EDITED BY BILL TRAVIS & ANNE WATSON SWAGER

Scheme implements multiple output ports

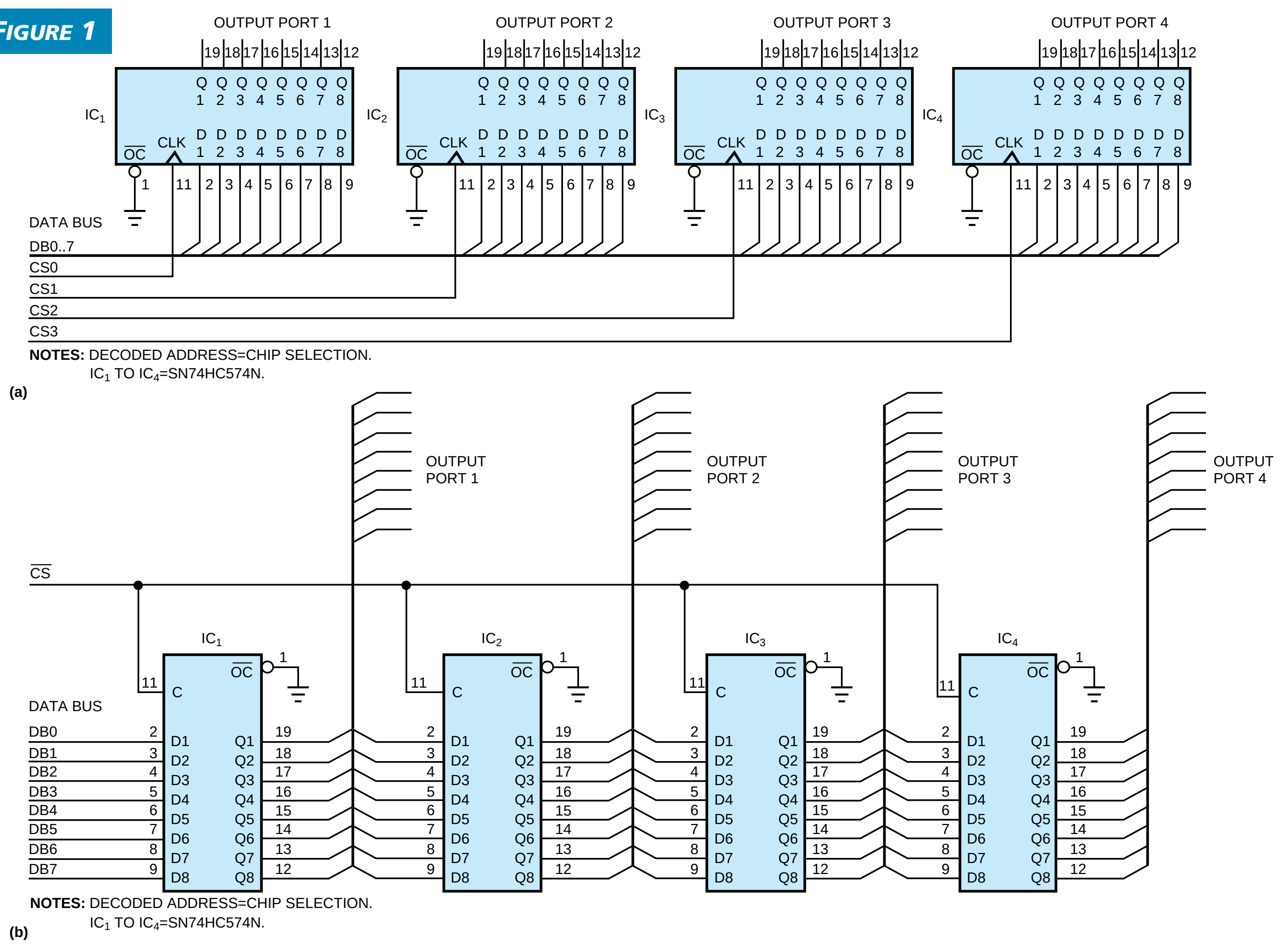
W KURDTHONGMEE, NAKORN SI THAMMARAT, THAILAND

In µP/µC systems, you sometimes need to use many output ports and update all the ports simultaneously. For instance, in systems that use multiplexing techniques, the output ports require refreshing for every scanning period. One example is a system of multiple dot-matrix LEDs. Suppose that an N-column, 8×8 LED matrix uses a row-scanning technique. Every eight-dot column of the n^{th} LED connects to the n^{th} port (n=1…N) and the m^{th} row (m=0…7), in which row a switching transistor controls all the LEDs. To update each row, the row's switching transistor turns off, and all N ports receive an update from the display buffer. The switching transistor for that row then turns on. The method in **Listings 1** and **2** and **Figure 1** allows you to simultaneously update all N output ports.

