design ideas

Edited by Bill Travis and Anne Watson Swager

Test batteries without a voltmeter

Nam Phan, Pasadena, CA

THE CIRCUIT IN **Figure 1** is an easy approach to testing batteries without exiting the voltmeter. The battery holders in sizes AAA, AA, C, and D make this tester so much faster than a voltmeter. You just put the battery into the holder and look at the circuit meter instead of getting the voltmeter out of the case, plugging in the probe, and turning on the meter. Holding the tips of the probes to the tips of the battery is clumsy.

The heart of this circuit comprises op amps that the circuit configures as comparators. When the voltages at the plus (noninverting) inputs are higher than the voltages at the minus (inverting) inputs, the op-amp outputs are equal to V_{CC}. When the plus inputs are lower than the minus inputs, the outputs are equal to V_{DD}. Every plus input connects to a potentiometer that controls the voltages going into the plus-input pin. The minus inputs all connect to battery holders.

You adjust the potentiometers in increments of 0.05V starting at 1.2V and ending at 1.55V. You can change this adjustment to increments of 0.2 or 0.3V, depending on how accurate you want the tester to be.

The output of each op amp connects to a 20-pin LED bar, which you place vertically to look like a meter. The circuit uses only eight of the LEDs. If the battery voltage is higher than 1.4V, the bottom five LEDs will light up because the minus input is greater than the plus input on the bottom five op amps. The top three LEDs do not light up because 1.4 is not higher than 1.45, 1.5, or 1.55.

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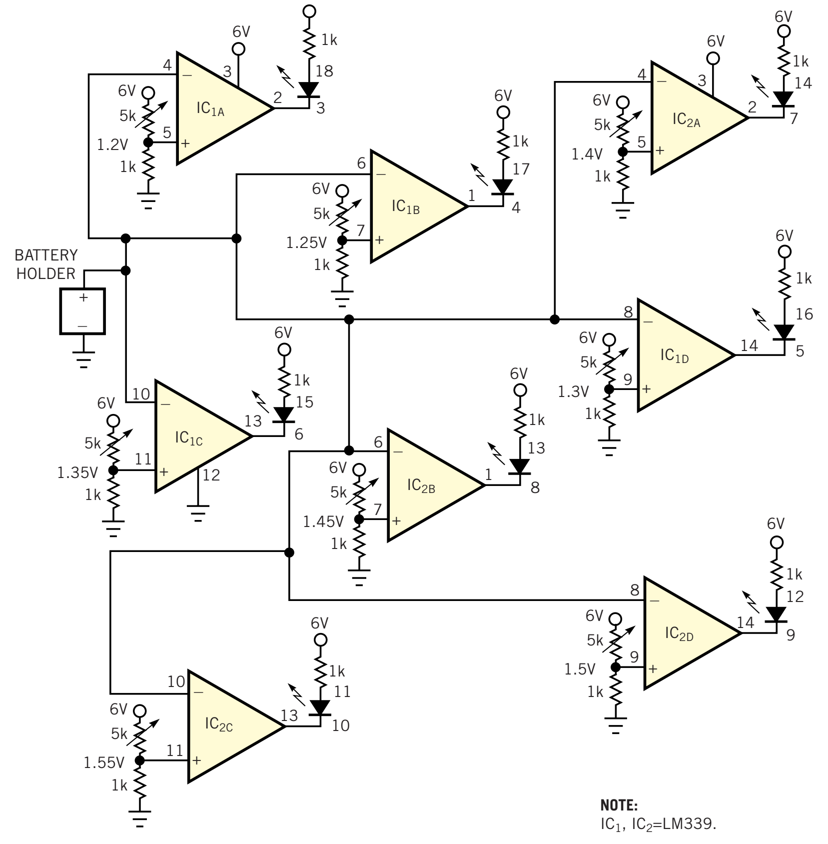
Figure 1



NOTE:
IC_1, IC_2=LM339.

This battery tester configures two dual op amps as comparators.

Electronic fuse emulates fast- or slow-blow fuses

John A Hasse, Colorado State University, Fort Collins, CO

The electronic-fuse circuit in **Figure 1** combines the properties of a current transducer and a solid-state relay to disconnect low power at preset levels. Using this circuit lets you avoid the bother of stocking and replacing fusible links.

The circuit simulates fast- or slow-blow fuses as large as 10A in 1 or 2A increments using a convenient pushbutton reset. This device can bracket trip levels of functioning equipment or help locate chronic faults. The circuit full-wave-rectifies the output from the Lem current transducer and applies the result or with a variable delay to a window comparator. The reference steps are 600 mV/1A at Pin 7 as a high level. Signals greater than the H pin of the CA3098 set a flip-flop in the CA3098, which removes drive to the solid-state relay. Forcing Pin 1 of the CA3098 from −1V to 1V resets the flip-flop and restores load power. An offset current through the 15-kΩ, 1% resistor adds −300 mV to the set level, which is equivalent to −1 or −2A from the integral switch settings of 1 to 10 with standard 30° indexing. The circuit blocks two switch positions from use. You adjust the LF411CN with no ac load to zero voltage at Pin 6 relative to dc common.

