

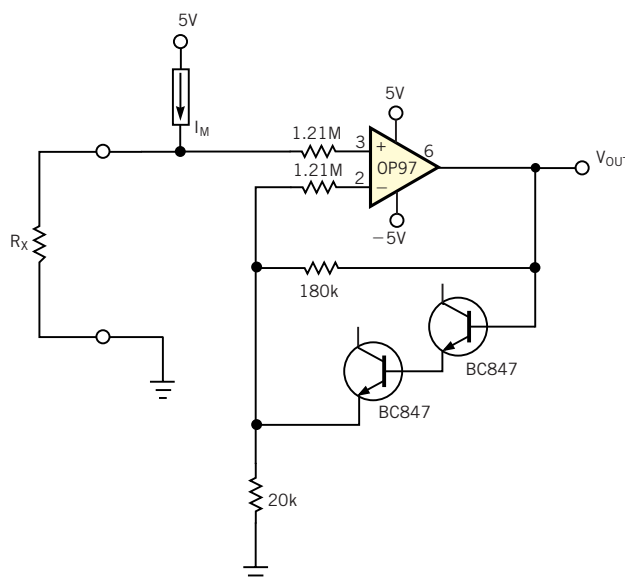
Edited by Bill Travis and Anne Watson Swager

Scheme cancels amplifier error

David Magliocco, CDPI, Scientrier, France

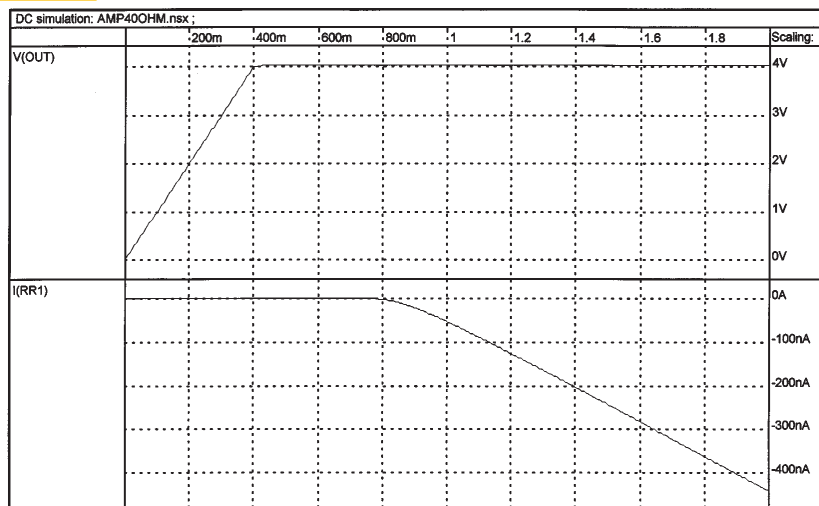
THE CIRCUIT IN **Figure 1**, using a low-offset amplifier, is a basic ohmmeter circuit common in multimeters, except for the addition of the two diode-connected transistors. A current source supplies a selectable current ranging from 100 nA to 1 mA to R_X . An A/D converter with a 400-mV reference voltage reads the voltage drop across R_X . Manufacturers of handheld DMMs limit I_M to 1 mA to save battery power. So, to measure resistance lower than 40 Ω with 10-m Ω resolution, you need to amplify the voltage drop across R_X by 10 times to fully use the ADC's dynamic range. For high-precision measurements, you need a low-offset, high-input-impedance amplifier. The moderate-power OP97 from Analog Devices is a good choice. Because the OP97's inputs have back-to-back diode protection, differential input voltages greater than 1V cause current to flow through the diodes, causing measurement errors. For example, errors can occur when you try to measure a high value of R_X , say a few megohms, with a wrong value of I_M .

Figure 1



The addition of two diodes in the feedback loop prevents excessive input current in the OP97.

