

Edited by Bill Travis

Optocouplers are handy for motor drive

Jean-Bernard Guiot, DCS AG, Allschwil, Switzerland

FIGURE 1A SHOWS a latching circuit based on an optocoupler, IC₁. If the off switch remains closed, pressing the on switch powers the LED in the optocoupler. Thus, the transistor in IC₁ turns on. You can now release the on switch, and the transistor remains on. You must adapt the current-limiting resistor, R, to the power-supply voltage and the optocoupler's characteristics. To turn off this latch, press the off switch, thereby cutting the current path. The output of this circuit comes directly from the collector of the transistor. If

you need an isolated output, you can use the circuit in **Figure 1b**, which works similarly to the circuit in **Figure 1a**. **Figure 1c** shows a similar circuit but with an NO (normally open) switch for both the off and on switches. Shorting the LED in IC₁ turns off the transistor in IC₁. Thus, IC₂ also turns off. Note that simultaneously pressing both the off and the on buttons turns on the output. But be aware that pressing the off button reduces the voltage across the circuit

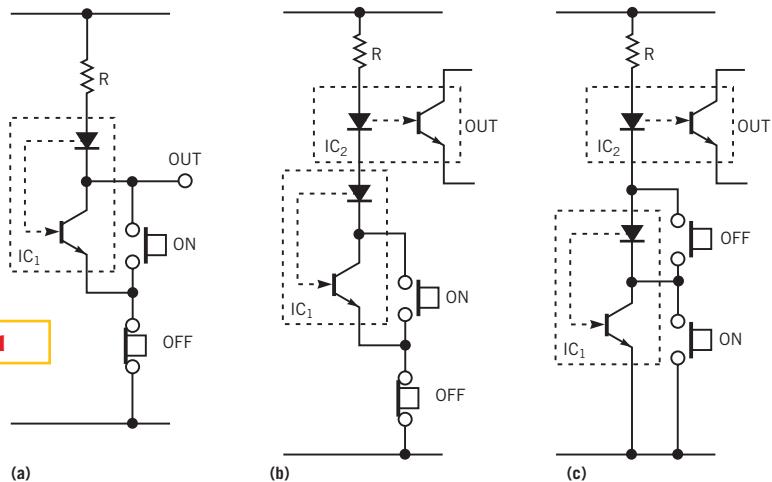
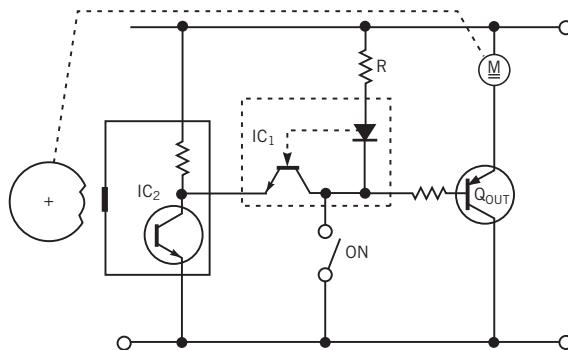


Figure 1

Various optocoupler-latching circuits are suitable for motor control. In (a) and the isolated circuit (b), simply pushing the on button turns on the circuit. In (c), you push both buttons simultaneously.

Figure 2



A notched cam controls a proximity switch, which determines the motor's stop positions.

below the resistor by 1 to 2V; you must consider this fact when you calculate the value of R.

Figure 2 is a simplified schematic of an application in which a motor must always stop at a defined position. "Simplified" means that it shows only the parts needed for illustrating the optocoupler's role

and omits protection, correct polarization, and a braking circuit, for example. IC₁ is the latching optocoupler. IC₂ is an npn-transistor, NO proximity switch. The proximity switch is on when metal is near its sensing area. A cam with a notch mounts on the motor axis. The motor should stop when the notch pass-

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es the sensing area of the proximity switch. Closing the on switch turns on transistor Q_{OUT} , thus allowing the motor to rotate, regardless of the status of the rest of the circuit. When you open the on switch, two things can happen:

- The notch is near the sensing area of the proximity switch. IC_1 and IC_2 are both off, so Q_{OUT} receives no base current. Therefore, the motor does not rotate.
- Metal is near the sensing area of the proximity switch, turning on the switch. The LED and, therefore, the

transistor, in IC_1 are still both on. Thus, the motor continues to rotate until the notch nears the sensing area of the proximity switch. At this point, the motor ceases to rotate.

All circuits were tested using a PC814 optocoupler from Sharp (www.sharp.co.jp). (The circuit in **Figure 2** has been running for a few months on several machines.) Optocouplers, such as the 4N33, with accessible transistor bases are more difficult to use in this application. Of course, these circuits cannot replace all relays. But they are convenient and effective

in applications in which the current and voltage are in the range of optocouplers. (You can add some amplification by adding some power Darlington transistors.) The main advantages of these types of circuits are that they are low-power, have no mechanical noise, have no switch bounce, cost only about 50 cents, require no critical components, and measure less than 6×10 mm.

