$$I_R = I_o\left(1+\frac{2}{1+\beta}\right)$$

2 transistors current source

$$R_o = r_{o2} = \frac{V_A}{I_{e2}}$$

$$I_{c2} = I_o$$

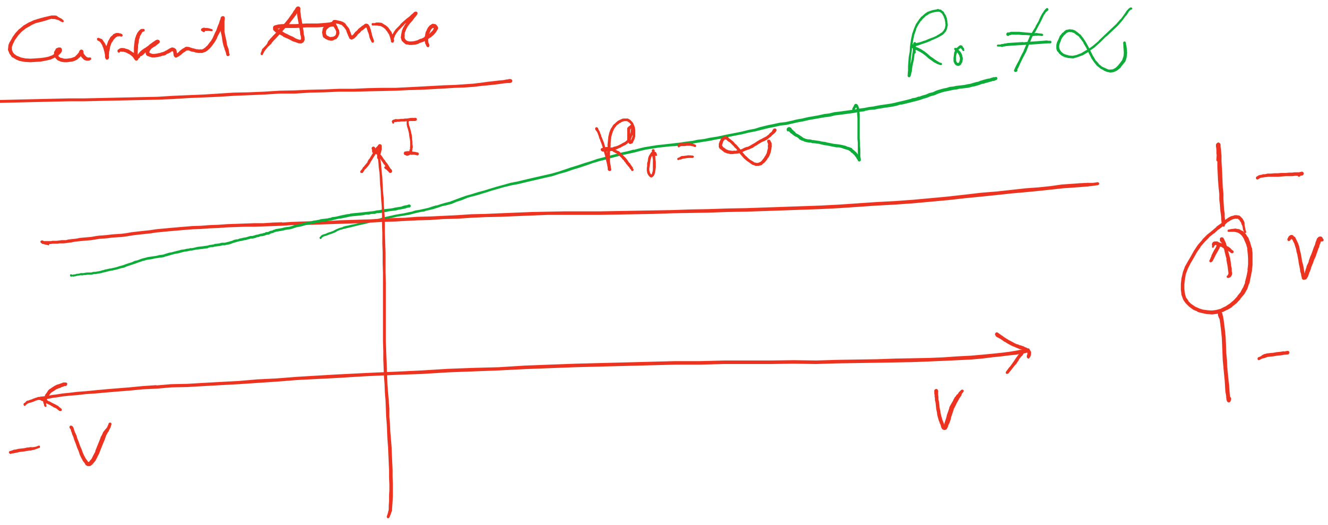
$$I_R = I_o\left(1+\frac{2}{\beta(1+\beta)}\right)$$

