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Microcontroller functions as voltmeter

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The circuit in **Figure 1** is an extension of a previous Design Idea on how to use an analog input in a microcontroller lacking a built-in ADC, and it takes into account tricks from another Design Idea on how to drive a seven-segment LED display without external switching transistors (**references 1** and **2**). This circuit adds a serial link and needs only a twisted pair to send each measurement to a compatible PC. The serial link was tested using a Microsoft (www.microsoft.com) Hyper Terminal configured at 115,200 baud; at 8, N, and 1; and with no flow control.

Briefly, the software drives one seven-segment LED display at a time, through lines RA0 and RB7. Setting the RA0 output high and RB7 as the

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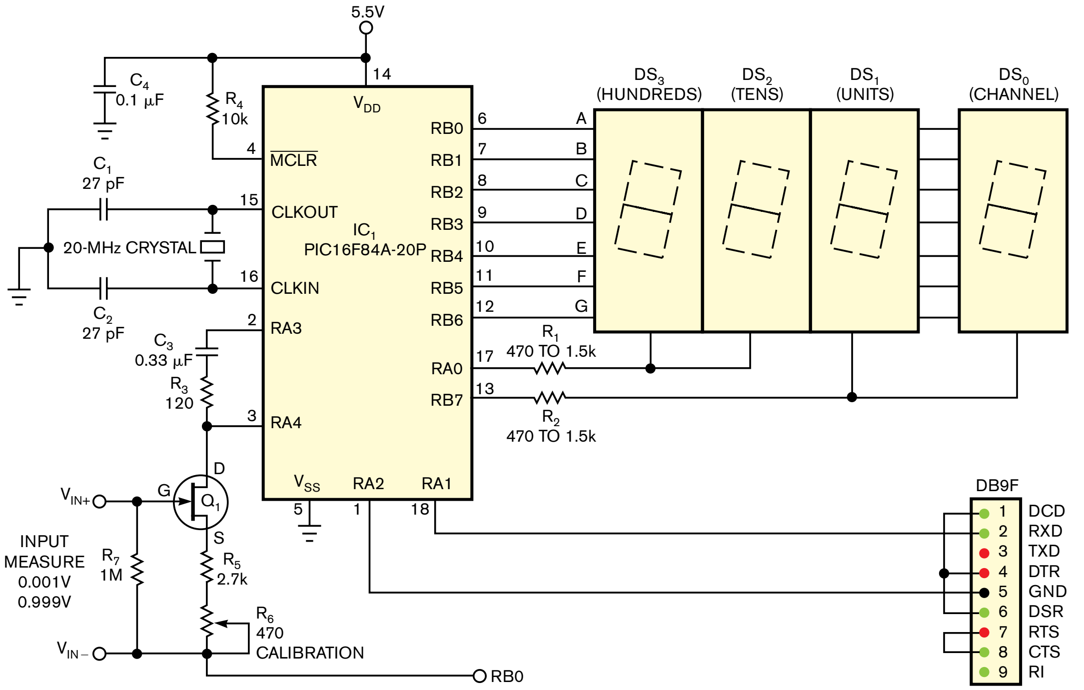

NOTES:
CURRENT LED IS 6.5 TO 2.1 mA.
DS_3 AND DS_1 ARE COMMON-ANODE, SEVEN-SEGMENT LED DISPLAYS.
DS_2 AND DS_0 ARE COMMON-CATHODE, SEVEN-SEGMENT LED DISPLAYS.
USE GRADE A ONLY FOR Q_1.

Figure 1 By using common-anode and common-cathode, seven-segment LED displays, the I/O ports of a microcontroller can drive the displays without using additional external components.

input activates common-anode display DS_3. Setting the RA0 output low and RB7 as the input activates common-cathode display DS_2. With RA0 as the input, setting the RB7 output high activates common-anode display DS_1, and, with RA0 as the input, setting the RB7 output low activates common-cathode display DS_0. While successively activating one display, only one line, RB0 to RB6, is configured as an output to drive one LED segment. This design no longer is limited to a V_{DD} of 3V or lower, because LEDs inversely connect in parallel, so the forward voltage of one diode limits the reverse voltage of the other. Using a red-diode display requires 1.6V.