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Linear regulator = low-cost dc/dc converter

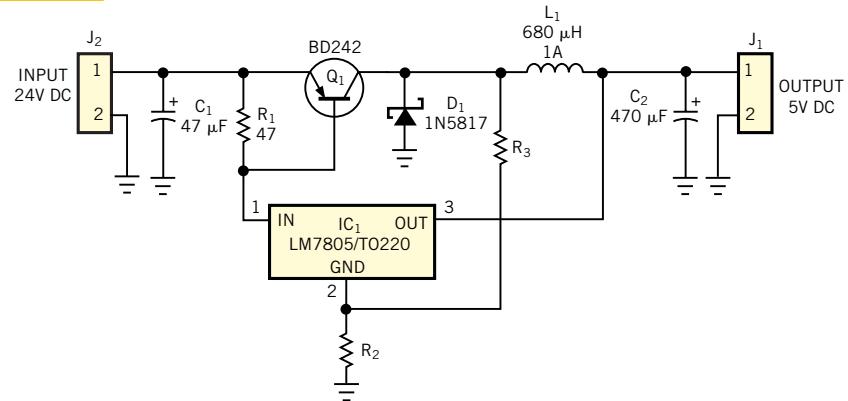
Susanne Nell, Breitenfurt, Austria

THE CIRCUIT IN **Figure 1** is a good choice if you need a power supply with high efficiency

Figure 1

and you don't want to use expensive dc/dc-converter ICs. The heart of the circuit is IC_1 , the common, inexpensive LM7805 linear regulator. The external switch is a pnp transistor; the circuit can easily source more than 1A output current. As an additional feature, the switching circuit automatically turns off if the load draws no or only a few milliamperes of currents. Under these conditions, the circuit works as a normal linear regulator. When you first apply input voltage, current flows through resistor R_1 and through the LM7805 to the output. Current also flows through the emitter-base junction of Q_1 and turns on the transistor. The current through inductor L_1 now rises, and the output capacitor, C_2 , charges. When the output reaches the rated output of the linear regulator (5V for the LM7805), the regulator switches off its output.

Now, transistor Q_1 switches off, because the LM7805 cuts off Q_1 's base current. When the switch turns off, the voltage across the inductor changes polarity, and current flows through diode D_1 . The current delivers more charge to C_2 , until all the energy stored in L_1 transfers to C_2 . If a load is present at the output, the load



You can use a linear regulator in a switching circuit to configure an inexpensive dc/dc converter.

current discharges C_2 . When the output voltage drops a few millivolts below the 5V output voltage of the LM7805, the LM7805 again starts sourcing current to the load. This action switches on Q_1 , and the cycle starts again. Under light- or no-load conditions, all the output current flows through the LM7805, and Q_1 always stays off. You can adjust the switcher's start current by selecting the value of R_1 .

You can also use this circuit for output voltages greater than 5V. You can replace the LM7805 with an LM7812 or an LM7815 to obtain 12 or 15V at the out-

put. For these higher voltages, you should add resistors R_2 and R_3 . These resistors add some hysteresis to the circuit, reducing the switching frequency. Typical values are 2.2 and 2.2 k Ω , respectively. With the circuit in **Figure 1**, you can attain efficiency approximately of 75% when you convert 24V to 12V. If you use a 5V regulator, efficiency drops to 65%, but that figure is still better than that of a pure linear regulator.

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Make eight-channel measurements through an LPT port

J Jayapandian, IGCAR, Tamil Nadu, India

THE CIRCUIT IN **Figure 1** represents a simple and cost-effective way to obtain eight-channel analog-signal acquisition through a PC's LPT port. IC₁, a 12-bit, serial-output MAX187 ADC, operates from a single 5V supply and accepts analog inputs of 0 to 5V. IC₂, an eight-channel MAX338 analog multiplexer, also operates from a single 5V supply. The circuit acquires eight analog inputs and displays eight independent digital readouts in a Microsoft Windows environment. The MAX338 connects one of eight inputs to a common output through the control of a 3-bit binary address. The design requires no external power supply; it instead derives power from the LPT port's data lines D4, D5, and D6 (pins 6 to 8 on the DB-25 connector). The low-power design consumes less than 1-mA of operating current. You derive the positive supply, V₊, and the logic supply, V_L, by using IC₃, a simple, ICL7660-based voltage-doubler circuit. The ICL7660 is a negative-voltage converter. The bits D0 through D3 (pins 2 to 4 on the connector) provide the channel-selection function. The controlling software in this design uses National Instruments' (www.natinst.com) LabView Version 6.0 graphics language. The software allows for channel selection through the Data port (0x378) and collects the ADC's serial data through one of the bits in the LPT1 Status port (0x379). (The Status port uses Pin 15 on the connector, the LPT port's Error input.) You can download the LabView software from the Web version of this Design Idea at www.ednmag.com.

Once the ADC completes the conversion, its Data Ready pin switches from high to low. The DRDY output of the ADC connects to the LPT's port Pin 10 on the connector (the Acknowledge input). The controlling software senses the DRDY signal through the Status port