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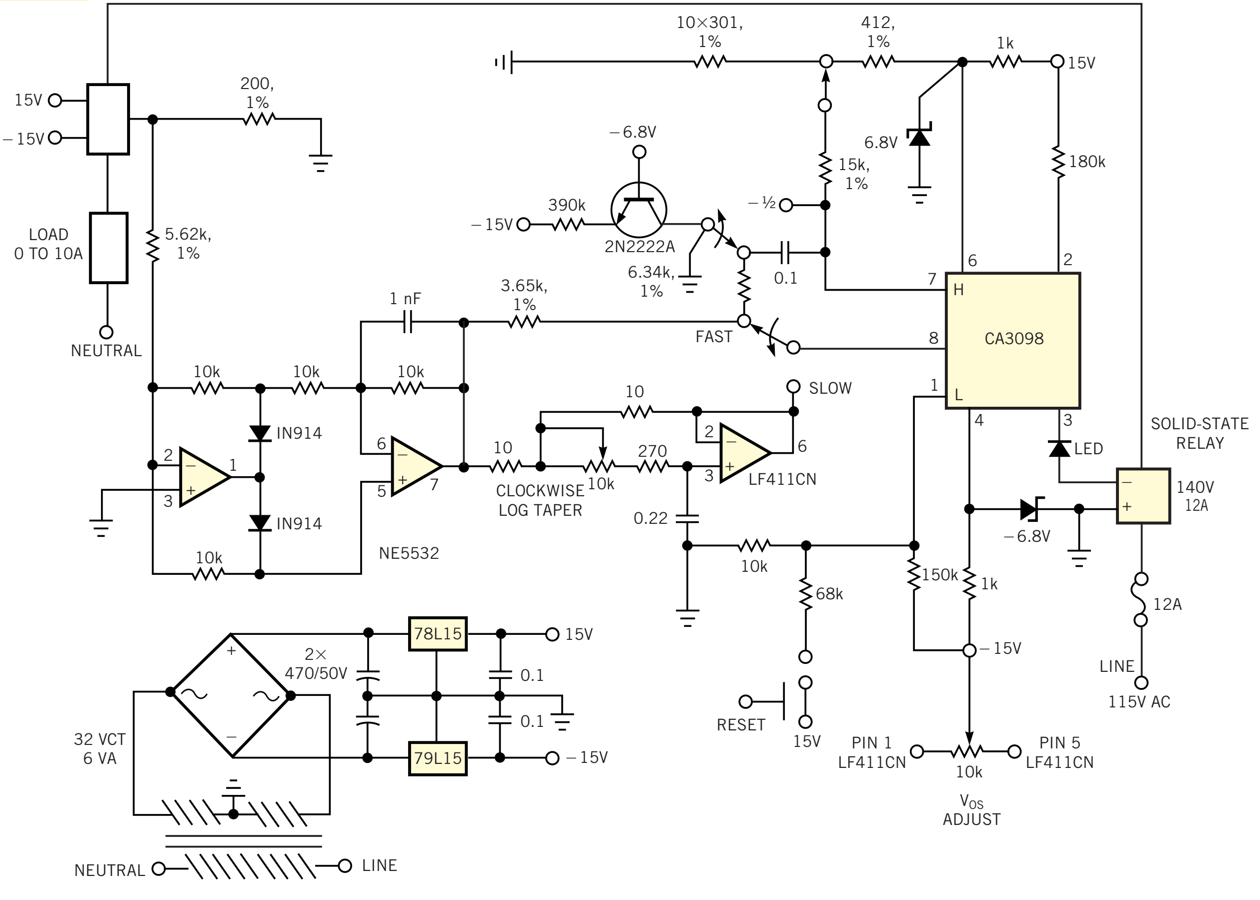
Figure 1



An electronic fuse combines the properties of a current transducer and a solid-state relay.

Amplitude-stable oscillator has low distortion, low cost

Moshe Gerstenhaber, Chau Tran, and Mark Murphy, Analog Devices Inc, Wilmington, MA

The multivibrator is a common circuit that consists of an amplifier with both positive and negative feedback (**Figure 1a**). When the output is positive, the positive input terminal equals ½V+, and the voltage at the negative input terminal changes toward V+. When this voltage exceeds ½V+, the output voltage rapidly changes to V−. The positive input terminal becomes ½V−, and the negative input terminal changes toward V−. When the voltage at the negative input terminal is less than ½V−, the process repeats (**Figure 1b**).

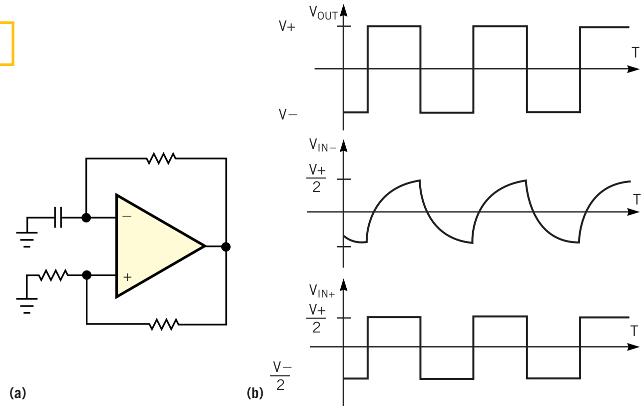
For the multivibrator to work, the bandwidth of the amplifier must be 10 times higher than the time constant of the passive network, and consideration of the high slew rate helps define the amplifier. The output is a square wave.

