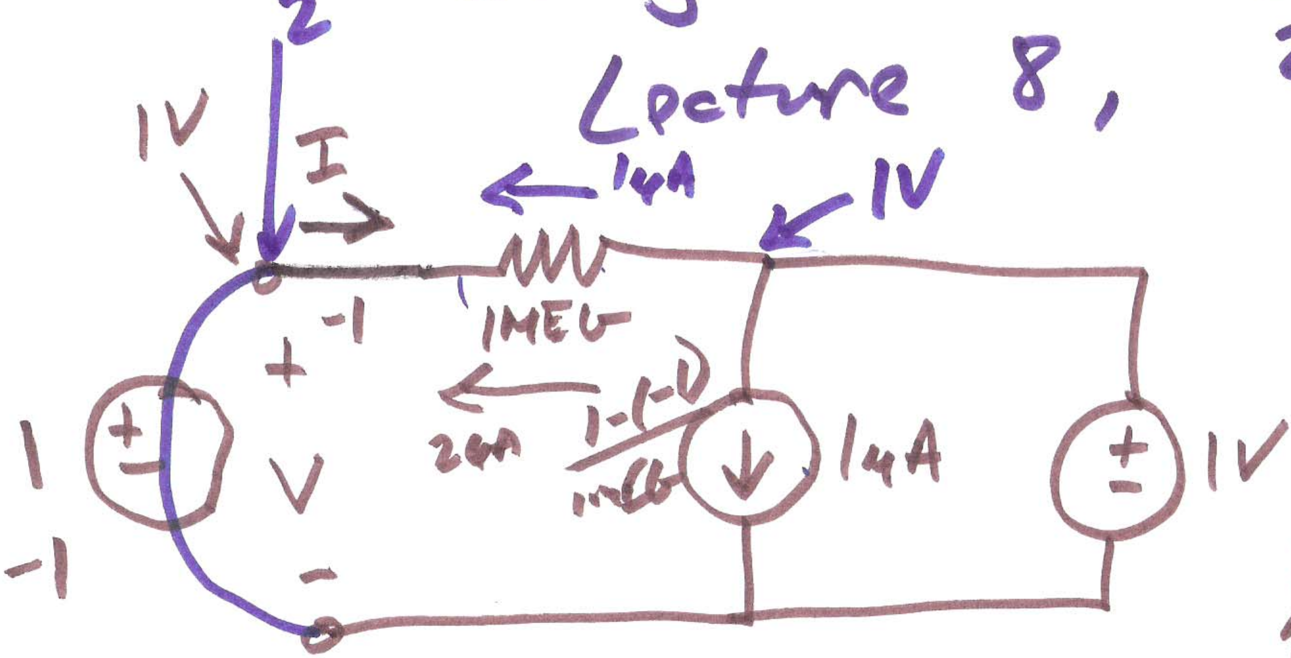
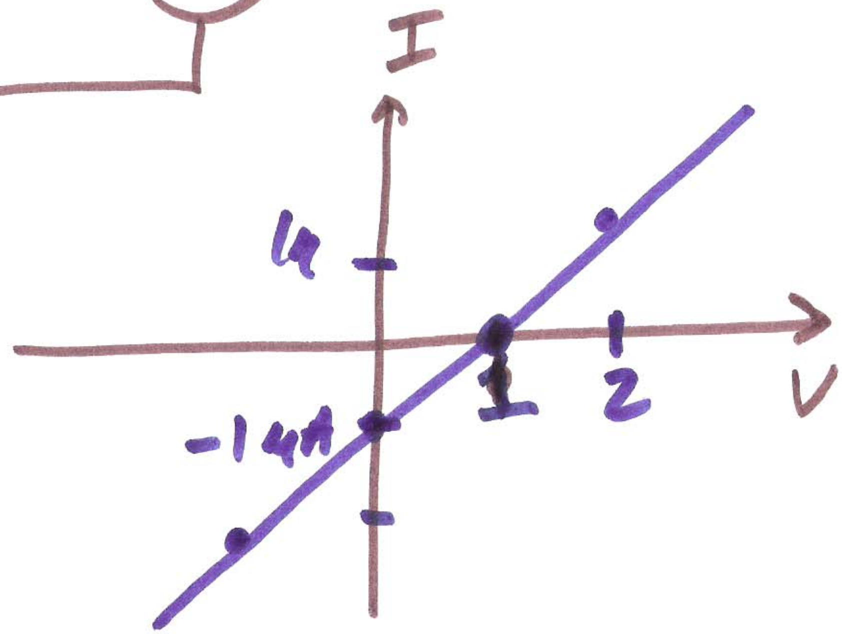
EE 422 ECG 622