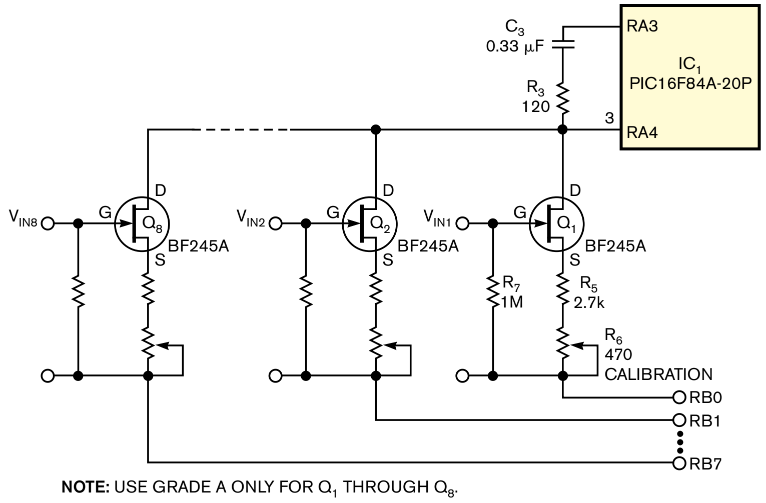

Figure 2 You can expand the number of voltages measured in Figure 1 by multiplexing additional transistor circuits.

Figure 2 illustrates the new aspects of this Design Idea. Q_1, R_5, and R_6 act as an equivalent variable resistor, R_X, which charges capacitor C_3. Instead of pulling R_X to ground, just connect it to one I/O—RB0, for example—of the microcontroller. If RB0 is an output with a low state, then the first analog channel activates, and the measure subroutine counts pulses of charge as high as 66% of V_{DD}; then, a look-up table converts this time delay to a three-digit millivolt value. To expand the number of analog inputs, you can connect as many as seven variable-resistor circuits in a parallel configuration—that is, each one connects between C_3 and one I/O line, RB1 through RB7. Notice that I/O lines connect to the display and also activate or deactivate the analog channels. When one analog-input channel activates through one I/O line with the output in the low state, the other lines are high-impedance inputs, which deactivate all other channels. Meanwhile, the display is off.

The circuit in **Figure 1** also adds a simple serial link with no added components. If you connect two I/O lines, RA1 and RA2, configured as outputs, to RXD (Pin 2) and GND (Pin 5) of an RS-232 connector, you can reproduce, by software, positive and negative voltages with respect to ground of the PC's RS-232 port. When RA1 is high and RA2 is low, then RXD has a positive voltage of 5V with respect to ground of the PC's RS-232 port. When RA1 is low and RA2 is high, then RXD has a negative voltage of −5V with respect to ground of the PC's RS-232 port. **Listing 1**, available at www.edn.com/070510di1, gives a practical example with a PIC16F84A-20P. It is not optimized but is fully commented to make it easy to translate to another Microchip (www.microchip.com) midrange device, such as a PIC16F628A, that supports a frequency of 20 MHz with more I/O lines.**EDN**

REFERENCES

1. Benabadji, Noureddine, "Microcontroller, JFET form low-cost, two-digit millivoltmeter," *EDN*, June 22, 2006, pg 71, www.edn.com/article/CA6343251.
2. Benabadji, Noureddine, "Ultralow-cost, two-digit counter features few components," *EDN*, Aug 17, 2006, pg 69, www.edn.com/article/CA6360316.

Simple test setup performs functional testing of linear, single-cell lithium chargers