Figure 2



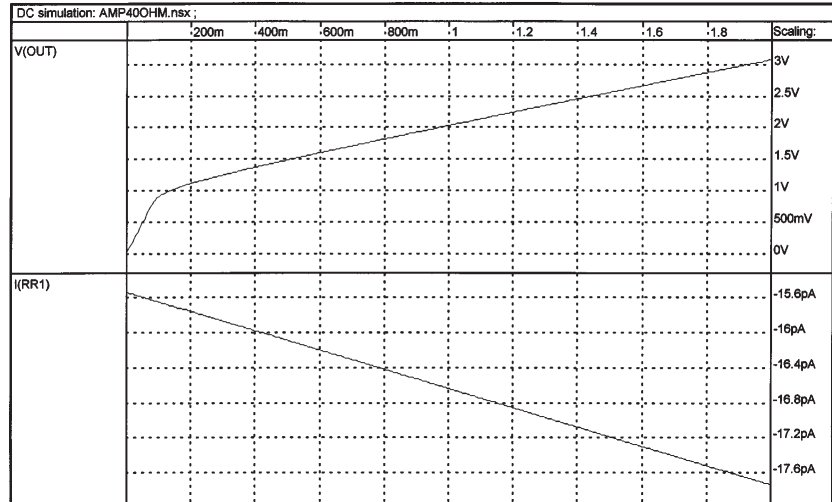
Without the diodes in **Figure 1**, the amplifier saturates, and current flows in the differential inputs.

Scheme cancels amplifier error.....	159
Serial port provides interrupts for 8031 μ C.....	160
ADC-to-PC interface transfers data in nibbles.....	162
Matched offsets put signals into ADC's range.....	164
Amplifier compensates piezoelectric-rate gyros.....	166
Digital camera subs as a scope camera.....	168
MOSFET pair makes simple SPDT switch.....	168
Motor controller operates without tachometer feedback.....	170

Not all the measurement current goes to R_x , so the converted value is inaccurate.

Figure 3

Figure 2 shows V_{OUT} and the current that goes into the noninverting input of the OP97 (without the diode-connected transistors), configured for a gain of 10, for input voltages as high as 2V. For V_{IN} greater than 1V, the leakage current becomes non-negligible in comparison with the lowest values of I_M . A simple way to limit the leakage current is to limit the gain of the amplifier for high input voltages. To prevent the differential input voltage from exceeding 1V, you can reduce the gain by limiting the voltage across the feedback resistor. When that voltage reaches approximately 0.8V, for example for $I_M R_x \approx 10$ mV, the two diode-connected transistors start to conduct and limit the gain. Transistors are better than signal diodes because they have lower leakage current at low voltages. Low leakage current is critical in avoiding additional errors when reading the output of the OP97. **Figure 3** shows V_{OUT} and the current that enters the non-



The diodes in **Figure 1** prevent the amplifier from saturating, so the input current remains negligible with respect to I_M .

inverting input of the OP97 for input voltages as high as 2V in the circuit of **Figure 1**. The leakage remains low in

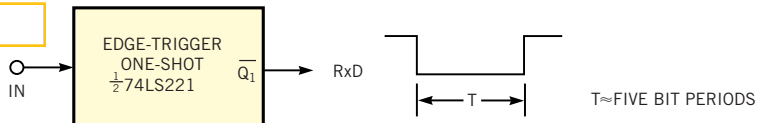
comparison with I_M . (DI #2447)
 To VOTE FOR THIS DESIGN,
 CIRCLE No. 301

Serial port provides interrupts for 8031 μC

N Kannan, Mediatronix Ltd, Trivandrum, India

YOU CAN USE THE RxD PIN of an 8031 μC for external interrupts (**Figure 1**). You program the serial port to receive in Mode 2 with a baud rate either $1/32$ or $1/64$ of the oscillator frequency, depending on the SMOD bit in the PCON register. In serial mode, the start bit should be a zero, and the stop bit should be a one for a valid reception. The μC generates the interrupt upon reception of a low start bit, nine data bits, and a high stop bit; the interrupt occurs at the end of reception. The one-shot multivibrator in **Figure 1** provides a low pulse (the start bit) to the RxD input with a width greater than one bit period; for example, four periods. The bit period depends on the baud rate. Whenever an external signal edge-triggers the one-shot,

Figure 1



You can use the serial port of an 8031 μC to generate interrupts.

the 8031 enters serial-reception mode and generates an interrupt after 10 bit periods. The only disadvantage of the method is that at least 10 bit periods should occur between interrupts. Also, you should use the μC 's ISR pin to reinitialize the controller for the next interrupt. If you can't guarantee the minimum period between interrupts, then you can use a dual 74LS221 one-shot

multivibrator. You can use the rising edge at $\overline{Q_1}$ to trigger a second one-shot and then use the output of the second to clear the first one-shot. This action forces $\overline{Q_1}$ to a high state for five to six bit periods to ensure a high stop bit. (DI #2441)

To VOTE FOR THIS DESIGN,
 CIRCLE No. 302

ADC-to-PC interface transfers data in nibbles

DS Oberoi, Jammu, India

THE CIRCUIT IN **Figure 1** uses a Centronics printer port to interface an eight-channel, 8-bit ADC to a PC. The circuit cuts the cost of addressing and decoder circuitry and saves one expansion slot for interfacing. The design uses three of the subport's various signals as control signals for channel selection, handshaking, and data transfer to the MAX158 ADC. These signals are programmable by means of a bit position in the control word of the respective port.