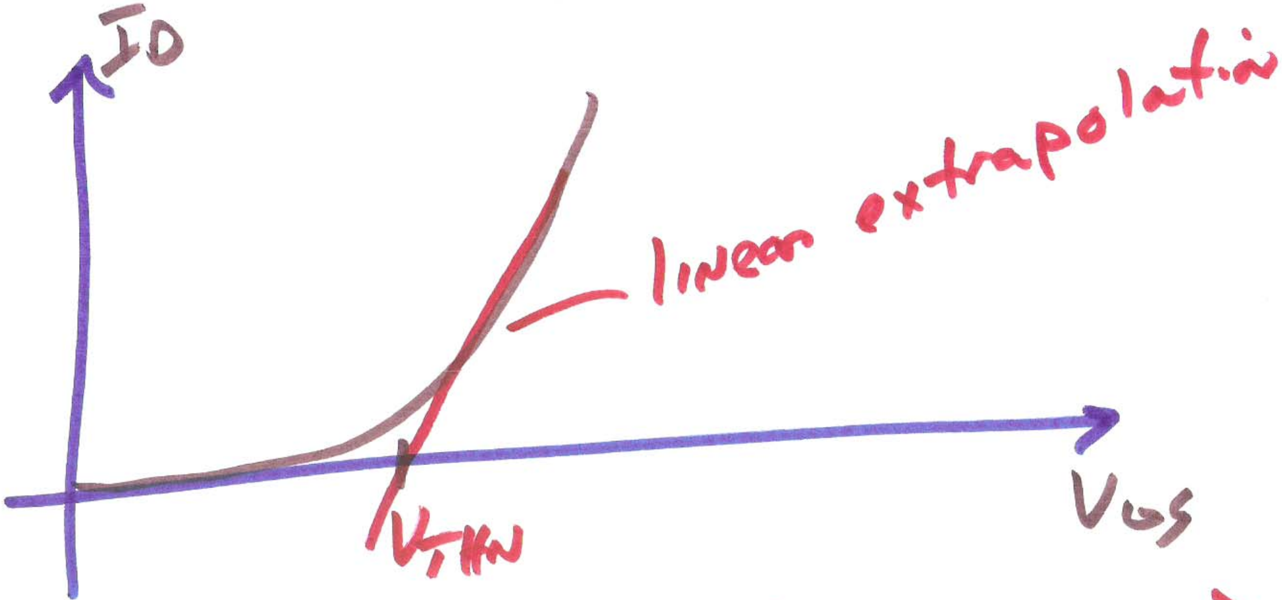
Analog IC Design

Lecture 8, 2/15/13

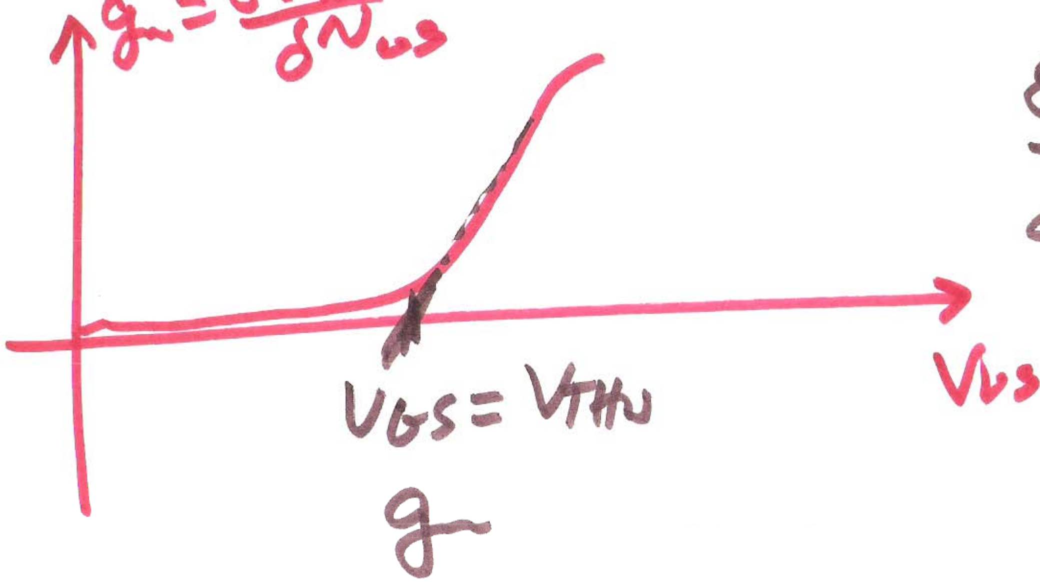




Threshold Voltage



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



