

Edited by Bill Travis

High-fidelity triangle-wave generator consumes only 6 μA

Glen Brisebois, Linear Technology Corp, Milpitas, CA

IDEAL TRIANGLE WAVES involve infinite d^2V/dt^2 , so high-fidelity triangle waves entail very high bandwidths. Micropower circuits have fairly low bandwidth, so generating good triangle waves with such circuitry becomes problematic. The circuits of **Figure 1** show two methods of generating triangle waves. The solitary-comparator circuit uses a relaxation-oscillator approach with the triangle approximation assuming an RC (exponential) nature (**Figure 1a**). When you need better linearity, adding an integrator improves the triangle approximation (**Figure 1b**). Both circuits

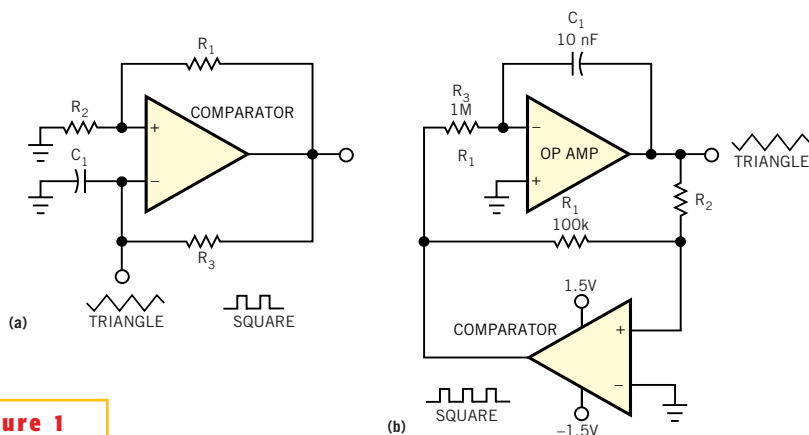


Figure 1

These popular methods of generating triangle waves have drawbacks, especially when your design requires low-power operation.

include a hysteretic-feedback path, as well as an RC or integrator feedback path comprising R_3 and C_1 . The hysteretic-feedback path keeps changing the direction of the RC integrator and setting the new target voltage, and the RC integrator sets the rate of change toward the new target. These circuits are robust and find wide usage.

The problem arises when you simultaneously require ultralow power consumption and relatively high-frequency operation. This scenario makes phenomenal demands on the micropower op amp. Consider that, every time the comparator reverses direction, it slams an instantaneous current into or out of the op amp's output through the two feedback paths. This situation would be acceptable, except that the amount of current it slams is greater than the op amp's total supply current. The result is a disastrous-looking waveform with enormous glitches stemming from the fact that the op amp cannot provide the instantaneous output-switch current demands. You can

gain some improvement by increasing the resistor values and reducing the capacitor values. However, the improvements are only incremental, and the circuit becomes noisier and more susceptible to interference.

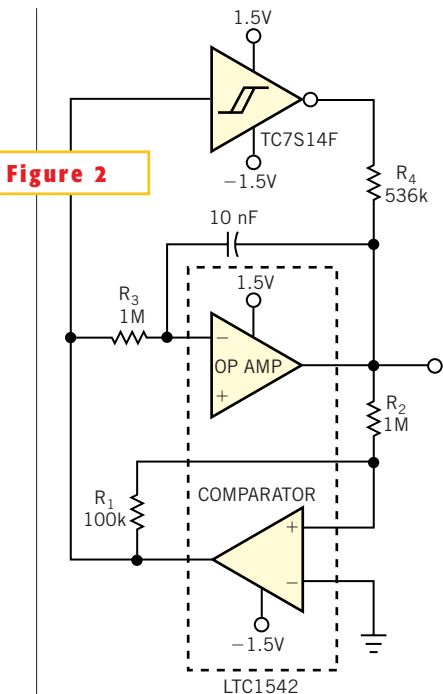


Figure 2

A simple CMOS inverter provides high-bandwidth current assist, improving the waveform drastically with minimal impact on supply current.

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But take heart; a simple and inexpensive solution is at hand. Why not let a CMOS inverter provide the instantaneous current and let the op amp simply provide the precision linearizing current?

