

## Convert 1 to 5V signal to 4- to 20-mA output

Thomas Mosteller, Linear Technology Corp

Despite the long-predicted demise of the 4- to 20-mA current loop, this analog interface is still the most common method of connecting current-loop sources to a sensing circuit. This interface requires the conversion of a voltage signal—typically, 1 to 5V—to a 4- to 20-mA output. Stringent accuracy requirements dictate the use of either expensive precision resistors or a trimming potentiometer to calibrate out the initial error of less precise devices to meet the design goals.

Neither technique is optimal in today's surface-mounted, automatic-test-equipment-driven production environment. It's difficult to get precise resistors in surface-mount packages, and trimming potentiometers require human intervention, a requirement that

is incompatible with production goals.

The Linear Technology LT5400 quad matched resistor network helps to solve these issues in a simple circuit that requires no trim adjustments but achieves a total error of less than 0.2% (Figure 1). The circuit uses two amplifier stages to exploit the unique matching characteristics of the LT5400. The first stage applies a 1 to 5V output—typically, from a DAC—to the noninverting input of op amp  $IC_{1A}$ . This voltage sets the current through  $R_1$  to exactly  $V_{IN}/R_1$  through FET  $Q_2$ . The same current is pulled down through  $R_2$ , so the voltage at the bottom of  $R_2$  is the 24V loop supply minus the input voltage.

This portion of the circuit has three main error sources: the matching of  $R_1$  and  $R_2$ ,  $IC_{1A}$ 's offset voltage, and  $Q_2$ 's

### DIs Inside

47 Linearize optical distance sensors with a voltage-to-frequency converter

50 Use a transistor as a heater

51 Monitor circuit conserves battery energy

► To see and comment on all of EDN's Design Ideas, visit [www.edn.com/designideas](http://www.edn.com/designideas).

leakage. The exact values of  $R_1$  and  $R_2$  are not critical, but they must exactly match each other. The LT5400A grade achieves this goal with  $\pm 0.01\%$  error. The LT1490A has less-than-700- $\mu$ V offset voltage over 0 to 70°C. This voltage contributes 0.07% error at an input voltage of 1V. The NDS7002A has a leakage current of 10 nA, although it is usually much less. This leakage

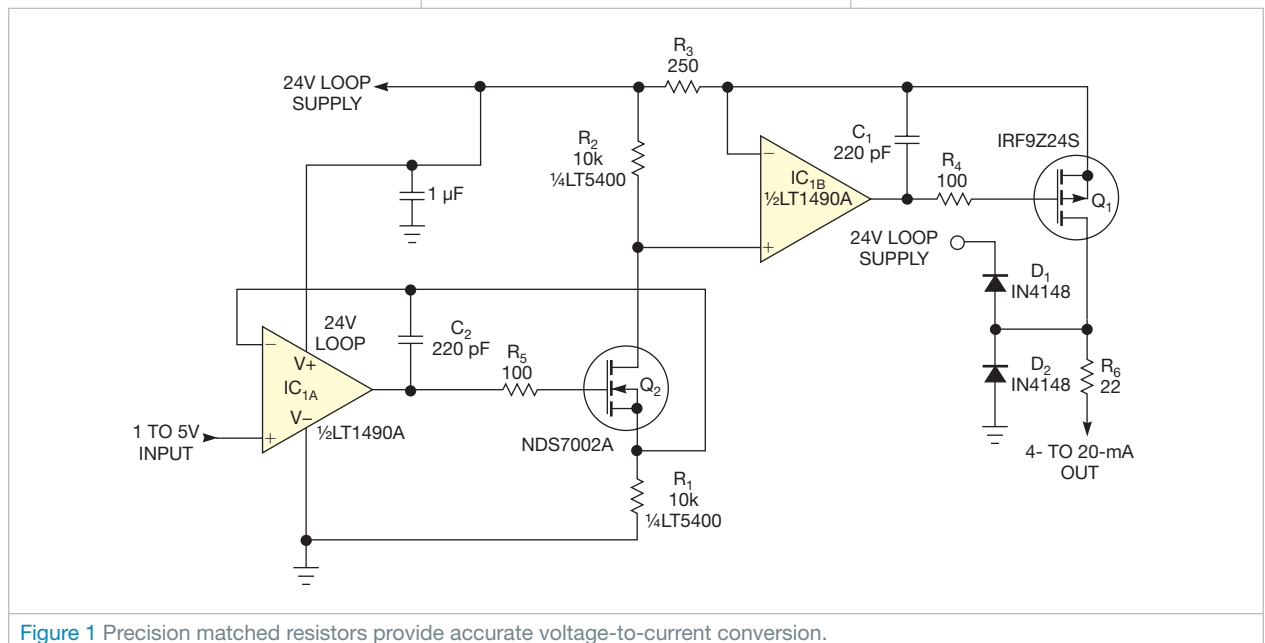


Figure 1 Precision matched resistors provide accurate voltage-to-current conversion.

current represents an error of 0.001%.

The second stage holds the voltage on  $R_3$  equal to the voltage on  $R_2$  by pulling current through  $Q_1$ . Because the voltage across  $R_2$  equals the input voltage, the current through  $Q_1$  is exactly the input voltage divided by  $R_3$ . By using a precision  $250\Omega$  current shunt for  $R_3$ , the current accurately tracks the input voltage.

The error sources for the second stage are  $R_3$ 's value,  $IC_{1B}$ 's offset voltage, and  $Q_1$ 's leakage current. Resistor  $R_3$  directly sets the output current, so its value is crucial to the precision of the circuit. This circuit takes advantage of the commonly used  $250\Omega$  current-loop-completion shunt resistor. The Riedon SF-2 part in the **figure** has 0.1% initial accuracy

and low temperature drift. As in the first stage, offset voltage contributes no more than 0.07% error.  $Q_1$  has less than 100-nA leakage, yielding a maximum error of 0.0025%.

Total output error is better than 0.2% without any trimming. Current-sensing resistor  $R_3$  is the dominant source of error. If you use a higher-quality device, such as the Vishay PLT series, you can achieve an accuracy of 0.1%. Current-loop outputs are subject to considerable stresses in use. Diodes  $D_1$  and  $D_2$  from the output to the 24V loop supply and ground help protect  $Q_1$ ;  $R_6$  provides some isolation. You can achieve more isolation by increasing the value of  $R_6$ , with the trade-off of some compliance voltage at

the output. If the maximum output-voltage requirement is less than 10V, you can increase  $R_6$ 's value to  $100\Omega$ , affording even more isolation from output stress. If your design requires increased protection, you can fit a transient-voltage suppressor to the output with some loss of accuracy due to leakage current.

This design uses only two of the four matched resistors in the LT5400 package. You can use the other two for other circuit functions, such as a precision inverter, or another 4- to 20-mA converter. Alternatively, you can place the other resistors in parallel with  $R_1$  and  $R_2$ . This approach lowers the resistor's statistical error contribution by the square root of two. **EDN**