3 transistors current source

$$R_o = r_{o2} = \frac{V_A}{I_{e2}}$$

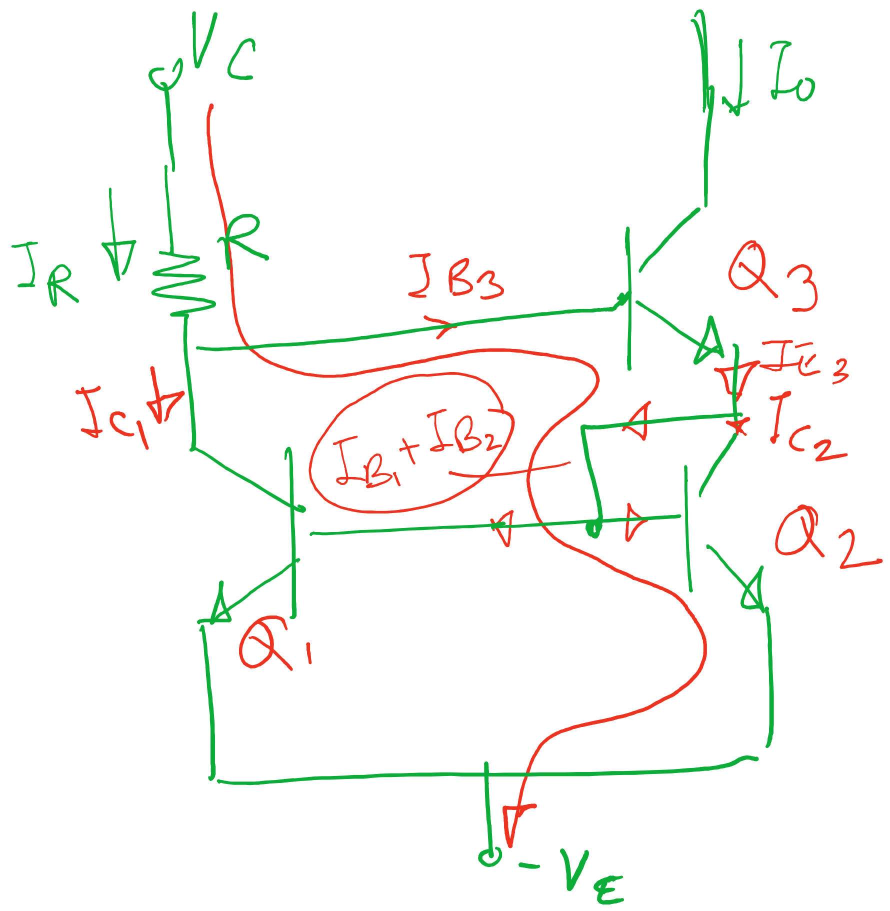
$$I_{c2} = I_o$$

Ideal. Current Source



1) Wilson Current Source.

$$R_o = \beta r_{o2}$$



$$V_C = I_R R + V_{BE3} + V_{BE2} - V_E$$

$$R = \frac{V_C + V_E - V_{BE3} - V_{BE2}}{I_R}$$

$I_o = 100\mu A$

$\beta = 100$

$V_{BE} = 0.7V$

$$I_R = I_{C_1} + I_{B_3}$$

$$V_{BE_1} = V_{BE_2}$$
$$I_{B_1} = I_{B_2}$$
$$I_{C_1} = I_{C_2}$$

$$I_{E_3} = (1+\beta) I_{B_3}$$

$$I_{E_3} = I_{B_1} + I_{B_2} + I_{C_2}$$

$$= 2I_{B_2} + I_{C_2} = \frac{2I_{C_2}}{\beta} + I_{C_2}$$

$$= I_{C_2}\left[1 + \frac{2}{\beta}\right] = (1+\beta) I_{B_3}$$

$$\therefore I_{C_2} = \frac{(1+\beta)}{\left(1+\frac{2}{\beta}\right)} I_{B_3} = \frac{(1+\beta)\beta}{(\beta+2)} I_{B_3}$$

