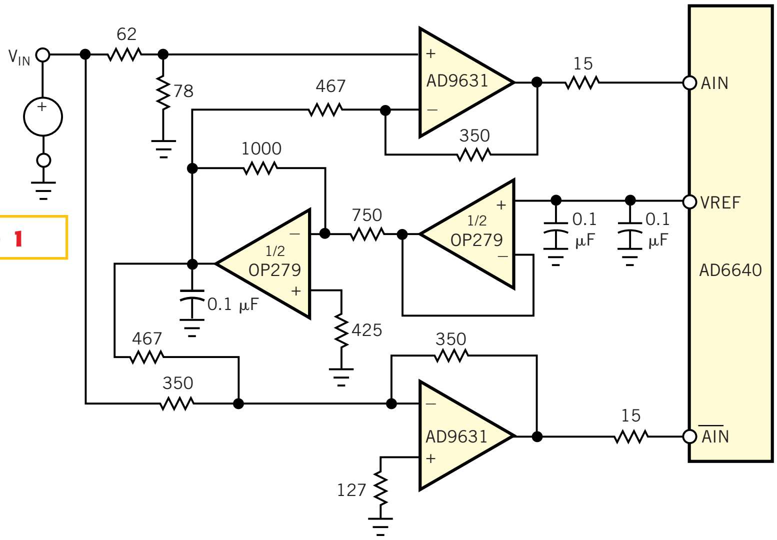
Edited by Bill Travis and Anne Watson Swager

Differential amp drives high-speed ADC

Chau Tran, Analog Devices Inc, Wilmington, MA

The schematic in **Figure 1** is the discrete-element version of an A/D-converter drive circuit. The circuit converts a single-ended input to a differential output. The ADC's reference voltage determines the common-mode range of the differential outputs. The circuit contains two AD9631 amplifiers—one connected in noninverting mode, and the other connected in inverting mode. The OP279 amplifiers buffer and scale the ADC's reference voltage to set the common-mode range of the two outputs. The circuit in **Figure 1** requires many resistors. The two 15Ω resistors help prevent oscillation arising from the capacitive inputs of the ADC. The circuit has several disadvantages, such as poor gain accuracy, high distortion, and limited speed. The circuit in **Figure 2** is an improved ADC driver.

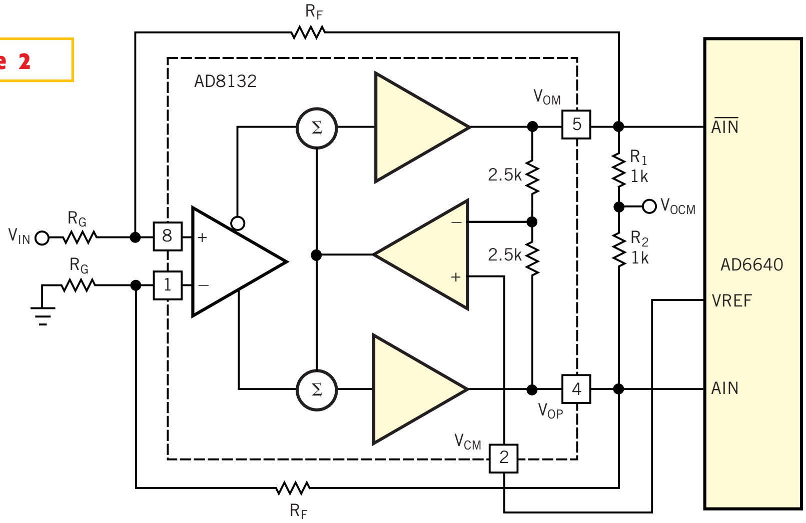
Figure 1



This ADC driver uses many resistors and is prone to errors.

The circuit consists of one AD8132 amplifier and four resistors. You can set the gain of the system by adjusting the ratio of R_F to R_G. The input accommodates both single-ended and dif-

Figure 2



An integrated amplifier provides improved accuracy and higher speed.

ferential signals. The circuit in **Figure 2** is a low-distortion, high-speed (300-MHz-bandwidth) driver. You can also use it to drive precision delta-sigma ADCs. **Figure 3** shows the performance at 10 MHz and unity gain ($R_F=R_G=499\Omega$). **Figure 4** shows the gain error and the low distortion in the circuit of **Figure 2**. The waveform at the node V_{OCM} indicates the output-balance error. The topology of **Figure 2**'s circuit also improves the common-mode rejection ratio, because it provides level-shifting to the reference voltage of the ADC.