Two approaches are available for implementing the parallel-output port. In the first approach, every output port has its own address. The address-enable lines of the output ports connect to the chip decoder. To update the output ports, the application program needs to directly refer to the port's address (**Figure 1a**). The native MCS-51 assembly routine in **Listing 1** simultaneously updates all N output ports in the configuration of **Figure 1**. Assume the addresses of these ports are OUTPUT_PORT0, OUTPUT_PORT1, OUTPUT_PORT1+1…OUTPUT_PORT(N–1).

Alternatively, you can connect all the output ports in the configuration of **Figure 1b**. In this method, only one address refers to all the output ports. For example, to update all N ports, the application program must refer to the ports' address and then iterate the following steps N times: Read data from address N from the buffer, route the data to the

FIGURE 1



One way to update output ports is to address every port (a); another method is to address them all simultaneously (b).

referred port, and let N=N–1.

Note that, in the above example, data from location n in the buffer updates the n^{th} port, where n is between 0 and N–1. **Listing 2** is the MCS-51 native routine to simultaneously update the output ports. Assume that the single address of the N ports is OUTPUT_PORT. By using this single-address configuration, you do not need to refer to output ports' addresses every time you need to update them. You thus eliminate one instruction in the update loop, making the routine shorter and faster. This routine is suitable for implementation in an interrupt-service routine. (DI #2151)

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LISTING 1—MCS-51 ROUTINE TO UPDATE OUTPUT PORTS

```
update_1:  mov   dptr,#OUTPUT_PORT0     ; Offset of output port
           mov   r0,#buffer             ; Offset of buffer
           mov   r1,#00h                ; Loop control
update_1:  mov   a,@r0                  ; Read from buffer
           movx  @dptr,a                ; Update current output port
           inc   dptr                   ; Next output port
           inc   r0                     ; Next location in buffer
           inc   r1
           cjne  r1,#N,update_1         ; Until N ports
           ret
```

LISTING 2—MCS-51 ROUTINE FOR SIMULTANEOUS UPDATE

```
update_2:  mov   dptr,#OUTPUT_PORT      ; Point to output port address
           mov   r0,#buffer             ; Offset of buffer
           mov   r1,#00h                ; Loop control
update_1:  mov   a,@r0                  ; Read from buffer
           movx  @dptr,a                ; Update current output port
           inc   r0                     ; Next location in buffer
           inc   r1
           cjne  r1,#N,update_1         ; Until N ports
           ret
```

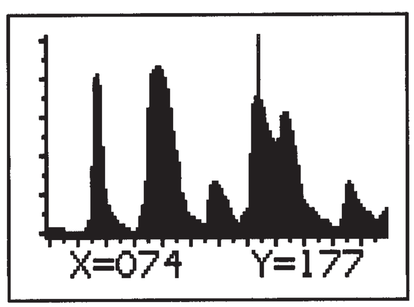
PIC plots pixels sans controller

DARYL CHRISTOPHER, JUNIATA COLLEGE, AND TOM FISHER, INEXPENSIVE SYSTEMS, HUNTINGDON, PA

It is sometimes desirable to display the output of a PIC μC graphically, rather than numerically. However, the operation increases system complexity and expense. In addition to the LCD itself, you usually need a graphics controller and at least 1 kbyte of RAM. However, you can obtain a satisfactory plot (**Figure 1**) without the use of a controller or any RAM. At first glance, the parameters seem daunting. The least expensive graphics LCDs (for example, the Optrex DMF696, at $39.51 from Digikey (Thief River Falls, MN)) have a resolution of 128×64 (width×height) pixels, which equates to 1024 bytes. A midrange PIC μC, such as the PIC 16C37A, has only 192 bytes of RAM available, including whatever you need for program variables.

Furthermore, you must frequently refresh the LCD: Optrex recommends a 70-Hz rate. The PIC's cycle time (the time it takes the μC to execute one command) is 200 nsec. The μC divides a 20-MHz oscillator input by 4 to produce the 5-MHz cycle frequency. Because the LCD needs 8192 pixels at an approximate 70-MHz refresh rate, the PIC has the time to issue only approximately nine commands for each pixel. Moreover, this time must include the timing pulses (**Figure 2**) as well as the data.

FIGURE 1



This simulated plot shows the blinking cursor at X=74 measuring Y=177.

The key to matching the PIC's capabilities to the task is recognizing that a graph is a specialized display. The plot is of a single-valued function of y vs x, so the display has 128 points at any time. The majority of the pixels carry no information whatsoever. Inasmuch as the maximum resolution possible on the vertical axis is only one part in 64, 1 byte (1-in-256 resolution) is more than adequate to contain one datum, and the 192 bytes of PIC RAM is more than enough for the plot. (To allow for borders, the graph in **Figure 1** actually has a plottable area of only 120×53 pixels.)

