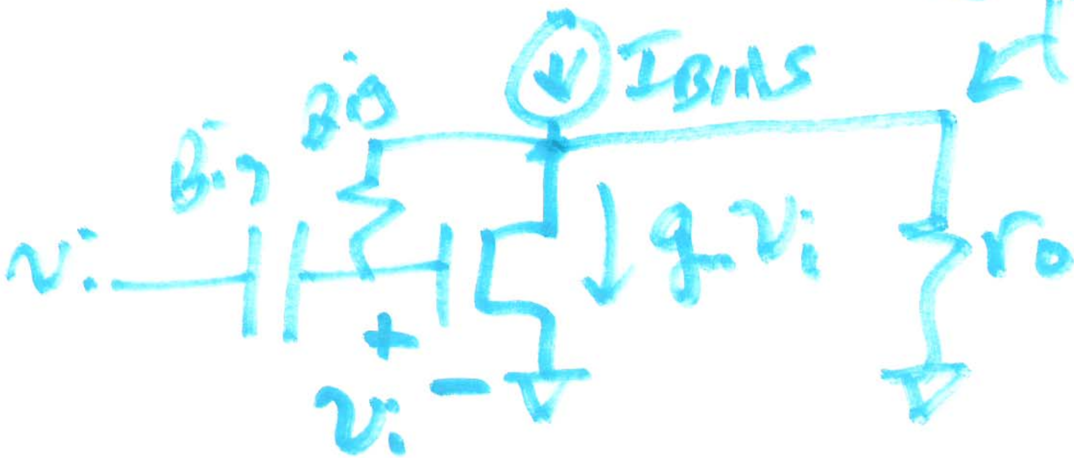
$$289\ V_{SD} = 5$$

$$V_{SD} = \frac{5}{289} = 17mV$$

2)

open-CKT gain

$|v_{out}| = g_m v_i r_o$



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

← open-CKT gain!

I_D

$$g_m r_o = \frac{\sqrt{2 I_D \cdot KP \cdot \frac{W}{L}}}{\lambda I_D} \Rightarrow g_m r_o \propto \frac{1}{\sqrt{I_D}}$$

