1.

$I_{D3} : I_{D4} : I_{D5} = 2K : 1 : 4$

$I_{D3} = I_{C1}$, $I_{D4} = I_{C2}$, $I_{D5} = I_{C3}$

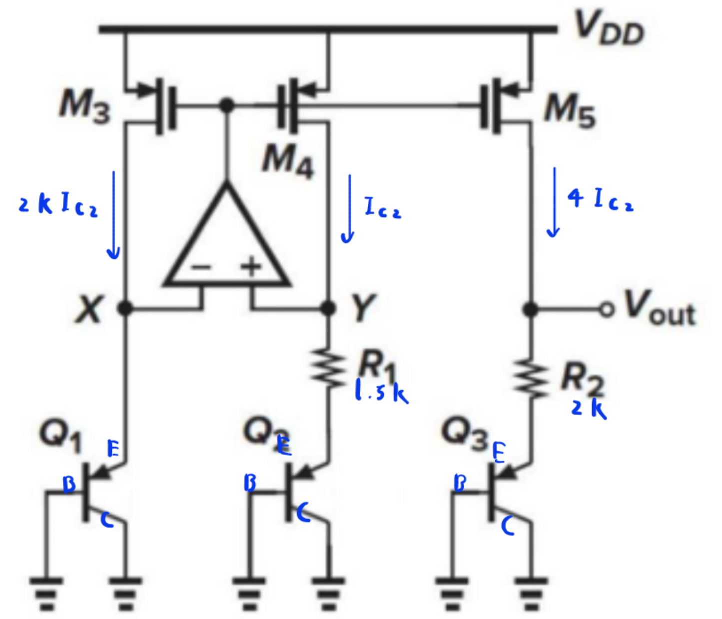

Fig.1

$\because V_{in+} = V_{in-}$ for ideal op amp

$\therefore V_X = V_Y$

$V_X = V_{BE1}$

$V_Y = V_{BE2} + R_1 I_{C2}$

$V_{BE1} = V_{BE2} + R_1 I_{C2}$

$V_T \ln \frac{I_{C1}}{I_S} - V_T \ln \frac{I_{C2}}{I_S} = R_1 I_{C2}$

$V_T \left(\ln \frac{I_{C1}}{I_S} - \ln \frac{I_{C2}}{I_S} \right) = R_1 I_{C2}$

$V_T \ln \frac{I_{C1}}{I_{C2}} = R_1 I_{C2}$

$V_T \ln(2K) = R_1 I_{C2}$

$I_{C2} = \frac{V_T \ln(2K)}{R_1}$

$V_{out} = V_{BE3} + 4 I_{C2} R_2$

$= V_{BE3} + 4 \frac{V_T \ln(2K) R_2}{R_1}$

$\frac{\partial V_{out}}{\partial T} = \frac{\partial V_{BE3}}{\partial T} + 4 \frac{R_2}{R_1} \ln(2K) \frac{\partial V_T}{\partial T} = 0$

$= -1.5m + 4 \frac{2}{1.5} \ln(2K)\, 0.087m$

$K = 12.675$ #

$I_C = I_S \cdot e^{\frac{V_{BE}}{V_T}}$

$\ln I_C = \ln(I_S) + \frac{V_{BE}}{V_T}$

$\ln I_C - \ln I_S = \frac{V_{BE}}{V_T}$

$V_T \left(\ln \frac{I_C}{I_S} \right) = V_{BE}$

2.

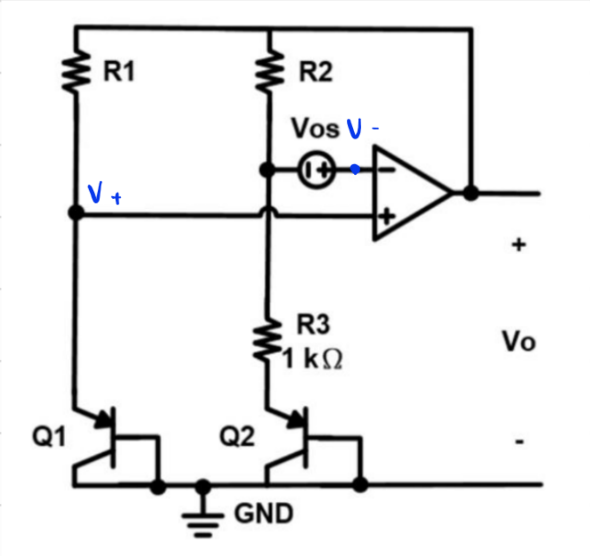

Fig.2

(a)

$$V_{BE1} = V_{BE2} + I_{C2} \cdot R_3$$

$$V_T \ln\left(\frac{I_{C1}}{I_{S1}}\right) = V_T \ln\left(\frac{I_{C2}}{6 I_{S1}}\right) + I_{C2} R_3$$

$$V_T \ln\left(6 \frac{I_{C1}}{I_{C2}}\right) = I_{C2} R_3$$

$\because$ ① $V_+ = V_-$

② $I_{C1} = \dfrac{V_o - V_+}{R}$, $I_{C2} = \dfrac{V_o - V_-}{R}$

$\therefore I_{C1} = I_{C2}$

$$V_T \ln(6) = I_{C2} R_3$$

$$I_{C2} = \frac{V_T \ln 6}{R_3}$$

$$V_o = V_{BE1} + I_{C2}(1k + R_2)$$

$$\frac{V_o}{\partial T} = \frac{V_{BE1}}{\partial T} + \frac{\ln 6}{R_3} \frac{\partial V_T}{\partial T} (1k + R)$$

$$0 = -1.79m + \frac{\ln 6}{1k} \cdot 0.087m(1k + R)$$

$$R = 10162.213\,\Omega$$

$$= 10.162\,k\Omega \quad \#$$

(b)

$\because V_+ = V_-$

$\therefore V_{BE1} = V_{BE2} + I_{C2} R_3 + V_{os}$

$$I_{C2} = \frac{V_{BE1} - V_{BE2} - V_{os}}{R_3}$$

$$V_o = V_{BE2} + (R + R_3)\left(\frac{V_{BE1} - V_{BE2} - V_{os}}{R_3}\right) \qquad \frac{V_{BE1} - V_{BE2}}{R_3} = 46.5857\,\mu A$$

$$= V_{BE2} + (10.162k + 1k)\left(46.5857 - \frac{20m}{1k}\right)$$

$$= V_{BE2} + 0.297 \quad \#$$