The circuit in **Figure 2a** is a sinusoidal oscillator. External compensation at Pin 5 forces the unity-gain bandwidth of the amplifier to be the same as the passive-network bandwidth.

Loop-gain analysis results in the following transfer function:

$$\frac{V_{OUT}}{V_{IN}} = -\frac{(1-2\pi f R_1 C_1 j)}{100\pi f \frac{1}{g_m} C_2 j(1+2\pi f R_1 C_1 j)}.$$

Figure 1



The common multivibrator has positive and negative feedback (a). When V_{OUT} is positive, V_{IN-} changes toward V+. When V_{IN-} exceeds V+/2, V_{OUT} changes to V− (b).

To meet the conditions necessary to sustain oscillation—loop gain equal to unity and phase equal to zero—choose $(1/g_m)\times C_2=1/(100\pi f)$ and $R_1\times C_1=1/(2\pi f)$.

The inverse transconductance, $1/g_m$, of the input stage, re, is equal to 52Ω. The design assures amplitude stability because re always increases with an amplitude increase, which reduces the loop gain. The ratio of the R_2/R_3 divider network sets the amplitude.

Figure 2b is a performance photo of the oscillator running at 4 MHz and 5V p-p. For better frequency stability, you can replace C_2 with a crystal of the desired frequency and low shunt capacitance.

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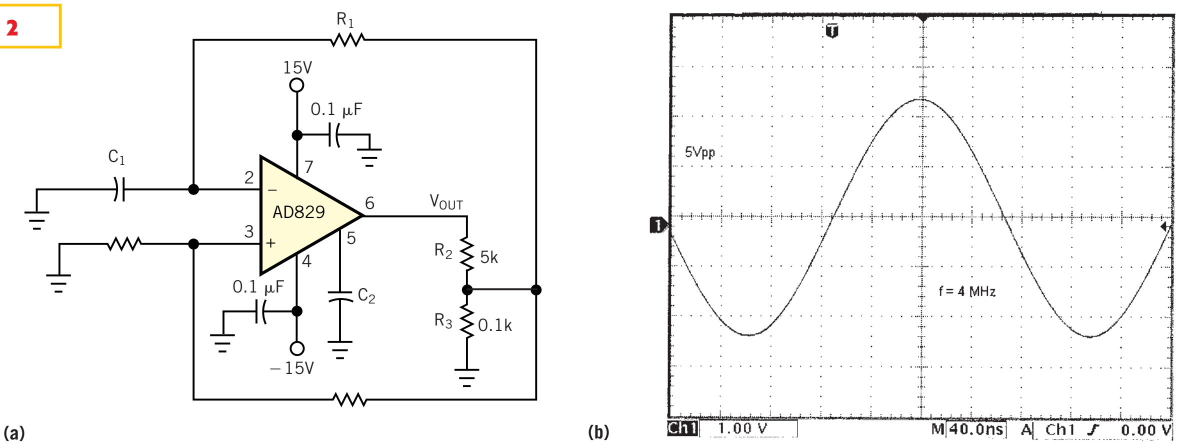
Figure 2



This stable oscillator (a) has low distortion (b).

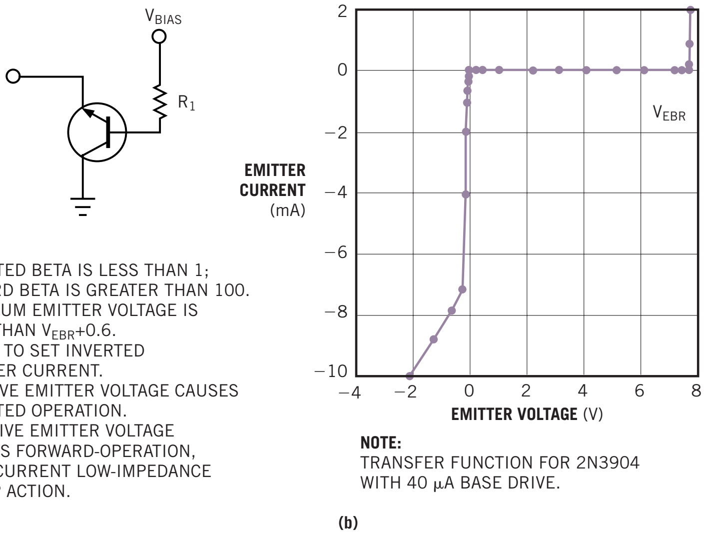
Inverted bipolar transistor doubles as a signal clamp

Art Hogrefe, Puma Instrumentation, State College, PA

A NUMBER OF CIRCUITS, such as level detectors and AM demodulators, benefit from a rectifier with a low offset voltage. Silicon diodes have an offset of approximately 0.6V and do not work well in low-level circuitry. A Schottky diode is a bit better with an offset of approximately 0.4V. A few germanium diodes are still available, but they do not tolerate the temperature range of silicon. Also, you can't include a germanium diode in an IC. A superior configuration uses a bipolar transistor for these applications.

Figure 1 shows the bipolar-inverted-clamp circuit and a typical transfer function. The collector connects to ground or any other desired reference voltage. A fixed current drives the base. In the absence of any external drive, the emitter voltage is near zero. Driving the emitter with an external voltage produces the transfer function in **Figure 1**.

