



Convert 1V to 5V Signal to 4mA to 20mA Output

By Thomas Mosteller, Field Applications Engineer
Linear Technology Corp

Despite the long-predicted demise of the 4mA to 20mA 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, 1V to 5V—to a 4mA to 20mA 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 1V to 5V output—typically, from a DAC—to the non-inverting input of op amp IC_{1A}. This voltage sets the current through R₁ to exactly V_{IN}/R_1 through FET Q₂. The same current is pulled down through R₂, so the voltage at the bottom of R₂ is the 24V loop supply minus the input voltage.

This portion of the circuit has three main error sources: the matching of R₁ and R₂, IC_{1A}'s offset voltage, and Q₂'s leakage. The exact values of R₁ and R₂ are not critical, but they must match each other exactly. The LT5400A grade achieves this goal with $\pm 0.01\%$ error. The LT1490A has less-than-700- μ 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 10nA, although it is usually much less. This leakage current represents an error of 0.001%.

The second stage holds the voltage on R₃ equal to the voltage on R₂ by pulling current through Q₁. Because the voltage across R₂ equals the input voltage, the current through Q₁ is exactly the input voltage divided by R₃. By using a precision 250 Ω current shunt for R₃, the current accurately tracks the input voltage.

The error sources for the second stage are R₃'s value; IC_{1R}'s offset voltage, and Q₁'s leakage current. Resistor R₃ directly sets the output current, so its value is crucial to the

precision of the circuit. This circuit takes advantage of the commonly used 250Ω 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. Q₁ has less than 100nA leakage, yielding a maximum error of 0.0025%.

Total output error is better than 0.2% without any trimming. Current-sensing resistor R₃ 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 D₁ and D₂ from the output to the 24V loop supply and ground help protect Q₁; R₆ provides some isolation. You can achieve more isolation by increasing the value of R₆, with the trade-off of some compliance voltage at the output. If the maximum output-voltage requirement is less than 10V, you can increase R₆'s value to 100Ω, 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 4mA to 20mA converter. Alternatively, you can place the other resistors in parallel with R₁ and R₂. This approach lowers the resistor's statistical error contribution by the square root of two.

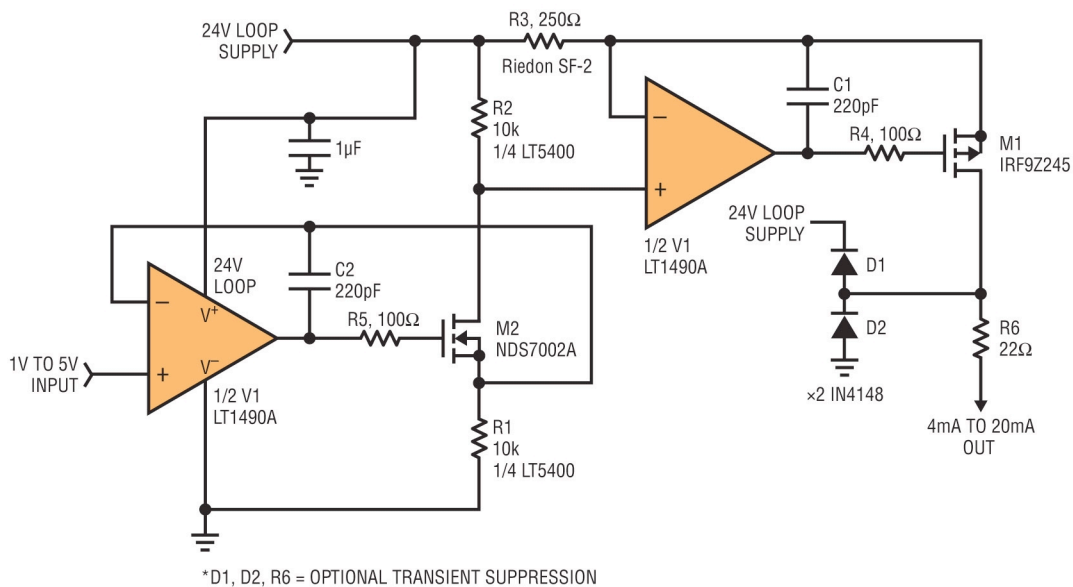


Figure 1. Precision matched resistors provide accurate voltage-to-current conversion.