Edited by Brad Thompson

Impedance transformer flags failed fuse

Kevin Ackerley, Future Electronics, Vancouver, BC, Canada

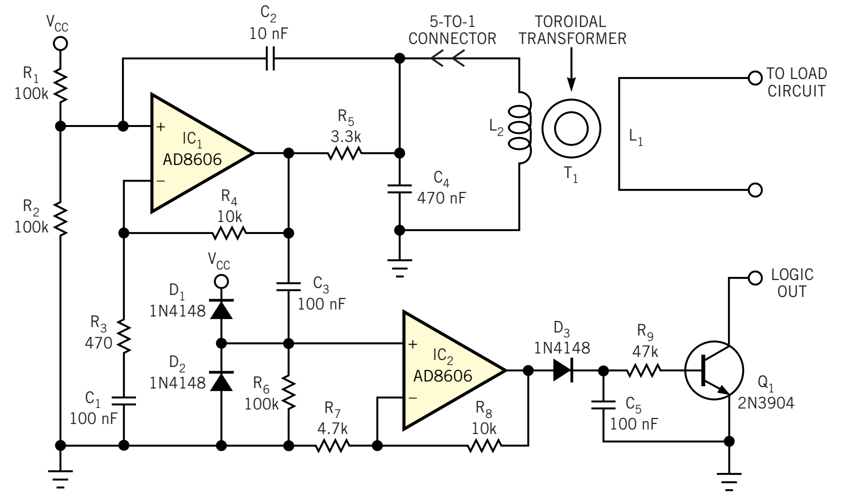

Figure 1 This sensor circuit operates from a single 5V power supply.

FIGURE 1 DEPICTS a circuit that detects the opening of a miniature circuit breaker or high-rupture-capability fuse in a high-reliability telecommunications power supply. The circuit generates an alarm when a failure changes the impedance of an electromagnetic sensor. Traditional fault-detection circuits sense the voltage difference developed across an open fuse, leakage current flowing through a fused circuit, or closure of an auxiliary (volts-free) contact by an actuator fuse. All three methods suffer from disadvantages: Voltage-difference circuits can introduce unacceptable delays as long as 30 minutes because the system's batteries sustain the bus voltage. Leakage-current sensors rely on the presence of a load that may not be present under certain conditions. Adding auxiliary miniature-circuit-breaker support circuits or special high-rupture-capability indicator fuses and their connectors can significantly increase system cost.

Capacitor C_4 and the secondary inductance, L_2, of transformer T_1 resonate at approximately 42 kHz, a frequency that minimizes noise production in the audio, RF, and psophometric noise bands. Operational amplifier IC_1 and associated components form an ac-coupled positive-feedback amplifier with a gain of 20.

Under normal operation, an intact fuse or closed circuit breaker completes a low-impedance path through T_1's single-turn primary (sense) winding. Transformer action presents a low impedance at the junction of C_2, C_4, and R_5 and reduces the loop gain around IC_1 to an amount insufficient to sustain oscillation.

When a fault occurs and interrupts current through T_1's primary winding, its secondary impedance increases, allowing full loop gain and permitting IC_1 to oscillate at 42 kHz, which L_2 and C_4 determine. Under fault conditions, T_1's turns ratio injects less than 10 mV of wideband conducted noise into the dc bus. Capacitor C_3 couples the oscillating signal to IC_2, a gain-of-3 amplifier, which in turn drives a peak detector formed by D_3 and C_5. Transistor Q_1 saturates and provides a logic-low signal to an external alarm. **Figure 2** shows a typical application for sensing backup-battery-circuit failure.

To design transformer T_1, you calcu-

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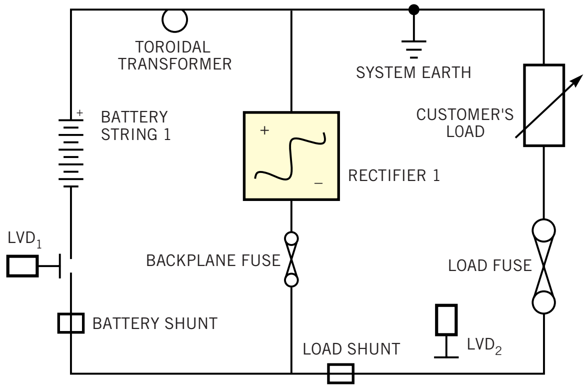

Figure 2 The system wiring diagram shows transformer T_1's primary winding. Low-voltage-disconnect units LVD_1 and LVD_2 isolate the 48V battery or the customer's load for maintenance.