Is this the best Design Idea in this issue? Vote at www.ednmag.com/ednmag/vote.asp.

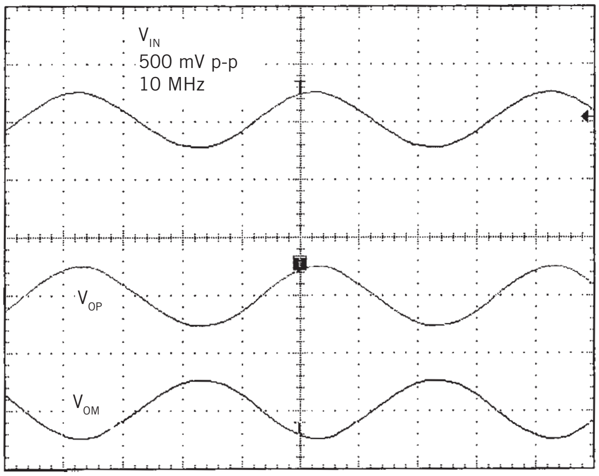


Figure 3 At 10 MHz and unity gain, the out-of-phase outputs have low distortion.

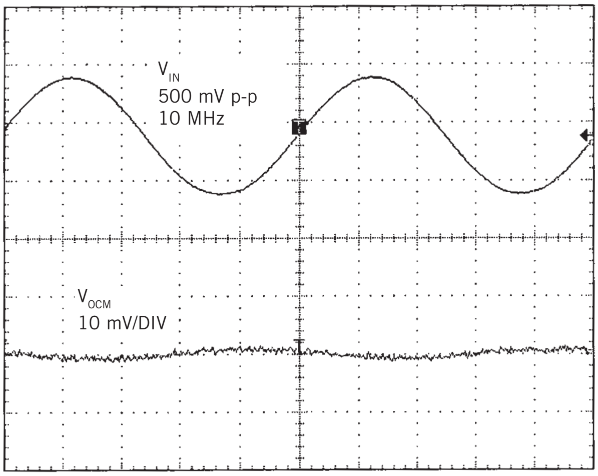


Figure 4 The output-balance error in Figure 2's circuit is lower than 1 mV with a 500-mV, 10-MHz input signal.

Circuit provides flexible gain ranges

Luo BenCheng, Chinese Academy of Sciences, Beijing, China

CERTAIN DESIGNS NEED a programmable-gain amplifier with a wide gain range and high accuracy and common-mode rejection. Usually, it's wise to exploit a programmable-gain instrumentation amplifier, such as an AD625. Unfortunately, the gain range of such standard parts is fixed at certain values, limiting their flexibility. **Figure 1** shows a multichannel, eight-level-programmable-difference-amplifier circuit. IC_1, an AD623, operates from a single supply. This amplifier is a low-power, low-cost instrumentation amplifier that offers good accuracy. A single external resistor sets the gain from 1 to 1000. IC_2, a CD4051, is a programmable, low-voltage 1-of-8 analog multiplexer, which connects to eight weighting resistors, R_0 to R_7, to increase the gain range of the circuit. The overall gain of the circuit depends on the value of the selected weighting resistor. You can compute the weighting resistors, R_0 to R_7, for a given input-output signal range as follows: $V_{OUT}=V_{IN}(1+2R_K/(R_X+R_{ON}))$, where R_{ON} is the on resistance of the CD4051, typically 125Ω. R_K is the 50-kΩ internal feedback resistor of the AD623, and R_X is one of the selected weighting resistors. IC_3, a CD4052, is a 2-of-8 programmable-difference-input IC. You can control the port-select pins, Z_0 and Z_1, of IC_3 and Z_2 to Z_4 of IC_2 with a µC, such as an AT89C51 or an 80C196. With the aid of some software, the circuit can provide self-adjusting gain.