$$I_R = I_{C_1} + I_{B_3}$$

$$= I_{C_2} + I_{B_3}$$

$$= \frac{(1+\beta)\beta}{(\beta+2)} I_{B_3} + I_{B_3}$$

$$= \left(\frac{(1+\beta)\beta}{(\beta+2)} + 1\right) I_{B_3}$$

$$= \left[\frac{(1+\beta)\beta}{(\beta+2)} + 1\right] \frac{I_{C_3}}{\beta}$$

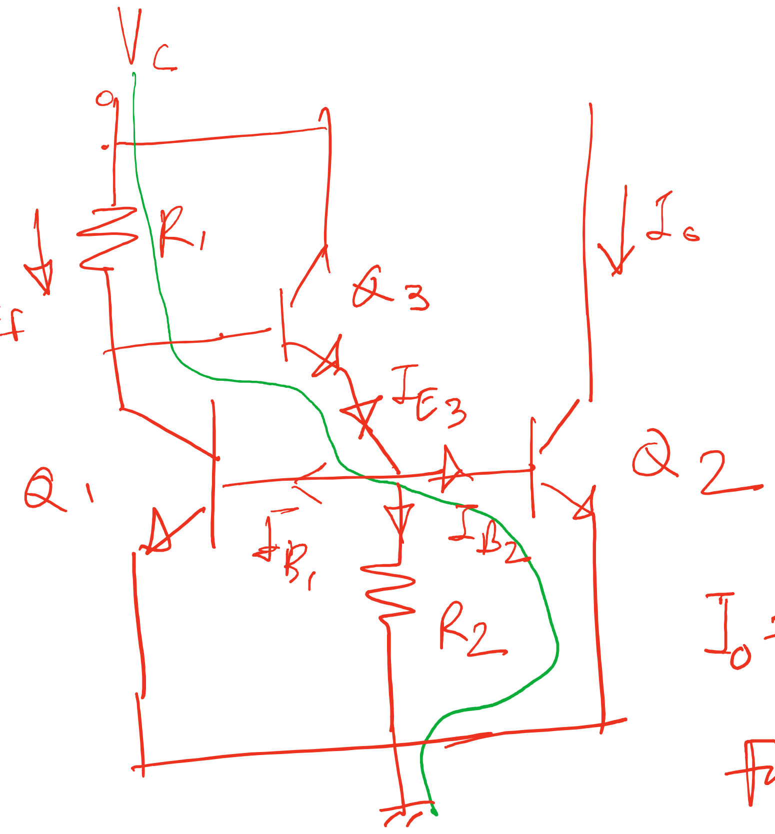
$$I_R = \left(\frac{101 \times 100}{102} + 1\right) \frac{100\mu}{100}$$

$$= 100\mu A$$

$$V_c = V_E = 5V$$

$$R = \frac{5+5-1.4}{100\,mA}$$

10.17 Prob.



$$R_1 = \frac{V_C - V_{BE_3} - V_{BE_2}}{I_R}$$

$V_C = 10V$

$\beta = 80$

$V_{BE} = 0.7$

$V_A = \infty$

$I_o = 0.7\,mA$

For $R_2 = 10k\Omega$

$$I_o = f\left(I_{REF},\ \beta,\ R_2\right)$$

$$I_{E3} = I_{B_1} + I_{B_2} + \frac{V_{BE}}{R_2}$$

$$= 2I_{B_2} + \frac{V_{BE}}{R_2} = (1+\beta) I_{B_3}$$

$$I_{B_3} = \frac{2I_{B_2}}{(1+\beta)} + \frac{V_{BE}}{R_2(1+\beta)}$$

$$I_R = I_{C_1} + I_{B_3}$$

$$= I_{C_2} + \frac{2I_{B_2}}{1+\beta} + \frac{V_{BE}}{R_2(1+\beta)}$$

$$= I_{C_2} + \frac{2I_{C_2}}{(1+\beta)\beta} + \frac{V_{BE}}{R_2(1+\beta)}$$

$$= \left[1 + \frac{2}{\beta(1+\beta)}\right] I_{C_2} + \frac{V_{BE}}{R_2(1+\beta)}$$