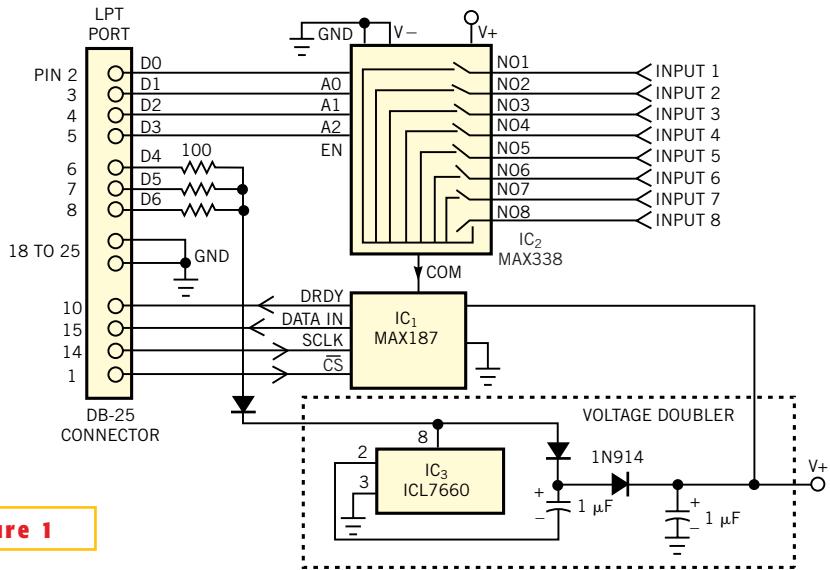


Figure 1

You can obtain eight-channel analog measurements through a PC's LPT port.

Figure 2

- CHANNEL 1
- CHANNEL 2
- CHANNEL 3
- CHANNEL 4
- CHANNEL 5
- CHANNEL 6
- CHANNEL 7
- CHANNEL 8



This front-panel view represents a LabView Virtual Instrument for an eight-channel ADC.

(0x379) on Pin 10 and sets the ADC's chip-select pin CS to low, through Pin 1 (Data Strobe output) in the Control port (0x37A). The routine then receives the MSB (most-significant bit) from the

ADC. After receiving the MSB, the software generates the serial-clock output (SCLK) through Pin 14 (Auto Line Feed output) in the Control port (0x37A) and then receives the remaining 11 bits from the ADC. Upon reception of all 12 bits, the CS input goes high to enable the ADC to accommodate new data in its tristate output buffer. The sequence continues, and the digital panel meter displays the acquired data. One input of the LPT port (control port 0x37A, Pin 15) acquires the serial, 12-bit data. The controlling software shifts most of the bits left, according to the bit position, and some of the bits right (because the serial data is in the fourth bit of the data in the status port (0x379)). The software sets other bits to zero.

Finally, a logical OR function of the 12 bytes/words delivers the 12-bit pattern of the acquired signal. For example, the 12th bit (MSB) appears as the first bit for transfer. This bit must be set as the 12th

position of the word; hence, the data received through the fourth bit, D3, must shift left through seven positions to be assigned as an 11th bit, and so on. In this sequence of data structuring, once the fourth bit (LSB 4) of the 12-bit pattern appears, it needs no shifting, because it is an actual D3 bit. The third bit, D2, requires shifting in the right position by one, and the D1 and D0 bits need right-shifting by two and three, respectively. This method of shifting and finally performing a logical-OR operation delivers

the exact 12-bit data pattern from the serial data received through one line of the parallel port.

D0 through D3 bits in the Data port (0x378) enable the channel selection. For each channel selection, the cited sequence of acquiring the data and conditioning it provides eight independent digital readouts. The downloadable LabView Virtual Instrument program (newmulti_MAX187.vi) is a self-explanatory graphics program for the data-acquisition process. In the program, a time de-

lay of 125 μ sec between SCLK and the serial-data read sets the data-transfer rate at 4 kHz. This time delay allows the read cycle to read exactly at the midpoint of the data bit to avoid improper data reads. You can reduce the time delay for faster data acquisition. **Figure 2** shows the front-panel view of the LabView Virtual Instrument.

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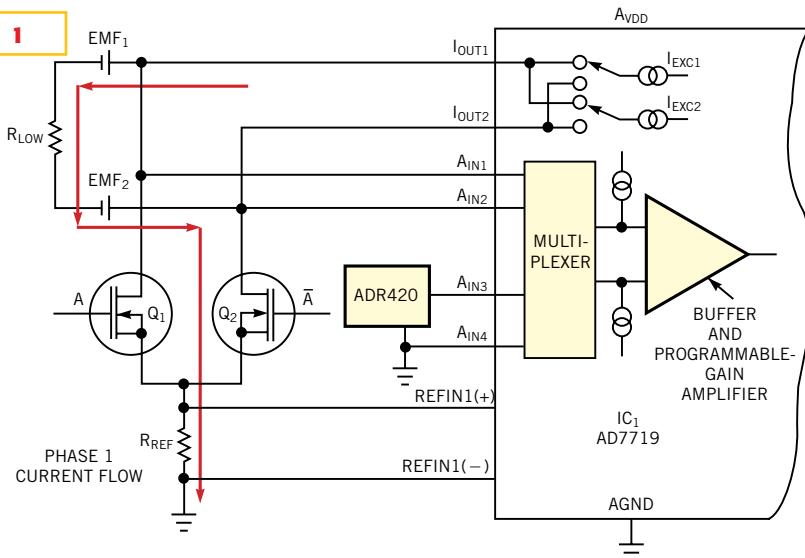
Eliminate thermoelectric EMF in low-ohm measurements

John Wynne, Analog Devices, Limerick, Ireland

WHEN TWO DIFFERENT-METAL CONDUCTORS connect together in a loop and one of the junctions is at a higher temperature than the other, an electrical current flows through the loop. The magnitude of this current depends on the type of metals involved and the temperature differential of the junctions. When you open such a loop, a thermoelectric voltage appears across the open ends. Again, the phenomenon depends on the type of metals involved and the temperature differential of the junctions. The junction of the two metals forms a thermocouple, so the thermoelectric voltage is a thermocouple voltage.