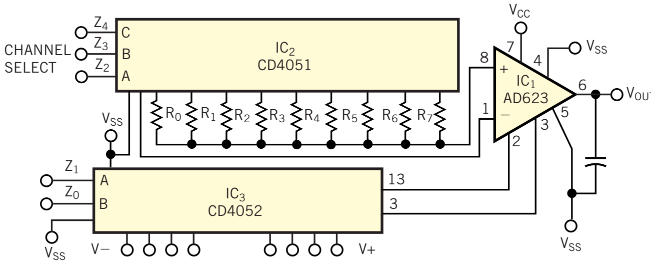


Figure 1 You choose the weighting resistors to obtain the optimum gain ranges for your application.

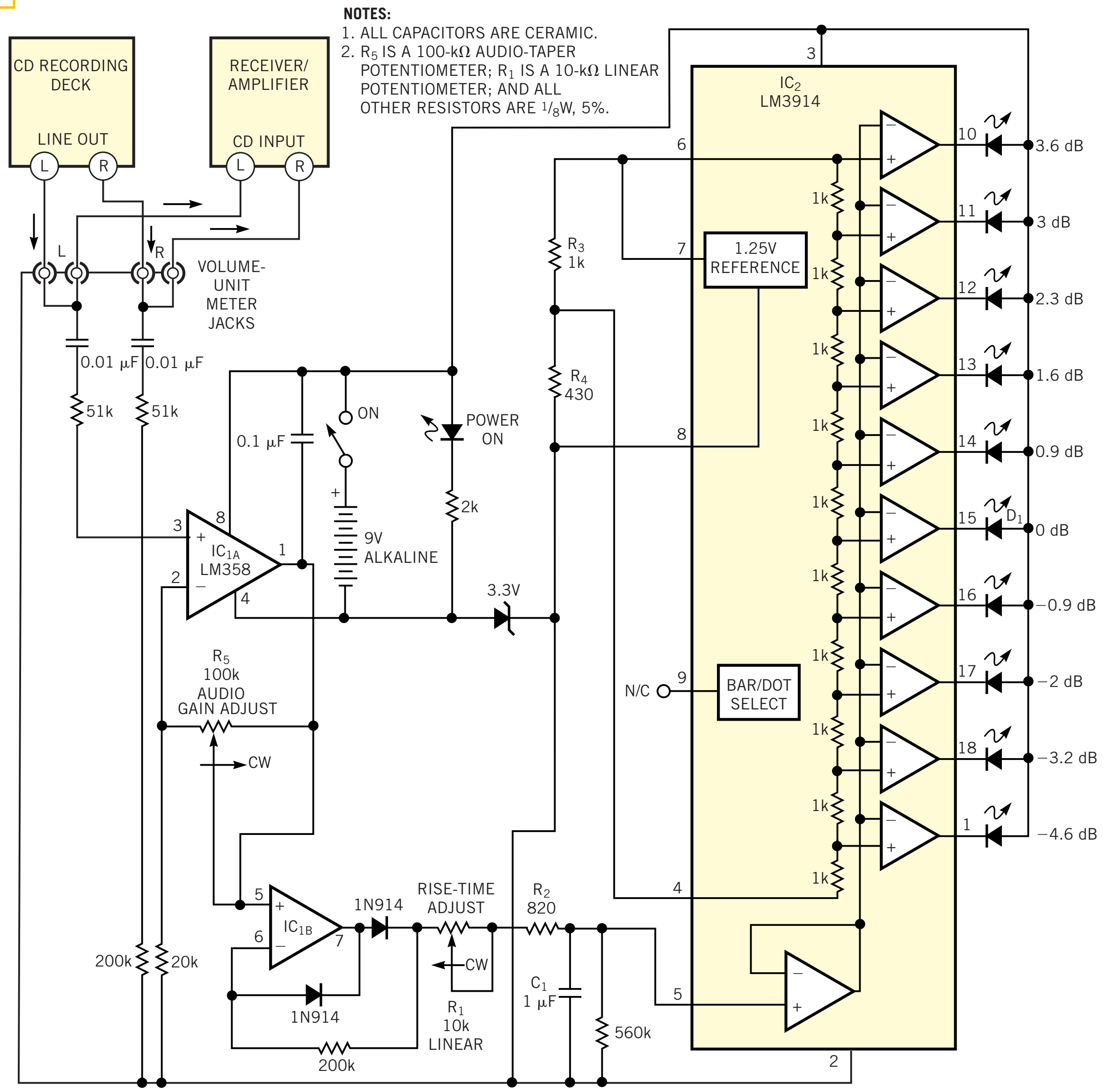
Is this the best Design Idea in this issue? Vote at www.ednmag.com/ednmag/vote.asp.

