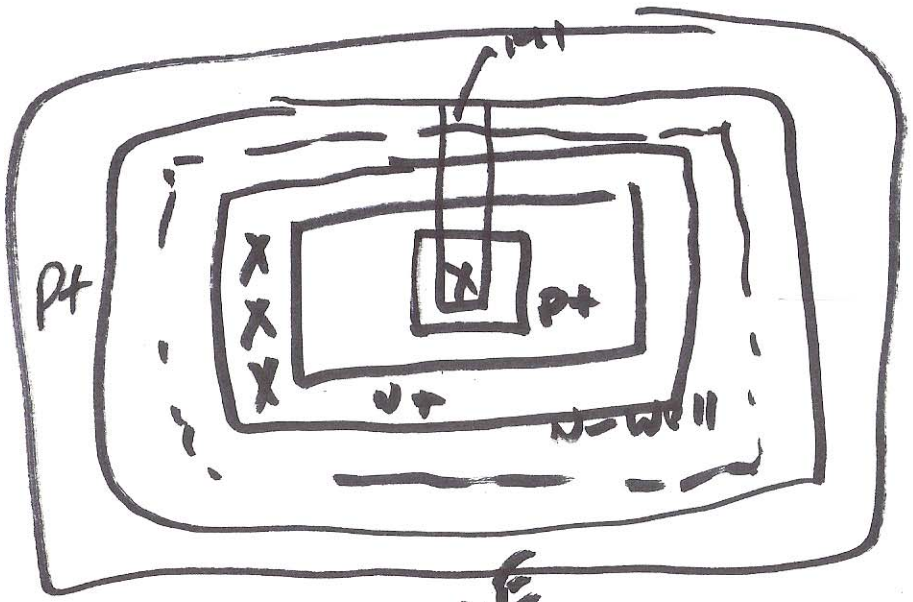
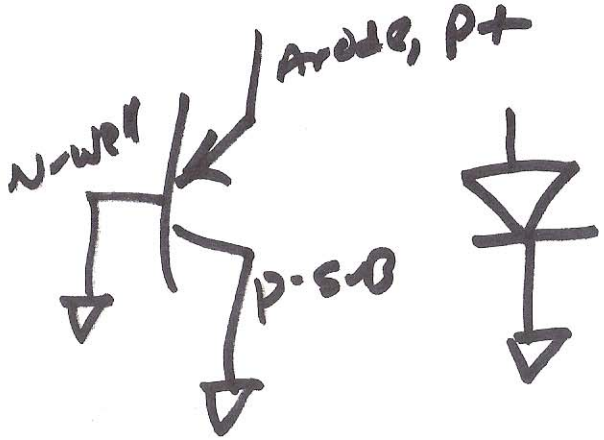
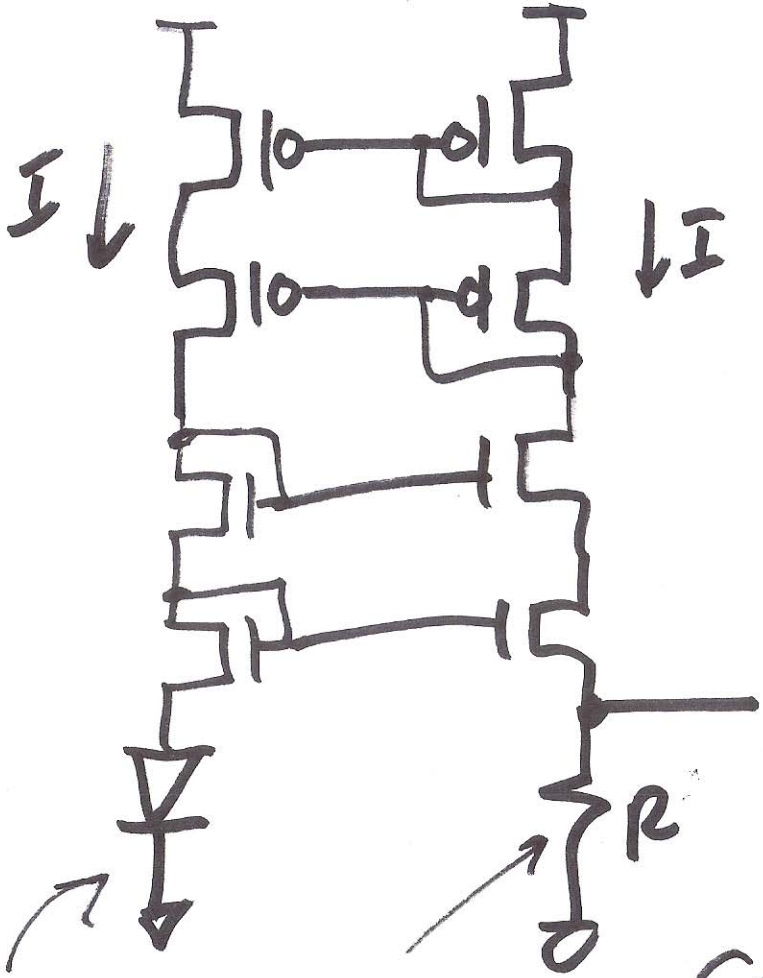
Sec. 23.2