Two signals, P_Slct1 and P_Slct2, when high and low, respectively, select the MAX158 ADC. This arrangement overcomes any accidental-selection problem, which can happen when you use a single select bit. A falling edge at the RD and CS pins of the MAX158 initiates a conversion, and the read operation latches the

multiplexer address inputs, A₀ through A₂, for the channel selection. The level at the INT pin of IC₂ indicates the status of the conversion process. A low level at INT indicates that conversion process is over and that the converted digital data is available. The INT pin interfaces to the port through the D_Rdy signal. The corresponding software repeatedly samples this line to check its status. When D_Rdy is low, the PC reads the converted digital data through IC₁.

Only five input lines to the printer port are available, so the 8-bit data transfer occurs in two nibbles from IC₁. The higher or lower nibble is available when IC₁'s Pin 1 or Pin 19 is low, respectively. Under the control of the N_Slct signal, only one of these pins is low at once. The software then combines two nibbles to complete

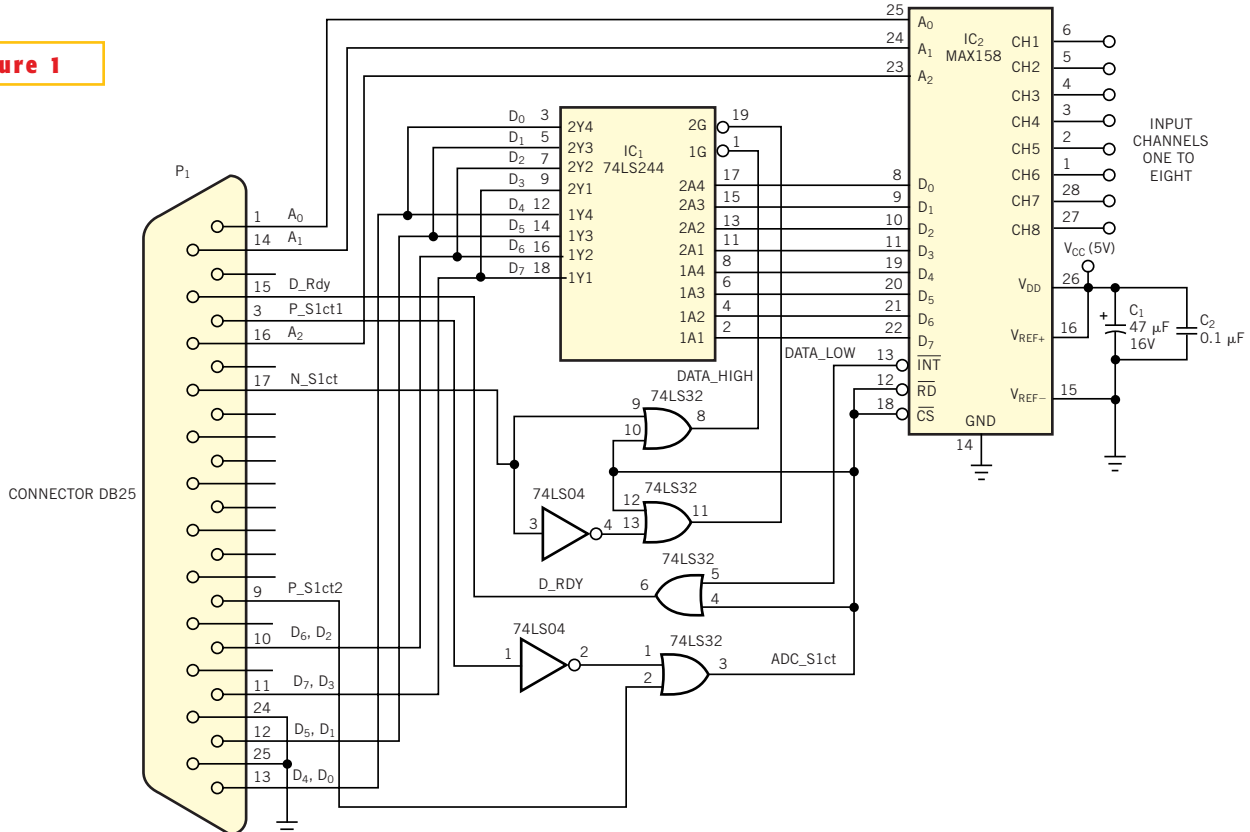
1 byte of data. The circuit uses the fifth input bit, which is the D_Rdy signal, to check the conversion status of IC₂.