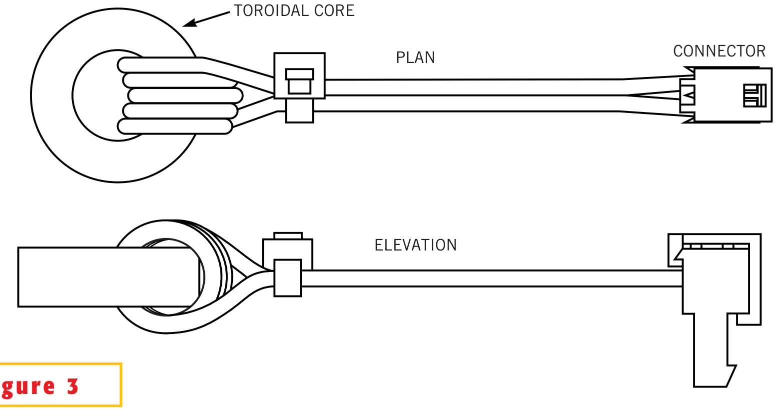

Figure 3

The primary winding (battery cable) passes through transformer T_1's center.

late the required impedance and turns ratio. **Equation 1** describes the basic transformer relationship:

$$\frac{Z_1}{Z_2} \propto \left(\frac{N_1}{N_2}\right)^2, \qquad (1)$$

where Z_1 is the impedance of the primary winding, Z_2 is the impedance of the secondary winding N_1 is the number of primary turns, and N_2 is the number of secondary turns.

Under normal operation with current flowing in the primary winding, the secondary impedance comprises the low primary-side impedance plus T_1's leakage reactance. When no current flows in the primary winding, the number of turns in the secondary and the toroidal core A_L (inductance per turn) determine the secondary winding L_2's inductance and number of turns per **Equation 2**:

$$L_2 = N_2^{\,2} A_L \text{ nH}, \qquad (2)$$

where N_2 is the number of turns around the toroidal core.

Ferrite-core manufacturers publish inductance-per-turn data that simplifies alteration of T_1's design, but if that data is unavailable, you can use **Equation 3** to calculate the inductance.

$$A_L = \frac{\mu_e \mu_o \times 10^6}{\sum(L/A)}, \qquad (3)$$

where μe, the effective permeability, equals the magnetic constant, $4\pi \times 10^{-7}\text{Hm}^{-1}$, I is the path length, and A is the cross-sectional area in millimeters squared.

Select a core that presents a high value of inductance to ensure that the difference between an open and a closed primary circuit causes a large change in relative secondary-winding impedance. Also, select a core material that doesn't saturate at full primary current.

Note that the core's central area must provide clearance for the battery cable (primary winding) and secondary winding. This application uses a Philips 3C85 toroidal ferrite core (part no. TN 16/9.6/6.3-3C85) with a secondary winding comprising five turns of 0.2-mm² insulated copper wire. (Philips, however, has discontinued the 3C85 ferrite core. Ferroxcube's type 3C90 ferrite may serve as a replacement. Specifications are available at www.ferroxcube.com.) **Figure 3** shows the completed transformer.□

Digital waveform generator provides flexible frequency tuning for sensor measurement

Colm Slattery, Analog Devices, Limerick, Ireland

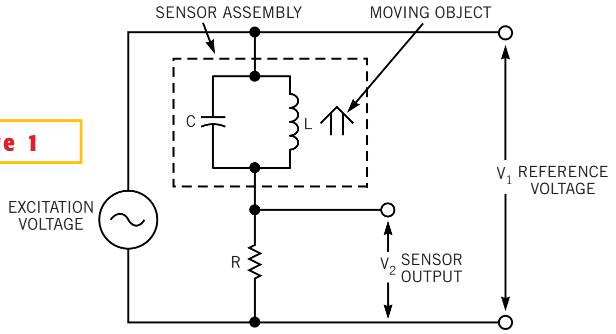

Figure 1

The amplitude and phase of the resonant-circuit sensor's output voltage, V_2, vary with moving object's position.