$$\frac{\delta g_m}{\delta V_{GS}} = \text{CONST}$$

Temperature effects

$$I_{D,SAT} = \frac{\mu_N \cdot C_{ox}'}{2} \cdot \frac{W}{L} \cdot (V_{GS} - V_{THN})^2$$

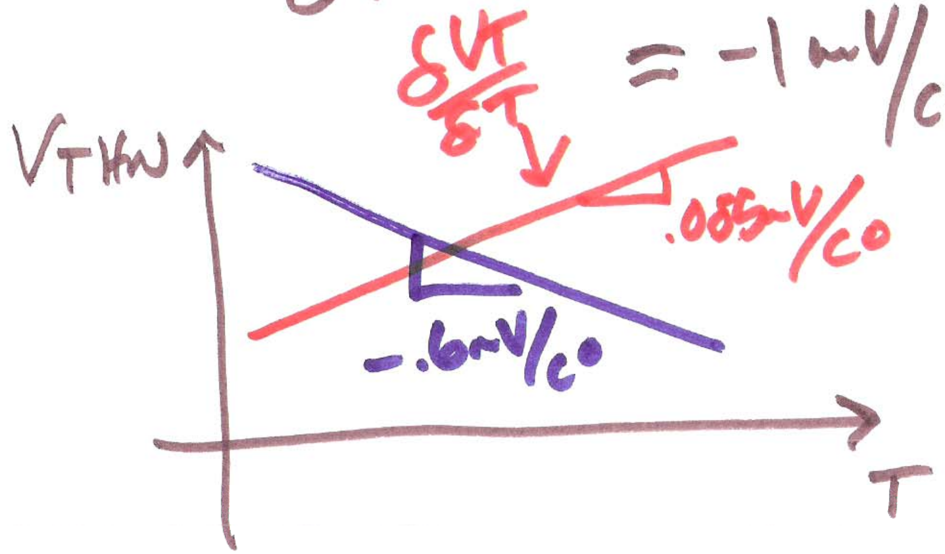
What changes with temperature?