Figure 2 shows the method. The circuit is identical to that of **Figure 1b**, except that the op amp need not provide the instantaneous switch current. Instead of the drastic change in output-current po-

larity at the triangle peaks, the op amp's output current slowly crosses zero at midsupply. In the improved waveform, the total supply current at 280-Hz operating frequency is 6.2 μA . □

High-current driver serves home-power-line modems

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HOME-BASED power-line networking signals are similar to xDSL (digital-subscriber-line) signals in that they both typically employ a form of OFDM (orthogonal frequency-division multiplexing). Both applications require high output current, wide bandwidth, and good linearity. This Design Idea describes a simple line-driver circuit, designed with an xDSL driver, to drive high-speed data over a home power line. **Figure 1** shows the AD8391 current-feedback amplifier connected in a negative-feedback circuit to drive wideband, discrete multitone-based signals through

Figure 1

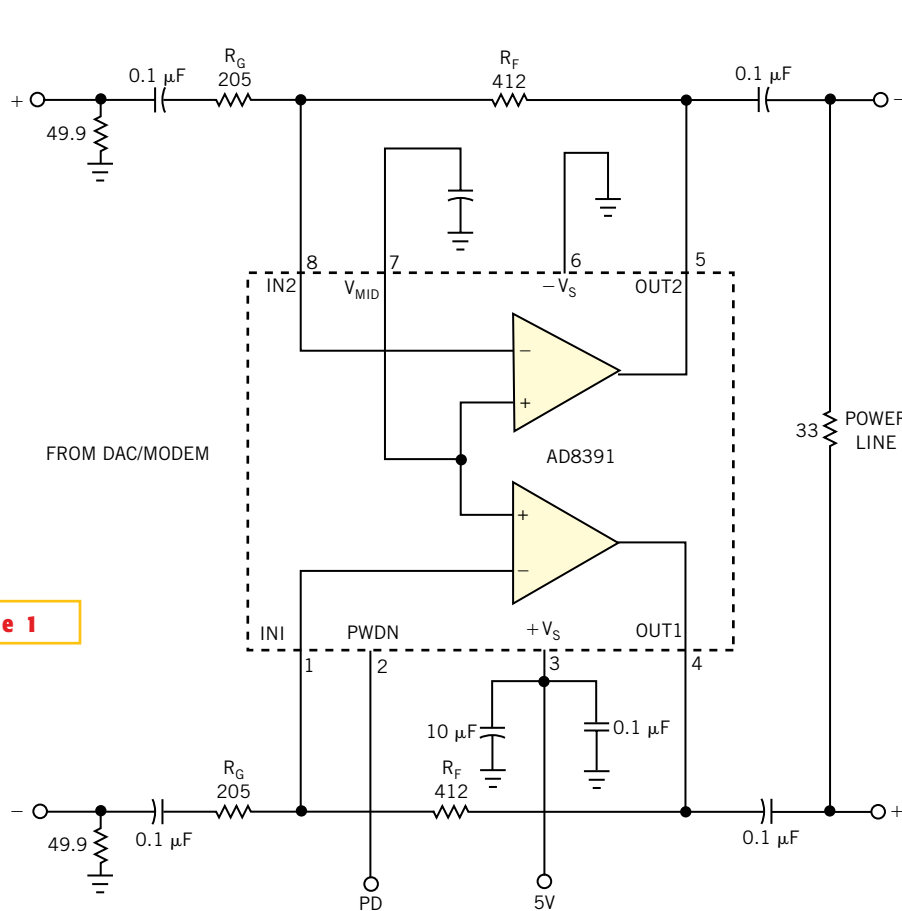
The advantage of current feedback is that it allows you the flexibility of increasing the gain beyond unity without being limited by the gain-bandwidth product. The AD8391 has 60-MHz bandwidth, 600V/ μsec slew rate and 250-mA output-drive-current capability, making it ideal for driving home power lines.