Variable-resistance sensors convert a fixed dc excitation voltage or current into a current or voltage that's a straightforward function of the quantity undergoing measurement. In another class of sensors, moving objects or fluids produce a sensor signal by altering an LC circuit's inductance or capacitance. **Figure 1** shows a basic ac-driven tuned-circuit proximity sensor, L and C, and sampling resistor, R. Under static conditions, L and C resonate and provide maximum impedance at one frequency. As an object approaches the sensor, the value of L or C varies and alters the circuit's resonant frequency. You can derive the object's position by exciting the sensor with a fixed frequency and measuring changes in the phase or amplitude of output voltage V_2 with respect to excitation voltage V_1. However, this approach limits the sensor's dynamic range and resolution.

As an alternative, you can drive the sensor with a swept-frequency ac source that tracks the sensor's resonant-frequency variation. **Figure 2** shows one approach in which IC_1, a DDS (direct-digital synthesis) device, produces a sine-wave excitation voltage. Lowpass filter IC_2 removes clock artifacts and harmonics, and amplifier IC_3 drives the sensor. Amplifier IC_4 boosts the sensor's output voltage, V_2, and drives IC_5, a dual-channel, 12-bit ADC, which simultaneously samples and digitizes reference voltage V_1 and IC_4's output. IC_5, a DSP-capable microcontroller, analyzes the sensor output's amplitude and phase, setting the frequency of IC_1 via alternate programming of either of IC_1's dual frequency-control registers. One of IC_6's serial ports delivers position data to an external controller. Using a DDS/DSP combination offers considerable flexibility when using various types of sensors. For example, certain sensors require a relatively narrow but high-resolution range of excitation frequencies, and others may work best with broadly swept excitation.□

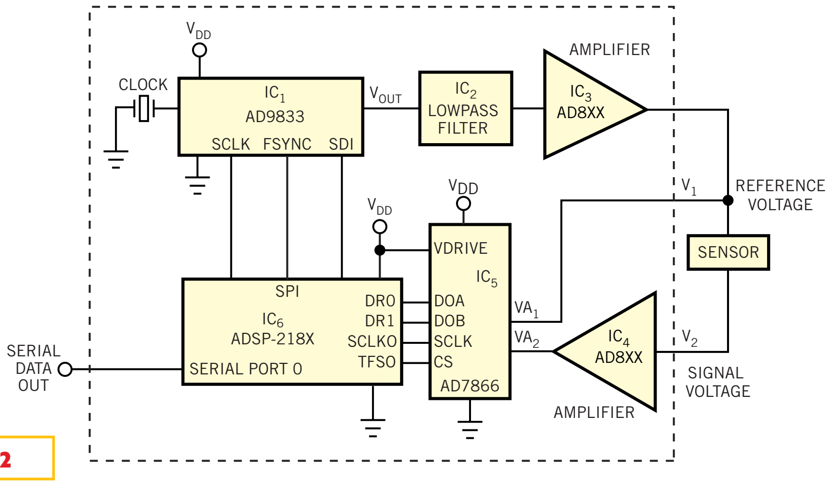

Figure 2

A swept-frequency source and a DSP controller combine to offer a versatile sensor-excitation system.

Battery-operated remote-temperature sensor drives 4- to 20-mA current loop

Scot Lester, Texas Instruments, Dallas, TX

You can remotely measure temperature using a 4- to 20-mA current loop as long as 4000 feet and a battery-powered, white-light LED driver. You usually configure this equipment to provide a programmable, constant current to an LED from a battery source. The TPS62300 series of ICs, for example, converts a battery voltage of 2.7 to 6.5V into a constant current, which you program using an external resistor and voltage on its I_{SET} pin. The current that normally drives the LED instead powers the loop (**Figure 1**).