Figure 1



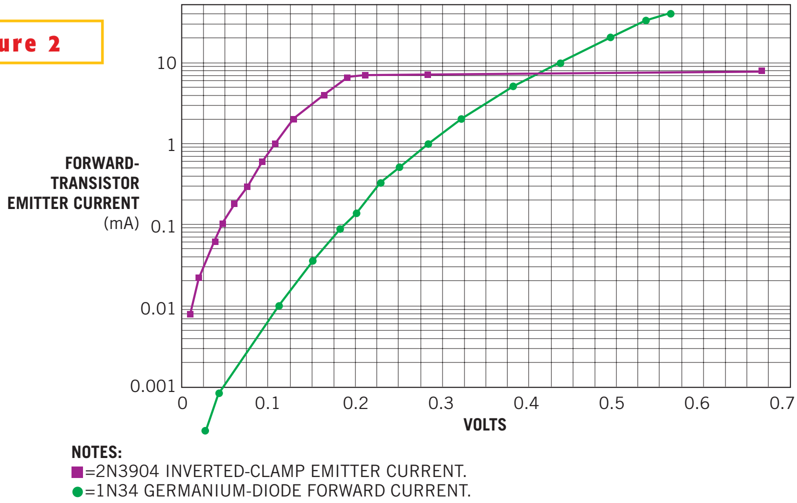
NOTES:
INVERTED BETA IS LESS THAN 1;
FOWARD BETA IS GREATER THAN 100.
MAXIMUM EMITTER VOLTAGE IS
LESS THAN V_{EBR}+0.6.
USE I_B TO SET INVERTED
EMITTER CURRENT.
POSITIVE EMITTER VOLTAGE CAUSES
INVERTED OPERATION.
NEGATIVE EMITTER VOLTAGE
CAUSES FORWARD-OPERATION,
HIGH-CURRENT LOW-IMPEDANCE
CLAMP ACTION.

NOTE:
TRANSFER FUNCTION FOR 2N3904
WITH 40 μA BASE DRIVE.

The bipolar inverted clamp (a) has an excellent rectification characteristic (b) because of the 2N3904's large forward-beta-to-reverse-beta ratio.

The circuit achieves this excellent rectification characteristic by using a transistor with a large forward-beta-to-reverse-beta ratio. Many of these transistors are still available. The 2N3904 provides excellent characteristics at a low cost. The reverse beta of the 2N3904 is only 0.25, so that for positive voltage on the emitter and, with 40 μA of base drive, the emitter current is around 10 μA. This current is sufficient in most level-detector applications for which the ac input amplitude changes slowly.

Figure 2



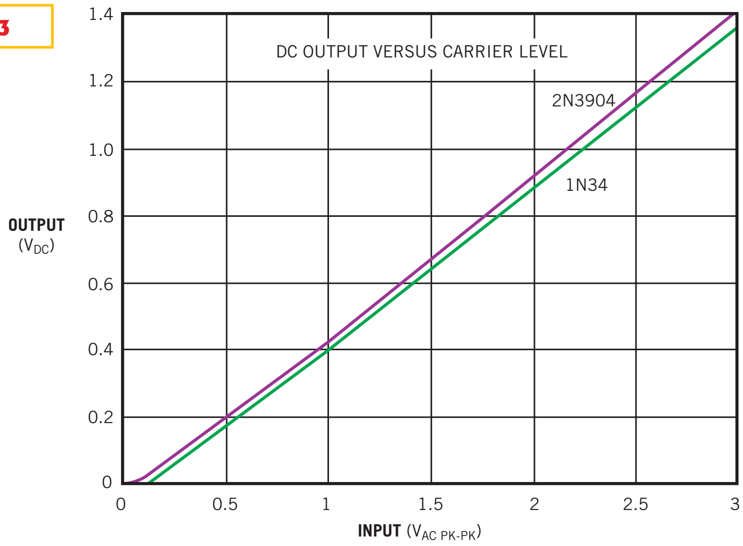
NOTES:
■=2N3904 INVERTED-CLAMP EMITTER CURRENT.
●=1N34 GERMANIUM-DIODE FORWARD CURRENT.

A logarithmic scale of the 2N3904's forward-transistor emitter current and the forward current of the 1N34 shows the impressive response of the 2N3904 at small voltages.

The emitter current at even small negative voltages is much greater than in the inverted region because the forward beta of the 2N3904 is greater than 100. Impedance is low up to the beta-limited forward current, at which point the impedance increases to approximately the value of R_1/beta. **Figure 2** shows the forward-transistor emitter current of the 2N3904 and the forward current of the 1N34 germanium point-contact diode. The logarithmic current scale shows the impressive response of the 2N3904 at small voltages.

Figure 3 shows the output as a level detector for the two clamps. The transistor circuit that produced these results is similar to the demodulator in **Figure 4** except the base drive is 40 μA. For the 1N34, the anode connects to grounded and the cathode connects to the input capacitor in place of the transistor's emitter. **Figure 3** shows that the two configurations have similar responses to input levels, and that the 2N3904 has a bit less offset, as you would expect from **Figure 2.** The output can drive a signal level meter or following electronics as part of an automatic-level-control or automatic-gain-control loop.