Parasitic diode references

Vertical pnps







for forward biased diode

$$I = I_S e^{V_D/nV_T}$$

$$V_{REF} = V_D = nV_T \ln\frac{I}{I_S}$$

$$V_{REF} = IR = V_D, \quad I = \frac{V_D}{R}$$

$$IR = nV_T \ln\frac{I}{I_S}$$

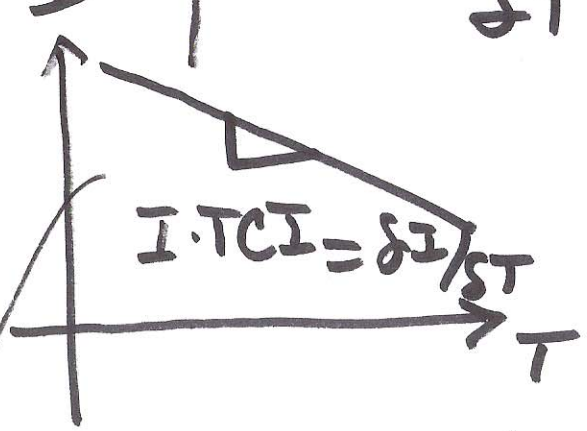
$$TCR = \frac{1}{R}\frac{\delta R}{\delta T}$$

$$R = \frac{nV_T}{I} \ln\frac{I}{I_S}$$

$$\frac{\delta V_D}{\delta T} = -1.6\frac{mV}{C^\circ}$$

CTAT

CTAT



$$\frac{\delta I}{\delta T} = \frac{\delta \frac{V_D}{R}}{\delta T} = \frac{\delta}{\delta T}\left(V_D \cdot R^{-1}\right)$$

$$\frac{\delta I}{\delta T} = \frac{1}{R}\frac{\delta V_D}{\delta T} - \frac{V_D}{R}\cdot\frac{1}{R}\frac{\delta R}{\delta T}$$

