Current Mirror

Collector current provided by simple biasing circuits depends upon supply voltage and temperature. This causes problems in devices which are operated in a temperature range and where the battery voltage changes with use (e.g. mobile phones). To avoid this problem, some sophisticated circuits are used to generate currents which are independent of supply voltage and temperature. These generated currents (or reference currents, I_{ref} shown in Fig. 1) are replicated throughout the device using a current mirror.

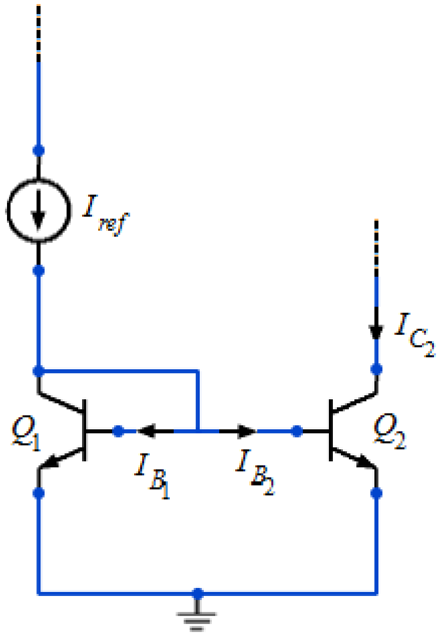

Figure 1

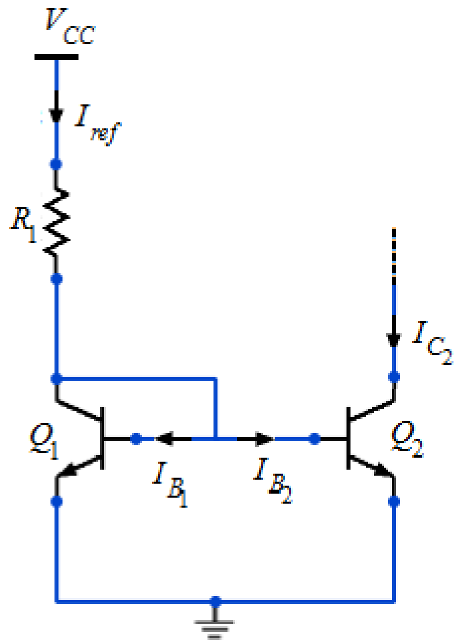

Figure 2

A basic current mirror circuit is shown in Fig. 2 (Q_1 and Q_2 are matched and they are biased to be in forward-active region) in which reference current is gerated from V_{CC} as,

$$I_{ref} = \frac{V_{CC} - V_{C1}}{R_1}$$

Also from Fig. 2

$$I_{ref} = I_{C_1} + I_{B_1} + I_{B_2} \quad \text{-------} \ (1)$$

considering the output resistances of both the transistors to be finite,

$$I_{C_1} = I_{S_1}\left(e^{\frac{V_{BE_1}}{V_T}}\right)\left(1 + \frac{V_{CB_1}}{V_A}\right) \quad \text{-------} \ (2) \qquad I_{C_2} = I_{S_2}\left(e^{\frac{V_{BE_2}}{V_T}}\right)\left(1 + \frac{V_{CB_2}}{V_A}\right) \quad \text{-------} \ (3)$$

$$I_{B_1} = \frac{I_{C_1}}{\beta\left(1 + \frac{V_{CB_1}}{V_A}\right)} \quad \text{-------} \ (4) \qquad I_{B_2} = \frac{I_{C_2}}{\beta\left(1 + \frac{V_{CB_2}}{V_A}\right)} \quad \text{-------} \ (5)$$

I_{S_1}, I_{S_2} are respective reverse saturation cur rents of Q_1 and Q_2 at base to collector jun ctions.
V_A is Early voltage.

$I_{S_1} = I_{S_2}$ as both the transistors are matched i. e. the emitter to base junction areas of both the transistors are same.

From Fig. 1. $V_{BE_1} = V_{BE_2}$.

Using (1), (2), (3), (4), and (5)

$$I_{C_2} = I_{ref}\left(\frac{1}{1+\frac{V_{CB_1}}{V_A}+\frac{2}{\beta}}\right)\left(1+\frac{V_{CB_2}}{V_A}\right)$$

as $\frac{V_{CB_1}}{V_A} \approx 0$, $I_{C_2} = I_{ref}\left(\frac{1}{1+\frac{2}{\beta}}\right)\left(1+\frac{V_{CB_2}}{V_A}\right)$ ------- (6)

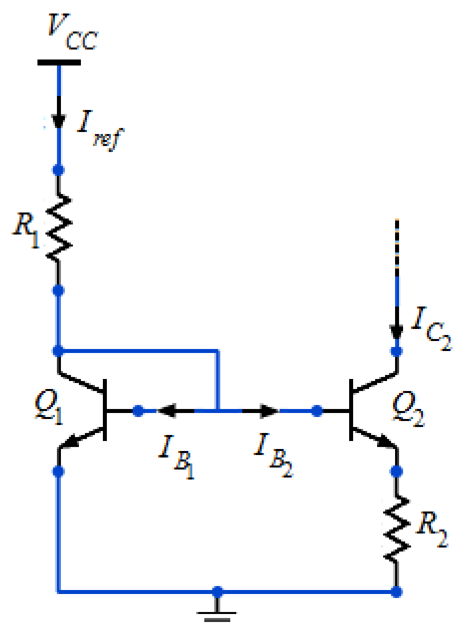

Figure 3

Lower magnitude of collector currents (I_{C2} of the order of micro amperes) can be obtained by increasing the ratio of emitter area of Q_2 to that of Q_1 in Fig. 2. This would require a large resistance R_1, costly interms of die area, if the circuit in Fig. 2 is used. Such low magnitude currents can be obtained with moderate values of resistance by modifying the circit in Fig. 1 so that the two devices Q_1 and Q_2 operate at different values of V_{BE}. The modified circuit known as the Widlar circuit is shown is Fig. 3.

From Fig. 3.,

$$V_{BE_1} = V_{BE_2} + I_{C_2} R_2 \text{ ------- } (7)$$

Substituting the values of V_{BE1}, V_{BE2} from (2) and (3) in (7) we can get a relation between I_{C1} and I_{C2} and hence between I_{C2} and I_{ref}.