Figure 3



NOTES:
FOR 2N3904, $V_{DC}=0.5V_{AC}-0.08$, AND $I_{BASE}=41$ μA.
FOR 1N34, $V_{DC}=0.5V_{AC}-0.11$.

When operating as demodulators, the two configurations have similar input-level responses.

The transfer function in **Figure 1** also shows a sudden increase in inverted current at approximately 7.6V, which occurs at the reverse breakdown voltage for the emitter-to-base junction. Because you know in this case that the base is near 0.6V, the breakdown voltage for the tested part is near 7V. Production circuits would have an input limit of 6.6V p-p because of the minimum specified breakdown voltage of 6V. Note that, for a small production, such as for test equipment, it is practical to select individual transistors to slightly increase the dynamic range. A 6V p-p input dynamic range is sufficient in many applications.

The RF demodulator in **Figure 4** has a base drive current of 300 μA. This current is necessary to track the RF-modulation envelope and depends on the size of the input capacitor, modulation frequency, and maximum signal amplitude. The reverse current, which is I_{BASE} times the reverse beta, must be large enough to discharge the input capacitor at the highest modulation frequency and amplitude to prevent distortion in the output waveform. **Figure 5** shows the running demodulator with the upper trace at the emitter node and the lower trace at the output.

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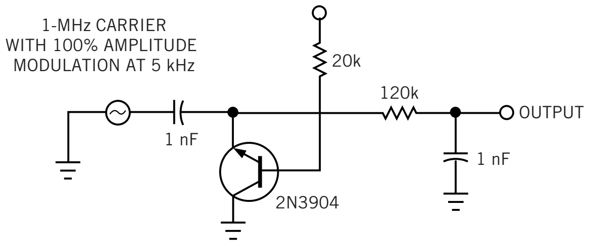
Figure 4



NOTES:
BASE-DRIVE CURRENT IS 300 μA, EMITTER REVERSE CURRENT IS APPROXIMATELY 75 μA.
2N3904 FORWARD BETA IS GREATER THAN 100;
REVERSE BETA IS APPROXIMATELY 0.25.
EMITTER-BASE REVERSE-BREAKDOWN VOLTAGE IS GREATER THAN 6V.
AC-DRIVE VOLTAGE IS LESS THAN 6.6V P-P.

Using the inverted clamp as an AM demodulator requires a base current of 300 μA to track the RF-modulation envelope.

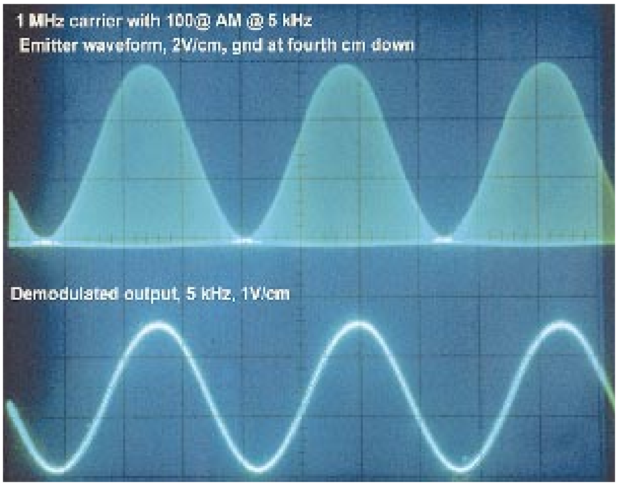


Figure 5

A scope photo shows the running demodulator; the upper trace is the emitter node, and the lower trace is the output.

