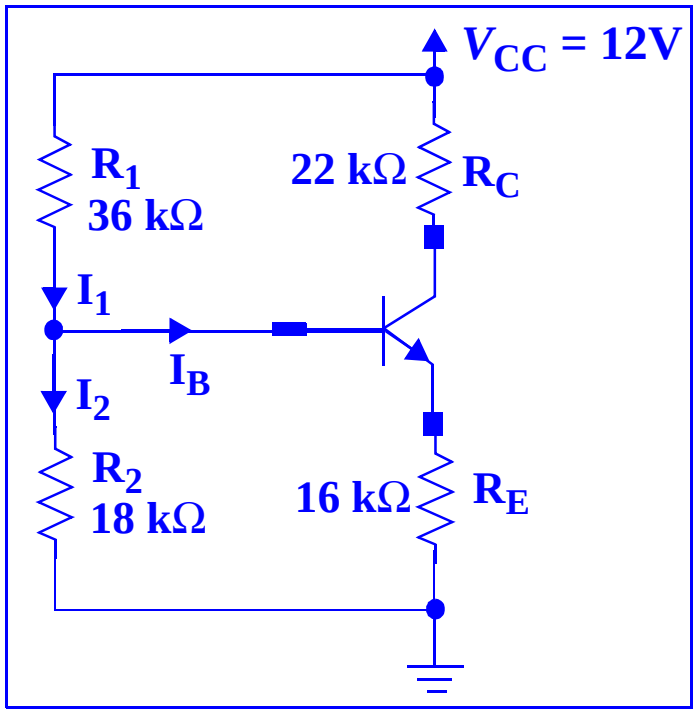
Design Objectives for Four-Resistor Bias Network

$$V_{EQ} = R_{EQ}I_B + V_{BE} + R_E I_E$$

$$I_E = \frac{V_{EQ} - V_{BE} - R_{EQ}I_B}{R_E} \text{ or}$$

$$I_E \approx \frac{V_{EQ} - V_{BE}}{R_E} \text{ for } R_{EQ}I_B \ll V_{EQ} - V_{BE}$$

R_{EQ} is designed so that its voltage drop is negligible.

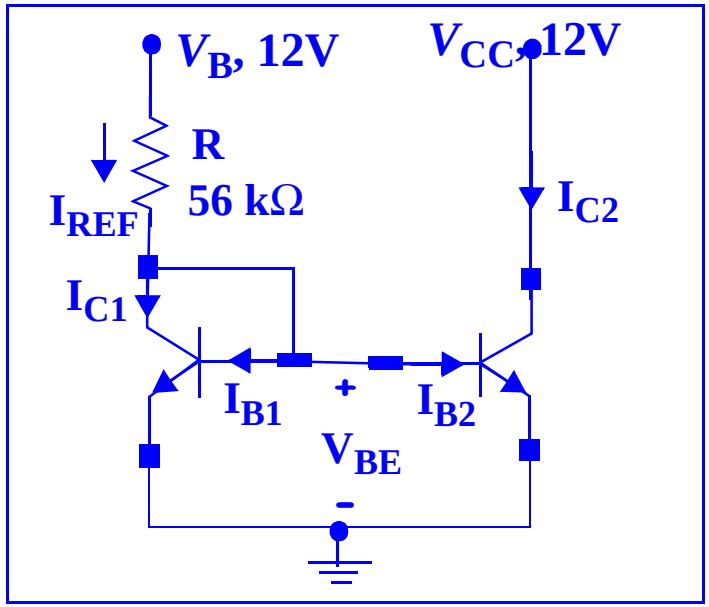


In this case, I_E is determined by V_{EQ}, V_{BE} and R_E. $I_E \approx \frac{V_{EQ} - V_{BE}}{R_E} = \frac{4 - 0.7}{16\text{k}} = 206\mu A$.