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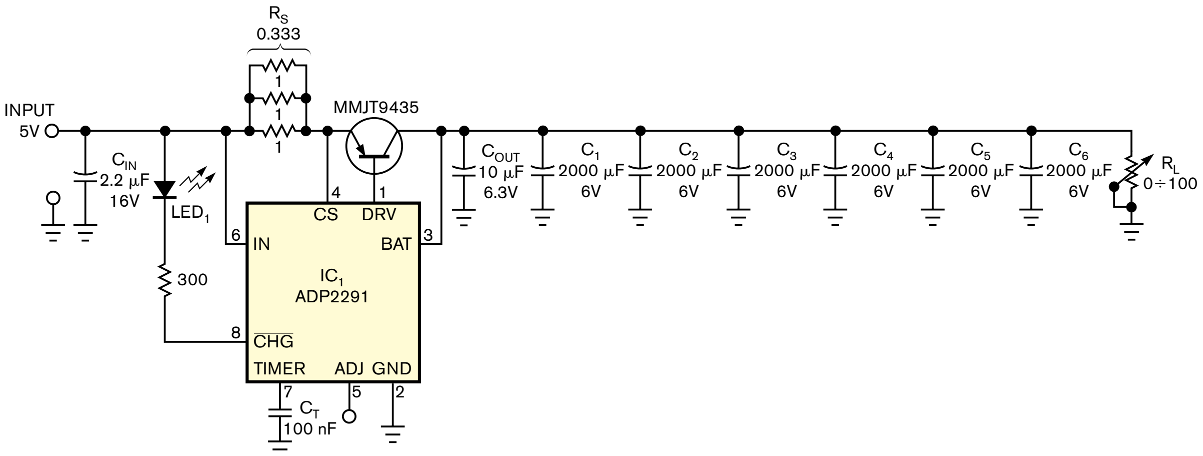
Most currently available battery chargers are switched-mode types. Yet, a niche application exists for modern lithium-ion, single-cell linear-IC chargers, which have per-cell voltage of 4.2V. Further, the 5V-dc supplies, which are convenient for supplying single lithium-cell chargers, are ubiquitous. A linear charger charges the lithium cell from the 5V supply voltage at an efficiency, η, of approximately 4.2V/5V, or 84%. Although this value is ideal, the practical value is somewhat lower because of the power consumption of the charger's control circuitry. However, its efficiency is comparable with that of the switched-mode chargers. Linear chargers also provide some additional



NOTES:
C_{IN} AND C_{OUT} ARE TANTALUM-CHIP CAPACITORS.
C_1 THROUGH C_6 ARE ALUMINUM-FOIL CAPACITORS.
C_T IS A CERAMIC-CHIP CAPACITOR.
LED_1 IS A 0805-SIZE, RED-CHIP LED.

Figure 1 A handful of off-the-shelf components allows you to qualitatively and quantitatively check the operation of a linear lithium single-cell charger.

benefits. They produce almost no EMI (electromagnetic interference), they require no inductors, and they require fewer capacitors than do switched-mode chargers.

The test setup in **Figure 1** employs IC_1, an Analog Devices (www.analog.com) ADP2291 for a lithium-cell linear charger. The device comes in 3×3-mm LFCSPs and QFN packages. The otherwise-welcome small dimensions of this IC pose an inspection problem. After soldering in the IC, you must perform a functional test of the charging circuit. You cannot rely on a visual inspection of solder joints, which are 0.5 mm apart.

In the charger circuit in **Figure 1**, for testing purposes, a bank of electrolytic capacitors substitutes for the lithium cell, dramatically reducing the charging interval and cutting the test time to seconds. Additionally, charging a capacitor has a well-defined course, and you can easily delete all previous charging and discharging by metallically short-circuiting the capacitor.

Also, a linear charger allows you to discharge the capacitor to 0V, which a lithium cell does not. After powering-on the circuit, you should momentarily light and then dim the LED annunciator to ensure that the charger is properly functioning. You estimate the time that the LED is on using the following **equation**:

$$t_{LEDON} \approx C\left(\frac{V_T}{I_{PR}} + \frac{V_{OUT}-V_T}{10I_{PR}}\right) = \frac{C}{I_{PR}}(9V_T + 1V_{OUT}),$$

where V_T is 2.8V, the threshold value of output voltage at which the charger enters its fast-charging mode; C is the total capacitance of the bank of capacitors that connect to output; I_{PR} is the precharge current; and V_{OUT} is 4.2V, the nominal output voltage at the end of the charging. The charge-current level is about 10 times that of the precharge mode. This condition occurs when you leave the ADJ (adjust) pin of the IC open. The first term in the parentheses of the **equation** corresponds to the precharge interval, and the second one expresses the charge interval. For a total capacitance of 0.012F, the precharge current is 46.5 mA, and the on-time of the LED is approximately 0.76 sec.