Another problem is to write code that is terse enough to maintain the required refresh rate. The fastest way to *move* a bit (pixel) out of the PIC is to rotate it through the carry flag and into an output port. This operation would normally mean wasting an entire output port, because the remainder of the port's pins would always contain "stale" shifted pixels. However, the PIC allows A/D input through pins designated for digital input, so all the I/O pins are usable. **Figure 3** shows the PIC 16C73 port assignments. **Listing 1** shows the code fragment that displays a single pixel on the screen.

Note that the routine requires only six cycles. However, if you include the start-of-line pulse (CP1, two cycles), subroutine calls (two cycles), and other overhead, the worst case requires 12 cycles. This time budget results in an unacceptable refresh rate of approximately 50 Hz. The screen areas that require unchanging information, such as borders, tick marks, and labels, are stored in program ROM. Because it would take too many cycles to recover this data from look-up tables (which are cumbersome in the PIC), you code each byte explicitly and clock them out 1 bit at a time using the routine in **Listing 2**.

You need approximately 700 lines of repetitious coding and a large, binary shape table to specify the static information; a good editor simplifies this chore. You implement a blinking x-axis cursor by periodically replacing the datum in the appropriate RAM location with 255 decimal. This operation has the effect of drawing a flashing vertical line above the pointed-to datum. By setting 64 screen scans with and 64 without the 255, you obtain a blink rate of approximately 2 sec. You control the cursor's position by rotating a 50-kΩ potentiometer that feeds the PIC's A/D converter through Pin RA2. As the cursor moves, the x and y coordinates of its position display numerically at the bottom of the graph. The updatable, three-digit x and y positions (requiring a total of 6 bytes of RAM) make up a classic character generator, with each numeral's shape stored in 7 bytes of RAM.

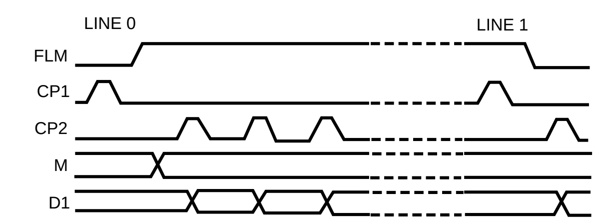
LISTING 1—CODE FRAGMENT FOR A SINGLE PIXEL

```
incf     FSR          ;Point the indirect address vector to the
                       next datum to be displayed.
movfw    IndF         ;Get that datum and place it in the working
                       register.
subwf    Ylevel       ;Compare the value of the datum to the height
                       of the scan line currently being written to
                       the screen. If the datum is greater, set the
                       Carry Flag.
bsf      PortC,CP2    ;Set the latch pulse so that the I/O pin
                       can change state.
rlf      PortA        ;Place the pixel information on the output pin.
bcf      PortC,CP2    ;Latch the pixel and send it to the LCD.
```

LISTING 2—CODE FOR OBTAINING STATIC INFORMATION

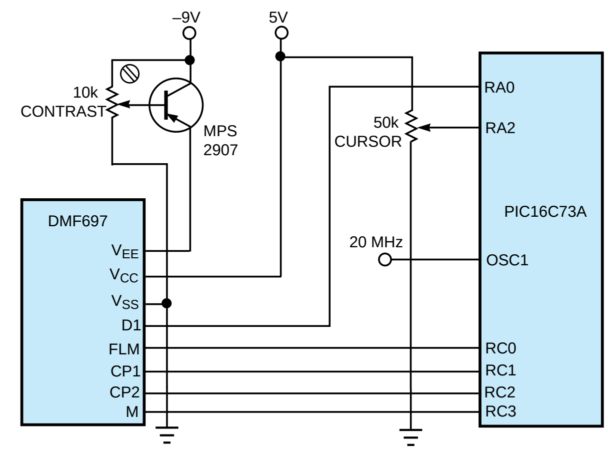
```
movlw    B'00000111'        ;Get the bit pattern of a portion
                             of the left border.
movwf    Byte               ;Store it in the pixel buffer.
call     Write_Text_Byte    ;Send the byte to the LCD one bit
                             (pixel) at a time.
```

FIGURE 2



The 16C73A sends these signals to the DMF697. FLM is start-of-scan, CP1 is start-of-line, CP2 is data latch, M is driver-voltage polarity, and D1 is data.

FIGURE 3



This minimal circuit displays the graph and permits cursor movement; it makes no provision for acquiring data.

