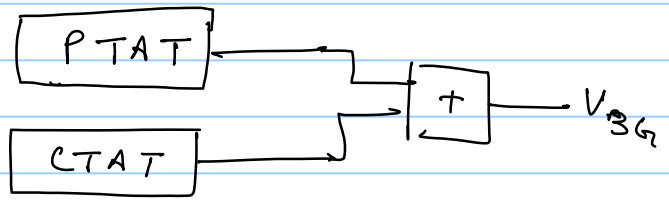
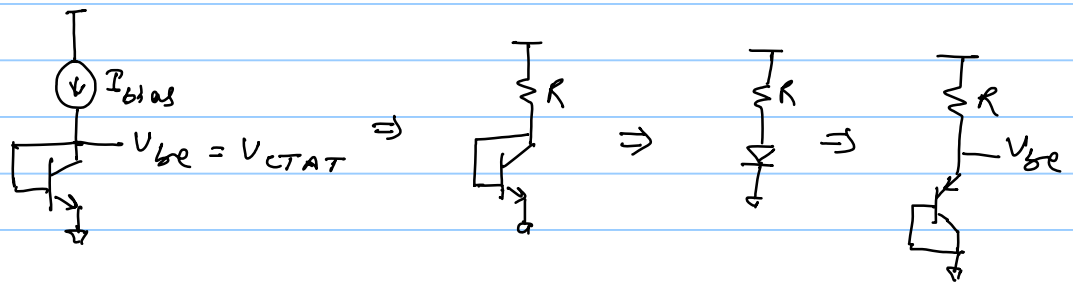
Bandgap Reference (BGR)



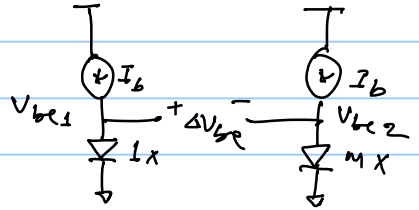
$$\frac{\partial V_{PTAT}}{\partial T} = -\frac{\partial V_{CTAT}}{\partial T}$$

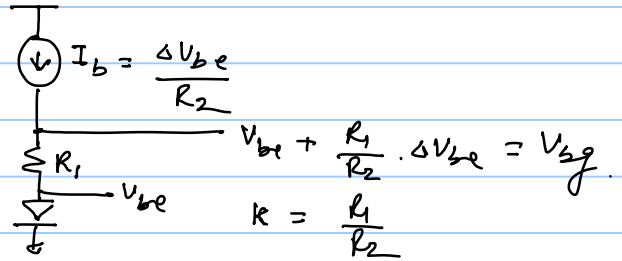
Implementing CTAT voltage

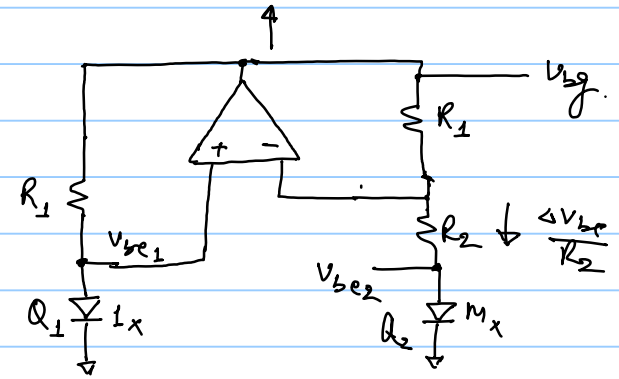


Implementing PTAT voltage

$\Delta V_{be} = V_T \ln(m) \rightarrow PTAT$







Area of $Q_2 = m \times Q_1$

$$V_{bg} = V_{be_1} + \frac{R_1}{R_2} \Delta V_{be}$$

$$= V_{be_1} + \frac{R_1}{R_2} V_T \ln(m)$$

$$= V_{be_1} + \alpha V_T \quad ; \alpha = \frac{R_1}{R_2} V_T$$

$$\frac{\partial V_{bg}}{\partial T} = 0 \Rightarrow \frac{\partial V_{be_1}}{\partial V_T} = -\alpha \frac{\partial V_T}{\partial T} = -9(86\,\mu V/K)$$