You can determine the value of the output threshold voltage by slowly turning the rotor of the variable-load resistor, R_L, from the minimum value of resistance until the LED dims. At that instant, you stop the rotor movement by disconnecting one end of the load resistor and measuring its value with an ohmmeter. The value of precharge current is then the output voltage divided by the measured value of the load resistor and the output voltage, or 4.2V. For the values of components in the **figure**, the experimentally determined value of a 44.4-mA precharge current is consistent with the typical value of 45 mA when the value of the current-sensing resistor is 0.33Ω (**Reference 1**).

You can measure the value of the threshold output voltage, V_T, as follows: Turn the rotor of the load resistor from minimum value of resistance while measuring the output voltage of the charger with a voltmeter. When the output voltage increases to about 2.6V, slowly proceed until the output abruptly changes to 4.2V. Using this method, you can determine the threshold voltage to be 2.75V.**EDN**

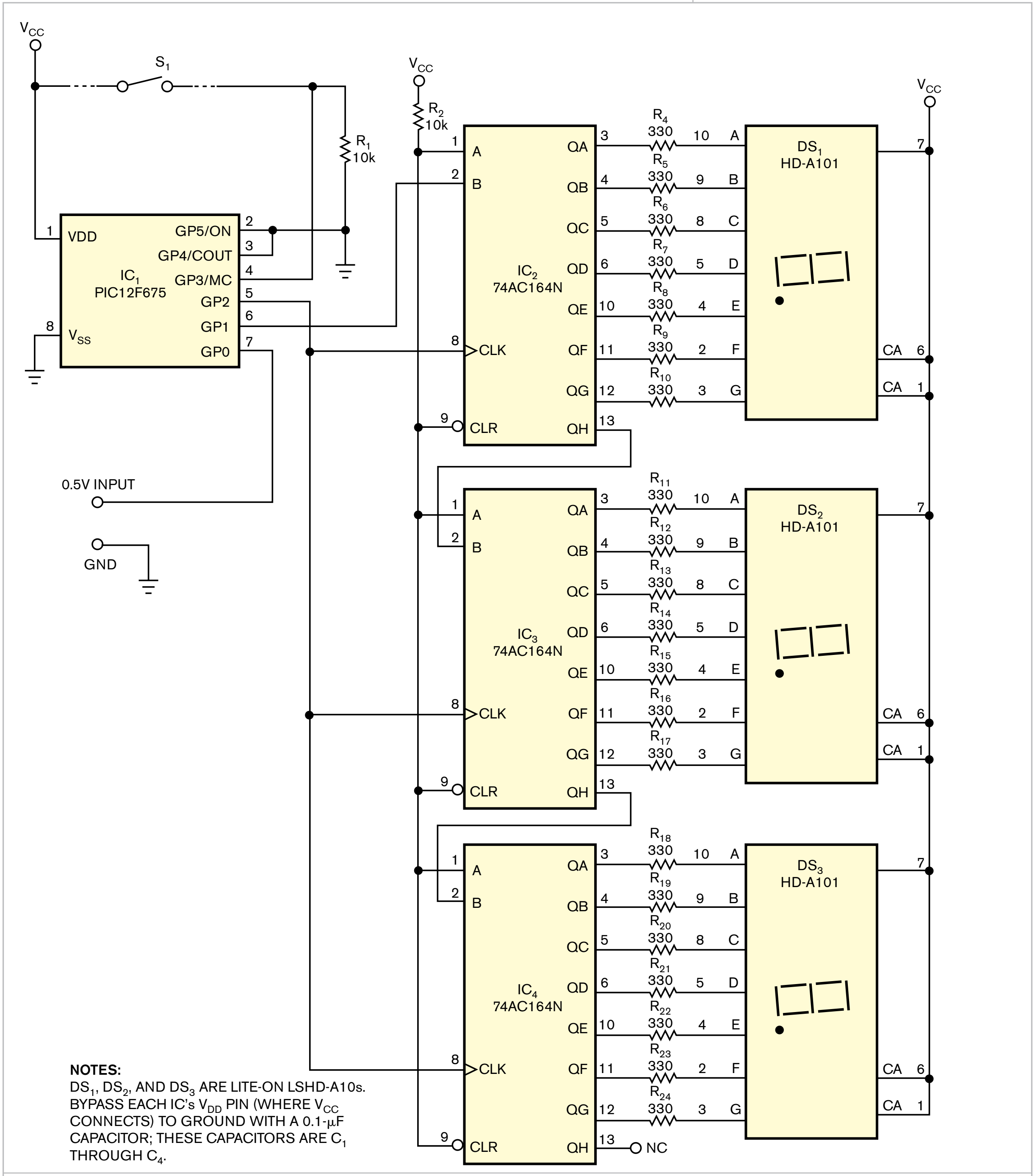
REFERENCE

1 "Compact, 1.5 A Linear Charger for Single-Cell Li+ Battery," ADP2291, Analog Devices, 2005, www.analog.com/en/prod/0%2C2877%2CADP2291%2C00.html.