V_{REF+} and bypass capacitors C₁ and C₂ connect to a 5V input supply, which results in a full 0-to-5V conversion. A 7805 regulator (not shown) generates V_{CC}.

The accompanying C program works satisfactorily and can scan all the channels one after the other and print the converted data on the screen. You can download the program from EDN's Web site, www.ednmag.com. Click on "Search Databases" and then enter the Software Center to download the file for Design Idea #2448. (DI #2448)

TO VOTE FOR THIS DESIGN,
CIRCLE No. 303

Figure 1



Only five input lines to the printer port are available, so the 8-bit data transfer from the ADC to the PC occurs in two nibbles from IC₁, under the control of the N_Slct signal from the PC.

Matched offsets put signals into ADC's range

Michael Petersen, Iowa State University, Ames, IA

THE CIRCUIT IN **Figure 1** measures a voltage that is negative with respect to the system's ground point. The constraint is that the a single supply powers the ADC, and its ground point is fixed relative to the measured voltage. A simple current source and matched resistor set provide the necessary offset to bring the voltage within the ADC's common-mode range.

This circuit was designed for measuring the current from a set of power trackers on the Iowa State University Solar Car, the PrISUM Phoenix. The power trackers provide impedance matching between the solar array and the main electrical bus on the car. Because the current shunt for the power trackers is on the low side and the ground reference point is on the electrical-system side of the shunt, the voltage is normally negative with respect to the system ground.

The current to be measured flows through the 0.01Ω shunt. Because the voltage is negative with respect to the system ground, you must add an offset to place the signal within the common-mode range of the ADC. The REF200

matched current sources and the $10\text{-k}\Omega$ matched resistors create this offset. This scheme provides a positive offset of approximately 1V with a reasonable temperature coefficient. Because the ADC measures a differential voltage, the exact offset is unimportant as long as both legs have the same offset and remain matched. For this application, 1V is an adequate offset because the maximum current expected to flow through the shunt is only 10A, which equates to a maximum differential voltage of only 0.1V. You can easily modify this offset for other current-and-shunt-resistor combinations by selecting different resistor values for the matched resistor pair. Take care not to make the resistance values too high because high values may cause settling-time errors on the ADC's input.

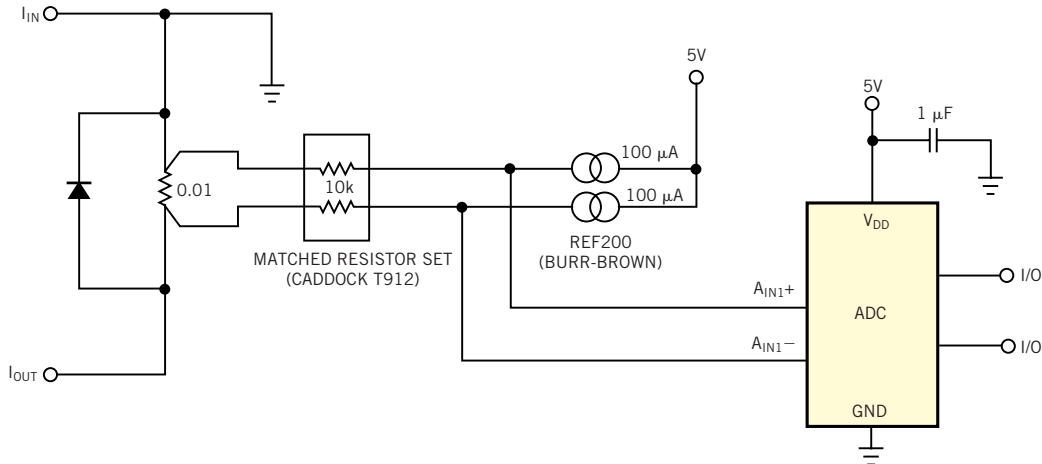
Suitable ADCs for this circuit are the AD7705 (Analog Devices) and the ADS121x (Burr-Brown Corp). These ADCs provide system-calibration capabilities that let you easily correct for slight mismatches in the current sources and resistors. The system-gain- and system-offset-correction features enable the cir-

