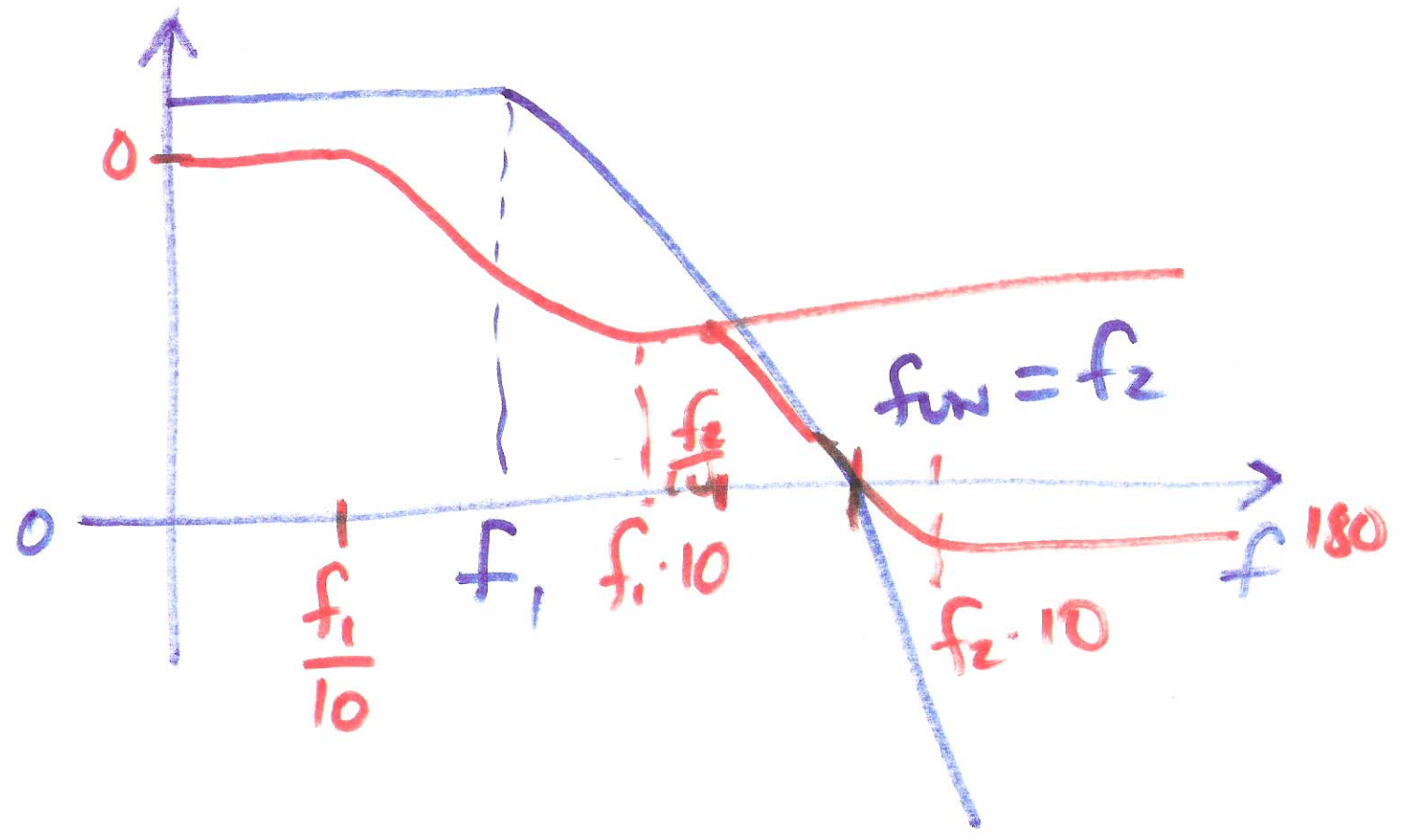


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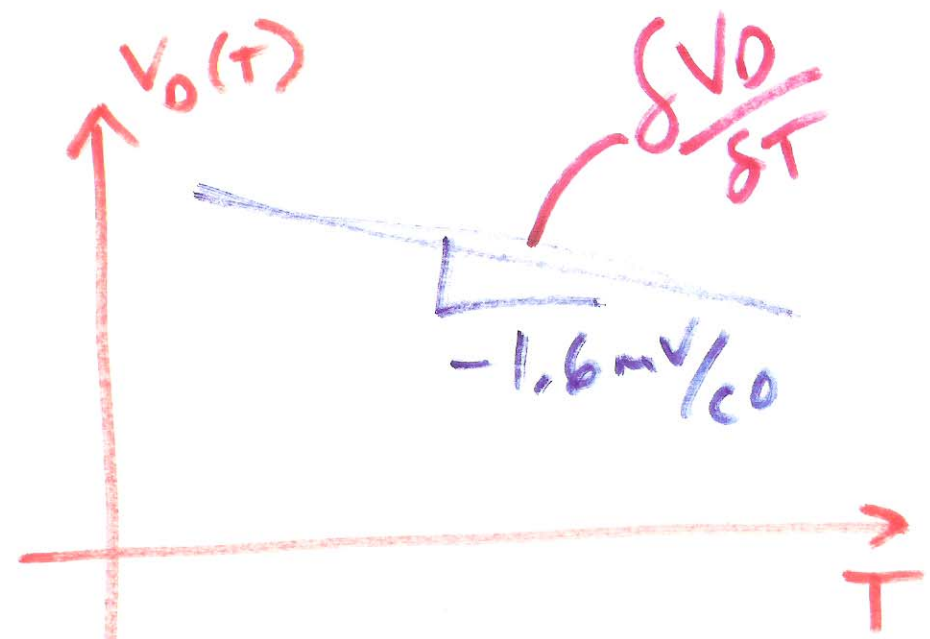
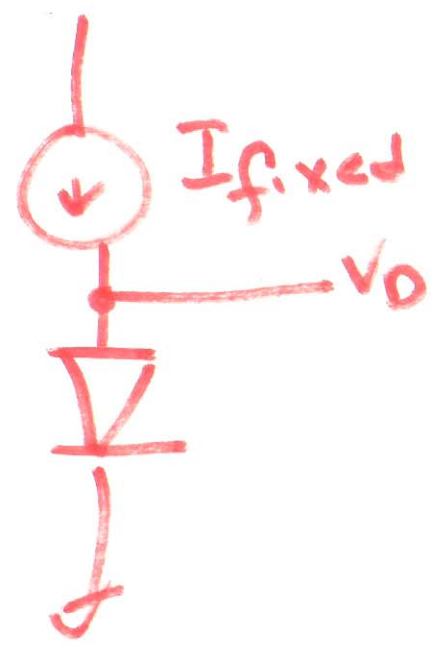


1)

$$I_0 = I_s e^{V_0 / NV_T}$$

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

$$V_0 = NV_T \ln \frac{I_0}{I_s}$$



Complementary to Absolute Temp (CTAT)

$T \uparrow V_0 \downarrow$

2)