μ_N & V_{THN}

$V_T = \frac{KT}{q}$

$$\frac{\delta V_{THN}}{\delta T} = -.6\ mV/C^o \quad 50nm$$

$$= -1\ mV/C^o \quad 1\mu\ \text{CMOS}$$



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

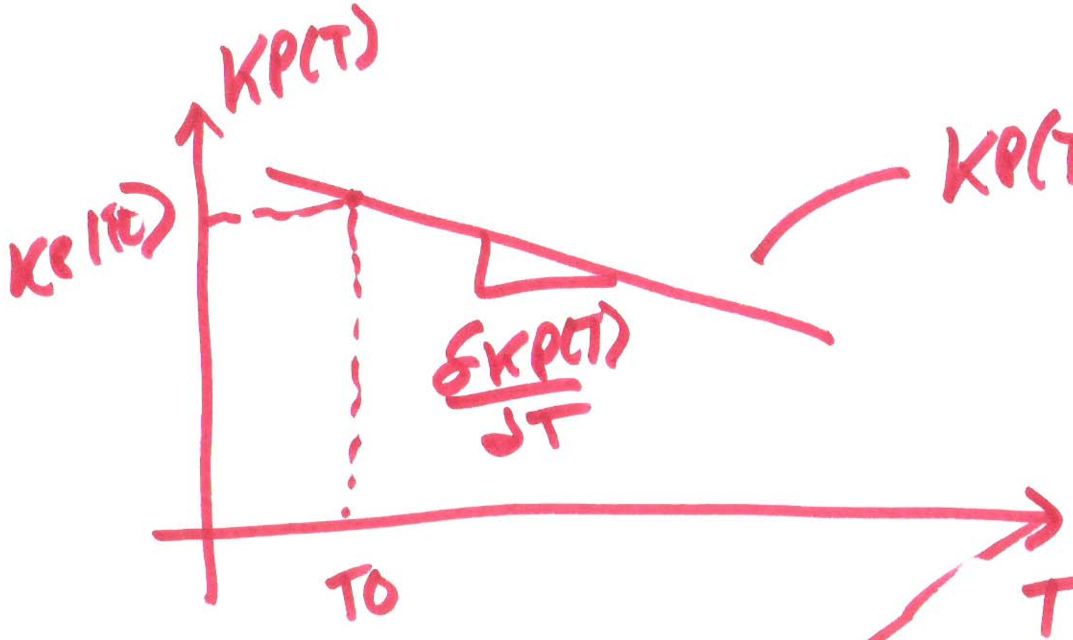
T_0 = Measured Temperature

$$KP(T) = \mu(T)\cdot C'_{ox} = KP(T_0)\cdot\left(\frac{T_0}{T}\right)^{1.5}$$

$KP(T_0) \rightarrow C'_{ox}\cdot\mu(T_0)$

$$\left.\frac{\delta KP(T)}{\delta T}\right|_{T_0 = CONST} = KP(T_0)(-1.5)\left(\frac{T}{T_0}\right)^{-2.5}\frac{1}{T_0}$$

$$\frac{1}{KP}\frac{\delta KP}{\delta T} = \frac{1}{KP(T)}\cdot KP(T_0)(-1.5)\left(\frac{T_0}{T}\right)^{2.5}\cdot\frac{1}{T_0} = -\frac{1.5}{T}$$