cuit to maintain accuracy even in the presence of these mismatches. To adjust for offset, apply zero current and instruct the ADC to perform the system-offset calibration. To perform gain calibration, apply a current that corresponds to full scale and instruct the ADC to perform the system-gain calibration. You can obtain these calibration values, store them in the μC , and then send them to the ADC upon subsequent power-ups, eliminating the need for calibration on every power-up.

The diode across the current shunt passes any high-current transients when you apply the power source. In the original design, this feature was necessary to pass the high-current surge that charged the power tracker's output capacitors when the power trackers switch into the system. Without the diodes, this surge destroyed the current shunt. Depending on the application and the size of the current shunt, these diodes may be unnecessary. (DI #2450)

TO VOTE FOR THIS DESIGN,
CIRCLE NO. 304

Figure 1



A simple current source and a matched resistor set provide the necessary offset to bring the voltage within the ADC's common-mode range.

Amplifier compensates piezoelectric-rate gyros

Jim Mahoney, Linear Technology Corp, Milpitas, CA

LOW-POWER, LOW-COST ceramic piezoelectric rate gyros are available, but they lack the low-temperature-coefficient characteristics of their quartz counterparts. However, you can use a servo amplifier to remove the dc level shift due to temperature-related drift effects (Figure 1). The original application of these small, rugged gyros was for damping video-camcorder jitter, but these devices suit many other applications, including camera-platform stabilization, radio-controlled-airplane- and helicopter-rate-damping-control assistance, remotely piloted vehicles, and computer-mouse motion sensors.

By setting the time constant of the servo loop in Figure 1, the circuit responds at an appropriate low frequency for the system under control. The time constant you use for the servo loop depends on the

dynamics of this system, but 10 to 50 times the lowest frequency of interest is a good starting point. The dc-level drift occurs at a slow rate and hence appears to be a valid response. However, the rate-gyro amplifier also passes some frequencies above the set frequency. (The corner frequency of the highpass filter depends on what the circuit is controlling.)

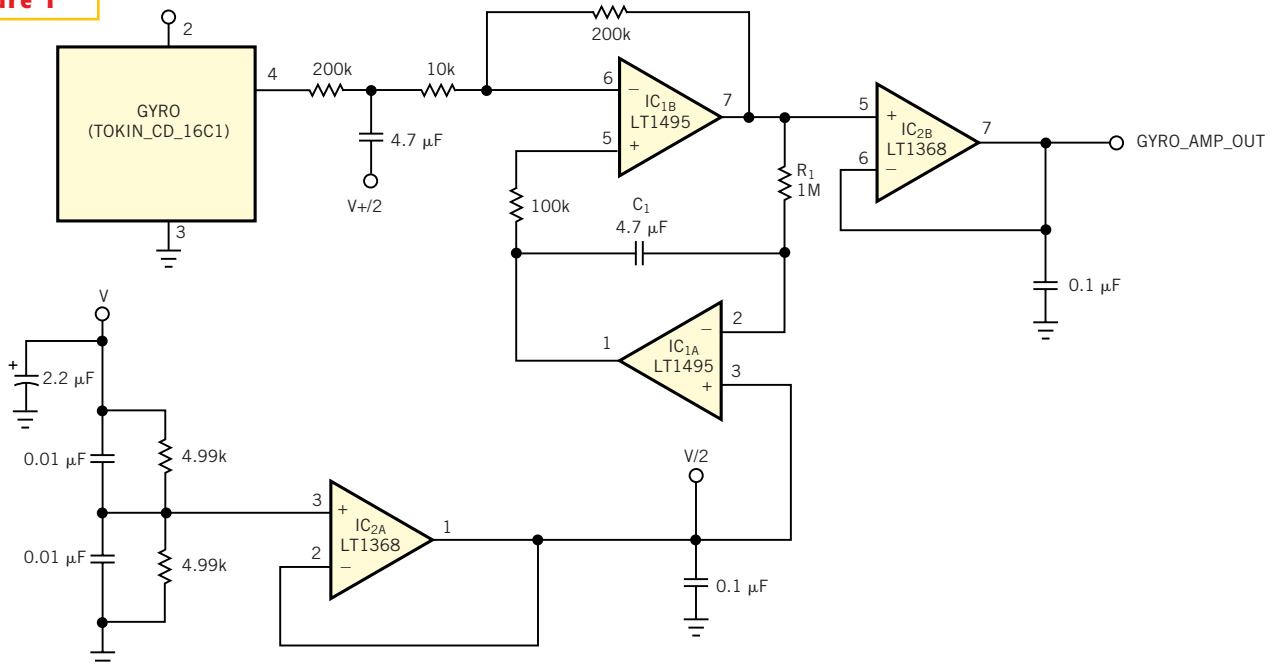
Amplifier IC_{1A} and its servo-driver stage, IC_{1B}, comprise a low-power op amp. The servo controlling the dc level ac-couples, or highpass-filters, the gyro's output by forcing the output of IC_{1A} to swing around $V \div 2$. The lowest frequency that the circuit passes is a function of the C_1/R_1 time constant. The maximum value of R_1 depends on the minimum input bias current of the op amp, which is 250 pA for the LT1495. If space permits,