Microcontroller provides low-cost analog-to-digital conversion, drives seven-segment displays

Name withheld by author's request

A previous Design Idea demonstrated how to use shift registers to increase a microcontroller's output capabilities (**Reference 1**). This expanded Design Idea provides low-cost analog-to-digital conversion and



NOTES:
DS1, DS2, AND DS3 ARE LITE-ON LSHD-A10s.
BYPASS EACH IC's V_{DD} PIN (WHERE V_{CC} CONNECTS) TO GROUND WITH A 0.1-µF CAPACITOR; THESE CAPACITORS ARE C_1 THROUGH C_4.

Figure 1 A low-cost microcontroller captures an analog voltage, converts it to a peak reading, and displays the results in decimal format on LED displays.

a three-digit, seven-segment display. Although applicable to other microcontrollers, the circuit in **Figure 1** uses a Microchip (www.microchip.com) PIC12F675 controller and three multiply sourced 74AC164 serial-input/parallel-output shift registers.

The circuit accepts incoming signals of 0 to 5V. The microcontroller, IC_1, performs the analog-to-digital conversion and subsequently converts the binary-voltage value to BCD (binary-coded-decimal) format. Next, the microcontroller converts the BCD values to hardware-specific seven-segment-display masks and shifts the masks to the 74AC164 registers, IC_2 through IC_4, which in turn drive the seven-segment displays.

INSTEAD OF DISPLAYING EACH INPUT VALUE AS IT'S CONVERTED, THE MICROCONTROLLER OPERATES AS A PEAK DETECTOR.

Available for downloading from the online version of this Design Idea at www.edn.com/070510di2, **Listing 1** implements an additional function. Instead of displaying each input value as it's converted, the microcontroller operates as a peak detector. When the maximum value changes, the microcontroller updates the three-digit display. A pushbutton switch, S_1, resets the maximum value. You can modify the code to apply other functions to the input data and calculate and display the data in other formats. In addition, you can modify the interrupt-driven conversion process to accommodate different sampling rates. When you modify the sampling rate or the ISR (interrupt-service routine), ensure that the ISR completes execution within a single sample period.**EDN**

REFERENCE

1. Raynus, Abel, "Squeeze extra outputs from a pin-limited microcontroller," *EDN*, Aug 4, 2005, pg 96, www.edn.com/article/CA629311.

Amplifier cancels common-mode voltage

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Since the dawn of time—or at least since the dawn of precision electronics—a major headache for analog designers has been CMV (common-mode-voltage)-induced errors, also known as the dreaded ground loop. Although almost mystical is the fear it strikes in the hearts of engineers, there's nothing particularly mysterious about CMV. CMV errors occur for a simple reason: The common voltage references—that is, ground—of circuitry in different places, such as sensors in one chassis and an ADC in another, are apt to differ. Therefore, when you