It is essential to frequently update the screen to continuously reverse the polarity of the LCD's electrodes and thus prevent the destruction of the display. The M line takes care of this operation by switching the polarity at the beginning of each screen scan. Although it is possible to invoke short routines between scans, if the PIC must perform lengthy routines, it is necessary to blank the screen by using a call to Erase_Screen. The program requires approximately 1.4 kbytes of program memory (in Page 1 ROM) and 135 bytes of data RAM. You can download the program as an MPASM 1.40-compatible source file from *EDN*'s Web site, www.ednmag.com. At the registered-user area, go into the Software Center to download the file from DI-SIG, #2153. Although using a PIC μC as an LCD controller/video RAM imposes severe restraints on what you can display, this approach reduces complexity and cost for simple graphs. (DI #2153) e

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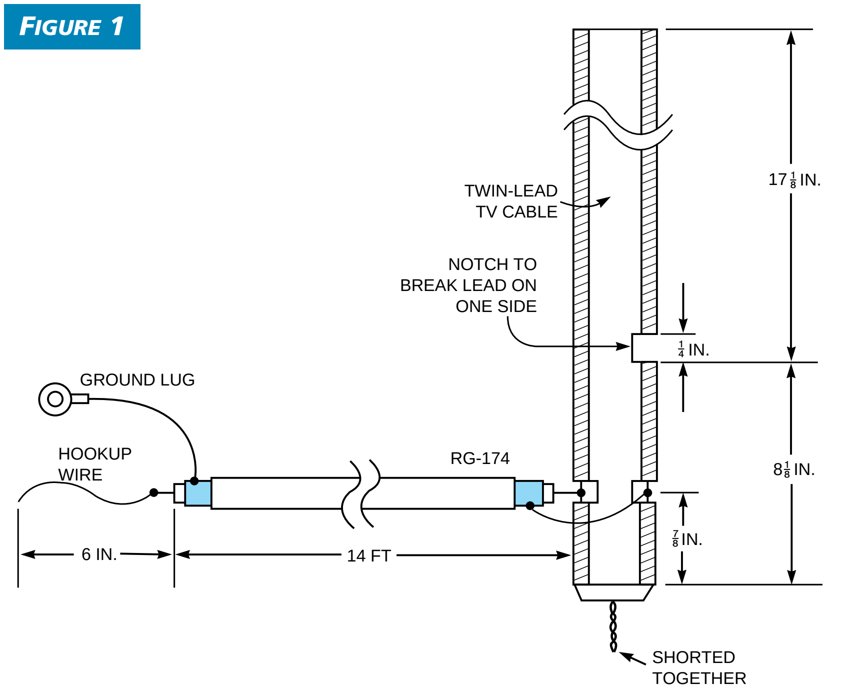
Antenna extension provides open-door policy

RICHARD PANOSH, VISTA, BOLINGBROOK, IL

Metal garage doors may be solid and secure, but they are not transparent to radio waves. If your garage has aluminum siding, you may experience frustration with the operation of your garage-door opener. If you must drive up to the door and nearly touch it or drive near a window to activate the door opener, this Design Idea is for you. The antenna extension in **Figure 1** moves the receiving antenna beyond the door so the system can respond to your command.

Construction is simple. The antenna is completely passive and uses a J-pole design. The antenna uses readily available 300Ω flat TV twin-lead and RG-174 50Ω miniature coaxial cable. The length suits an opener that operates at 310 MHz. Most popular openers, such as Stanley, Genie, and Chamberlain, operate at this frequency. However, some units operate at 315 MHz, some replacement controls operate at 390 MHz, and some automobile manufacturers offer 380-MHz designs. You can usually find the operating frequency in the user's manual, or you can obtain it directly from the manufacturer.

FIGURE 1



A sensitivity treatment for your garage-door opener uses readily available coaxial cable and TV twin-lead in a simple configuration.

A J-pole antenna consists of a half-wave antenna matched to the low impedance of the coaxial cable by means of a quarter-wave matching stub. In **Figure 1**, the half-wave antenna comprises the piece of wire above the notch cut into one side of the 300Ω flat TV twin-lead cable. You solder the lower ends of the stub together. Experiments show that the optimum location of the coaxial tap is 7/8 in. above the shorted end. You use 14 ft of RG-174 coaxial cable as the lead-in. Route this lead above the garage door and out through the weather stripping without drilling any holes. Be sure that the center conductor of the coaxial cable connects to the half-wave side of the twin-lead and that the ground braid connects to the notched side of the twin-lead. Solder both these connections and cover them with clear silicone rubber to protect them from weather conditions.

Prepare the end of the coaxial cable that connects to the existing garage-door antenna by exposing the center conductor and soldering on a 6-in. length of hookup wire. You can insulate the connection with heat-shrink tubing or tape. Twist the hookup wire tightly around the existing antenna wire for its full length to form a gimmick capacitor suitable for coupling the signal into the receiver without unduly loading the receiver and altering its characteristics. Secure the shield of the RG-174 coaxial cable to the frame of the door opener to effectively ground it. You can locate the antenna above the garage door on the wood trim. Do not staple across the 300Ω twin-lead.