In the sample circuit, which occupies 50 mm², the LED driver drives the 4- to 20-mA current loop proportionate to a sensed temperature of −10°C at 4 mA and 50°C at 20 mA. The driver applies 0.6V to the I_{SET} pin and monitors current flow from the pin. This current is multi-

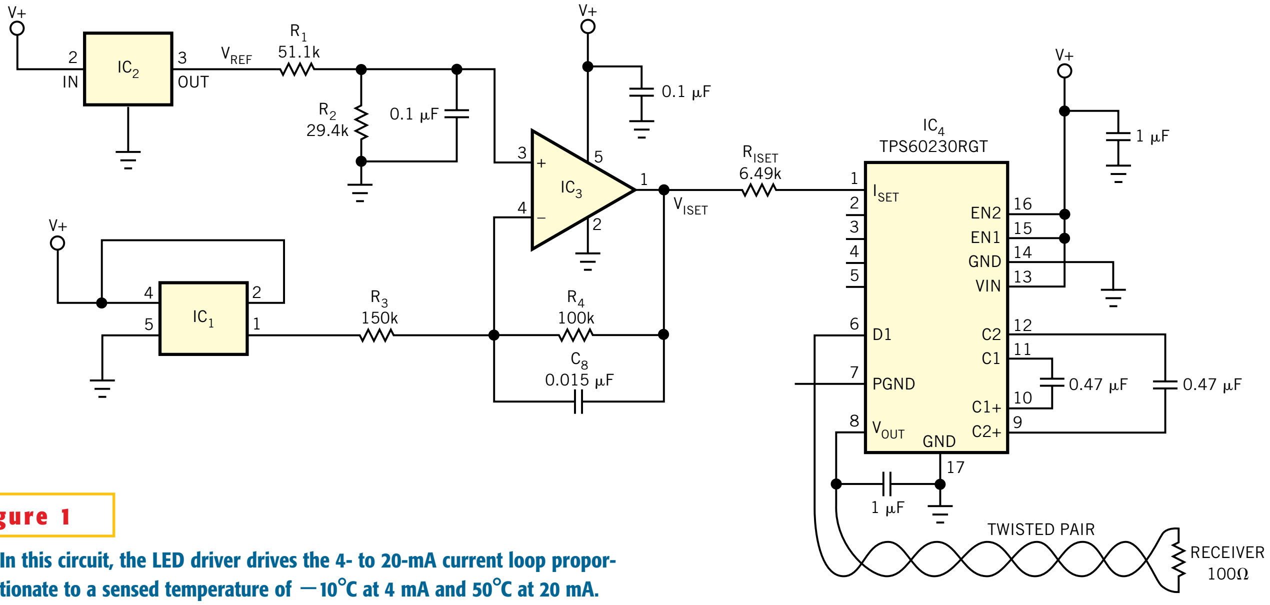

Figure 1

In this circuit, the LED driver drives the 4- to 20-mA current loop proportionate to a sensed temperature of −10°C at 4 mA and 50°C at 20 mA.

plied by 260 and mirrored to the LED drive output:

$$I_{LOOP} = 260 \times \left(\frac{0.6 - V_{ISET}}{R_{ISET}}\right).$$

Because resistor R_{ISET}, which is tied to the I_{SET} pin, is fixed in the example, the output current is proportional to the voltage, V_{ISET}, which the output of op amp IC_3 determines. Using a 6.49-kΩ resistor for R_{ISET} means that V_{ISET} needs to be 0.1V to provide 20 mA of loop current and 0.5V to provide 4 mA.

The TMP36 temperature sensor, IC_1, provides 750 mV of output at 25°C and varies its output voltage by 10 mV/°C. The output of the TMP36 is 0.4V at −10°C and 1V at 50°C. Because these voltages do not directly match the voltage requirements of V_{ISET}, you use a REF2912 voltage reference, IC_2, with the OPA374 op amp to scale the output of the TMP36 to the required voltage for the LED driver, IC_4. In general terms, the current in the current loop for the circuit is:

$$I_{LOOP} = \left(\frac{260}{R_{ISET}}\right) \times \left(\begin{array}{l} 0.6 - V_{REF} \times \left(\frac{R_2}{R_1 + R_2}\right) \times \\ \left(1 + \frac{R_4}{R_3}\right) + V_{TEMP} \times \left(\frac{R_4}{R_3}\right) \end{array}\right).$$