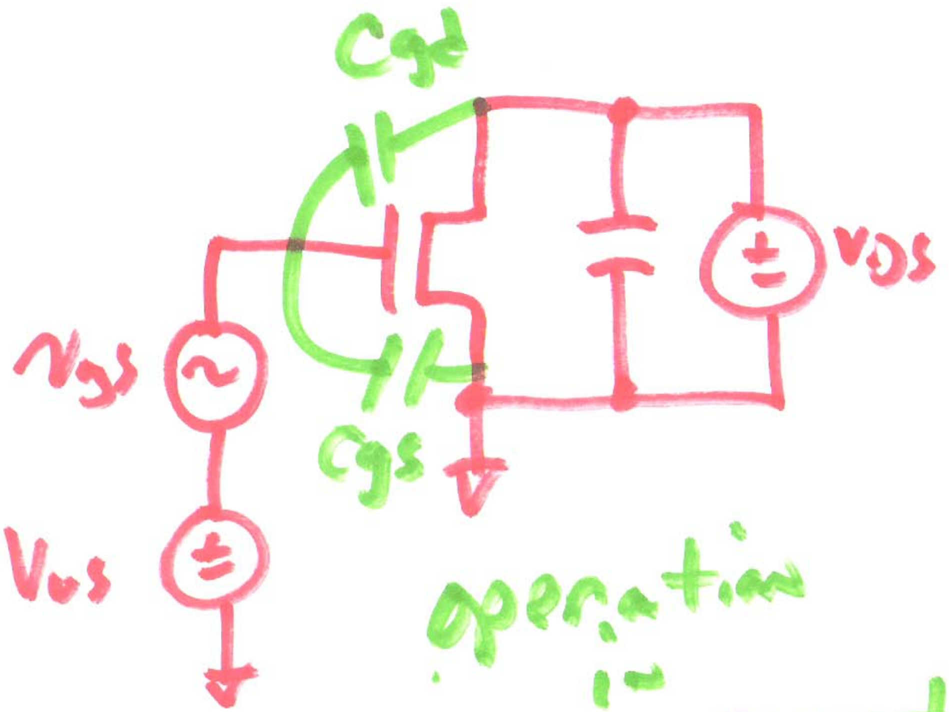
$I_D \uparrow \; g_m r_o \downarrow$

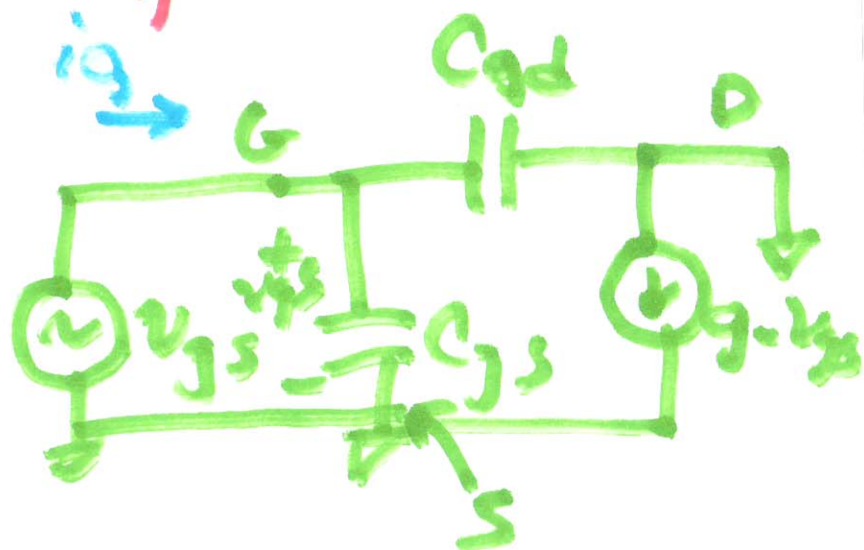
W/L

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

($V_{GS} - V_{THN}$ → $V_{DS,SAT}$, V_{ovn})

$f_T \rightarrow$ transition freq.





operation in saturation

$$i_d = g_m v_{gs}$$

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

$$1 = \left| \frac{i_d}{i_g} \right| = \frac{g_m}{2\pi f_T (C_{gs} + C_{gd})}$$

$$f_T = \frac{g_m}{2\pi (C_{gs} + C_{gd})}$$

$$C_{gs} \gg C_{gd}$$

$$f_T \approx \frac{g_m}{2\pi C_{gs}} = \frac{\mu_n \cdot \frac{\epsilon_{ox}}{t_{ox}} \cdot \frac{W}{L} \cdot (V_{GS} - V_{THN})}{2\pi \cdot \frac{2}{3} \cdot \frac{\epsilon_{ox}}{t_{ox}} \cdot W \cdot L}$$

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

$$f_T \Big|_{\text{long channel}} \propto \frac{1}{L^2}$$

short $f_T \propto \frac{1}{L}$

$$GFT = g_m r_o \cdot f_T$$

$$= \frac{KP \cdot \frac{W}{L} \cdot (V_{GS} - V_{THN}) \cdot KP \frac{W}{L} (V_{GS} - V_{THN})}{\lambda \frac{KP}{2} \frac{W}{L} (V_{GS} - V_{THN})^2 \cdot \frac{2}{3} \cdot C'_{ox} \cdot W \cdot L}$$

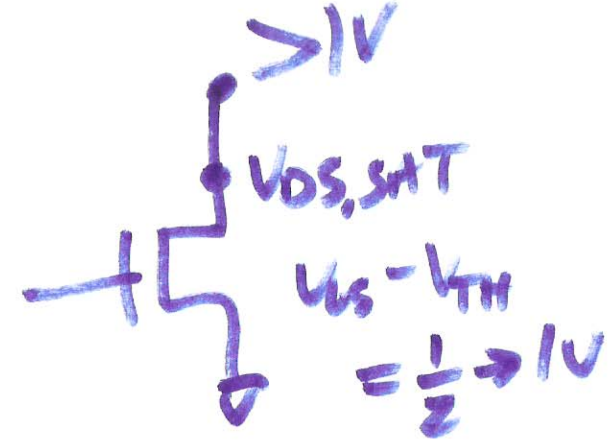
($KP = \mu_n C'_{ox}$)

General design

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

$2 \le L \le 5$

$$GFT \propto \frac{\mu}{L^2}$$



high-speed

$V_{ovn} \rightarrow$ 10% of VDD or more

Min L!