Mount the twin-lead to the door using adhesive pads and nylon cable ties or by means of a single small nail or screw at each end through the center web of the twin-lead. You can attach the coaxial cable to the garage rafters or ceiling with the same nylon cable ties and adhesive to keep it out of the way of moving parts. Route the cable above the door to allow normal operation of the door and out below the garage-door header beam so that the door's weather stripping seals when the door closes.

The addition of this antenna extension to any garage-door opener markedly increases operating range. Measurements show an improvement of approximately 2.5 dB, equivalent to a 30 to 40% increase in range. The improvement is especially noticeable for installations in which the garage is effectively shielded by metal doors, metal siding, and a lack of windows. (DI #2152) e

To Vote For This Design, Circle No. 383

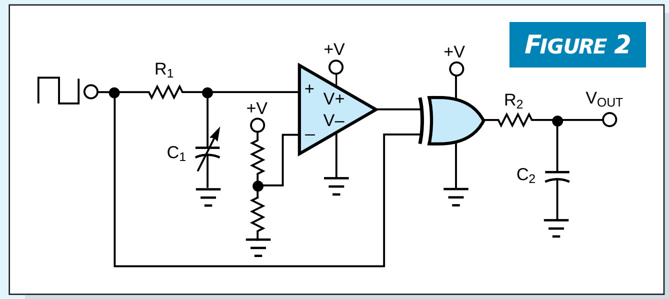
Dual comparators stabilize proximity detector

Arthur Harrison, US Army Research Laboratory, Adelphi, MD, and Joseph Stern, Maxim Integrated Products, Sunnyvale, CA

In the proximity detector of **Figure 1**, a 4-in.-sq piece of copper-plated pc board serves as an antenna that forms one plate of a capacitor. An approaching (grounded) person serves as the other plate, producing a capacitance value of 2 to 5 pF that increases as the person approaches. At 6 in. from the copper plate, for example, the person produces a capacitance value of approximately 2 pF.

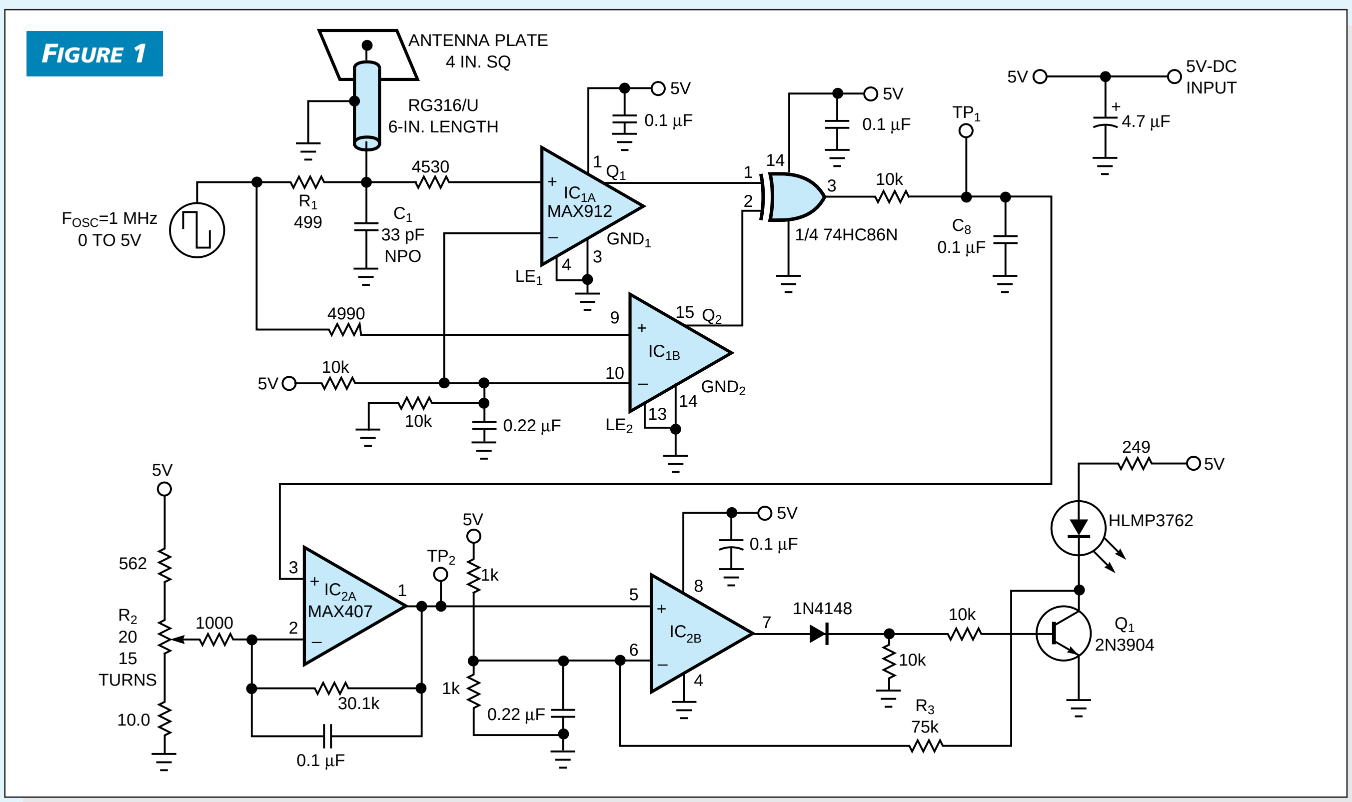
A simplified circuit illustrates how the circuit transforms distance/capacitance into a proportional voltage (**Figure 2**). Transitions of the input square wave apply directly to the lower input of the exclusive-OR (XOR) gate but are delayed $0.693 \times R_1 \times C_1$ sec before the comparator reconstructs the transitions and applies them to the upper XOR input. R_2 and C_2 filter the resulting XOR output to produce a voltage proportional to distance.

