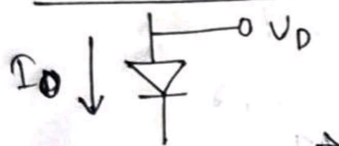
Design of Bandgap Reference (BGR) Voltage

- Specifications
  - $V_{DD} = 3.3V$
  - $I_{DC} = 5\mu A$
  - $N=2$ for PTAT generation.

CTAT : Negative Temp. coefficient



$$I_0 = I_S e^{V_D/V_T}$$

$$\Rightarrow \frac{I_0}{I_S} = e^{V_D/V_T}$$

$$\Rightarrow \ln \frac{I_0}{I_S} = \frac{V_D}{V_T}$$

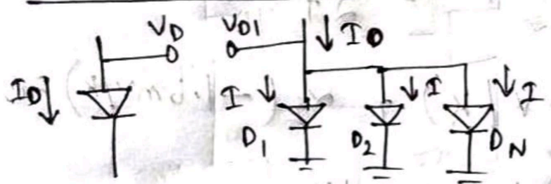
$$\Rightarrow \boxed{V_D = V_T \ln\left(\frac{I_0}{I_S}\right)} \quad \text{--- (i)}$$

$\left[\frac{KT}{q}\right] \leftarrow$ weak f^n of temp.

$I_S \propto T$

So, as $I_S \uparrow \Rightarrow \ln\left(\frac{I_0}{I_S}\right) \downarrow \Rightarrow V_D \downarrow$

PTAT : Positive temp. coeff.



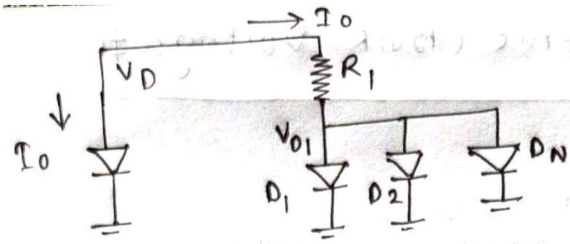
$\Rightarrow I_0 = nI$

So, $V_{D1} = V_T \ln\left(\frac{I}{I_S}\right)$

$$\Rightarrow \boxed{V_{D1} = V_T \ln\left(\frac{I_0}{nI_S}\right)} \quad \text{--- (ii)}$$

$$V_D - V_{D1} = V_T \ln\left(\frac{I_0}{I_S}\right) - V_T \ln\left(\frac{I_0}{nI_S}\right)$$

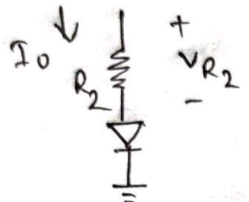
$$\boxed{V_D - V_{D1} = \underbrace{V_T}_{\uparrow V_T \propto T \uparrow} \underbrace{\ln(n)}_{\text{const.}}} \quad \text{--- (iii)}$$



$V_D - V_{01} = I_0 R_1 = V_T \ln(n)$

$\Rightarrow I_0 = \frac{V_T}{R_1} \ln(n)$

$\Downarrow$



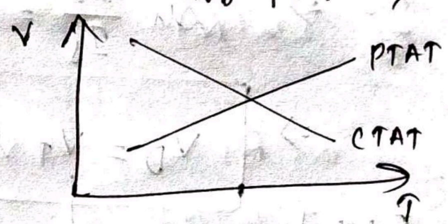
$V_{R_2} = I_0 R_2 = \underbrace{V_T \ln(N) \frac{R_2}{R_1}}_{\alpha_1}$

$\boxed{V_{R_2} = \alpha_1 V_T} \Rightarrow PTAT$

Separate PTAT

as $T \uparrow \Rightarrow V \uparrow$

$\alpha_1 = \ln(N) \frac{R_2}{R_1}$



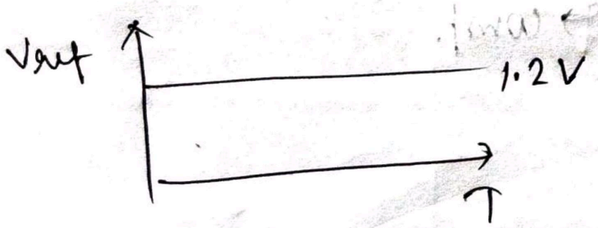
$V_{ref} = \alpha_1 PTAT + \alpha_2 CTAT$
$= \alpha_1 V_T + \alpha_2 V_D$

$\frac{\partial V_{ref}}{\partial T} = 0 \Rightarrow \alpha_1 \frac{\partial V_T}{\partial T} + \alpha_2 \frac{\partial V_D}{\partial T} = 0$