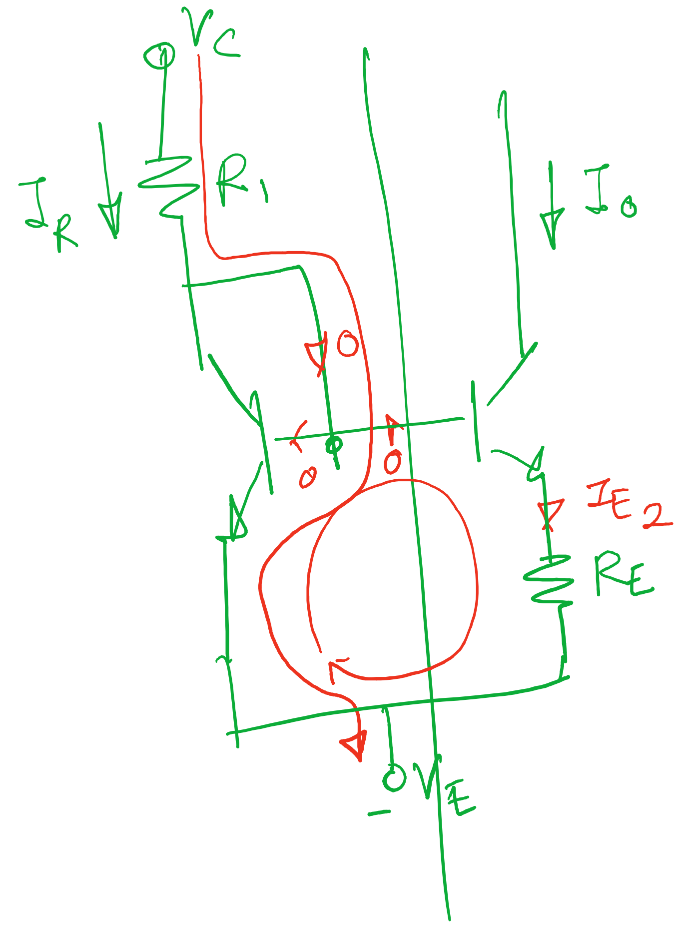
$$= \left[1 + \frac{}{\beta(1+\beta)}\right]^{+c_2} \quad r_2(1+\beta)$$

Wildar Current Source.

* Low Design Resistance.
* High output Resistance

$$R_o = r_{o_2}\left(1 + g_{m_2} R_E'\right)$$

$$R_E' = R_E \| r_{\pi_2}$$



Base current is negligible

$$V_{BE_1} \neq V_{BE_2}$$

$$V_{BE_1} = V_{BE_2} + I_{E_2} R_E$$

$$I_{c_2} = I_{E_2} = I_o$$

Given

$$\boxed{\begin{array}{c} I_R \\ I_o \\ V_{BE} \end{array}}$$

$$\therefore \quad V_{BE_1} = V_{BE_2} + I_o R_E \qquad (1)$$

$$R_1 = \frac{V_C + V_E - V_{BE_1}}{I_R}$$

$$I_C = I_S\left(e^{V_{BE}/V_T} - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

$$V_A = \infty$$

$$I_C = I_S\left(e^{V_{BE}/V_T} - 1\right)$$

$$\simeq I_S e^{\frac{V_{BE}}{V_T}}$$

$$I_R \quad I_S e^{V_{BE_1}/V_T} \qquad \frac{V_{BE_1} - V_{BE_2}}{V_T}$$

$$\frac{I_R}{I_o} = \frac{\cancel{I_s}\, e^{\ldots}}{\cancel{I_s}\, e^{V_{BE2}/V_T}} = e^{\frac{\ldots}{V_T}}$$