Data-acquisition circuit measures almost everything

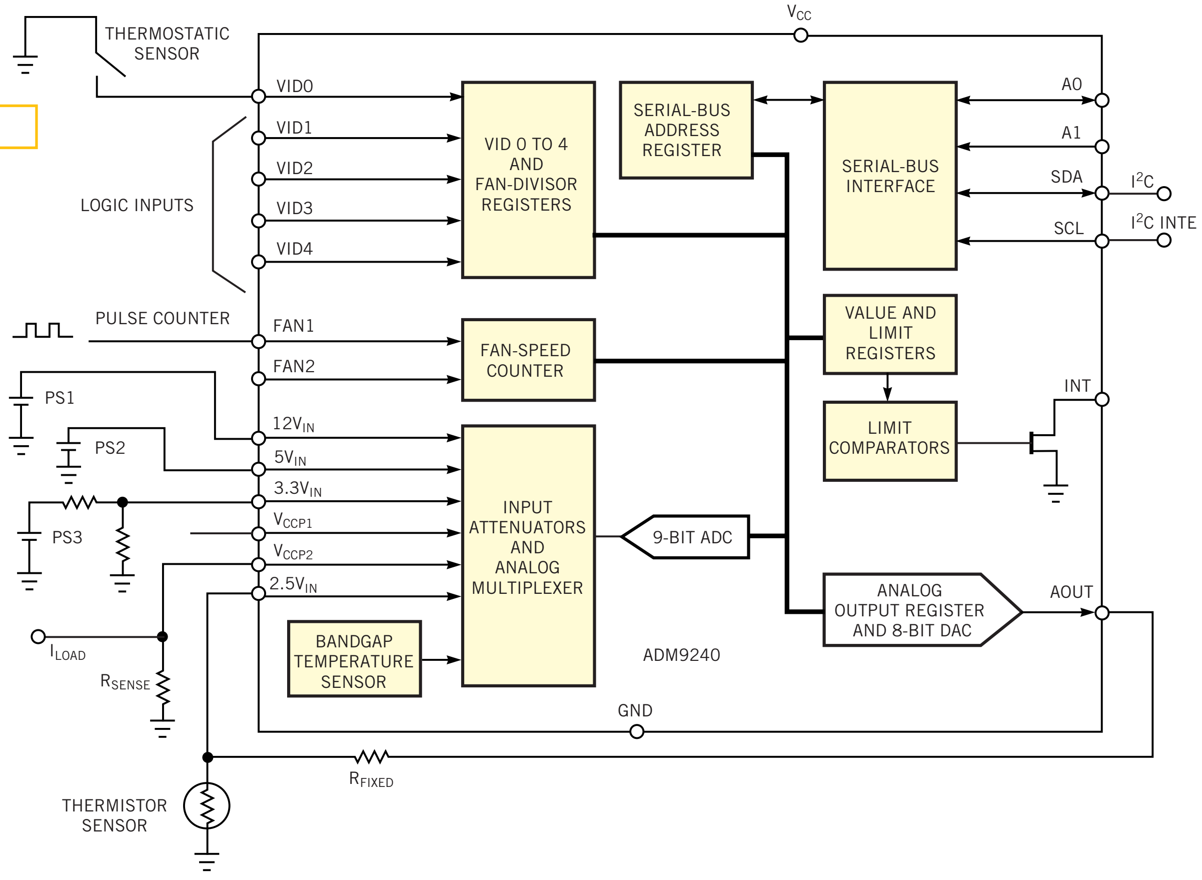
Matt Smith, Analog Devices, Limerick, Ireland

Using a product developed for PC-motherboard environmental monitoring, you can configure a low-cost, general-purpose DAS (data-acquisition system) (**Figure 1**). The DAS can directly monitor multiple voltage channels as well as temperature and frequency. It can also directly monitor digital sensors. Using only a few additional components, the system can accommodate other sensor and transducer elements. The flexibility exists to expand the scheme to cover additional input channels if necessary. For voltage sensing, the ADM9240 contains a multichannel ADC that can directly monitor as many as six input channels. The original intent of the ADC was to monitor power supplies on PC motherboards, but the converter is flexible enough for general-purpose use. The maximum input-voltage ranges for the channels are 3.3, 3.6, 4.4, 6.64, and 16V. **Figure 1** shows the system monitoring two power supplies: PS1 and PS2. The DAS can monitor voltages greater than the channel range by using a simple voltage divider at the front end, as illustrated with PS3.

The ADM9240's on-board DAC (originally intended as a fan-speed controller) can serve as a programmable, precision reference source. This function, for example, would facilitate measuring resistance-type sensors on the voltage-sensing channels. You could also use it as a bridge-excitation voltage source for accurate bridge-sensing elements. You can determine an unknown resistance value, such as a thermistor, by setting the DAC's output voltage to a known level with a known fixed resistance (**Figure 1**). You can implement current sensing by placing an accurate series resistor (R_{SENSE}) in the ground line and monitoring the voltage drop across the resistor. The DAS also provides temperature sensing by using an on-chip bandgap silicon sensor. The system can directly monitor temperatures over a −40° to +85°C range.

The DAS provides two frequency-monitoring channels. You can use them

Figure 1



A data-acquisition IC originally intended for PC motherboards can monitor a multitude of parameters.

to monitor pulsed digital output from a tachometer or as general-purpose frequency counters. Five digital-input lines were originally intended to monitor digital voltage-identification lines. You can use them for general-purpose input lines, whose inputs can sense high- or low-level status signals from digital sensors or from alarm channels. In **Figure 1**, the DAS monitors a thermostatic sensor. The DAS handles control and reading functions via a simple two-wire SMBus or an I^{2}C interface to a µP or µC. If a dedicated I^{2}C controller is not available, then you can use a port "bit-banging" technique. Easy expansion is also possible by selecting a different device address. Using a different device-address bus entails no additional communication lines, because multiple devices can reside on the same bus.

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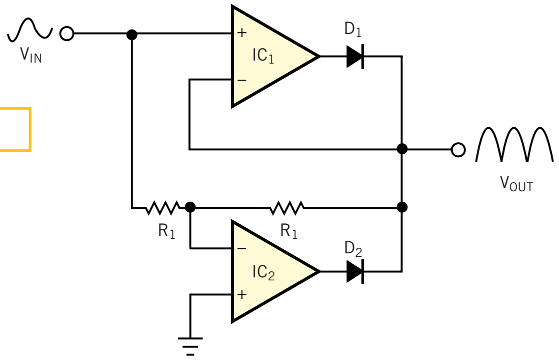
Full-wave rectifier has programmable gain