$\Rightarrow \alpha_1 (85 \mu V/K) + \alpha_2 (-1.6 mV/K) = 0$

∴ assuming $\alpha_2 = 1$, $\alpha_1 = \frac{1.8 \, mV/K}{85 \mu V/K} = 18.82$

$\boxed{V_{ref} = 18.82 \times 26 \, mV + 1 \times 0.7 \, V \simeq 1.2 \, V}$



Calulation of registor value :-

$I_0 = 5\mu A$, $N = 2$

$$V_D - V_{D1} = I_0 R_1 = V_T \ln(N)$$

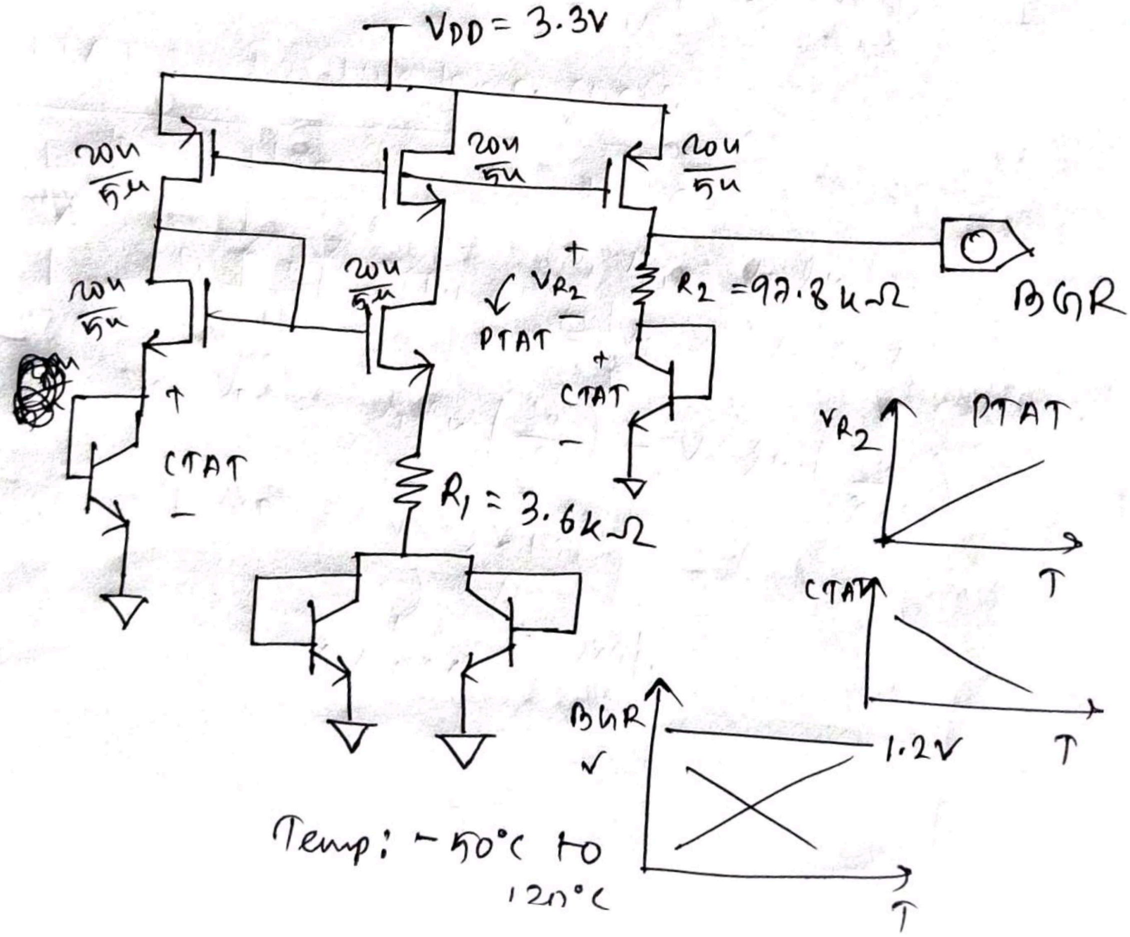
$$R_1 = \frac{26mV}{5\mu A} \times \ln(2)$$

$$\boxed{R_1 = 3.604\,k\Omega}$$

$$\alpha_1 = \frac{R_2}{R_1} \ln(N)$$

$$R_2 = \frac{\alpha_1 R_1}{\ln(N)} = \frac{18.82 \times 3.604k}{\ln(2)}$$

$$\boxed{R_2 = 97.8\,k\Omega}$$



Temp: −50°C to 120°C

Insted of ptat the label will BGR