$$\ln \frac{I_R}{I_o} = \ln e^{\frac{V_{BE1} - V_{BE2}}{V_T}}$$

$$\ln \frac{I_R}{I_o} = \frac{V_{BE1} - V_{BE2}}{V_T}$$

$$V_{BE1} - V_{BE2} = V_T \ln \frac{I_R}{I_o}$$

$$V_{BE1} - V_{BE2} = I_o R_E$$

$$\boxed{I_o R_E = V_T \ln \frac{I_R}{I_o}}$$

$I_{REF} = 0.5\,mA$ $\qquad$ $I_o = 50\,\mu A$

D 10:29

$V_C = 5\,V$

$V_E = 5$

$$R_1 = \frac{V_C + V_E - V_{BE1}}{I_R}$$

$$= \frac{5 + 5 - 0.7}{0.5\,mA} = 18.6\,K\Omega$$

$=$

$$I_o R_E = V_T \ln \frac{I_R}{I_o} = 0.026 \times \ln \frac{0.5m}{50\mu}$$

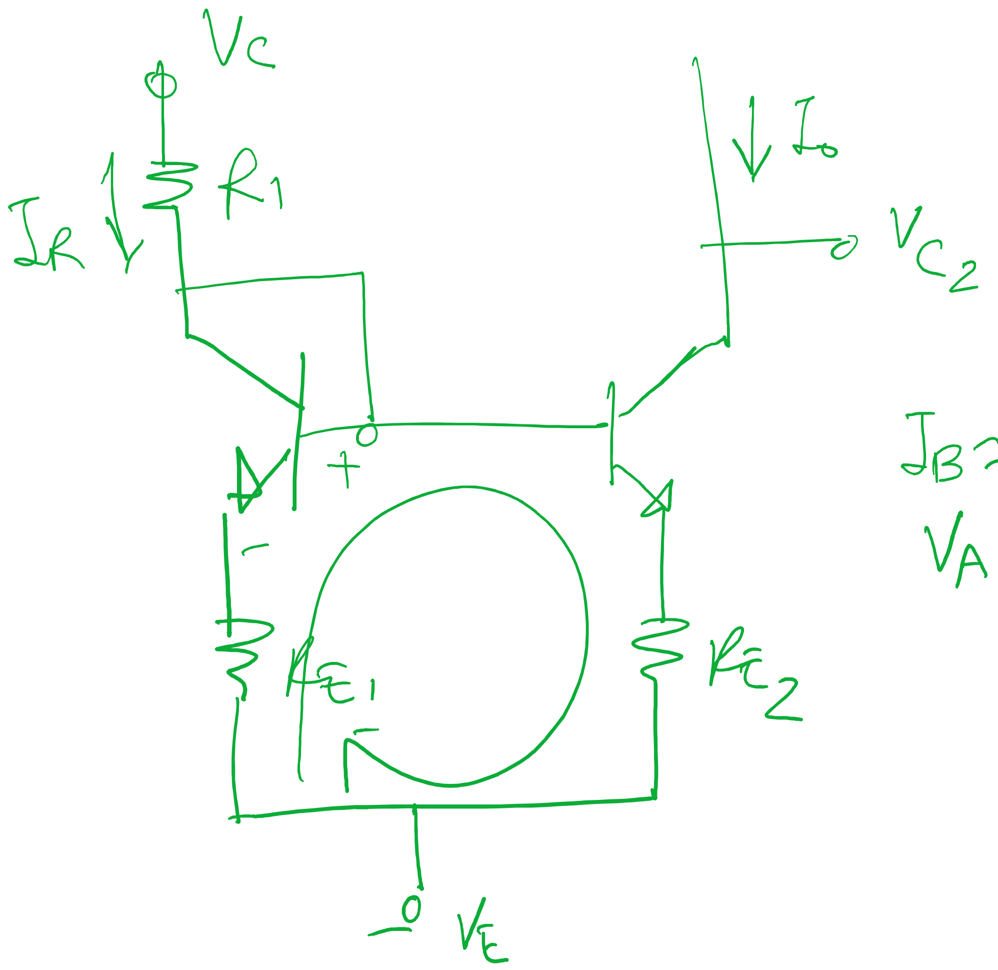
$I_o R_E = V_T \ln \frac{\quad}{I_o} = \ldots\ 50\mu$

$= 0.06 = V_{BE_1} - V_{BE_2}$

$\therefore \quad R_E = \frac{0.06}{I_o} = \frac{0.06}{50\mu} = 1.197\,k\Omega$

$V_{BE_2} = V_{BE_1} - 0.06$

10.34



$I_B \simeq 0$
$V_A = \infty$

Show That

$$\boxed{I_o R_{E_2} - I_R R_{E_1} = V_T \ln \frac{I_R}{I_o}}$$

$V_{BE_1} = V_{BE_2} + I_{E_2} R_{E_2} - I_{E_1} R_{E_1}$

$V_{BE_1} - V_{BE_2} = I_o R_{E_2} - I_R R_{E_1}$

Boltzman Const

Boltzman const

$$V_T = \frac{KT}{q}$$

Temp in Kelvin

273 + 27 = 300°K

Charge in C.

1.6×10^{-19} C

0.0258