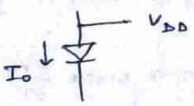
# Design of Band Gap Reference

Specification ⇒ $V_{DD} = 3.3V$ $I_{DC} = 5\mu A$ $N = 2$ for $P_{TAT}$ gen

**CTAT**



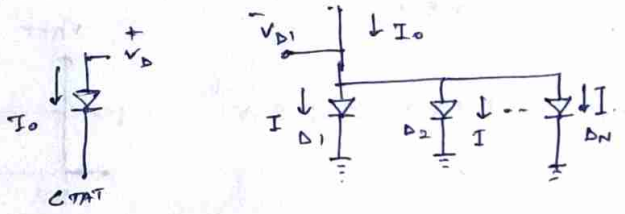

$$I_o = I_s e^{V_D/V_T}$$

$$\downarrow V_D = V_T \ln\left(\frac{I_o}{I_s\uparrow}\right) \downarrow$$

↓ weak fun of temp ; ↓ strong fun of temp.

$\uparrow I_s \propto T \uparrow$

**$P_{TAT}$**




$$I_o = nI$$

$$V_{D1} = V_T \ln\left(\frac{I}{I_s}\right)$$

$$V_D = V_T \ln\left(\frac{I_o}{nI_s}\right) \quad -(2)$$

$$V_D - V_{D1} = V_T \ln\left(\frac{I_o}{I_s}\right) - V_T \ln\left(\frac{I_o}{nI_s}\right)$$

$$\boxed{V_D - V_{D1} = V_T \ln(n)} \quad -(3) \Rightarrow P_{TAT}$$

$\uparrow V_T \propto T \uparrow$

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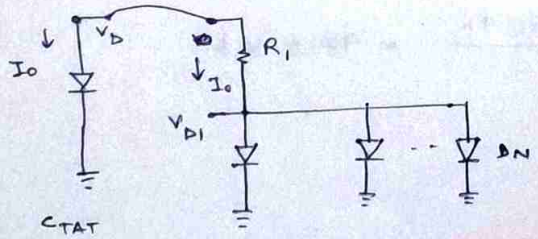
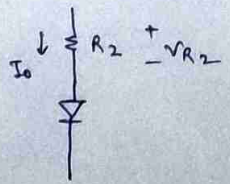



$$V_D - I_o R_1 = V_{D1}$$

$$V_D - V_{D1} = I_o R_1 = V_T \ln(n)$$

$$I_o = \frac{V_T}{R_1} \ln(N)$$

separate.

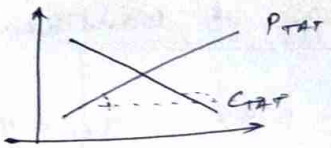



$$V_{R2} = I_o R_2 = V_T \ln(N)\left(\frac{R_2}{R_1}\right)$$

$$\boxed{V_{R2} = V_T \alpha_1} \Rightarrow P_{TAT}$$

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

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




$$V_{REF} = \alpha_1 P_{TAT} + \alpha_2 C_{TAT}$$

$$\boxed{V_{REF} = \alpha_1 V_T + \alpha_2 V_D}$$

$P_{TAT} \Rightarrow$ slope $\frac{\partial V_T}{\partial T} = ?$ from wave form.

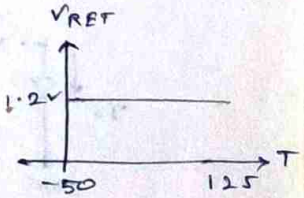
$C_{TAT} \Rightarrow$ slope $\frac{\partial V_D}{\partial T} = ?$ ↓ sharply decreases.