Substituting for the component values shown in the **figure** yields:

$$I_{LOOP} = 0.0267 \times V_{TEMP} - 0.00644.$$

The output of the LED driver can drive loops with as much as 180Ω of resistance with battery voltages as low as 2.7V. Therefore, the LED driver can drive more than 1500 feet of 24 AWG or 4000 feet of 20 AWG twisted-pair wire with a 100Ω load resistor at the receiver. You can achieve much longer distances with higher battery voltages. Because this circuit powers the current loop, the battery life for these circuits depends on the measured temperature. For the circuit shown, a loop current of 13.3 mA corresponds to a measured temperature of 25°C. Therefore, using two AA alkaline batteries in series should provide more than 120 hours of remote-temperature monitoring at room temperature. The accuracy for the circuit is about 2.5% of full scale without any calibration. For tighter accuracy, reduce the range of the measured temperature or calibrate the output.□

Precision current source is software-programmable

Joe Neubauer, Maxim Integrated Products Inc, Sunnyvale, CA

WITH THE ADDITION OF a few inexpensive miniature components, the hard-wired, voltage-controlled current source of yesterday becomes a software-programmable voltage-controlled current source (**Figure 1**). A digital potentiometer, IC_1 in conjunction with a precision op amp, IC_2, sets current through a pass transistor, I_{SET}, and a shunt regulator, IC_3, provides a constant reference voltage across the digital potentiometer. By operating in its linear region, the transistor controls load current in response to the applied gate voltage. Each incremental step of the digital potentiometer increases or decreases the wiper voltage, V_{IN+}, at the op amp's noninverting input. Thus, V_{IN+} varies with respect to the reference voltage, which in turn remains stable with respect to the supply rail:

$$V_{IN+} = \frac{V_{REF}\left[R_{TOTAL(DP)}/(\text{TOTAL NO. OF STEPS})\right]}{R_{TOTAL(DP)}}.$$

Many types of digital potentiometer are currently available, and the interface to these devices, besides the hard-wired type, can be one, two, or three wires. IC_1, for example, has a three-wire SPI interface, and provides an end-to-end resistance of 50 kΩ with 256 incremental settings. Thus, each increment of the digital potentiometer changes V_{IN+} by:

$$V_{IN+} = \frac{3V(50\text{ k}\Omega/256)}{50\text{ k}\Omega} = 11.72\text{ mV}.$$

Op amp IC_2 regulates current through the pass transistor, and the digital potentiometer sets current through the R_{SENSE} resistor. The voltage across R_{SENSE} determines current through the pass transistor, I_{SET}: $I_{SET} = (V_{CC} - V_{IN+})/R_{SENSE}$.

The circuit can provide any current level for which the external components, R_{SENSE} and the pass transistor, can handle the associated power dissipation (P=IV). Because the ratio setting of digital potentiometers is good, with a typical ratiometric resistor temperature coefficient of 5 ppm/°C), precision and stability for the current source depend primarily on the precision and stability of IC_3 and R_{SENSE} combined.□

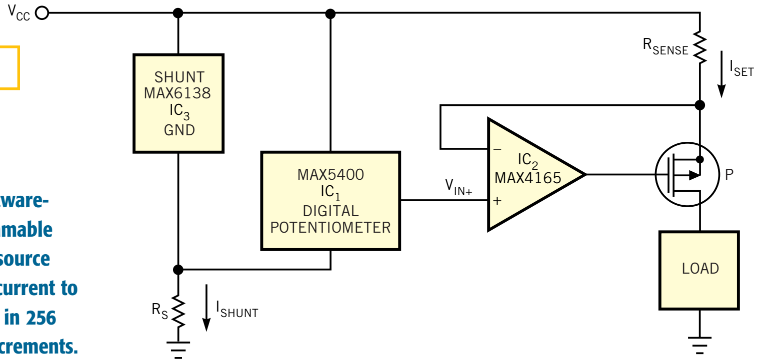

Figure 1

This software-programmable current source applies current to the load in 256 equal increments.