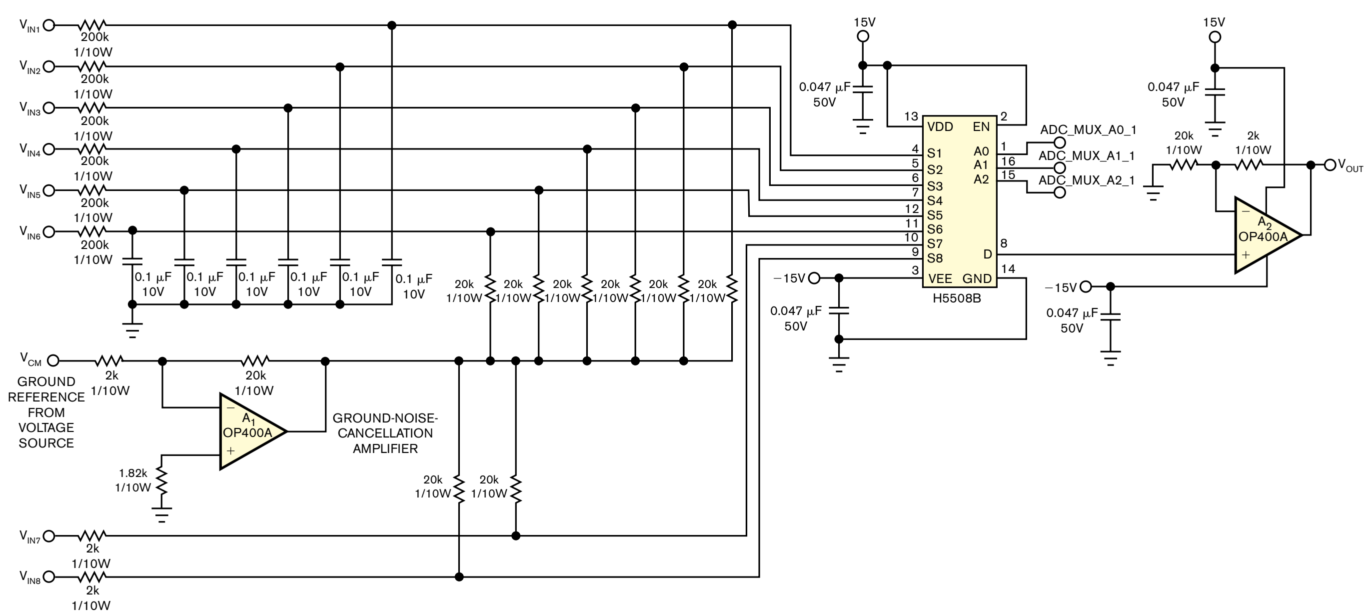

Figure 1 Amplifier A_1 amplifies and inverts the common-mode voltage by a factor of −10. Then, the circuit applies this signal to an array of passive summation networks. An analog multiplexer selects the desired input signal, and op amp A_2 supplies a compensating gain.

route signals between remotely located circuits, the CMV differential appears as additive noise and offset, corrupting the desired signals.

Many approaches exist for eliminating CMV errors. These methods include the brute-force approach of using massive amounts of copper in ground interconnections, fully differential instrumentation-amplifier signal conditioners, and galvanic isolators. Each has its place, depending on such factors as the severity of the CMV problem and the number of signal channels needing CMV remediation. One of the most popular and effective CMV remedies is differential amplification, in which you perform an analog subtraction to remove the CMV component from the signal. The downside of this method is that it requires a dedicated amplifier for every signal channel. The circuit in **Figure 1** is a variation on that same differential-amplifier idea, but it combines two shared CMV amplifiers with simple passive-resistor pairs among eight multiplexed channels to provide CMV cancellation for a large number of analog channels at minimum component count.

ONE OF THE MOST POPULAR AND EFFECTIVE CMV REMEDIES IS DIFFERENTIAL AMPLIFICATION, IN WHICH YOU PERFORM AN ANALOG SUBTRACTION TO REMOVE THE CMV COMPONENT FROM THE SIGNAL.

Here's how it works. Amplifier A_1 amplifies and inverts the CMV by a factor of -10. You then apply this CMV to an array of passive-summation networks—one for each input signal. The 10-to-1 ratio of the two legs of each network combines the incoming input-voltage and CMV signals with the –10V CMV ground-noise reference: $V=10/11\times(V_I+V_{CM})+1/11\times(10\times V_{CM})=10/11\times V_I+10/11\times(V_{CM}-V_{CM})=10/11\times V_I$. V_{CM} is attenuated by a factor depending mainly on the accuracy of 20- versus 2-kΩ resistor-ratio matching. For 1% matching, the CMRR (common-mode-rejection ratio) is approximately 100-to-1, or 40 dB; for 0.1% matching, CMRR is 1000-to-1, or 60 dB.

The analog multiplexer then selects the desired input voltage for input to the 11/10 scale-factor-correction amplifier, A_2. The optional 0.1-μF filter capacitors provide a modicum of low-pass noise filtering, and you should tailor them for the bandpass requirements of your application. The approximately 180 μsec, or approximately 88 Hz, is too slow for many applications and too fast for others. EDN