C_1 should be a good low-leakage type, such as polystyrene, Teflon, or polypropylene. A Mylar capacitor compromises the integrator's performance.

The gyro and its amplifier can be some distance from the main processing circuit, and cable capacitance can cause many op amps to oscillate. However, the LT1368, IC_{2B}, at the output can drive cable capacitance without stability problems. The LT1368, IC_{2A}, also serves to drive a filter capacitor to provide a low-noise $\frac{1}{2}V$ reference point for the LT1495 servo driver. (DI #2453)

TO VOTE FOR THIS DESIGN,
CIRCLE NO. 305

Figure 1



Servo amplifier IC_{1A} removes the dc level shift due to temperature-related drift effects of a piezoelectric-rate gyro.

Digital camera subs as a scope camera

Allen Moore, Redmond, WA

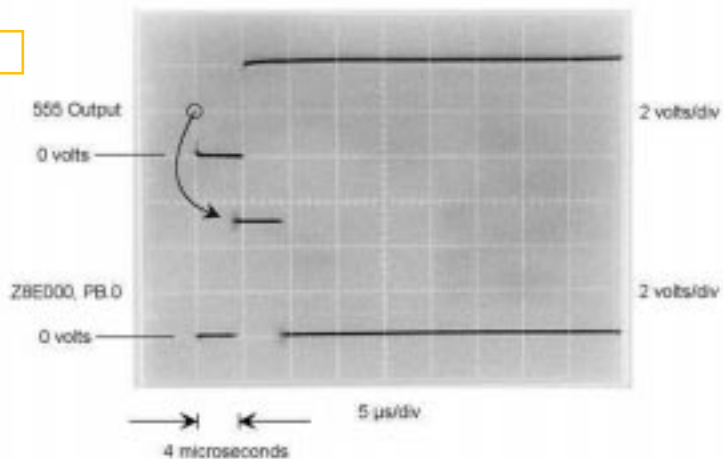
A DIGITAL CAMERA can be a handy substitute for an oscilloscope camera for older scopes that cannot output hard copy or digital data. A digital camera provides instant results and allows you to easily enhance the image and then add it to reports or Web pages.

If the scope has an illuminated graticule, turn up the illumination. A tripod is useful for repeated shots but is otherwise unnecessary. Position the camera and adjust the camera's zoom so that the oscilloscope screen fills the picture. Adjust lighting and position to minimize reflections.

After you take the picture, transfer it to a PC. You can then use an image-editing program to crop, rotate, and otherwise enhance the photo as necessary. To add annotations, such as text and arrows, to the image, you can import the image into a drawing program, although some image-editing programs offer this capability as well. You can then print the final image, insert it in a document, or add it to a Web page.

For output to monochrome devices, such as a black-and-white printer, it can be advantageous to first convert the color image to monochrome and then re-

Figure 1



If you use an old oscilloscope lacking hard-copy- or digital-output capability, you can use a digital camera to capture, save, and annotate the oscilloscope image

verse the result: Change the white to black and the black to white. This procedure results in sharp, dark lines for the oscilloscope traces against a light-gray background. Some digital cameras have a monochrome mode.