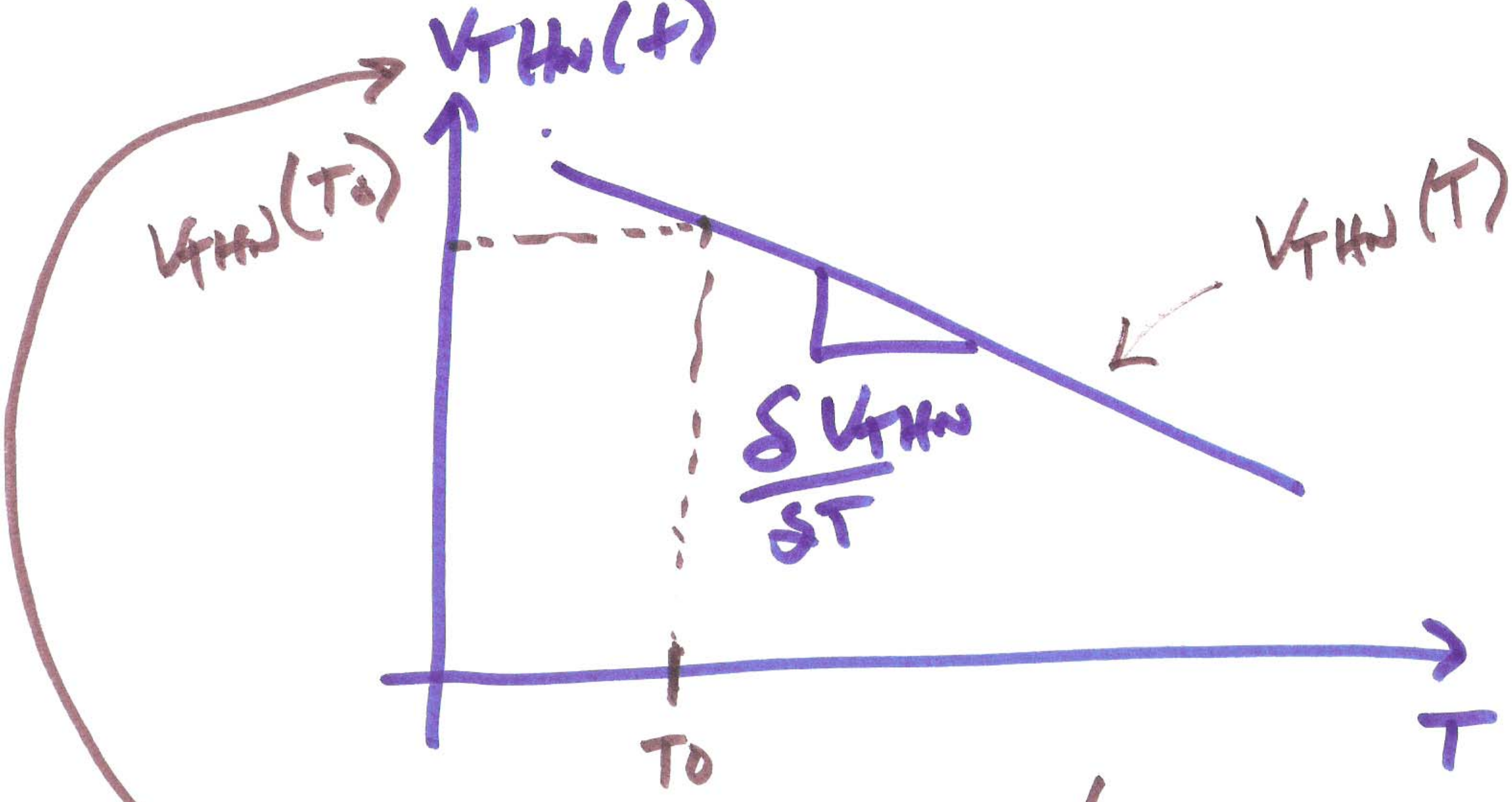


$$KP(T) = KP(T_0)\left(1 + TC_{KP} \cdot (T - T_0)\right)$$

$$TC\Big|_{KP} = \frac{1}{KP(T_0)} \frac{\delta KP(T)}{\delta T}$$

$$TC\Big|_{KP} = \frac{1}{KP} \cdot \frac{\delta KP}{\delta T} = \frac{-1.5}{T}$$