When you try to measure small voltages or low impedances, thermal EMFs (electromagnetic fields) are likely to cause errors in the readings. A standard way that digital-multimeter manufacturers deal with the problem is to initially take one reading and then to reverse the excitation and take a second reading. Reversing the current excitation through a low-value resistor or thermocouple junction reverses the polarity of the desired signal but does not affect the polarity of the unwanted EMF voltages. Subsequently averaging the two readings elim-

Figure 1



In this configuration, the excitation current flows in R_{LOW} from top to bottom.

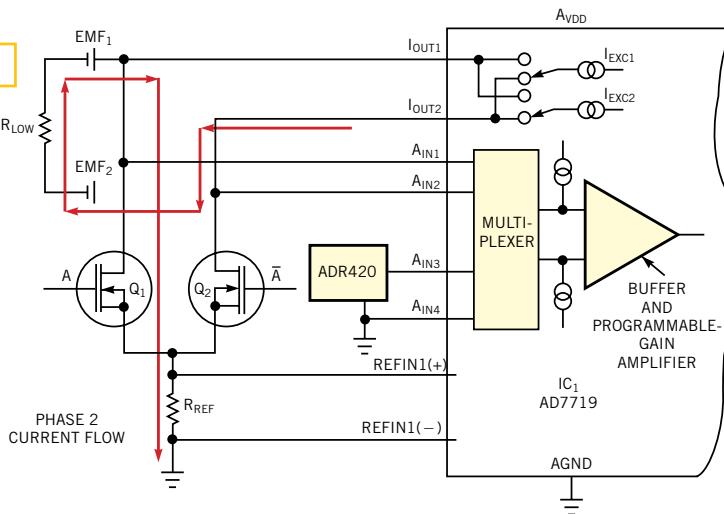
inates the thermoelectric EMFs from the final result (**Reference 1**). **Figure 1** shows IC₁, an AD7719 ADC measuring a low-value resistor, R_{LOW} . The diagram also shows two thermoelectric EMFs, EMF₁ and EMF₂, representing summations of all the thermoelectric EMFs on the way from and to the ADC and the resistor.

These EMFs would normally cause an error if you were to take a single measurement of R_{LOW} .

However, you can program each of the AD7719's two current sources, I_{EXC1} and I_{EXC2} , to appear at either of the package pins, I_{OUT1} and I_{OUT2} . This feature allows you to reverse the excitation current

through the low-value resistor. You can thus take two measurements and eliminate the effects of EMF_1 and EMF_2 . To increase the excitation current and thereby increase the measurement sensitivity, the two internal 200- μ A excitation currents appear in parallel with each other. Thus, a single 400- μ A current source makes up the excitation current, I_{EXC} , in this design. Transistors Q_1 and Q_2 steer the excitation current through the reference resistor, R_{REF} , to ensure that the same polarity reference voltage always appears, regardless of the excitation-current direction. Port pins P1 and P2 (not shown) of the AD7719 drive the transistors in antiphase mode. A value of 6.8 k Ω for R_{REF} is suitable and ensures a typical ratiometric reference voltage of 2.5V.

Figure 2



In this configuration, the excitation current reverses, and flows from the bottom of R_{LOW} to the top.

Figures 1 and 2 show the current flow in each phase of a measurement. During Phase 1, the excitation current flows out of I_{OUT1} , through R_{LOW} , and through R_{REF} via Q_2 to ground. During Phase 2, the excitation current flows from I_{OUT2} , through R_{LOW} , and through R_{REF} via Q_1 to ground. During Phase 1, $V_{DIFF(PHASE1)} = V_{AIN1} - V_{AIN2} = V_{EMF1} - V_{EMF2} + (I_{EXC})(R_{LOW})$. You now switch the current sources. During Phase 2, $V_{DIFF(PHASE2)} = V_{AIN1} - V_{AIN2} = V_{EMF1} - V_{EMF2} - (I_{EXC})(R_{LOW})$. You now combine the two measurements in software to cancel the thermoelectric

$$EMFs: V_{DIFF} = V_{DIFF(PHASE1)} - V_{DIFF(PHASE2)} = (I_{EXC})(R_{LOW})$$

Finally, you need to turn this ratiometric measurement into an absolute one. You achieve this result by measuring a known voltage using the “unknown” ratiometric reference voltage. Taking a reading of this known voltage but with an unknown reference allows you to infer the unknown reference value and, hence, the absolute value of V_{DIFF} on pins A_{IN1} and A_{IN2} . An absolute voltage reference, such as an ADR420, supplying

2.048V output, provides the known voltage. It connects to the second pair of differential inputs, A_{IN3} and A_{IN4} , and into the main 24-bit ADC channel.

REFERENCE

1. *Low Level Measurements, Fifth Edition*, Keithley.