High-resolution volume-unit meter simplifies CD recording

Chester Simpson, National Semiconductor, Santa Clara, CA

Digitally recorded music on CDs offers superior quality to that recorded on vinyl records or tape, but most prerecorded CDs have an annoying characteristic: The average volume levels of the recorded signal can vary by as much as 14 dB from disk to disk. Significant variances, such as 4 dB, can occur from track to track on a single CD. This variation can be a problem when recording your own CDs because you can end up with large variations in loudness between songs.

Figure 1



NOTES:
1. ALL CAPACITORS ARE CERAMIC.
2. R_5 IS A 100-kΩ AUDIO-TAPER POTENTIOMETER; R_1 IS A 10-kΩ LINEAR POTENTIOMETER; AND ALL OTHER RESISTORS ARE 1/8W, 5%.

A high-resolution, average- (not peak-) reading volume-unit meter produces an accurate reading of loudness.

CD digital-recording decks typically have peak-reading-only volume-level meters. This feature is adequate to prevent clipping but does a poor job of reading the average volume, or loudness, level. If you set the recording levels just below the peak clip level, average volume variances of 6 to 8 dB can result due to varying levels of dynamic-range compression in recording the original material.

A high-resolution, average- (not peak-) reading volume-unit meter produces an accurate reading of loudness (**Figure 1**). The meter connects to the line outputs from the recording deck to monitor signal level. IC_{1A} sums the left and right channels and adjusts gain. This adjustment allows you to calibrate the 0-dB LED, D_1, to the signal level of your CD recorder.

IC_{1B} is a precision rectifier, which sends the positive portion of the signal to the input of IC_2, an LM3914 dot/bar-display IC. R_1, R_2, and C_1 filter the signal to the input of IC_2 to provide an averaging effect. R_1 adjusts the rise time of the signal, which increases or decreases the meter's ability to track a fast rising signal. Increasing R_1 slows rise time, making the meter more average-reading than peak-reading.

IC_2 contains all the necessary circuitry to drive a 10-LED string as well as an internal reference. R_3 and R_4 bias up the bottom of the resistor string to 0.4V above the ground pin, which effectively reduces the total decibel range of the meter and increases the resolution and accuracy of each LED step.

Another feature of IC_2 is that the resistors connected to Pin 7 externally program the LED current. The resistor values in **Figure 1** result in an LED current of approximately 8 mA. To conserve power, the circuit leaves the bar/dot-select pin, Pin 9, open to select "dot" mode. IC_2 has some built-in overlap, so that at least three LEDs are on at any time during typical operation of the meter, which eliminates flicker and makes the meter easier to view.

You use this volume-unit meter with the peak-reading meter in the recording deck. You should initially set up the recording levels by finding the loudest portion of the music and adjusting the record level of the deck to approximately 4 to 5 dB below the peak clip level the meter shows on the CD deck. The CD-deck makers advise against any clipping because it causes distortion. Backing off by 4 to 5 dB from the clip level allows some headroom in case later-recorded tracks have higher dynamic range (the ratio of peak signal level to average signal level). You should then set the gain-adjust potentiometer, R_5, so that the 0-dB LED lights on the loudest sound. Adjust subsequent track-record levels to this same level, based on the average loudness, to ensure that the deck's recording meter does not exceed the clip level.

Adjust R_1, the rise-time adjust, so that the meter will respond to average level changes but miss fast peaks. This control is user-adjustable, and the optimum setting depends on the music type.

The meter's bandwidth is approximately 250 Hz to 2 kHz; the upper limit depends on R_1's setting. This bandwidth selects the range of sound that most reflects perceived loudness based on the ear's frequency response. Lower bass signals typically have large signal levels in absolute magnitude, but the ear hears these signals less due to the Fletcher-Munson effect. If they register on the meter display, the bass-frequency signals would indicate higher loudness than you actually hear.