The XOR output's duty cycle is proportional to the sum of the R_1-C_1 network's delay and the comparator's propagation delay, so a small variation in comparator delay can mask small changes in antenna capacitance. The circuit in **Figure 1** overcomes this limitation using a dual comparator (IC_1). Passing the XOR inputs through nearly identical comparators largely nullifies the effect of offset voltage, drift, and propagation delay through the comparators.



Exclusive-ORing two inputs, one delayed by the R_1-C_1 network, and subsequent filtering by R_2 and C_2 implements a capacitance-to-voltage conversion.

Figure 1's delay capacitance consists of a 33-pF capacitor, C_1, in parallel with 15 pF (6 in. of coaxial cable at 30 pF per foot) and the 4-in.-sq antenna plate. This capacitance charges to 5V through R_1 during each positive half cycle of the input square wave. When no one is near the detector, this capacitance equals 48 pF and produces a delay of 16.5 nsec at the upper XOR input. With a hand 6 in. from the detector, the capacitance rises to 50 pF and produces a delay



This proximity detector lights the LED when a person approaches the antenna plate within a threshold distance set by potentiometer R_2.

of 17.3 nsec, yielding a time difference of only 0.8 nsec.

To detect such small time differences—over temperature and with accuracy—the comparators must be stable in offset voltage and propagation delay. (Changes in offset voltage as well as propagation delay affect delay time.) One 10-nsec comparator is generally stable to within 1 nsec. To resolve subnanosecond intervals, use the dual-comparator approach of **Figure 1**, which increases the useful resolution by a factor of four to five.

Op amp IC_{2A} offsets and amplifies the dc voltage at TP_1, which corresponds to the distance between hand and antenna plate. A hand movement toward the antenna causes the voltages at TP_1 and TP_2 to rise. IC_{2B} and Q_1 serve as a comparator with hysteresis, which compares the TP_2 voltage with 2.5V. Thus, any TP_2 voltage above 2.5V (which corresponds to a proximity of 6 in.) turns on the LED. You can adjust potentiometer R_2 to set a threshold other than 6 in., and you can connect a DVM at TP_2 to read out the proximity in inches. R_3 adds hysteresis to ensure a well-defined transition.

To ensure frequency stability for the high-speed dual comparator in **Figure 1**, the copper-clad pc board should have a ground layer in addition to the circuit layer. Power-supply bypassing should include 0.1-µF ceramic capacitors that sit very close to the comparators' supply terminals. (DI #2150)

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Low-cost switcher converts 5 to 24V

Paul C Florian, Plano, TX

The low-cost, three-transistor boost switching regulator in **Figure 1a** is a modified astable multivibrator comprising Q_1, Q_2, and L_1, which substitutes as a load for Q_2. At the full output power of 200 mW, the oscillation frequency is approximately 60 kHz. The efficiency is 65% with V_{OUT} equal to 24V and sourcing 8 mA.

When the base of Q_2 is high, energy stores in L_1's magnetic field. When the circuit drives the base of Q_2 low, the induced voltage from L_1's magnetic field collapses to add with the supply voltage. This voltage spike charges C_1 through D_1. When the accumulated charge in C_1 results in a voltage equal to the zener voltage of D_2 plus 0.6V, Q_3 pulls Q_2's base to ground, decreasing the amount of time Q_2 is on in subsequent oscillations and thereby decreasing the energy transferred to C_1. This feedback through D_2 regulates the output voltage to 24.6V±the tolerance of D_2. To change the output voltage of the circuit, simply change the zener voltage of D_2.