Another constraint is power dissipation. Choose $I_2 \le I_C/5$. Now, power dissipated in R_1 and R_2 is less than 17% of total quiescent power. Also, $I_2 \gg I_B$ for $\beta_F \ge 50$.

Basic Current Mirror

For V_{BE} = 0.7V, β_F = 100, V_A = 0V and I_S = 1.4×10^{-16}A (redundant). Find I_{REF} and I_{C2}. Assume that both transistors are matched.



Both transistors operate in forward-active region.

$$I_{REF} = \frac{V_B - V_{C1}}{R} = \frac{12 - 0.7}{56k} = 202\mu A$$

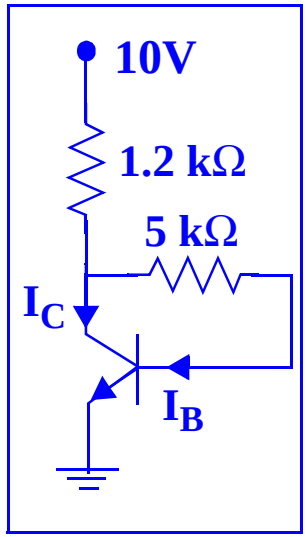
$$I_{REF} = I_{C1} + I_{B1} + I_{B2} \text{ but } \frac{I_{C1}}{\beta_F} = I_{B1} = I_{B2}$$

$$\therefore I_{REF} = I_{B2}(\beta_F + 2) \Rightarrow I_{B2} = 1.98\mu A$$

Therefore, $I_{C2} = \beta_F I_{B2} = 198\mu A \approx I_{REF}$

$$I_S = \frac{I_C}{e^{V_{BE}/V_T}} = \frac{198\mu A}{e^{0.7/0.025}} = 1.37\times10^{-16} A$$

Two-Resistor Bias Circuit



Find the Q-point for the circuit shown if $\beta_F = 75$ and $V_{BE} = 0.7V$.

$$10 = 1.2k(I_C + I_B) + 5kI_B + V_{BE}$$

Assume transistor operates in forward-active region,

$I_C = \beta_F I_B$ and $10 = 1.2k(\beta_F I_B + I_B) + 5kI_B + V_{BE}$.

$$I_B = \frac{10 - V_{BE}}{1.2k(\beta_F + 1) + 5k}$$

$$I_C = \beta_F I_B = \beta_F\left[\frac{10 - V_{BE}}{1.2k(\beta_F + 1) + 5k}\right] = 75\left[\frac{10 - 0.7}{1.2k(75 + 1) + 5k}\right] = 7.25mA$$

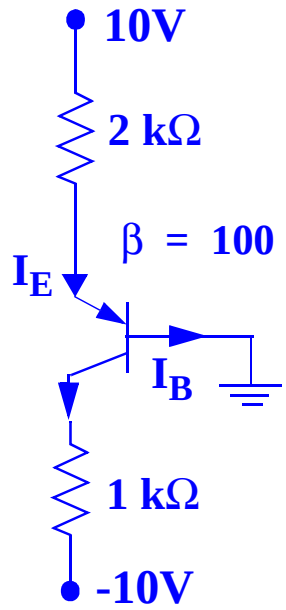
$$V_{CE} = 10 - 1.2k(I_C + I_B) = 10 - 1.2k\left(I_C + \frac{I_C}{\beta_F}\right) = 1.18V$$

Since $V_{CE} > V_{BE} > 0$, our assumption is correct.

A PNP Transistor Example

Find the Q-point of the shown circuit

since the emitter is connected to a higher potential than the base we have $V_{EB} = 0.7V$



The emitter current is found through the loop

$10 = 0.7 + 2I_E$ to get $I_E = 4.65mA$

Assuming forward active region we have $I_C = \alpha I_E = 4.6mA$

Checking the region of operation by calculating V_{CB} we get

$$V_{CB} = -10 + I_C \times 1K = -5.4V$$

it follows that the Collector-base junction is reverse-biased and our assumption of forward active region is correct