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Parallel port controls arbitrary-waveform generator

Art Kay, Texas Instruments Inc, Tucson, AZ

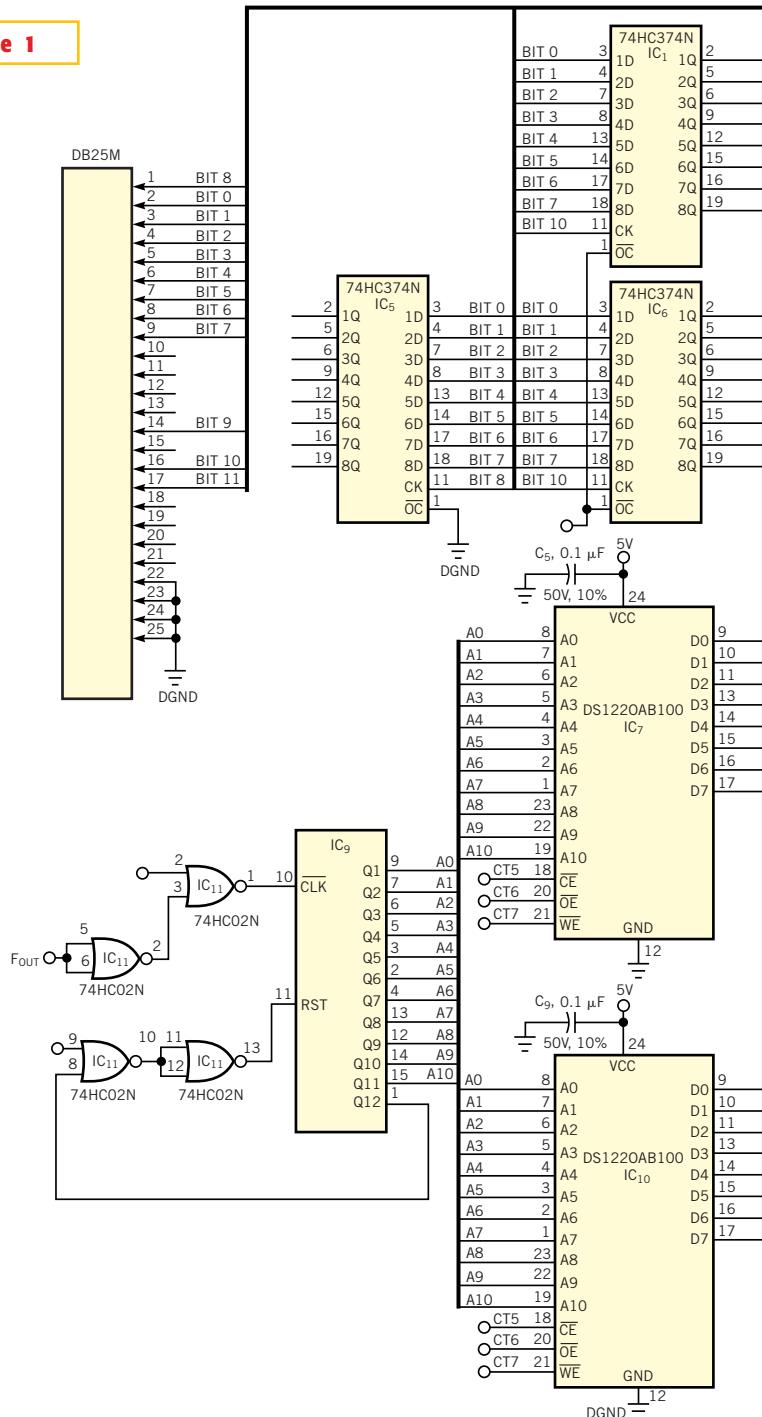
YOU CAN USE the parallel port of your PC and a few additional components to generate a powerful, easy-to-use arbitrary-waveform generator. By using a Visual Basic program with the circuit in **Figure 1**, you can generate any waveform (for example, sinusoid, triangle, amplitude- or frequency-modulated, or exponential decay) by simply entering its characteristic equation. For this circuit, the parallel port connects to four latches (IC_1 , IC_2 , IC_3 , and IC_6). IC_3 provides control signals, IC_1 and IC_6 transfer data to the memory, and IC_2 controls a VFC (voltage-to-frequency) converter. During the load-waveform operation, the waveform data transfers from the parallel port via latches IC_1 and IC_6 to the memory chips IC_7 and IC_{10} . The binary counter, IC_9 , increments the memory addresses in sequence to allow loading each memory location with a unique 16-bit binary word. Each binary word corresponds to a waveform data point. During the load-waveform operation, the memory's configuration allows writing information to it (for example, $\sim OE=1$, $\sim WE=0$).

During the output-waveform operation, latches IC_1 and IC_6 disconnect from the bus, and the memory delivers the stored data (for example, $\sim OE=0$, $\sim WE=1$). For each accessed location, one of the binary words stored during the load-waveform operation transfers to IC_9 , a DAC7621. This transfer causes the DAC to deliver one output point in the waveform. The VFC causes IC_9 to clock through all possible addresses. IC_{11} resets the counter when the memory sequences through all possible addresses. When IC_9 resets to zero, the waveform begins to repeat itself. Thus, each waveform comprises 2048 data points. The number of points, N , and the clock frequency, C , control the frequency of the arbitrary waveform: $f_{AWG} = 1/NT_C$, where T_C is the period of the clock frequency.

IC_2 , IC_3 , and IC_4 form a circuit that adjusts the clock frequency, C , via the par-

(text continued on pg 104)

Figure 1



With the aid of some Visual Basic software and a few ICs, a computer's parallel port forms an effective arbitrary-waveform generator.