$$\frac{\partial V_{be}}{\partial T} = -1.5\,mV$$

$$\alpha = 17.437$$

$$\frac{R_1}{R_2} \times \ln(m) = 17.437$$

$$m = 10$$

$$\frac{R_1}{R_2} = \frac{17.437}{\ln(m)} = 7.5$$

$R_2 = 100\,k\Omega$

$R_1 = 750\,k\Omega$

V_{bg} at room temp.

$$V_{bg} = V_{be} + \alpha V_T = 0.7\,V + 0.453 \quad (V_T = 26\,mV)$$
$$\simeq 1.15\,V$$

Now choose $\frac{\partial V_{be}}{\partial T} = -2\,mV/K$

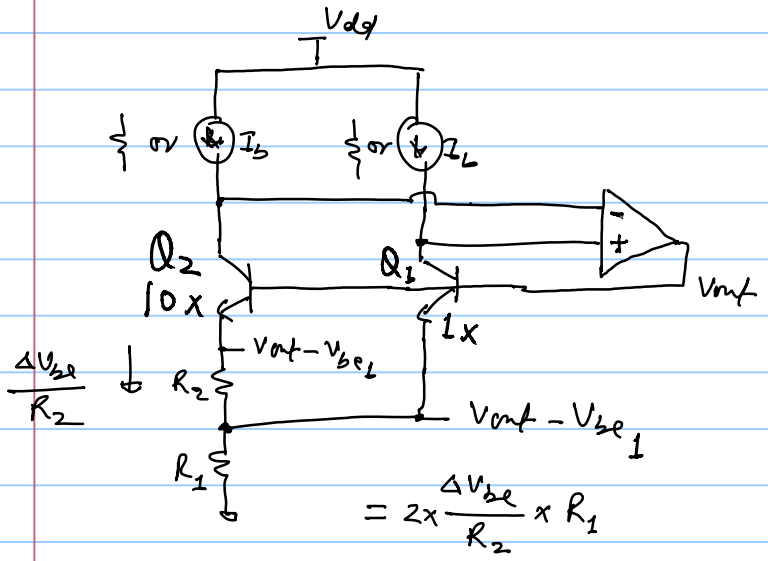
$$\alpha = \frac{2mV}{86\mu V} \simeq 23$$

$$V_{bg} = V_{be} + 23 \times V_T$$

$$= 0.7 + 0.598 \simeq 1.3\,V$$

$V_{bg} = 1.15\,V$ to $1.3\,V$ for $\frac{\partial V_{be}}{\partial T} = -1.5\,mV/K$ to $-2\,mV/K$

Alternate topology



$$V_{out} = V_{bg} = V_{be_1} + 2x \frac{\Delta V_{be}}{R_2} \times R_1$$

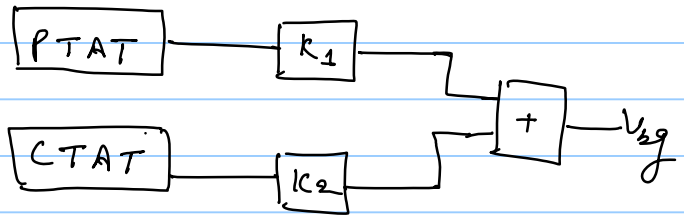
Brokaw Bandgap

V_{bg} = 1.15 V to 1.3 V

V_{dd} required is > 1.3 V ($\simeq$ 1.5 V)

Sub-1V Bandgap

operates at $V_{dd} \leq 1.2$ V



$V_{bg} = K_1 V_{PTAT} + K_2 V_{CTAT}$

$V_{CTAT} = V_{be} \simeq 0.7$ V

$K_2 < 1$