The ear also perceives very-high-frequency sounds less loudly than absolute magnitude would suggest, although the effect is not as pronounced as the low-frequency roll-off. So, to get an accurate approximation of loudness, the meter measures the middle range where the ear is most sensitive.

The battery current was measured and found to be 22 mA while operating, which means the expected battery life of a 9V alkaline battery should be at least 20 hours. Because the meter sets only record levels, you can switch it off during recording to conserve the battery.

The circuit connections to the external stereo system are in the line coming from the line outputs of the CD-recording deck and going to the input of the receiver/amp. The meter effectively connects in parallel with the input of the receiver/amp. For this reason the volume-unit meter's input impedance is very high to prevent loading the line output.

Is this the best Design Idea in this issue? Vote at www.ednmag.com/ednmag/vote.asp.

Small, portable altimeter operates from a single cell

Todd Owen, Linear Technology Corp, Milpitas, CA

SOME SPORTS ENTHUSIASTS want to know altitude changes from an initial elevation. A small, lightweight, portable altimeter is easy to design using modern micromachined pressure transducers. Inverting barometric pressure and compensating for nonlinearities in air-pressure changes with respect to altitude produces a reasonably accurate altimeter.

Figure 1 shows a small, handheld altimeter based on a micromachined pressure transducer. The circuit takes advantage of the inverse relationship between air pressure and altitude. The aim of this circuit is to be small, lightweight, and portable. Accuracy is not paramount; errors as high as 3%, such as a 300-ft error at 10,000-ft altitude, are acceptable. The speed of the circuit is also not critical: Extreme changes in altitude in milliseconds may prove fatal to whoever is attempting to read the output.

The heart of the altimeter is an NPC-1220-015-A-3L pressure transducer. This 5-kΩ bridge provides 0 to 50 mV of output voltage for a 0- to 15-psi pressure range. To power the transducer and signal-conditioning circuitry, a micropower dc/dc converter, IC_1, generates 5V from a single AA battery, and a charge pump generates a −5V supply.

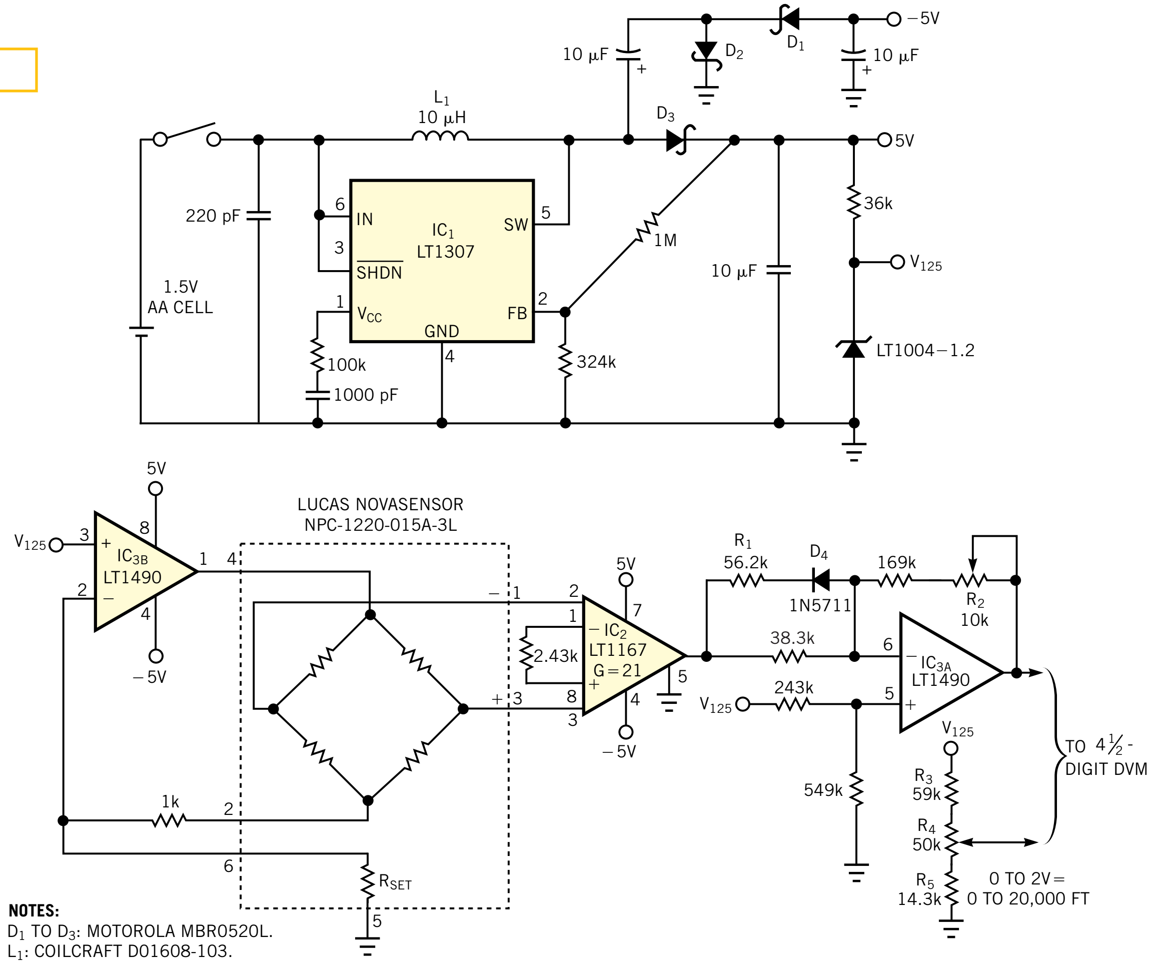
The output of the transducer drives an instrumentation amplifier, IC_2, which provides an initial gain of 21. A nonlinear gain stage comprising IC_{3B} and associated components then inverts the output of the instrumentation to provide a voltage that is inversely proportional to air pressure. D_4 and R_1 introduce the nonlinear gain, and the final output is directly proportional to altitude.