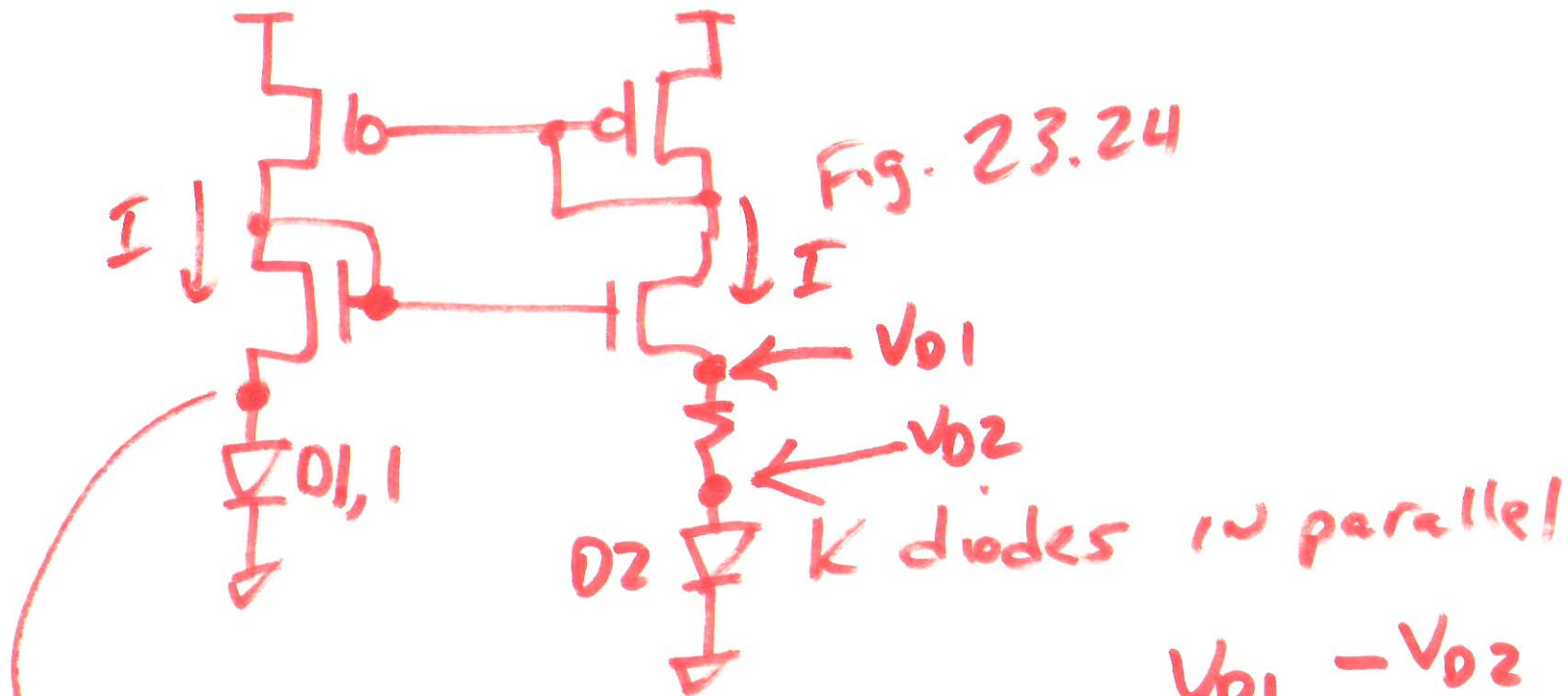


Fig. 23.24

K diodes in parallel

$$V_{01} = NV_T \ln \frac{I}{I_S}$$

$$V_{02} = NV_T \ln \frac{I}{KI_S}$$

$$I = \frac{V_{01} - V_{02}}{R}$$

