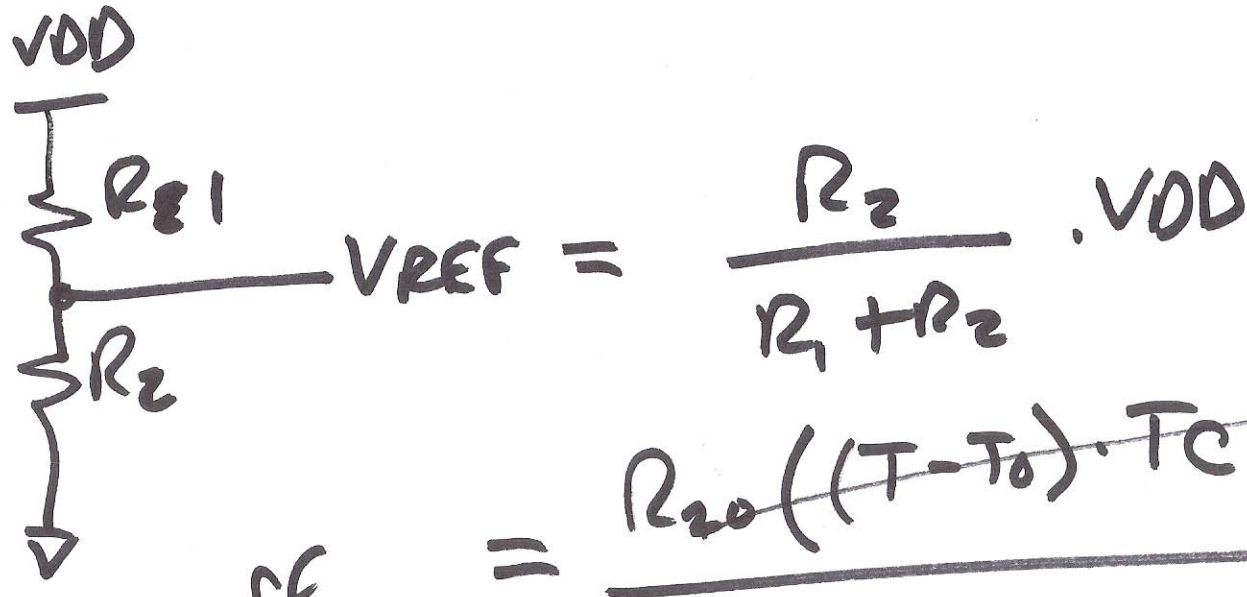
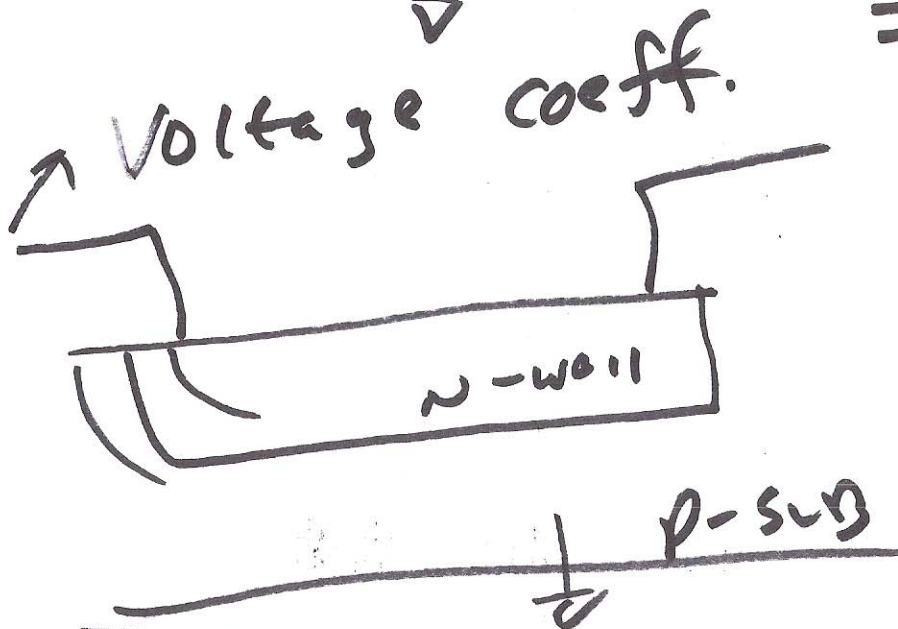


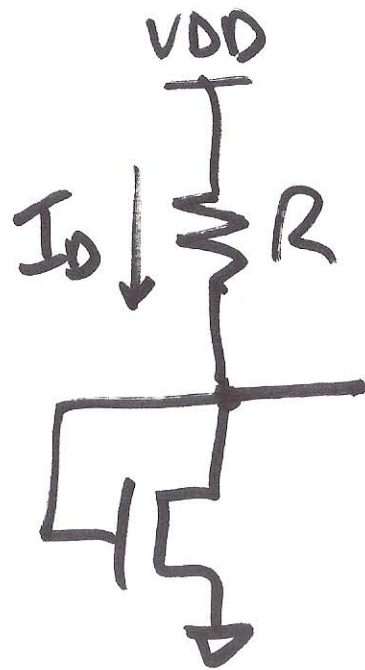
# 23.1 Voltage References



$$= \frac{R_{20} \left( (T - T_0) \cdot TC_{R2} \right)}{R_{20} \left( (T - T_0) TC_{R2} + 1 \right) + R_{10}}$$



