Circuit achieves constant current over wide range of terminal voltages

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A common circuit for achieving this task uses a sense resistor, a transistor, and a power device. **Figure 1** shows the circuit using a power transistor, Q₁. The circuit provides an approximate constant current at high voltages, but it doesn’t enter regulation until it reaches nearly 60V due to the base current the transistor requires. **Figure 2** shows the circuit using a MOSFET, Q₂, for the power device. With a MOSFET, you can use smaller biasing resistors, and the circuit comes into regulation at a much lower terminal voltage.

![Figure 1](image1.png)

**Figure 1** Resistor R₁ sets a constant current through Q₁.

![Figure 2](image2.png)

**Figure 2** This circuit substitutes a MOSFET for Q₁ in Figure 1 and uses smaller resistors.
Unfortunately, the current-sense resistor, $R_1$, in figures 1 and 2 doesn’t sense the bias current. As the terminal voltage increases, the terminal current also increases because of the increased bias current. A simple way to improve the regulation of both circuits is to add resistor $R_4$ and PNP transistor $Q_3$ (Figure 3). $R_4$ and $Q_3$ form a constant-current source to the collector of $Q_2$. The circuit diverts any excess bias current through the collector of $Q_3$ to sense resistor $R_1$. Thus, as the terminal voltage increases, the bias current remains relatively constant, and the current regulation appears much flatter. The negative temperature coefficient of the base-to-emitter junction of transistor $Q_2$ causes another problem with this kind of circuit. The temperature coefficient is approximately $-1.6 \text{ mV/}°\text{C}$, which causes the current value to vary widely with temperature.

One way to approach this problem is to add a 6.2V zener diode, $D_1$, in series with the emitter of $Q_2$, which increases the sense voltage (Figure 4). A 6.2V diode has a positive temperature coefficient, which counteracts the negative temperature coefficient of the transistor. Furthermore, the total sense voltage is much larger, so 100 mV or so of voltage change with temperature does not seriously affect the regulated current. Figure 5 shows a PSpice simulation of the circuit that uses a MOSFET for $Q_1$. 

Figure 3 The addition of $Q_3$ and $R_4$ improves current regulation.

Figure 4 Adding a zener diode improves current regulation over temperature.

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Figure 5 A constant current in $Q_1$ has a steep rise relative to $V_{op}$.