Impedance transformer flags failed fuse

Kevin Ackerley, Future Electronics, Vancouver, BC, Canada

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 C₄ and the secondary inductance, L₂, of transformer T₁ resonate at approximately 42 kHz, a frequency that minimizes noise production in the audio, RF, and psychometric noise bands. Operational amplifier IC₁ 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 T₁’s single-turn primary (sense) winding. Transformer action presents a low impedance at the junction of C₂, C₄, and R₅ and reduces the loop gain around IC₁ to an amount insufficient to sustain oscillation.

When a fault occurs and interrupts current through T₁’s primary winding, its secondary impedance increases, allowing full loop gain and permitting IC₁ to oscillate at 42 kHz, which L₁ and C₅ determine. Under fault conditions, T₁’s turns ratio injects less than 10 mV of wideband conducted noise into the dc bus. Capacitor C₃ couples the oscillating signal to IC₂, a gain-of-3 amplifier, which in turn drives a peak detector formed by D₂ and C₆. Transistor Q₁ 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 T₁, you calcu-
late the required impedance and turns ratio. Equation 1 describes the basic transformer relationship:

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

(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 $L_2$ (inductance per turn) determine the secondary winding $L_2$'s inductance and number of turns per Equation 2:

$$L_2 = N_2^2 A_T \, \text{nH},$$

(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.

$$A_T = \frac{\mu B H}{2 \pi} \times 10^6 \sum \left( \frac{L}{A} \right).$$

(3)

where $\mu$, the effective permeability, equals the magnetic constant, $4\pi \times 10^{-7} \text{H/m}$, $L$ 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-mm$^2$ 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

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. Amplifi-
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 ISET 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 ISET pin and monitors current flow from the pin. This current is multi-
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, IC1, in conjunction with a precision op amp, IC2, sets current through a pass transistor, ISET, and a shunt regulator, IC3, to provide 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 changes 

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

Substituting for the component values shown in the figure yields:

\[ I_{\text{LOOP}} = 0.0267 \times V_{\text{TEMP}} - 0.00644. \]

The output of the LED driver can drive loops with as much as 180\( \Omega \) 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 100\( \Omega \) 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.

---

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

![Figure 1](https://www.edn.com)