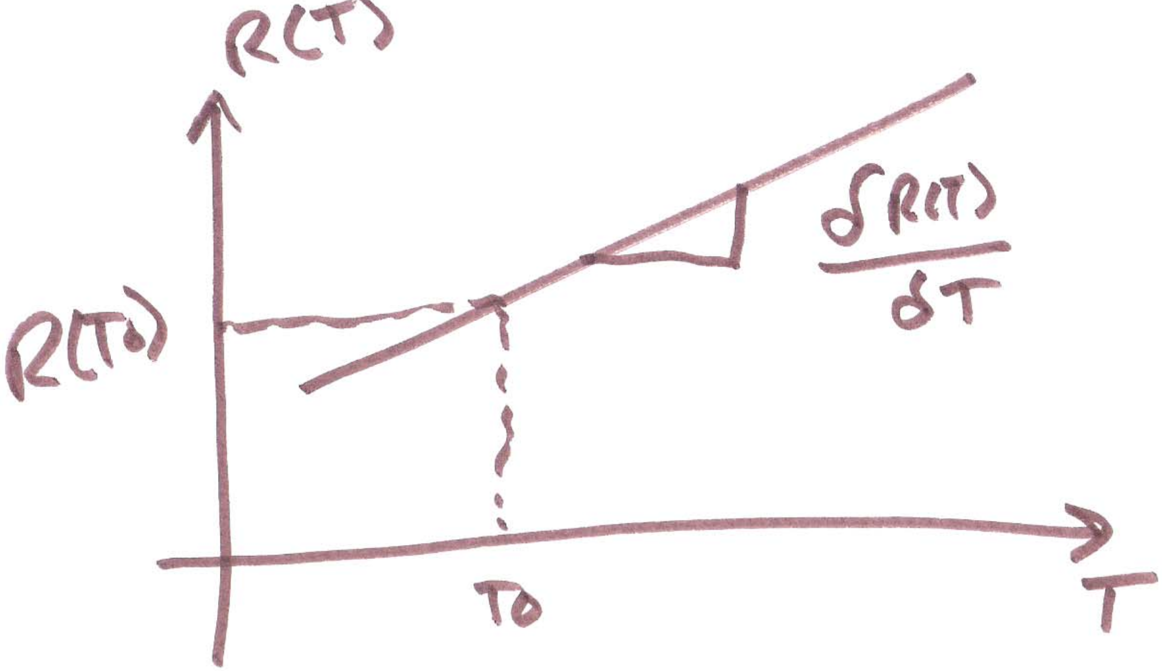
T is in Kelvin



$$V_{THN}(T) = V_{THN}(T_0)\left(1 + TCV_{THN}(T - T_0)\right)$$

$$V_{THN}(T_0) \cdot TCV_{THN} = \frac{\delta V_{THN}}{\delta T}$$

$$TCV_{THN} = \frac{1}{V_{THN}(T_0)} \cdot \frac{\delta V_{THN}}{\delta T}$$



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

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

$$TCR = 2{,}400\ \text{PPM}/C^\circ$$

$$TCR = \frac{1}{R(T_0)} \cdot \frac{\delta R(T)}{\delta T}$$

$$\text{PPM} = 10^{-6}$$

$$TCR = 2{,}400 \cdot 10^{-6}/C^\circ = 0.0024/C^\circ$$

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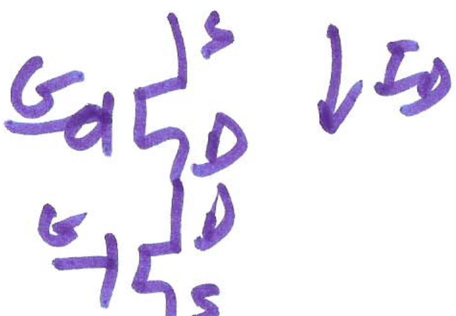
@ Smaller V_{GS} threshold change with Temp. Dominates

$I_D \nearrow$ $T \nearrow$

@ larger V_{GS} μ change with temperature Dominates

$I_D \searrow$ $T \nearrow$

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

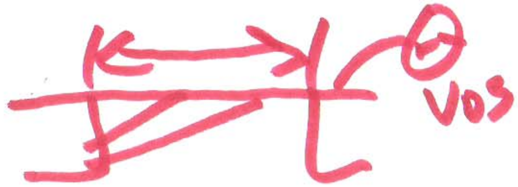


V_{GS} $-.8 \nearrow -.7$ pmos

$V_{SG} = .8$

open-CKT gain

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



$L\downarrow$ $g_m r_o \downarrow$

$\lambda \uparrow$

λ → channel length modulation parameter

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

$$g_m r_o \propto \frac{1}{\sqrt{I_D}}$$

lower I_D, more gain

$L\downarrow$ $f_T \uparrow$

$$f_T \approx \frac{g_m}{2\pi \cdot \frac{2}{3} C_{ox}' \cdot L \cdot W} = \frac{\mu \frac{W}{L}(V_{GS} - V_{THN})}{2\pi \cdot \frac{2}{3} \cdot L \cdot L}$$