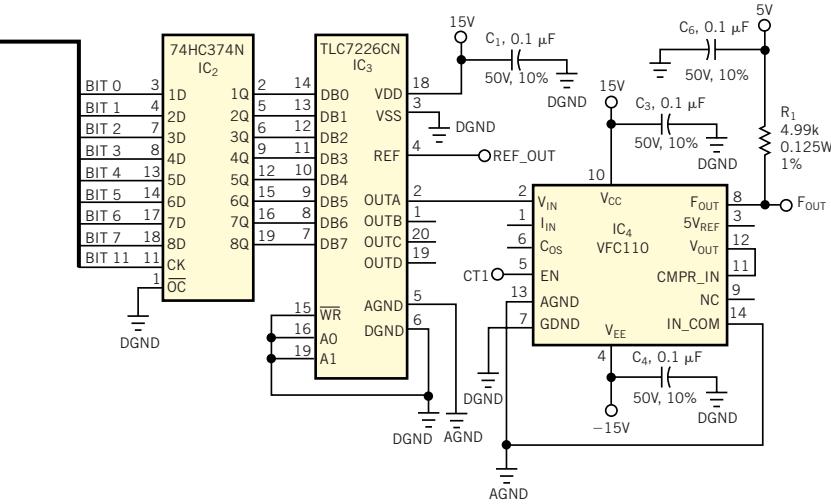
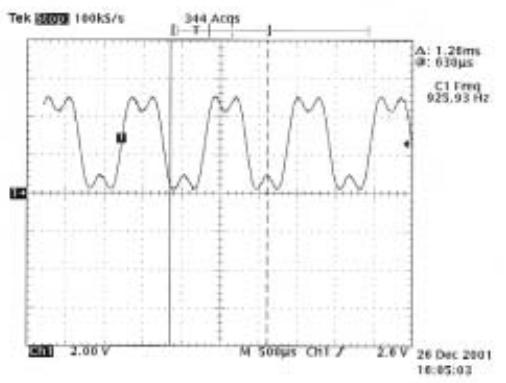
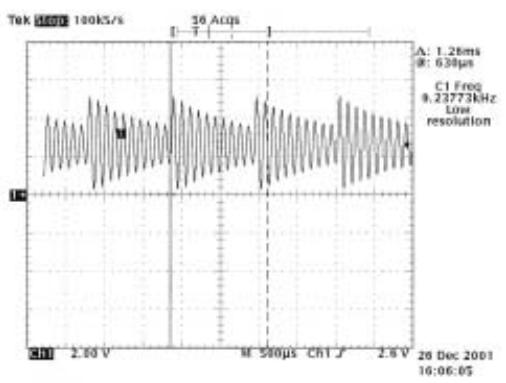
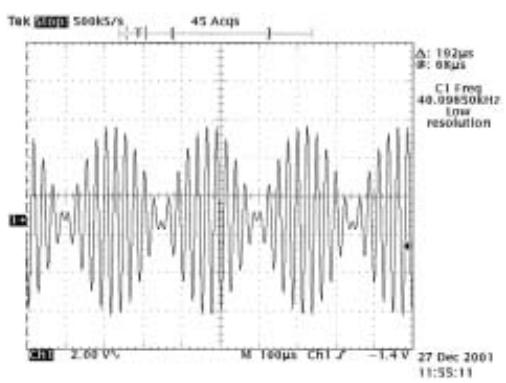
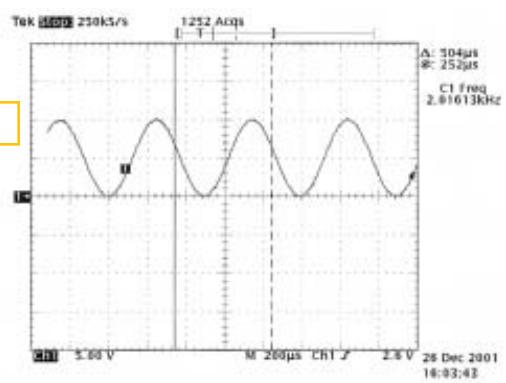
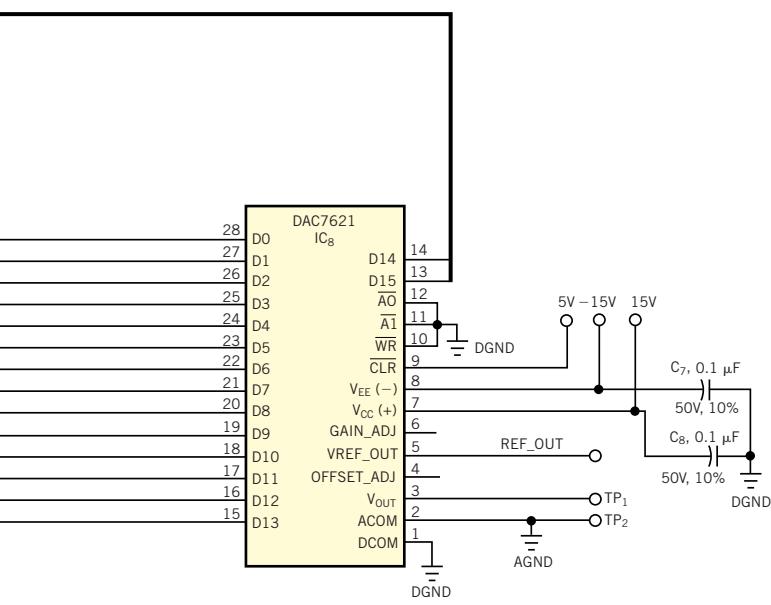


