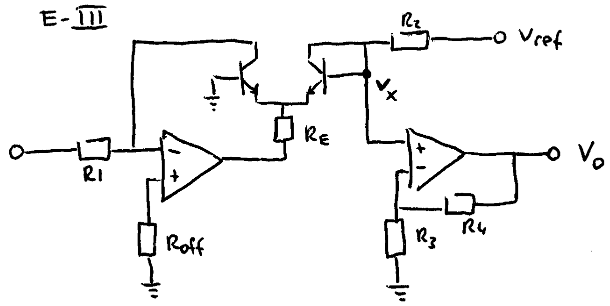
F.P. 2 E-III

(a)



left: $I_i = \frac{V_i}{R1}$ (V- is terra virtual)

$V_{BE1} = \frac{kT}{q} \ln \frac{V_i}{R1 \cdot I_s}$

$V_x = -V_{BE1} + V_{BE2}$

$V_{BE2} = \frac{kT}{q} \ln \frac{V_{ref}}{R2 \cdot I_s}$ when $V_x \sim 0$

● $V_x = \frac{kT}{q} \ln \left(\frac{V_{ref}}{V_i} \frac{R_1}{R_2} \right)$

ex. $R_1 = R_2$

$V_i = 10 V_{ref} = 10$ V

$V_x \approx 60$ mV — compare

$V_{ref} - V_x = 0.94$ V instead of 1 V

(6% error in calculation)

$\Delta V_x^* = -\frac{kT}{q} \ln 0.94 = -1.6$ mV

(b) $\left| \Delta \frac{V_o}{V_o} \right| = \frac{1.6}{60} \times 100\% = 2.7\%$

$V_o = \frac{R_4 + R_3}{R_3} \cdot V_x$

● $= \frac{R_4+R_3}{R_3} \cdot \frac{kT}{q} \ln \left(\frac{V_{ref}}{V_i} \cdot \frac{R_1}{R_2} \right) = -\frac{R_4+R_3}{R_3} \frac{kT}{q} \ln \left(\frac{V_i}{V_{ref}} \cdot \frac{R_2}{R_1} \right)$

(c) $V_o = c \frac{T}{R3}$; $(R_4 \gg R_3)$; $c = \frac{R_4}{q} \cdot k$, $R3 = (1+\alpha T) \cdot R3_0$

$\frac{dV_o}{dT} = \frac{d\left(c \frac{T}{R3}\right)}{dT} \cdot \frac{dT}{dT} + \frac{d\left(c \frac{T}{R3}\right)}{dR3} \cdot \frac{dR3}{dT}$

$= c \cdot \frac{1}{R3} - c \frac{T}{R3^2} \cdot \alpha R3$

$\frac{dV_o}{dT} = 0 \Rightarrow \frac{c}{R3}(1 - \alpha T) = 0 \Rightarrow \alpha = \frac{1}{T}$

(d) p. 11 de Sebenta : $R_{off} = R1$

$V_- = V_+$ (opamp ideal)

$V_- = V_+ = -R_{off} I_b$

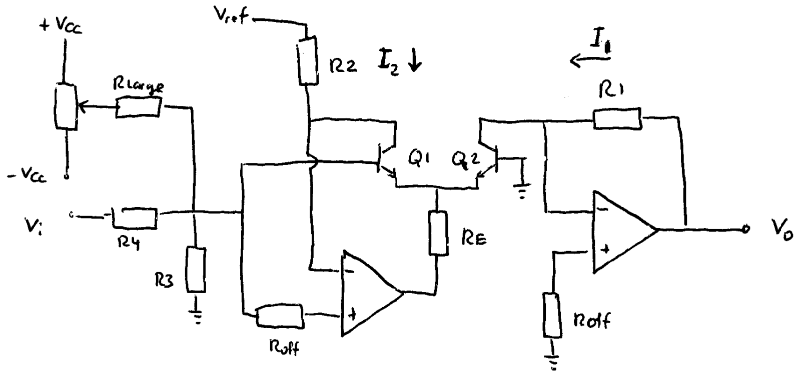
$I_i = (V_i - V_-)/R1 = (V_i + R_{off} I_b)/R1$

$I_{c1} = I_i - I_b = \frac{V_i}{R1} + \frac{R_{off}}{R1} I_b - I_b$

$R1 = R_{off} \Rightarrow I_{c1} = V_i / R1$

2: amplificador anti-logarítmico (exponential)

a)



$V_{b-1} = V_i \cdot \frac{R_3}{R_3 + R_4}$, $V_{b-1} = 0 - V_{be-2} + V_{be-1}$

$= -\frac{kT}{q} \ln \frac{I_1}{I_s} + \frac{kT}{q} \ln \frac{I_2}{I_s} = \frac{kT}{q} \ln \frac{I_2}{I_1}$

$I_1 = \frac{V_o}{R1}$, $I_2 = \frac{V_{ref}}{R2}$ $\Rightarrow V_{b-1} = \frac{kT}{q} \ln \frac{V_{ref}}{V_o} \cdot \frac{R1}{R2}$

$V_i \cdot \frac{R_3}{R_3 + R_4} = \frac{kT}{q} \ln \frac{V_{ref}}{V_o} \cdot \frac{R_1}{R_2} \Rightarrow \frac{V_{ref}}{V_o} \cdot \frac{R_1}{R_2} = \exp\left(\frac{qV_i}{kT} \cdot \frac{R_3}{R_3 + R_4} \right)$

$V_o = \frac{R_1}{R_2} V_{ref} \exp\left(-\frac{qV_i}{kT} \cdot \frac{R_3}{R_3 + R_4} \right)$

b) $V_i = 0 \Rightarrow V_o = \frac{R_1}{R_2} V_{ref}$. teóricamente

para $V_i = 0$, ajustar o potenciometro até que $V_o = \frac{R_1}{R_2} V_{ref}$