The image in **Figure 1** illustrates the results of this procedure in capturing a timing measurement using a Sony Mavica MVC-FD7 camera set to monochrome mode. After image capture, the

next step is cropping the resulting JPEG image using Microsoft Photo Editor 3.0 and then applying a reverse effect to swap the black and white tones. Finally, importing the image to Micrografx Windows Draw 6.0 allows you to add annotations, such as in the **figure**. (DI #2452)

TO VOTE FOR THIS DESIGN,
CIRCLE NO. 306

MOSFET pair makes simple SPDT switch

Howard Chen, Vishay Siliconix, Santa Clara, CA

WITH AN N-AND P-CHANNEL MOSFET, you can easily implement a single-pole double-throw (SPDT) switch to isolate part of a circuit and power it from a secondary supply for standby operation while the rest of the circuit is off (**Figure 1**). By using a complementary pair, you can use a single control input for the MOSFETs. An

Si4501DY MOSFET in this topology exhibits less than a 0.1V drop at 5A for the main element and contains both MOSFETs in an SO-8 package.

When the 2N7002 or similar control MOSFET ties the gates together and pulls them to ground, the p-channel MOSFET is on. Pulling the gates above the supply rail by turning the 2N7002 off results in

turning the n-channel MOSFET on. Pulling the gate of the p-channel MOSFET above the source potential has no effect; the MOSFET remains off with low leakage.

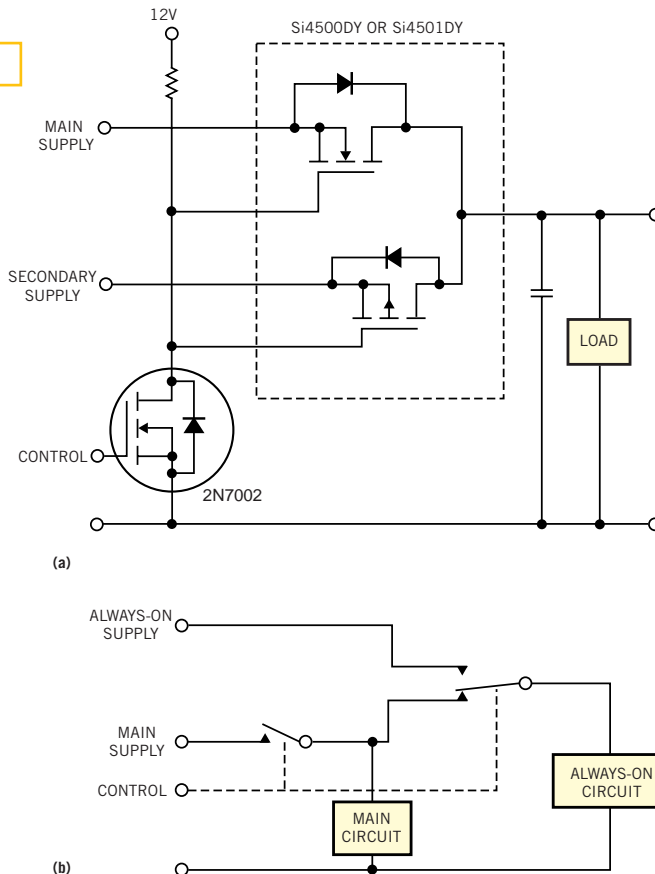
The resultant switch is a break-before-make configuration, which is necessary to ensure that the secondary, or always-on, supply never has to power the whole

circuit. However, due to the fast switching of the MOSFETs, extra capacitance beyond normal design rules is probably unnecessary to maintain the operating voltage.

The arrangement of the n-channel device in the circuit ensures that the internal diode does not conduct while the subcircuit is isolated. In this direction, the n-channel MOSFET also provides a fail-safe path for the circuit's power through the diode. The forward voltage of the p-channel MOSFET's diode blocks any current from "back-feeding" the secondary supply, assuming that the two supplies are close in voltage.

An example of an application for this circuit is the Advanced Configuration and Power Interface in desktop computers providing instant-on and low power consumption in standby. The main power supply is a high-power switching power supply, and the secondary supply is a 60-Hz transformer with linear regulation. (DI #2451)

Figure 1



An n- and p-channel MOSFET pair comprises a break-before-make, single-pole, double-throw switch (a). The switch isolates part of a circuit and powers it from a secondary supply during standby operation when the rest of the circuit is off (b).