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

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

assume $\alpha_2 = 1 \Rightarrow \alpha_1 = \frac{1.6m}{85\mu} = 18.82$

$$V_{REF} = 18.82 \times 26m + 1 \times 0.7 = 1.189 \simeq 1.2\ V$$



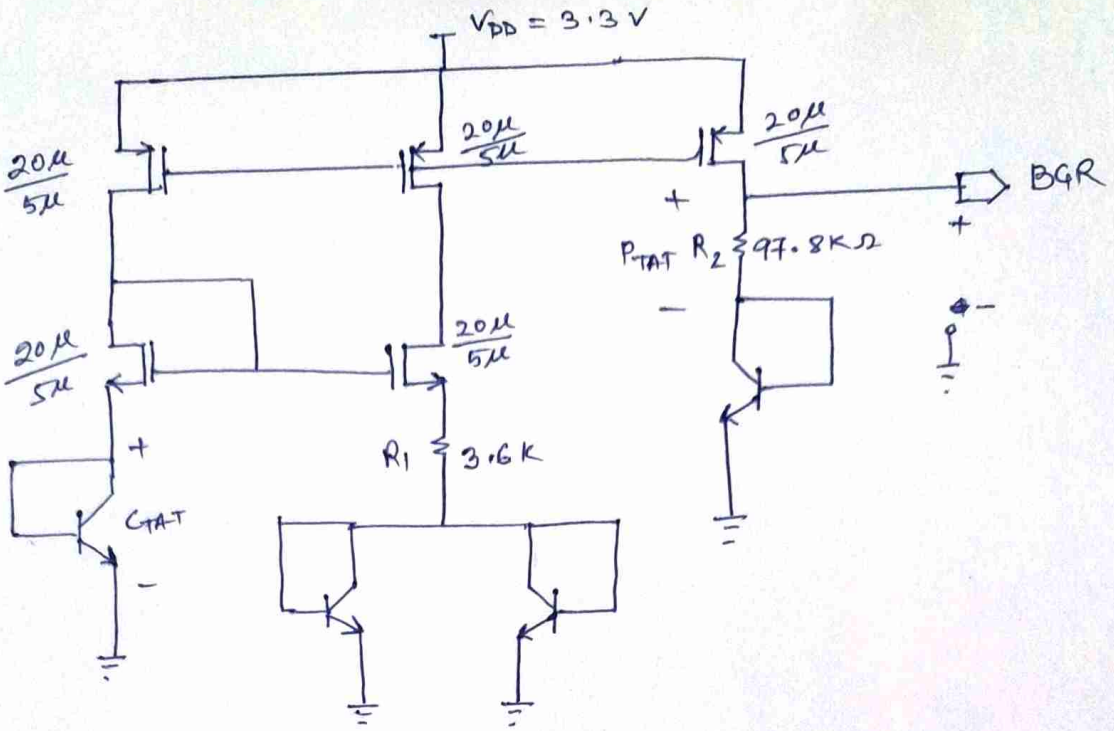

Now, $I_o = 5\mu A$, $\therefore N = 2$ for $P_{TAT}$

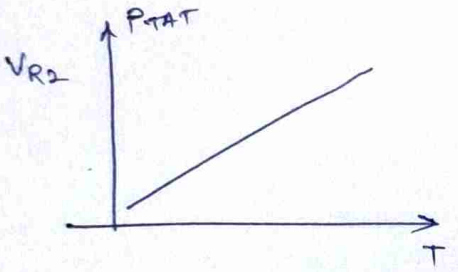
$$V_D - V_{D1} = I_o R_1 = V_T \ln(N)$$

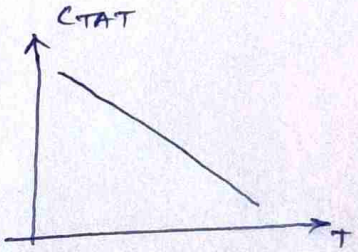
$$R_1 = \frac{V_T \ln(N)}{I_o} = \frac{26m \times \ln(2)}{5\mu} = 3.604\ K\Omega$$

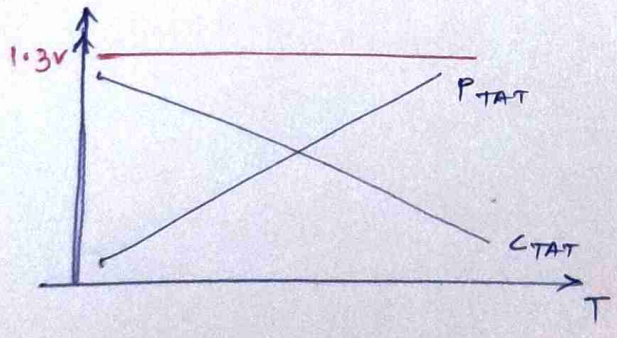
also, $\alpha_1 = \frac{R_2}{R_1} \ln(N)$

$$R_2 = \frac{\alpha_1 R_1}{\ln(N)} = \frac{18.82 \times 3.604K}{\ln(2)} = 97.8\ K\Omega$$




dc analysis.

Temp varies from −50°C to 125°C.