Figure 2



Depending on the points stored in memory, the circuit in Figure 1 can generate virtually any waveform.

allel port. The clock rate C controls the frequency of the arbitrary waveform. The output frequency of IC₄, a VFC110 VFC, is directly proportional to its input voltage. With a full-scale input of 10V, the VFC110 delivers 4 MHz. IC₃ provides a voltage output of 0 to 10V, thus providing frequency control from near 0 Hz to

4 MHz. The voltage output of IC₃ receives its programming via the parallel port, thus allowing computer control of the clock rate. Thus, the circuit provides a frequency range of 7.6 Hz (1/(2048×64 μsec)) to 125 kHz (1/(32×250 nsec)). **Figure 2** shows various sample outputs of the circuit. You can download the

software files associated with this Design Idea from the Web version of the article at www.ednmag.com.

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The Wien-bridge oscillator is reborn

Michael Fisch, Agere Systems, Longmont, CO

IN 1940, WILLIAM HEWLETT and David Packard launched a product from a garage. The product was a Wien-bridge oscillator. It consisted of a single-pole highpass filter in series with a single-pole lowpass filter. To keep the gain constant, the circuit used an incandescent pilot light to provide AGC (automatic gain control). As is true for all incandescent bulbs, the pilot light has nonlinear resistance. When you turn on the circuit, the cold lamp's resistance is low, resulting in high gain. As the gain increases, the resistance of the warming lamp increases. Thus, the lamp provides an AGC function. The circuit has been in use for more than 60 years and is still in use. The only problem with the Wien-bridge oscillator is that below unity gain it does not func-

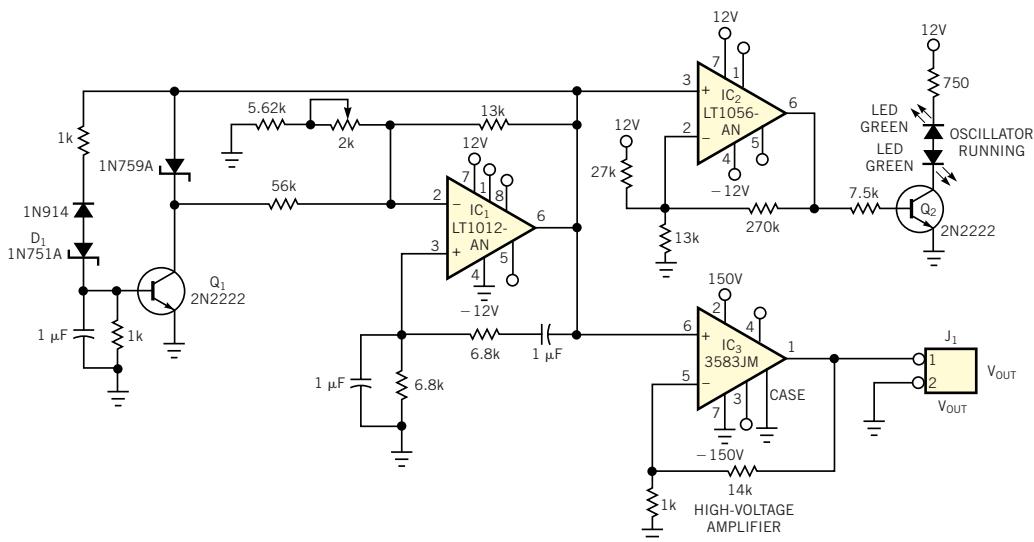
tion. When working for a telephone company, I had to develop a 20-Hz, high-voltage sine-wave ringer circuit. The circuit had to be adjustable from 20 to 200V p-p. The most difficult part was that I had to adjust the oscillator's gain to a value below unity.

The basic oscillator had to have gain slightly greater than unity to make the positive-feedback network oscillate. It also needed an AGC loop to control the greater-than-unity gain. So, I added a third loop around the oscillator and dubbed it a voltage-controlled, regulated-output feedback circuit. The end result (**Figure 1**) is a simple push-pull circuit. By adding D₁, a zener diode, to another feedback loop, I maintained the amplitude even when I adjusted the gain

to a value lower than unity. The 5.2V zener diode maintains the gain. The result is that when the gain falls below unity, the amplitude tries to decrease but cannot do so, because the zener-diode voltage pulls it back up. IC₂, the LT1056AN amplifier serves as a driver for the two LEDs, which alternately turn on and off at the frequency of the oscillator. IC₁, an LT1012AN amplifier has very low offset voltage. IC₃, a high-voltage TI/Burr-Brown (www.ti.com) amplifier, produces the final output of 20 to 200V. The final result—a major breakthrough—is a Wien-bridge sine-wave oscillator that you can adjust below unity gain, and the circuit still maintains its AGC.

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Figure 1



This Wien-bridge oscillator is, according to the author, the first oscillator that can function at gains below unity.

Optical sensor needs no tweaking

Ron Mancini, Texas Instruments, Bushnell, FL

THE TRANSFER GAIN of optical sensors spans a 16-to-1 ratio because of variations in the LED, phototransistor, ambient temperature, and optical path. The wide transfer-gain variation complicates output-resistor selection in dc-coupled circuits. You must size the output resistor to prevent high transfer gains from causing output-stage saturation, but low transfer gains yield low output-voltage swings with low-value resistors. You usually need to make adjustments to match the dc output voltage to the transfer gain, and reliable operation requires readjustment under extreme temperature and dust conditions. The circuit in **Figure 1** eliminates the need for adjustments. The circuit uses dc-coupled feedback to control the current in the output resistor. Hence, the output voltage is predictable and constant.