The circuit in **Figure 1** operates with a 5V supply, has a voltage gain of $-2(-R_F/R_G)$, and drives a 33 Ω load. The 33 Ω load emulates the worst-case impedance of a home power-line network, which can vary greatly from home to home. The driver is transformer-coupled to the power line. The amplitude of the output signal is 2.8V p-p into the differential power line (hot and neutral)

with a peak-to-average ratio of 4V/V. The feedback resistor, R_F , and the gain resistor, R_G , maximize circuit bandwidth and stability. For this circuit, an acceptable bandwidth is approximately 30 MHz. The following **equation** shows the relationship between closed-loop bandwidth (f_{CL}), R_G , and R_F for current-feedback amplifiers.

$$f_{CL} = \frac{1}{2\pi C_P R_F \left(1 + \frac{R_{IN-}}{R_F} + \frac{R_{IN-}}{R_G} \right)}$$

C_P , the internal capacitance, sets the corner frequency of the open-loop transimpedance function, and R_{IN-} is the input impedance of the inverting terminal of each amplifier. (**Figure 1** does not



An xDSL driver uses current-feedback technology to make an efficient home-power-line driver.

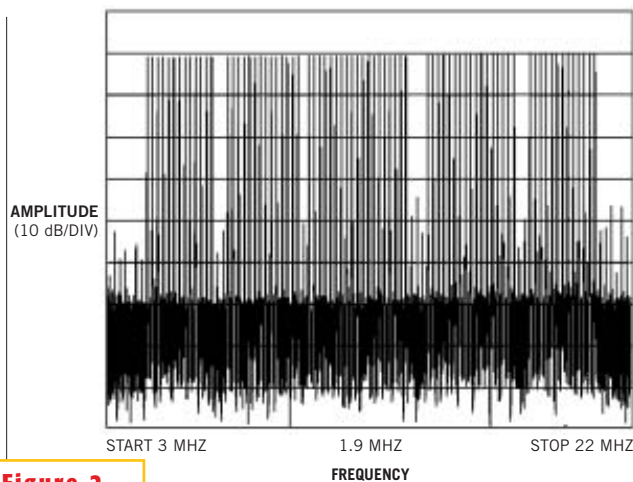


Figure 2

The output spectrum of the power-line driver in Figure 1 shows that the worst-case empty-tone distortion is -35 dBc.

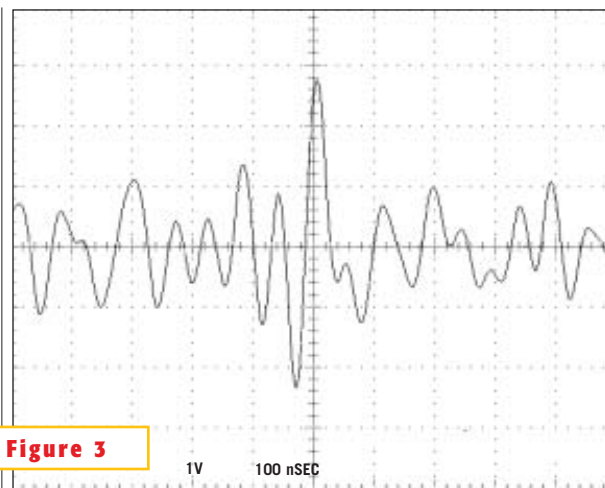


Figure 3

This plot represents the time-domain characteristic of the power-line driver.

show C_p and R_{IN} .) It is important to note that R_F dominates the expression, thus controlling the closed-loop bandwidth. The 49.9Ω resistors on the inputs of the circuit terminate the signal source. You should adjust these values based on each application. The four $0.1\text{-}\mu\text{F}$ capacitors

provide ac coupling on the input and output lines. The test signal is a composite waveform constructed from the sum of 75 sinusoids of pseudorandom phase. Each tone in the test waveform may have one of four phases to emulate QPSK (quadrature phase-shift keying). The si-

nusoids are orthogonally spaced from 4 to 21 MHz, leaving the amateur-radio bands empty. Figure 2 shows that the worst-case empty-tone distortion is -35 dBc. This figure is adequate for most practical power-line applications. Figure 3 shows the output in the time domain. □

Circuit forms fast, portable light pulser

SK Kaul and IK Kaul, Bhabha Atomic Research Centre, Trombay, Mumbai, India

THE ABSENCE of a fast one-shot multivibrator in the entire TTL family, as well as the low-voltage swing and unwieldy supply requirements of ECL, drove us to exploit the fast transition times and low propagation delays of F-series gates. The application called for the implementation of a compact, portable, fast light pulser for field testing fast photomultipliers in gamma-ray astronomy work. The use of only two ICs helped to minimize the size and power consumption (Figure 1). The normally high pulses at the output gate, G4, in IC_2 have rise and fall times of approximately 2.5 nsec and a duration of