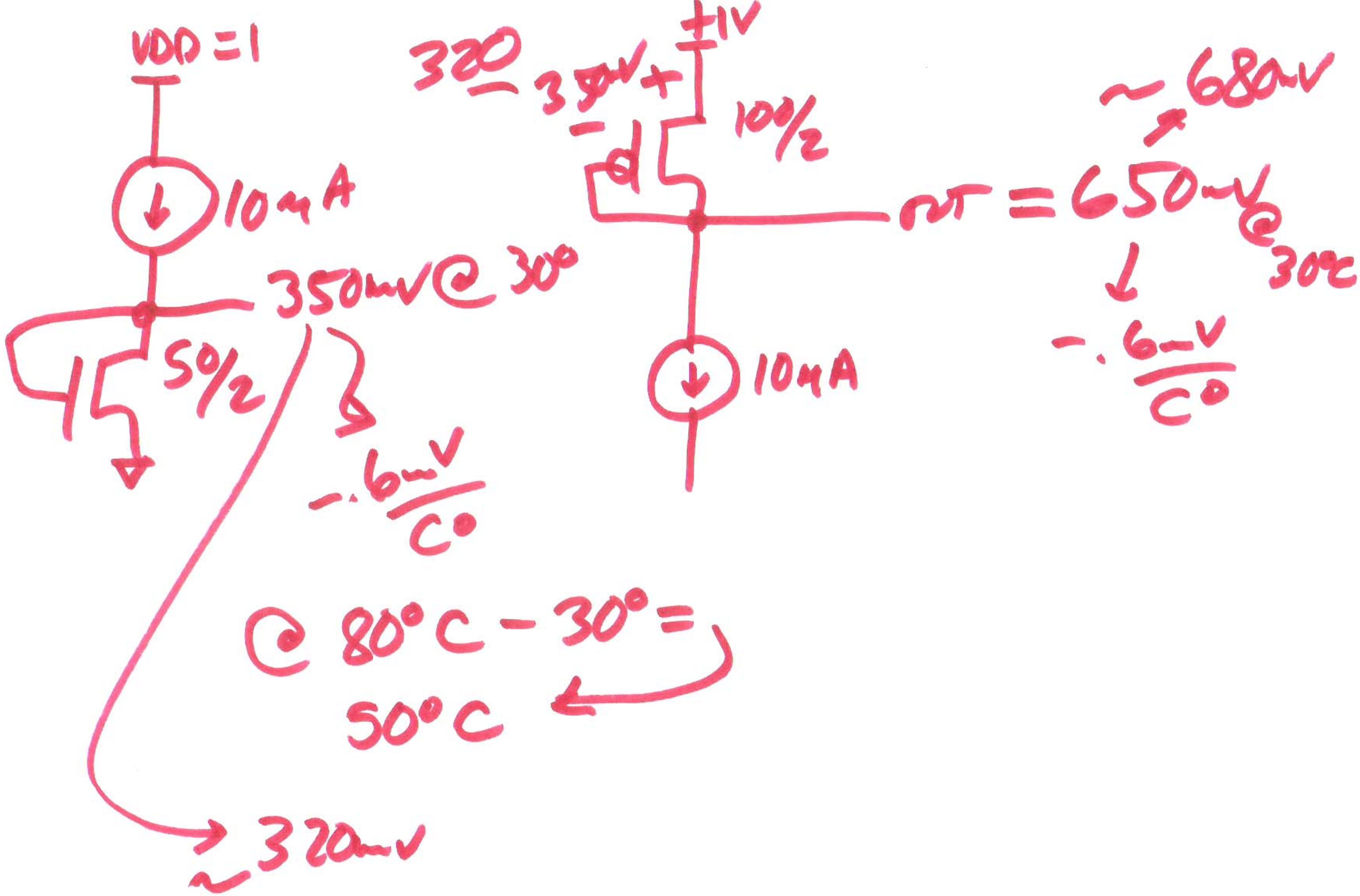
($\frac{2}{3} C_{ox}' \cdot L \cdot W$ = C_{gs})

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

$$G \cdot FT \propto \frac{\mu_n}{L}$$

$V_{ov} = V_{GS} - V_{THN} \Rightarrow 5\%$ VDD general design

9.23)


VDD = 1
10uA
350mV @ 30°
50/2
-.6mV / C°
@ 80°C - 30° =
50°C
~320mV
320
350mV
+1V
10/2
out = 650mV @ 30°C
~680mV
-.6mV / C°
10uA