R_2 performs gain calibration in the signal-conditioning circuitry. This potentiometer calibrates out any normal variations in part tolerances and sets the altimeter for a 100-mV change in output for every 1000 ft of altitude. The circuit has some initial offset, as well as an offset that is determined by barometric-pressure variations. You can use R_3 to R_5 to null this offset, giving a 0 to 1V output for 0 to 10,000 ft of altitude.

Altimeter testing was performed using a DeHavilland DHC-6 Twin Otter for an ascent to 13,000 ft, followed by free descent—limited by the engineer's parasitic drag—to 3000 ft. Subsequent deployment of an aerodynamic decelerator (Precision Aerodynamics Icarus Omega 190) prevented engineer injury or circuit damage. Aircraft rental for testing is available at many local airports. Extensive instruction in free descent and the use of aerodynamic decelerators are highly recommended before undertaking testing of this nature. Contact USPA at 1-703-836-3495 for further information.

Is this the best Design Idea in this issue? Vote at www.ednmag.com/ednmag/vote.asp.

Figure 1



To produce a reasonably accurate altimeter, conditioning circuitry inverts the barometric pressure of a micromachined pressure transducer and compensates for nonlinearities in air-pressure changes with respect to altitude.

Circuit breaker monitors leakage current

Sharath Kumar, Gemplus R&D Centre, Dubai, United Arab Emirates

The residual-current circuit breaker in **Figure 1** continuously monitors the supply lines for any leakage current and immediately disconnects the supply if necessary. Load-supply wires, both live and neutral, pass through the magnetic core of the CR4311-5 transducer (www.crmagnetics.com), which monitors the supply current. Under normal circumstances, because the current flowing in both conductors is equal and opposite, no flux is generated in the transducer core. However, under faulty conditions, the current in the live wire exceeds the current in the neutral wire, which catalyzes the production of flux in the core. This transducer core has a secondary winding that generates a voltage based on the produced flux. The generated voltage ranges from 0 to 10V and is directly proportional to the sensed ac currents.

A high-speed comparator, IC_{1B}, detects this generated voltage and compares it with a set reference. If the detected voltage is within a tolerable range, the relay remains active, and the load remains connected to the mains supply. However, if this voltage exceeds tolerable limits, the circuit immediately deactivates the relay, thereby disconnecting the faulty load. Any further or repeated attempts to restart the device with the faulty load result in repeated tripping of the relay. You have to manually disconnect the faulty load and restart the device.