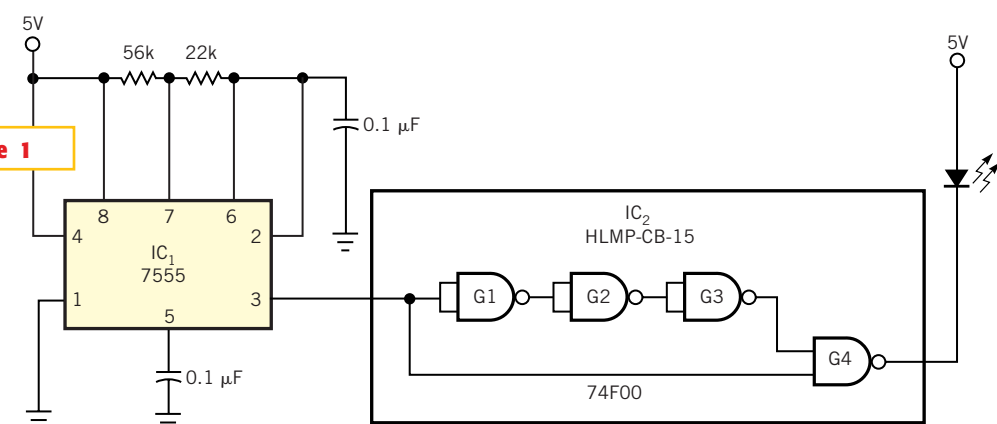


Figure 1

This circuit provides fast light pulses in a blue LED.

less than 10 nsec, corresponding to three gate delays. These pulses are ideally suited to pull low the cathode of a fast, blue HLMPCB-15-type LED with the anode clamped at 5V. The gate forces almost the entire 5V supply voltage across the LED. This high swing ensures optimum

brightness of the LED, which is soldered to the edge of a small pc-board strip. Rechargeable batteries are clamped onto the other side of the pc board. Using a CMOS version of the timer, IC_1 , the circuit has a current drain of less than 4 mA. □

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3V supply delivers 12V p-p to piezo speaker

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LOW-PROFILE PIEZOELECTRIC speakers can provide quality sound for portable electronic devices, but they require voltage swings greater than 8V p-p across the speaker element. Yet, most portable devices include only a low-voltage power source, and conventional amplifiers operating from batteries cannot provide enough voltage swing to drive a piezoelectric speaker. One approach to this problem is to use IC₁ in **Figure 1**, which you can configure to drive a piezoelectric speaker with as much as 12V p-p and operate from a single 3V supply. IC₁, a MAX4410, combines a stereo-headphone driver with an inverting charge pump that derives a negative

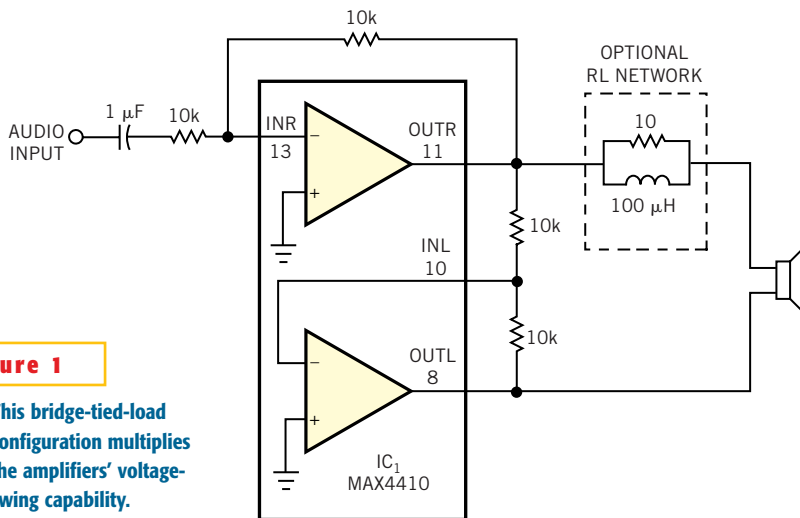


Figure 1

This bridge-tied-load configuration multiplies the amplifiers' voltage-swing capability.