$$I = \frac{V_D}{R}$$

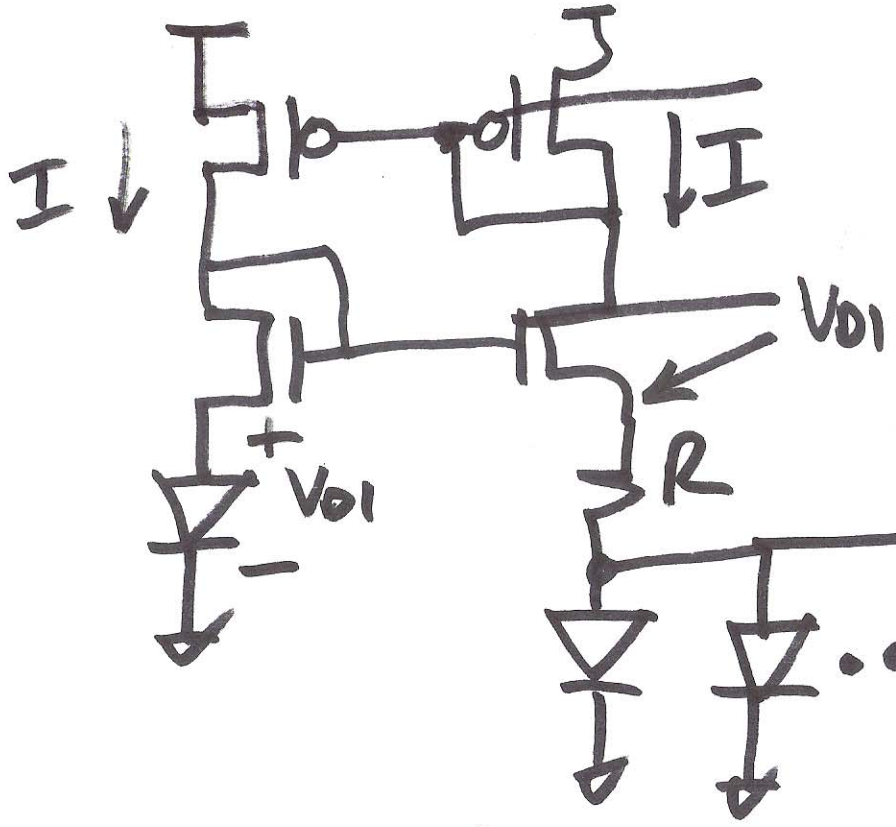
$$= I\left(\frac{1}{V_D}\frac{\delta V_D}{\delta T} - \frac{1}{R}\frac{\delta R}{\delta T}\right)$$

Complimentary to Absolute Temp

$$TCI = \frac{1}{I}\frac{\delta I}{\delta T} = \frac{1}{V_D}\frac{\delta V_D}{\delta T} - \frac{1}{R}\frac{\delta R}{\delta T}$$

$$I(T) = I(T_0)\left(TCI\,(T - T_0) + 1\right)$$

$$V_T = \frac{KT}{q} \qquad \frac{\delta V_T}{\delta T} = \frac{K}{q} = 0.085 \frac{mV}{C^\circ}$$



$$V_{D1} = NV_T \ln \frac{I}{I_S}$$

$$V_{D2} = NV_T \ln \frac{I}{KI_S}$$

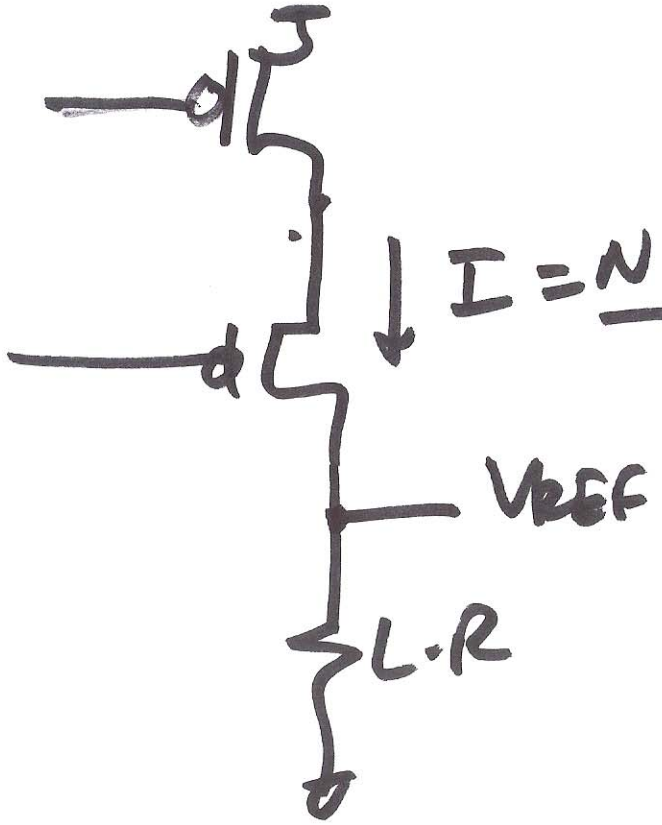
$$I = \frac{V_{D1} - V_{D2}}{R}$$

$$\boxed{I = \frac{NV_T \ln K}{R}}$$

$$\ln a - \ln b = \ln \frac{a}{b}$$

PTAT

23.25



Thermal-Voltage reference (PTAT)