1)



$$\beta_N = K_P N \cdot \frac{W}{L}$$

$$V_{REF} = V_{GS} = \sqrt{\frac{2I_D}{\beta_N}} + V_{THN}$$

$$\frac{V_{DD} - V_{REF}}{R} = I_D$$

$$V_{REF} = \sqrt{\frac{2(V_{DD} - V_{REF})}{R \cdot K_P N \cdot \frac{W}{L}}} + V_{THN}$$

for <sup>temp</sup> dep.  $V_{DD} \gg V_{REF}$

2  
3)

$$\frac{\delta V_{REF}}{\delta T} = \frac{\delta V}{\delta T} \sqrt{\frac{2V_{DD}}{R \cdot K_{PN} \cdot \frac{W}{L}}} + V_{THN}$$

$$= \frac{\delta}{\delta T} \left( 2V_{DD} \cdot R^{-1} \cdot K_{PN}^{-1} \cdot \frac{W}{L} \right)^{\frac{1}{2}} + \frac{\delta V_{THN}}{\delta T}$$

$$= \frac{\delta V_{THN}}{\delta T} + \frac{1}{2} \frac{2V_{DD} \cdot \frac{W}{L}}{\sqrt{2V_{DD} \cdot R \cdot K_{PN} \cdot \frac{W}{L}}} \left[ -R^{-2} K_{PN}^{-1} - R^{-1} K_{PN}^{-2} \right]^{\frac{1}{2}}$$

3  
9)

$$= \frac{\delta V_{THN}}{\delta T} + \frac{1}{\sqrt{2}} \left( \frac{2V_{DD}}{2 \frac{W}{L}} \frac{\delta R^{-1} K_P^{-1}}{\delta T} \right)^{-1/2}$$

$$\frac{\delta V_{REF}}{\delta T} = \frac{\delta V_{THN}}{\delta T} + \sqrt{\frac{2 \frac{W}{L}}{V_{DD}}} \cdot \left( -R^{-2} K_P^{-1} \frac{\delta R}{\delta T} - K_P^{-2} R^{-1} \frac{\delta K_P}{\delta T} \right)^{-1/2}$$

$$TCV_{REF} = \frac{1}{V_{REF}} \cdot \frac{\delta V_{REF}}{\delta T} = \frac{1}{R K_P} \cdot \frac{1}{R} \frac{\delta R}{\delta T} - \frac{1}{R K_P} \cdot \frac{1}{K_P} \frac{\delta K_P}{\delta T}$$

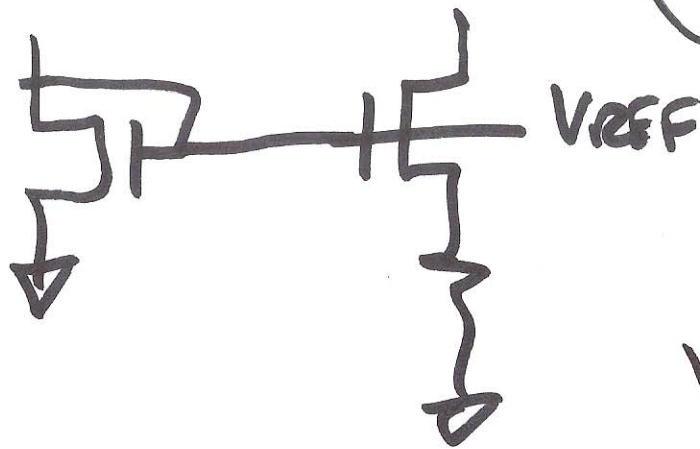
$\underbrace{\hspace{10em}}_{TCR}$ 
 $\underbrace{\hspace{10em}}_{TCKP}$

4  
8)



$$V_{GS1} = V_{GS2} + I_D \cdot R$$

$$V_{GS1} = \sqrt{\frac{2I}{\beta}} + V_{THN} = \sqrt{\frac{2I}{\beta}} + V_{THN} + I \cdot R$$



$$I = \frac{2}{R^2 \kappa \mu_n \cdot \frac{W}{L}} \left(1 - \frac{1}{\sqrt{\kappa}}\right)^2$$

$$V_{REF} = \sqrt{\frac{4}{R^2 \beta^2}} \cdot \left(1 - \frac{1}{\sqrt{\kappa}}\right) + V_{THN}$$

$$V_{REF} = \frac{2}{R \cdot \beta} \left(1 - \frac{1}{\sqrt{\kappa}}\right) + V_{THN}$$

$\kappa = 4$

$$V_{REF} = \frac{1}{R \cdot \beta} + V_{THN}$$

$$\frac{\delta V_{REF}}{\delta T} = -\frac{1}{R\beta}(-.003) - \frac{1\mu V}{C^{\circ}}$$

$$= \frac{1}{6.5K \cdot \frac{10}{2} \cdot 120\mu}(-.003) - \frac{1\mu V}{C^{\circ}}$$

$$+.00077 - \frac{1\mu V}{.001}$$

$$-230 \mu V / C^{\circ}$$