Thermal Voltage

$$V_T = \frac{kT}{q} \simeq 26\,mV \text{ @ } 300K$$

$T \nearrow \quad R \nearrow$

$$R = \frac{1}{q(\mu_N \cdot N + \mu_P P)}$$

$T \nearrow \quad N, P \nearrow$

$T \nearrow \quad \mu \downarrow$

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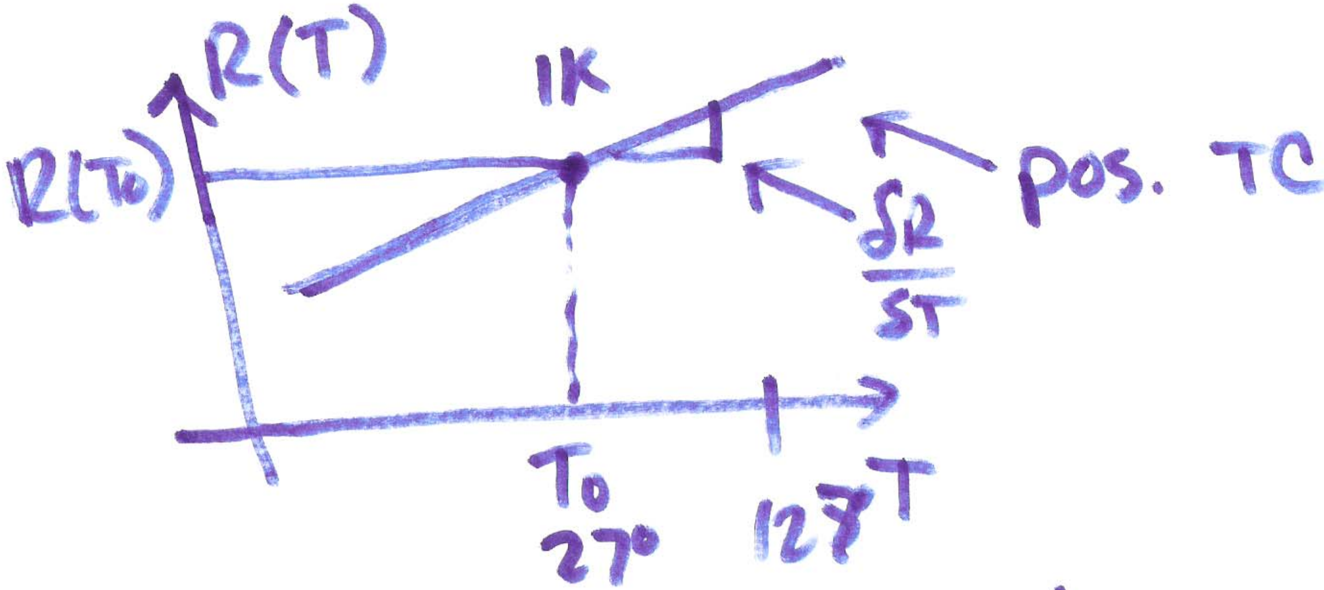

$2{,}000\ \mathrm{ppm}/C^\circ$

$$R(T) = R(T_0)\left(1 + TCR(T - T_0)\right)$$

$$= R(T_0) + \underbrace{R(T_0)\cdot TCR}(T - T_0)$$

$TCR = 0.002$

$$R(T_0)\cdot TCR = \frac{\delta R}{\delta T}$$

$1{,}000 +$

$0.002(127-27)\cdot 1{,}000$

$\underline{\underline{1200\,\Omega}}$

$$\boxed{TCR = \frac{1}{R}\frac{\delta R}{\delta T}}$$

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

$$TCKP = \frac{1}{KP}\frac{\delta KP}{\delta T} \quad \mu(T) = \mu(T_0)\left(\frac{T_0}{T}\right)^{1.5}$$

$$KP(T) = KP(T_0)\left(\frac{T_0}{T}\right)^{1.5}$$

$$-\frac{1.5}{T} = \frac{1}{KP}\frac{\delta KP(T)}{\delta T} = \frac{\delta}{\delta T}\left(\frac{T_0}{T}\right)^{1.5}$$

$$= \frac{\delta}{\delta T}\left(\frac{T}{T_0}\right)^{-1.5}$$

$$= \frac{-1.5}{T_0}\left(\frac{T}{T_0}\right)^{-2.5}$$