$$V_{REF} = L \cdot \cancel{R} \cdot \frac{N V_T \ln k}{\cancel{R}}$$

$$V_{REF} = L \cdot N \cdot \ln k \cdot V_T$$

$0.085 \frac{mV}{°C}$

$$\frac{\delta V_{REF}}{\delta T} = L \cdot N \cdot \ln k \cdot \frac{k}{q}$$

$$\frac{\delta I}{\delta T} = N \cdot h k \cdot \frac{\delta}{\delta T}\left(V_T R^{-1}\right)$$

$$= N \cdot h k \frac{\delta}{\delta T}\left(\frac{K}{q}\frac{1}{R}\frac{T}{} - \frac{V_T}{R}\cdot\frac{1}{R}\frac{\delta R}{\delta T}\right)$$

$$= \frac{N h k V_T}{R}\left(\frac{1}{T} - \frac{1}{R}\frac{\delta R}{\delta T}\right)$$

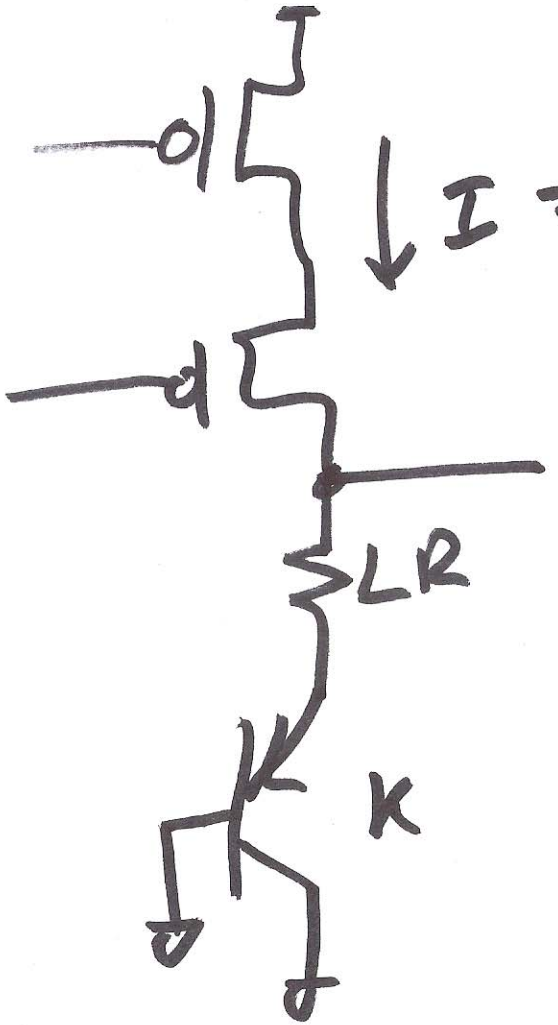
$$\frac{\delta I}{\delta T} = 1330 \times 10^{-6} \cdot \frac{1}{I} \qquad .00333 - .002 = .00133$$

$$= 1330 \times 10^{-6} \cdot 10^{-6} I$$

$$\frac{.00133}{C^\circ} = \frac{1}{I}\frac{\delta I}{\delta T} = \frac{1}{T} - \frac{1}{R}\frac{\delta R}{\delta T}$$

at 300

6)



$$I = \frac{NV_T \ln K}{R}$$

$\ln K$: +0.085 $\quad -1.6\,mV/°C$

$$V_{REF} = L \cdot NV_T \ln K + V_D$$

↑ Bandgap voltage

$$\ln K\,(0.085) = 1.6$$

for $\frac{\delta V_{REF}}{\delta T} = 0$

$K = 8, N = 1$

$$L = \frac{1.6}{2 \cdot 1 \cdot 0.085} = 9.4$$

$V_{REF} = (9.4) \cdot 1 \cdot 26mV \cdot 2 + .7 \simeq 1.2V$

(6)