Chuck and Chris Wojslaw, Xicor Inc, Milpitas, CA

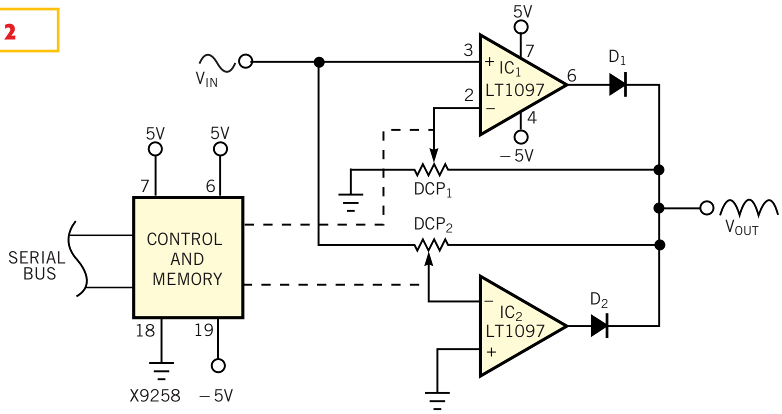
THE TRADITIONAL approach to the design of a full-wave rectifier (**Figure 1**) is to set the gains of IC$_1$ and IC$_2$ to 1 and use the steering diodes D$_1$ and D$_2$ to sum the sinusoidal half-cycles of the input to form the rectified output. For the positive half-cycle of the input signal, IC$_1$ is a noninverting amplifier with a gain of 1. For the negative half-cycle of the input signal, IC$_2$ is an inverting amplifier with a gain of −1. This full-wave-rectifier circuit often combines with a lowpass filter to form a low-cost ac/dc converter. If you need a full-wave rectifier with amplification, the combination of these two functions in one circuit can provide savings in cost, component count, and board space. The circuit in **Figure 2** combines rectification and programmable amplification. The two 256-tap Xicor digitally controlled potentiometers, DCP$_1$ and DCP$_2$, control the gains of the noninverting amplifer, IC$_1$, and the inverting amplifier, IC$_2$, respectively. The gain of IC$_1$ is $_1G_1=255/P1$, where P1 $(0 \le P1 \le 255)$ is the programmed decimal value of DCP$_1$. Similarly, the gain of IC$_2$ is $G=-(255-P2)/P2$. The performance of this circuit takes advantage of the resistor matching inherent in the digital potentiometers. The measured data falls within 2% of calculated values.

Figure 1



This full-wave-rectifier circuit has a fixed gain of 1.

Figure 2



You can program the gain of this full-wave rectifier from unity to 255.

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Method synchronizes slaves in power-line communications

Jose Sebastia and Diego Munoz, University of Valencia, Spain

In PLC (power-line-communication) applications, the communications system usually uses one master and a large number of slaves (for example, 64). The idea presented here is an easy method for the synchronization of slaves, using one µC and a few other components. The µC is a PIC16C7X, which has three important properties for this application: a watchdog timer, an external interrupt, and a sleep instruction. The watchdog timer is a free-running, on-chip RC oscillator that requires no external components. The watchdog timer continues running even if the µC clock stops in the event of a sleep instruction. During normal operation, a time-out from the watchdog timer generates a device reset. If the device is in sleep mode, a watchdog timer time-out causes the device to wake up and continue normal operation.

In PLC applications, the ac power-line voltage is 24V ac (for outdoor applications) or 220V ac (for household applications) at 50 or 60 Hz. With a period of 20 msec, the power-line voltage has a zero crossing every 10 msec. These zero crossings serve as a timer for the slaves. Each zero crossing activates the µC's interrupt when the slave is sleeping and wakes up and updates the timer/counter. In **Figure 1**, a single resistor connects the 24V-ac line to the µC. Each slave has a counter/timer, and all counter/timers count simultaneously. To synchronize the slaves, this method uses the watchdog timer, which has a normal time-out period of 18 msec. If this time elapses without activation of the interrupt, the µC wakes up and starts the counter/timers of all the slaves. At this moment, the slaves are synchronous with the master. When the output of pin RC0 of the µC in **Figure 2** is at 0V, the pin draws current, I_{OUT}. This current activates the optically coupled triac, enabling a 24V-ac power line for the slaves. When the RC0 output is high, the result is a short circuit in the ac power line. At this point, the slaves begin the synchronization subroutine (**Listing 1**). You can download **Listing 1** 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 #2602.

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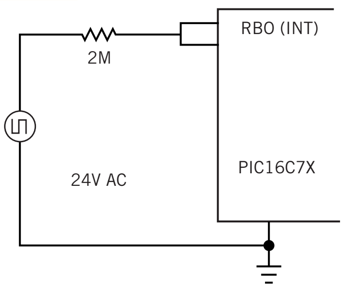
LISTING 1—SYNCHRONIZATION SUBROUTINE