The op amp's input current and the current in D_3 is negligible, so $I_1 = I_2$, and the output voltage is 2.7V when the phototransistor is on (light path unbroken). The output voltage is 0V when the phototransistor is off (light path broken). The op amp's output-voltage swing accommodates the variation in transfer gain. This output voltage assumes the value required to make the LED current times the transfer gain equal to the phototransistor's emitter current. The input-current equation is as follows:

$$I_1 = \left(\frac{V_{CC} - V_{REF}}{R_1} \right) = \left(\frac{5 - 3}{20 \text{ k}\Omega} \right) = 100 \mu\text{A}.$$

The range of transfer gain is 80 to 5: $5 \leq I_3/I_2 \leq 80$. The op amp's output-voltage range is limited, especially with the high output-current requirement, thus the design uses a TLC071 that can source 20 mA at 3.5V in this design:

$$R_{3MAX} \leq \left(\frac{V_{OUTMAX} - V_{D1}}{I_{3MAX}} \right) = \left(\frac{3.5 - 0.7}{8 \text{ mA}} \right) = 350 \Omega.$$

When the light is blocked, the phototransistor's emitter current goes to zero. The input current, I_1 , can't flow into Q_1 because it is off, so the op amp heads for the positive rail. If the op amp's output stage saturates, the recovery time is unpredictable, so you insert the zener-diode combination D_2 and D_3 to prevent saturation. As the op amp's output voltage approaches 3.4V ($V_{D2} + V_{D3}$), the diodes clamp the output voltage, thus preventing saturation. $R_3 = 270 \Omega$ so that it can supply adequate LED current without incurring op-amp saturation. When this circuit drives a saturated logic circuit, you should buffer the output with a hysteresis gate or a comparator with hysteresis.

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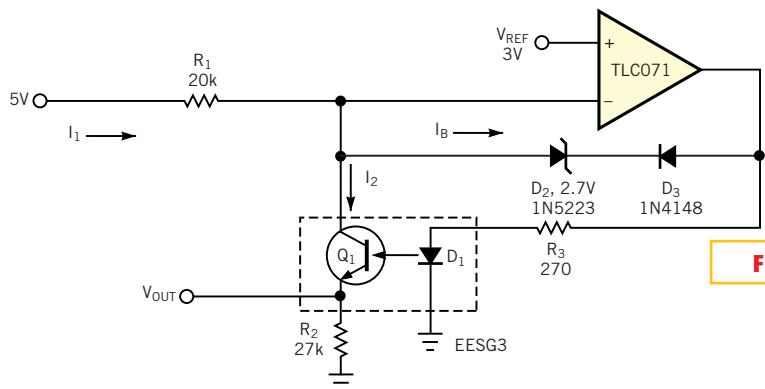


Figure 1

The op-amp feedback keeps the phototransistor's current constant, so the circuit requires no adjustments for transfer gain.

Power-line outage flashes red alert

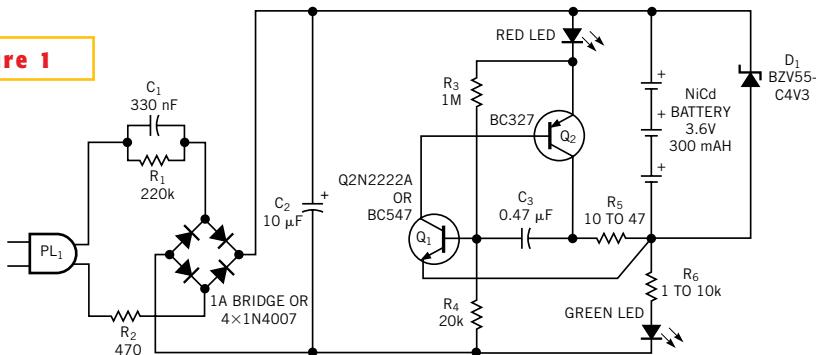
Vasiliy Borodai, Zaporozhje, Ukraine

THIS DESIGN IDEA EXPANDS ON a circuit in a previous one to configure a power-outage detector with a flashing alarm (Figure 1, Reference 1). The circuit plugs into a mains outlet and uses

trickle-charged nickel-cadmium batteries. The green-LED monitors the presence of line voltage. The BZV55-C4V3 zener diode, D₁ protects the batteries against overvoltage. Voltage bias from R₆

and the green LED keeps Q₁ off, so the Q₁-Q₂ RC oscillator remains off. When a power outage occurs, capacitor C₂ discharges in approximately 2 to 3 seconds, and the dc bias disappears. Now supplied by the batteries, the RC oscillator starts, and the red LED flashes at a rate of approximately 2 Hz. R₃ and C₃ set the flashing frequency. You can use an infrared LED instead of the visible LED. The infrared LED couples with an infrared receiver to provide a convenient remote alarm.

Figure 1



A green LED indicates normal power-line voltage; a flashing red LED denotes a power outage.

REFERENCE

1. Terrade, J M, "Free-line indicator stops interruptions," *EDN*, Dec 7, 2000, pg 187.

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