Many process-control sensors, such as thermistors and strain-gauge bridges, require accurate bias currents. By adding a single current-setting resistor, $R_1$, you can configure voltage-reference circuit IC$_1$ to produce a constant and accurate current source (Figure 1). However, the source's errors depend on the accuracy of both $R_1$ and IC$_1$ and affect measurement accuracy and resolution. Although you can specify high-precision resistors whose accuracy exceeds that of most commonly available voltage-reference ICs, the voltage reference's error dominates this current source's accuracy. Although the manufacturer minimizes the voltage reference's temperature sensitivity and output-voltage error, sensitivity to power-supply variations can affect its accuracy, especially in process-control applications that must operate over a wide range of supply voltages.

A cascode-connected pair of JFETs, $Q_1$ and $Q_2$, form a constant-current source that minimizes the reference circuit's sensitivity to supply-voltage fluctuations and extends IC$_1$'s operating voltage beyond its 5.5V maximum rating. In addition, $Q_1$ and $Q_2$ effectively increase the current source's equivalent resistance from a few megohms almost into the gigohm range. In the circuit's Norton model, equivalent resistance represents the parallel resistance across an ideal current source.
An N-channel JFET operates as a depletion-mode device at its maximum saturated drain current when its gate-to-source bias voltage is 0V. In contrast to a depletion-mode MOSFET that requires a gate-bias voltage to conduct, the JFET operates in a default on-state and requires gate-bias voltage to cut off conduction. As its gate-to-source voltage becomes more negative with respect to the source, a JFET's drain current goes to zero at the pinch-off voltage. The JFET's drain current varies approximately with its gate bias: \( I_D \approx I_{DSS} \times (1 + V_{GS}/V_P)^2 \), where \( I_D \) is drain current, \( I_{DSS} \) is the saturated drain current, \( V_{GS} \) is the gate-to-source voltage, and \( V_P \) is the pinch-off voltage.

Assume that IC₁'s output voltage, \( V_{REF} \), remains constant at 1.8V. Because the output voltage drives \( Q_2 \)'s gate, IC₁'s input voltage, \( V_{IN} \), equals \( V_{REF} - V_{GS(Q2)} \) or \( 1.8V - (-1.2V) = 3V \). Thus, \( Q_2 \)'s gate-to-source voltage rests at its nominal pinch-off voltage of 1.2V and varies in step with small changes in current source. As the power-supply voltage varies from 3V to more than 30V, then the input voltage remains almost constant, as you would expect, because \( V_{REF} \) also remains constant. The cascoded-JFET configuration increases the current source's Norton equivalent resistance beyond that of the voltage reference and \( R_1 \) alone. You can use a single JFET, but stacking two JFETs further enhances the circuit's effective impedance. Note that IC₁ doesn't degrade accuracy because the JFETs hold IC₁'s input voltage virtually constant, and IC₁ effectively cancels initial gate-to-source-voltage variations and temperature effects that \( Q_1 \) and \( Q_2 \) introduce.

Negative feedback in the Kirchhoff-voltage loop that comprises \( V_{IN} \), \( V_{REF} \), and \( V_{GS(Q2)} \) allows the drain current to reach an equilibrium bias point that satisfies \( Q_2 \)'s transfer equation. Comprising the sum of \( (V_{REF}/R_1) + I_{GND} \) plus IC₁'s internal "housekeeping" current, \( I_{GND} \), \( Q_2 \)'s drain current remains constant. Adding \( Q_1 \) reduces the effects of \( Q_2 \)'s output impedance to insignificance. Adjusting the value of \( R_1 \) varies the circuit's output current over a useful range of 200 \( \mu \)A to 5 mA, with \( Q_2 \)'s saturated-drain-current specification imposing an upper limit. If you select a JFET with higher saturated drain current, make sure not to exceed \( Q_2 \)'s maximum power dissipation.

Note that the circuit's lower power-supply-voltage limit must exceed the circuit's compliance voltage, 3V, plus the voltage drop that the sensor introduces: \( I_{SOURCE} \times R_2 \). The circuit's upper power-supply voltage must not exceed \( I_{SOURCE} \times R_2 + 30V \). For example, supplying a current of 2.5 mA to a 1-kΩ pressure-sensor bridge, \( R_2 \), limits the power-supply-voltage range to 5.5 to 32.5V. The circuit's output current varies less than 1 \( \mu \)A over a wide range of power-supply voltages (Figure 2).

![Figure 2](image-url) Setting \( R_1 \) to values of 1 kΩ, 750Ω, and 510Ω delivers output currents of approximately
1.8, 2.5, and 3.6 mA that are insensitive to a wide range of power-supply voltages.

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