Many VCOs require tuning voltages as high as 20V, and you can use this switching regulator to generate a 0 to 20V tuning voltage from a 0 to 5V control voltage (**Figure 1b**). The circuit configures one-half an LM358N as a noninverting amplifier with a gain of 4. C_1 eliminates gain for the noise generated by the 24V supply. You can manually adjust the tuning voltage using R_1 or control the voltage using feedback from a PLL. (DI #2159)

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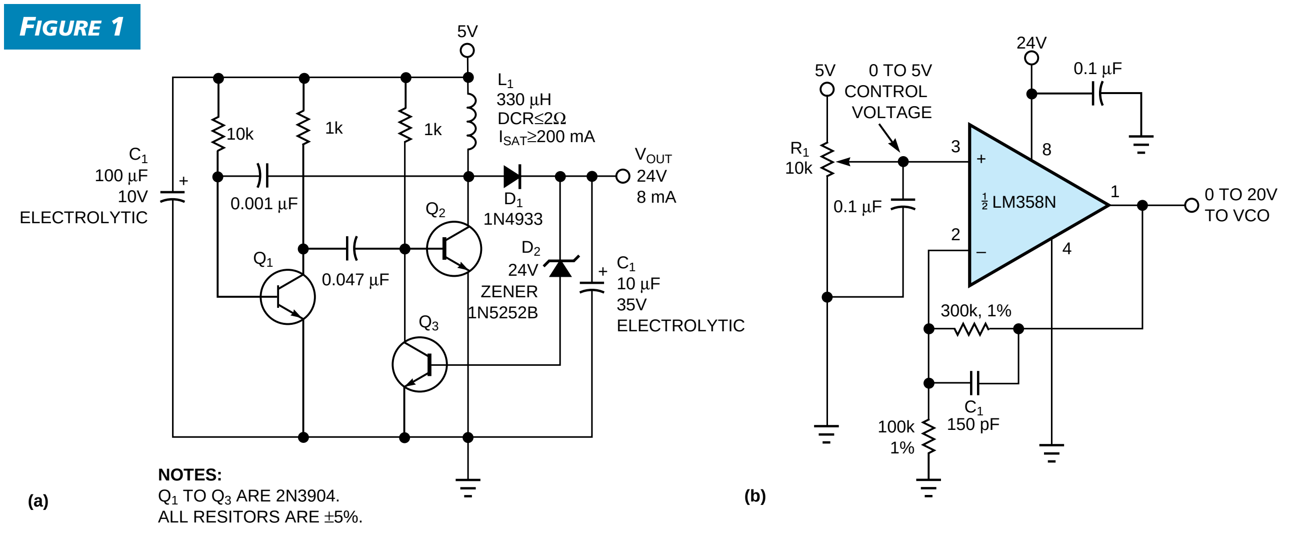
FIGURE 1



A simple three-transistor switching regulator (a) supplies 24V and 8 mA. The circuit can help provide a 0 to 20V VCO tuning voltage from a 0 to 5V control voltage (b).

60-Hz modulator records process variables

WARREN JOCHEM, RESEARCH TRIANGLE INSTITUTE, RESEARCH TRIANGLE PARK, NC

The circuit in **Figure 1** allows you to record process variables (4 to 20 mA, 0 to 10V dc) on a three-phase power monitor designed to record only ac waveforms. Many of these recorders have a seventh channel, normally used for recording neutral current, which you can use as a process-variable input. The circuit operates by generating a 0 to 1V-rms output sine wave whose amplitude is a function of a 0 to 10V-dc input signal. IC_1 can be any rail-to-rail quad op amp rated for ±5V power supplies. Input stage IC_{1A} buffers the input-voltage divider R_1-R_2 and drives the two-quadrant multiplier, IC_{1B}. IC_{1B} acts as a multiplier by using Q_1 to switch its gain from 1 to –1.

When Q_1 is off, IC_{1B} has a gain of –1. Switching Q_1 at 60 Hz chops the dc signal applied to the input into a 60-Hz square wave whose amplitude is proportional to the input signal. The chopping signal comes from Schmitt trigger IC_{1C}. A portion of the ac power signal goes to IC_{1C} through voltage divider R_8-R_7. R_9 and R_{10} provide a small amount of hysteresis to prevent oscillation and ensure fast switching. The output of IC_{1C} is the 60-Hz square wave that controls Q_1. The chopped signal from IC_{1B} connects to the switched-capacitor filter, IC_2. This eight-pole lowpass filter converts the square wave from IC_{1B} to a sine wave.