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

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

$$\frac{\delta I}{\delta T}$$

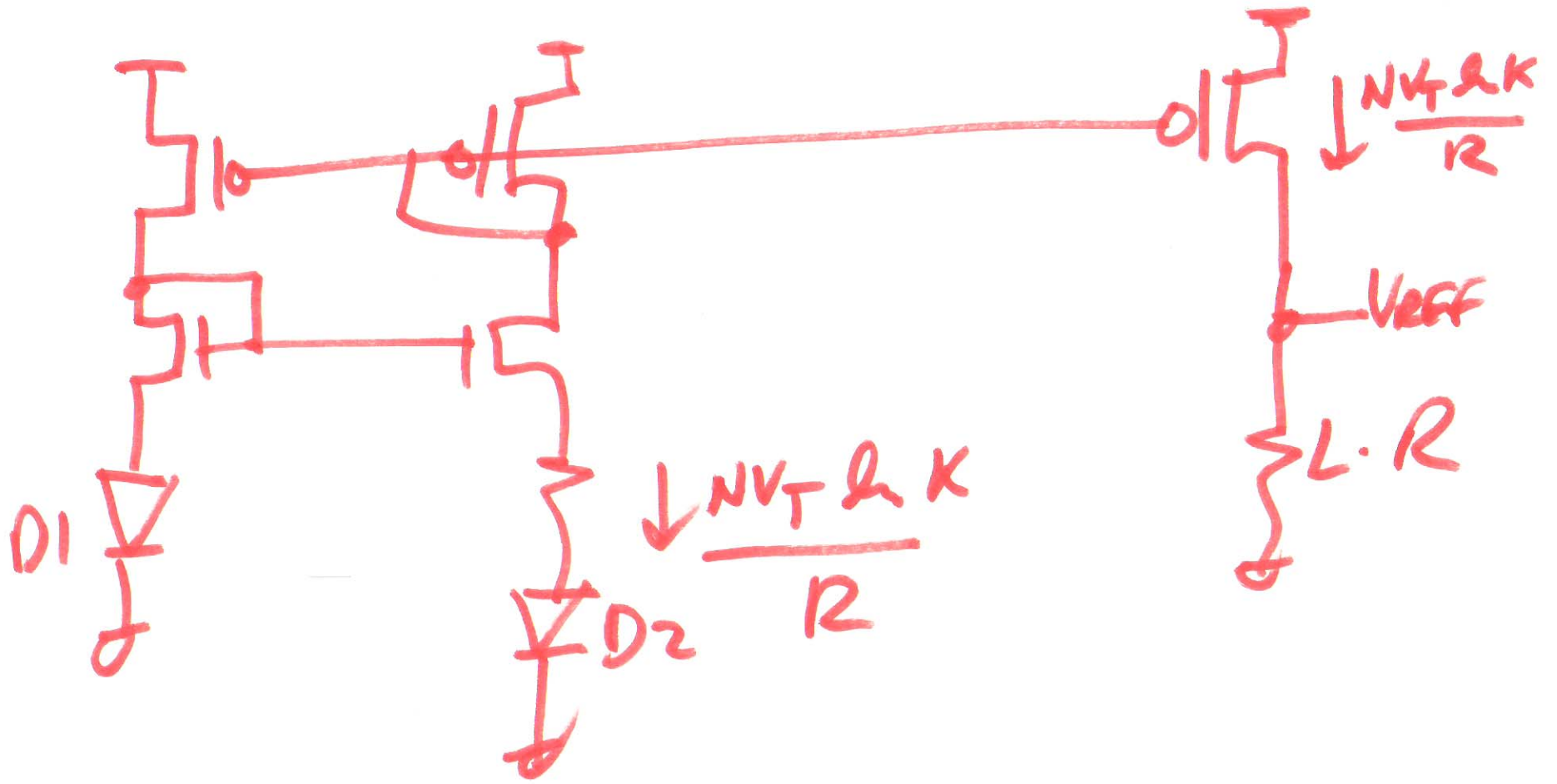
3)