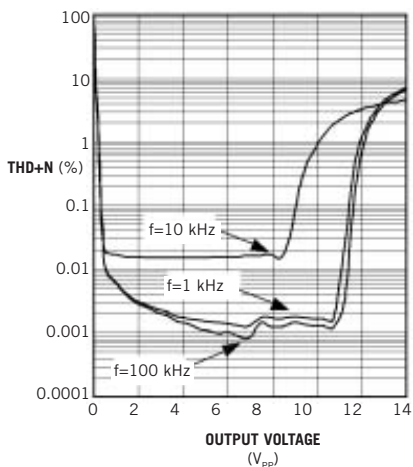


Figure 2 Testing the circuit yields this THD+N versus output voltage for the Figure 1 circuit.

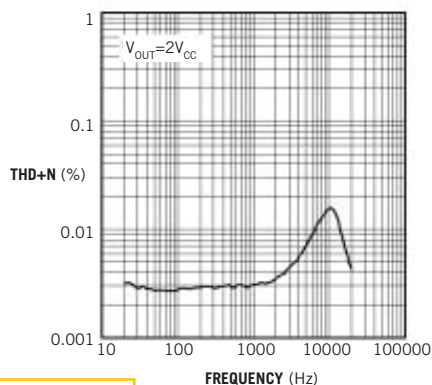


Figure 3 Testing the circuit yields this THD+N versus frequency for the Figure 1 circuit.

–3V supply from the positive 3V supply. Thus, providing the drive amplifiers with an internal $\pm 3V$ supply allows each output of IC₁ to swing 6V p-p. Configuring IC₁ as a BTL (bridge-tied load) driver again doubles the maximum swing at the load to 12V p-p. In the BTL configuration, IC₁'s right channel serves as the master amplifier. It sets the gain of the device, drives one side of the speaker, and provides a signal to the left channel. If you configure IC₁ as a unity-gain follower, the left channel inverts the output of the right channel and drives the other leg of the speaker. To ensure low distortion

and good matching, you should set the left-channel gain using precision resistors.

We tested the circuit with a Panasonic (www.panasonic.com) WM-R57A piezoelectric speaker, yielding the THD+N (total-harmonic-distortion-plus noise) curves (figures 2 and 3). Note that THD+N in-

creases as frequency increases in both graphs. Because the

speaker appears to the amplifier as a capacitor, the speaker's impedance decreases as frequency increases, resulting in a larger current draw from the amplifier. IC₁ remains stable with the speaker, but a speaker with different characteristics might cause instability (**Figure 4**). In that case, you can isolate the speaker's capacitance from the amplifier by adding a simple inductor/resistor network in series with the speaker (within the dotted lines on **Figure 1**). The network maintains stability by maintaining a minimum high-frequency load of approximately 10 Ω at the IC's output. □