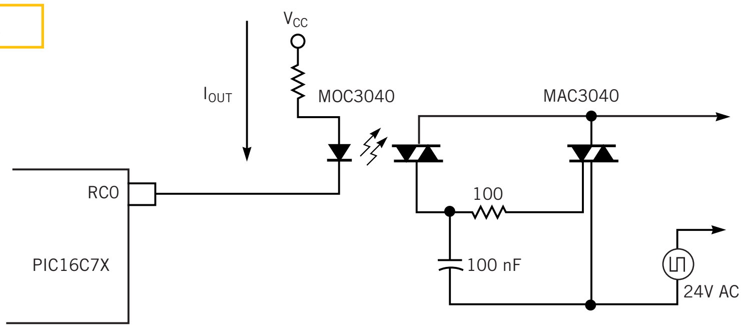
```
BUCLE
          clrw                     ; clear the W register
          SLEEP                    ; the microcontroller is sleeping
          clrwdt                   ; clear the watch-dog register
          btfsc     WAKEUP,5       ; the bit 5 of register WAKEUP show that the
                                   ; interruption is of synchronisation if is 1. But
                                   ; if is 0 the wake up of micro is due at WDG, and
                                   ; clear the TIMER1.
           goto     por_RB0        ;
          goto      wdg_sincro     ;

wdg_sincro
          clrf      TMR1           ; clear the TMR1 register
          bsf       flag,SINCRO    ; the bit flag in the SINCRO register show what the
                                   ; synchronisation are make.
          goto      BUCLE;

por_RB0
          bcf       WAKEUP,5       ; clear the bit of show the synchronisation
          incf      TMR1           ; This is the internal counter for each slave
          goto      BUCLE;

; Subroutine of interruption
__INT
          bsf       WAKEUP,5       ; if the micro wakes up due to the interruption,
                                   ; the bit 5 of WAKEUP register is 1 for indicate
                                   ; this.

          RETFIE
```

Figure 1



The ac power line can directly drive the PIC16C7X interrupt pin.

Figure 2



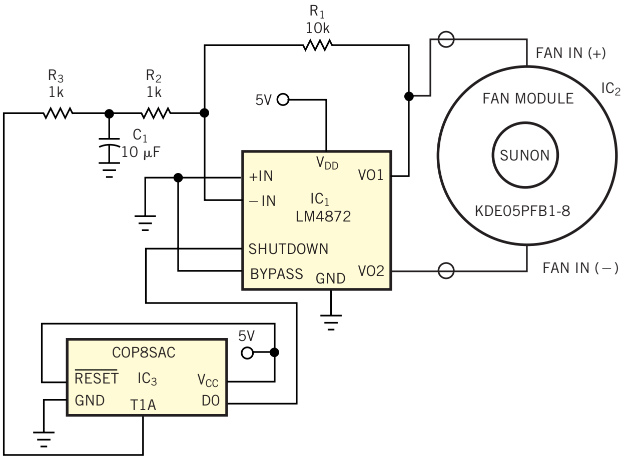
An optically coupled triac controls power for the slaves.

Audio amp makes efficient fan controller

Wallace Ly, National Semiconductor Corp, Santa Clara, CA

You can use discrete transistors to vary power to a fan to control its speed. However, with a simple modification, you can use an audio-amplifier IC to control a fan module (**Figure 1**). The LM4872 "Boomer" is an audio amplifier capable of delivering 1W maximum output power. A COP8SAC µC connects to the audio amplifier and the fan module. The µC's T1A output pin delivers a PWM signal to an RC network, which produces a dc signal. The dc output of the RC network is proportional to the duty cycle of the PWM signal. The dc signal drives the audio amplifier, which powers the fan via its bridge-configuration outputs. **Listing 1** demonstrates how to control the PWM signal from the µC. For standby operation, set the D0 bit; this operation puts the LM4872 in shutdown mode. We also recommend that you put the µC in shutdown mode. In shutdown mode, the total quiescent current is approximately 4 µA, so the circuit in **Figure 1** is ideal for battery-powered applications. You can download **Listing 1** 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 #2608.

Figure 1



An inexpensive µC and audio-amplifier IC form an efficient fan controller.

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LISTING 1—FAN-DRIVER C FILE

```
#include "8saa.h"                         // Include file for the COP8SLB
void init_params();                       // Initializtion routine
void shutdown(unsigned int state);        // Shutdown amplifier routine
void fan_speed(unsigned int state);       // The Speed of the fan
                                          // Alters the PWM duty cycle
                                          // In percent of (on) vs (off)
void main(){

        init_params(); // initialize the parameters

        // Make sure the amplifier is on
        shutdown(0);

        // Scale up the fan speed

        // Turn up the fan speed
        fan_speed(20);

        // Scale down the fan

        //fan_speed(10);


        // Shutdown the amplifier (off)
        shutdown(1);

        while(1);  // forever loop

}

// The shutdown routine

void shutdown(unsigned int state){

if (state==0)

   PORTDD.0=0;     // Turn the pin low
   else
      PORTDD.0=1;  // else turn the pin high

}
```

```
// The intialization parameters

void init_params(){

        // Turn PWM on out
        PORTGC.3=1;   // Set so the portgc pin is high
        PORTGD.3=1;   // Lower the portgd pin for PWM mode

        // Make the high byte zero

        T1RAHI=0;
        T1RBHI=0;

        // Set to PWM: TxA Toggle
        // Autoreload RA, RB

        CNTRL.T1C1=1;
        CNTRL.T1C2=0;
        CNTRL.T1C3=1;

}


// The change fan speed routine

void fan_speed (unsigned int state){


        // Detect if it is less or equal to 100 percent
        if (state<101){

           T1RALO=state;         // Initialize the state
           T1RBLO=state-100;     // Turn the lower half state-100
           CNTRL.T1C0=1;         // Set the timer enabled bit

          }

}
```