$$I = \frac{Nk}{f} \cdot T \cdot R^{-1} \cdot Lk$$

$$\frac{\delta I}{\delta T} = \frac{Nk}{f} \cdot \frac{1}{R} Lk + (-1) R^{-2} \frac{NkT}{f} Lk$$

This correct

$$\frac{1}{I} \frac{\delta I}{\delta T} = \frac{\frac{Nk}{f} \cdot \frac{1}{R} Lk}{\frac{Nk}{f} \cdot T \cdot \frac{1}{R} Lk}$$



$$V_{REF} = L \cdot N \cdot V_T \cdot L \cdot K$$

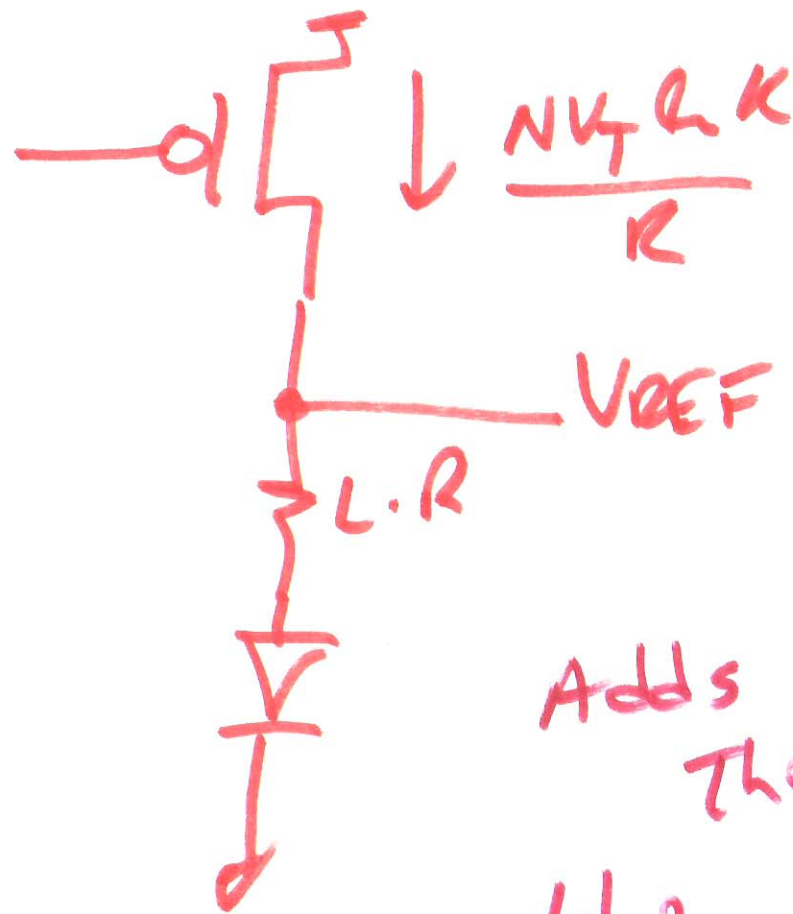
$$\frac{\delta V_{REF}}{\delta T} = \frac{L N K L K}{N}$$

Boltzmann  
↓  
# of diodes in //

5)

**PTAT**

$V_{REF} \uparrow$   
proportional  
to  
Absolute  
temp.



$$V_{REF} = \frac{nV_T k}{R} \cdot LR + V_0$$

BANDgap  
 Adds PTAT from  
 Thermal to  
 the CTAT from  
 the diode  
 (Bandgap  $E \downarrow$   
 $T \uparrow$ )

6)

$$V_{REF} = \frac{N V_T}{E} \underbrace{R_K \cdot L}_{k=8, R_K \approx 2} + V_D$$

$$\frac{\Delta V_{REF}}{\Delta T} = 2 \cdot \underbrace{\frac{k}{q}}_{0.085 \frac{mV}{Co}} \cdot L + \frac{\Delta V_D}{\Delta T}$$

-1.6mV

Ideally

$$\frac{\Delta V_{REF}}{\Delta T} = 0$$

$$1.6mV \stackrel{?}{=} .170mV \cdot L$$

$$L = 9.41$$

$$V_{REF} \approx 1.25V$$

7)