TO VOTE FOR THIS DESIGN,
CIRCLE NO. 307

Motor controller operates without tachometer feedback

Bruce Trump, Burr-Brown Corp, Tucson, AZ

SPEED CONTROLLERS have long exploited the reverse-EMF characteristics of dc motors to control their speed. These linear driver circuits use power op amps to create a negative resistance drive to the motor that counteracts the voltage drop in the motor's series resistance (Reference 1). The circuit in Figure 1 shows an implementation of this type of speed control using a PWM drive, which reduces power dissipation in the drive circuitry.

Control voltage V_{IN} sets the speed, and IC_1 , Q_1 , and R_3 convert V_{IN} to a 0- to 200- μ A current. The current source controls the duty cycle of the PWM driver, IC_2 , at Pin 3. D_1 , D_2 , and R_5 prevent the circuit from pulling the control input too low, which can cause an inversion in the control loop.

Motor current flows through the internal switching transistor in IC_2 out the common terminal and through the cur-

rent-sense resistor, R_s . The circuit filters and scales the voltage across the sense resistor to provide positive feedback to the input circuitry through R_2 . With the proper amount of positive feedback, an increase in motor load increases motor current, which increases duty-cycle drive to maintain constant speed.

The equation of speed balance is

$$I_M(R_M + R_S) = I_M R_S \left(\frac{R_1}{R_1 + R_2} \right) \left(\frac{V +}{R_3 \times 200 \mu A} \right)$$

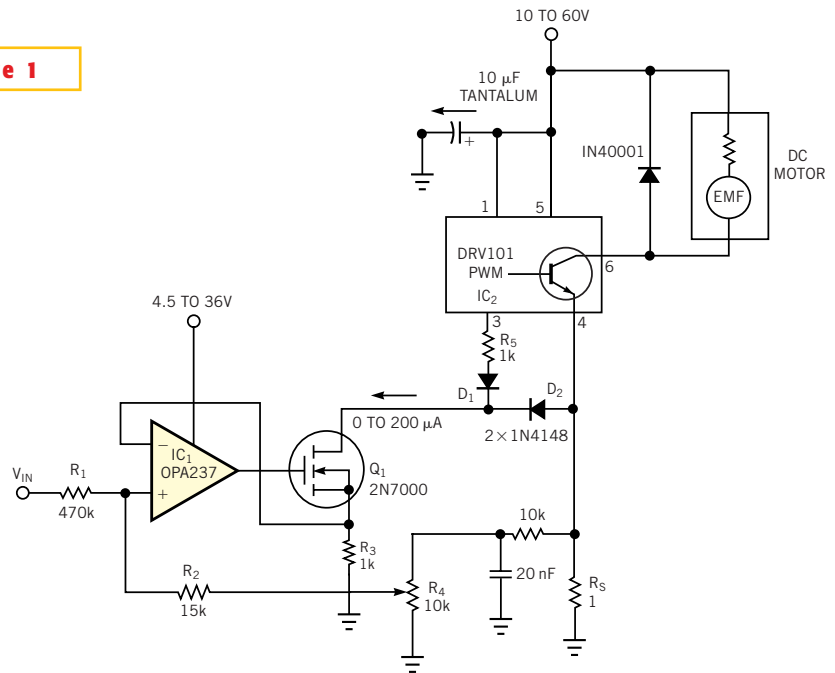
This model neglects losses in the switching circuitry of IC₂. Depending on supply voltage, such losses may significantly affect the required feedback. Unlike the power op amp implementation of the scheme, the absolute supply voltage affects this compensated PWM controller. The voltage lost in switching is not truly resistive and can be tricky to model. In practice, you can optimize the speed control by adjusting the positive feedback control at R₄. With proper adjustment, motor speed remains relatively constant with substantial changes in load. Although less accurate than true closed-loop tachometer-feedback controllers, this low-cost technique provides a dramatic improvement over simple voltage drive. (DI #2449)

REFERENCE

1. Burr-Brown Applications Bulletin AB-152

TO VOTE FOR THIS DESIGN,
CIRCLE NO. 308

Figure 1



Positive feedback derived from current-sense resistor R₅ increases the duty-cycle drive from PWM controller IC₂ to compensate motor speed with varying loads.