Capacitor C_2 sets the filter's 71-Hz cutoff frequency. C_5 and R_6 form a 16-Hz highpass filter that removes any dc offset from the output of the switched-capacitor filter. IC_{1D} buffers the filter and provides a 0 to 1V-rms, 60-Hz output. Calibration involves applying a 10V-dc signal to the input and adjusting R_2 until the output reads 1V rms on an ac voltmeter. Measurements show linearity within ±1% over the entire input range. To use the recorder, connect the input to the process variable under measurement, and connect the output to any voltage-input channel on the 1V-rms power recorder. You can also use the circuit on current-input channels designed to use low-voltage, 1V-rms current clamps. To record 4- to 20-mA signals, shunt the input with a 500Ω resistor. (DI #2157) e

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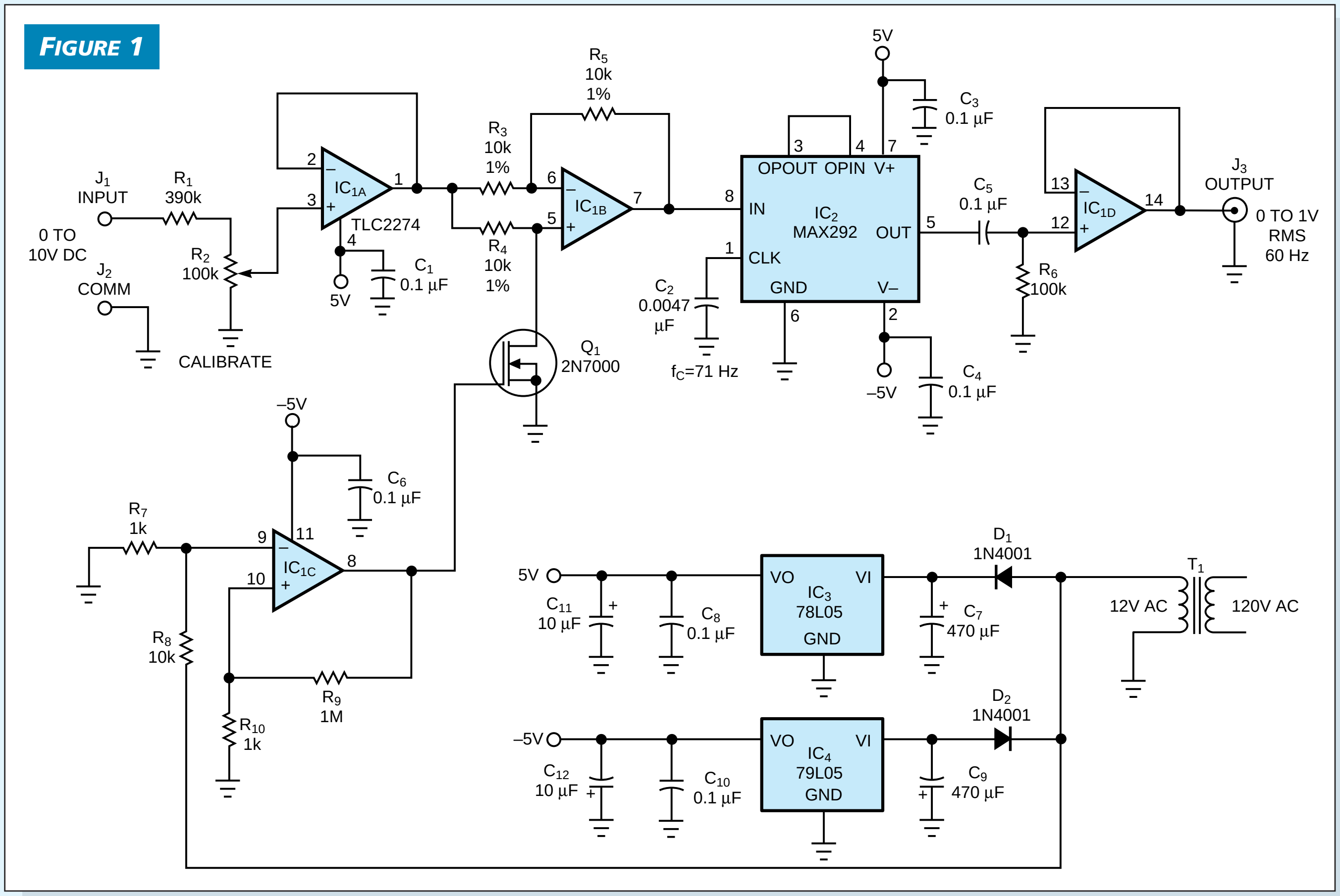
FIGURE 1



Chopper techniques convert a dc input signal from a process variable to a 60-Hz ac signal for measurement on a three-phase power monitor.

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