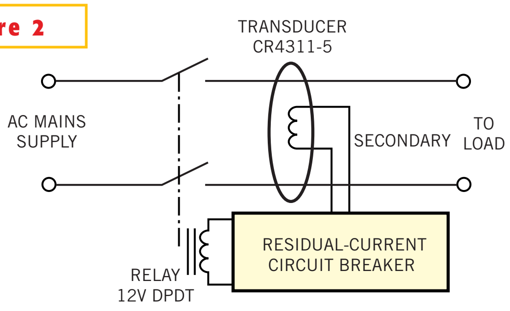
The circuit configures IC_{1B} as a precision, fast-acting voltage comparator. IC_{1A} provides a stable 6V reference to IC_{1B}. When the voltage on the noninverting input of IC_{1B} rises above the preset reference voltage on its inverting input, the output goes high. This output controls Q_1. When Q_1 turns on, Q_2 turns off, which deactivates the relay.

Two trim potentiometers facilitate tripping at user-preset levels. R_2 controls the coarse setting, and R_1 provides for finer adjustments. Typically, the muscles in the human body can tolerate current up to 20 mA. Hence, R_1 and R_2 must have settings that cause the relay to trip at leakage currents of greater than 15 mA that the transducer senses from the load-mains supply wires. R_3 allows control over the hysteresis. D_1 to D_3 provide protection. C_1 and C_2 are decoupling and charge-pump capacitors, respectively.

A 12V, 0.5A mains power-supply unit is sufficient to effectively run the circuit. The relay contacts must have a rating suitable for the load. **Figure 2** shows the wiring layout for attaching the circuit to an ac-mains circuit. All components are standard industrial grades and are commonly available.

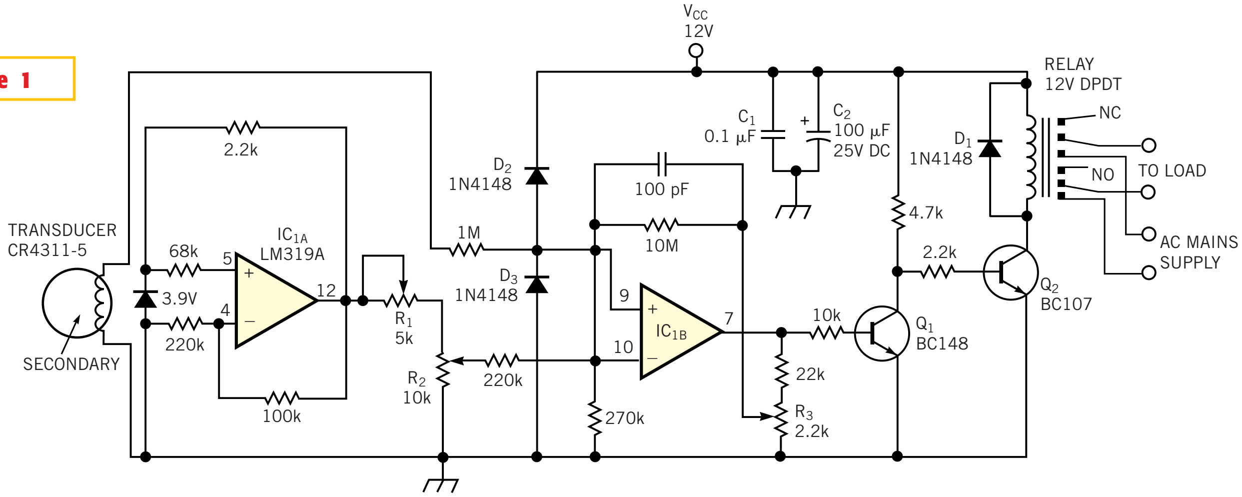
Is this the best Design Idea in this issue? Vote at www.ednmag.com/ednmag/vote.asp.

Figure 2



The residual-current circuit breaker uses a transducer to monitor the supply current and a relay to disconnect the mains from the load.

Figure 1



IC_{1B} is a precision, fast-acting comparator and controls whether the relay is active based on a preset reference-voltage level.