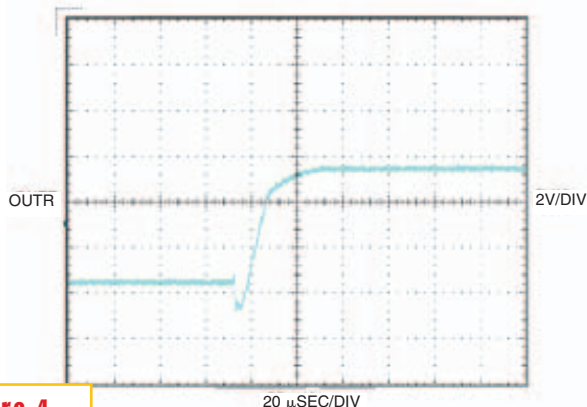


Figure 4

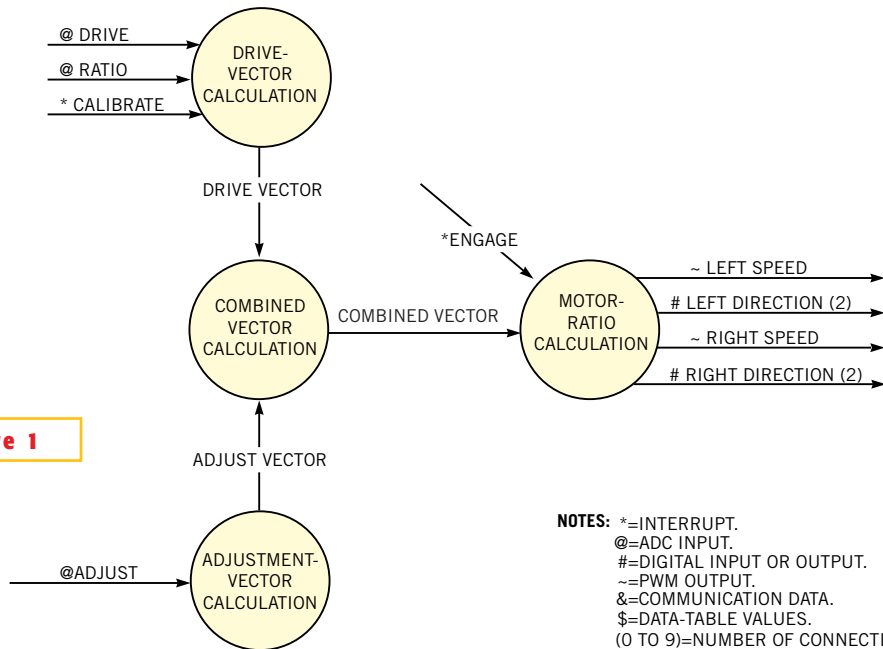
Step response at the OUTR output of IC₁ in Figure 1, which drives a WM-R57A piezoelectric speaker, shows that IC₁ remains stable with the speaker.

Code provides adjustable differential drive for robots

Alton Harkcom, EGO North America, Newnan, GA

INTELLIGENTLY modifying the motor-drive commands to a robot can give you control finesse during competitions. Moving a joystick hard right, for example, might have different effects, depending on the robot's speed and direction. Software running on an inexpensive microcontroller (in this case, an NEC (www.nec.com) PD78F9814) manages this control by calculating separate drive and adjust vectors and then combining the vectors and calculating the appropriate power ratio for two tread motors (Figure 1). This demonstration system uses a simple treaded toy vehicle to show how the ratio-drive concept works and requires

Figure 1



NOTES: *=INTERRUPT.
 @=ADC INPUT.
 #=DIGITAL INPUT OR OUTPUT.
 ~ =PWM OUTPUT.
 &=COMMUNICATION DATA.
 \$=DATA-TABLE VALUES.
 (0 TO 9)=NUMBER OF CONNECTIONS.

An NEC microcontroller calculates the appropriate power ratios for two tread motors in a robot.

no sensors in the vehicle. The microcontroller controls the tread motors with simple forward/reverse signals based on the calculated motor speeds and directions.

Listing 1, which you can download from the Web version of this Design Idea at www.edn.com, shows the main routine for this application. It begins by initializing all the signals and then calibrating them with the joystick at the idle position (MID) and each extreme (LO and HI). The code uses several sets of variables. Drive variables (DriveRaw, DriveHI, DriveMID, DriveLO, and Drive) specify

the combined drive speed for the motors. Ratio variables (RatioRaw, RatioHI, RatioMID, RatioLO, and Ratio) specify the ratio of right-to-left motor balance. Adjust variables (AdjustRaw, AdjustHI, AdjustLO, and Adjust) specify the adjustment value to the ratio value. The adjustment reduces the ratio value to better control left/right balance at particular speeds. Range-conversion variables (RangedUpper, RangedLower, and Ranged) rerange the ADC inputs to the desired 0 to 100% values for the motor speed and direction. After the code cal-

culates the Left and Right motor vectors, another routine uses these vectors to drive the motors. If Right is greater than 1, for example, the drive routine enables a RightForward PWM signal and disables the reverse signal. For experimentation purposes, you can use a 1A quad half-H bridge to route the speed and direction signals to the motors. In actual competitions, you need a heavier duty motor controller because the motor-stall currents can exceed 1A. □

Microcontroller produces analog output

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A BRUSHLESS DC MOTOR needs several voltage levels to control its speed: 0V to stop the motor, 5V to run it at maximum speed, and some voltages between these extremes to run it slower. When you use such a motor in a system under microcontroller supervision, the microcontroller should generate all these voltages.

But a microcontroller is a digital device, and it usually has no analog output. Several methods are available to overcome this deficiency. For example, you could use a DAC, a digitally programmable potentiometer, or some analog switches connected to resistor dividers. However, when you need only a few intermediate voltage

levels, it would be more attractive to find a method that uses microcontroller software. This Design Idea exploits the fact that you can program a microcontroller's I/O pins as either input or output. When you program a pin as output, you set its voltage level to high (5V) or low (0V). When you program a pin as input, it has

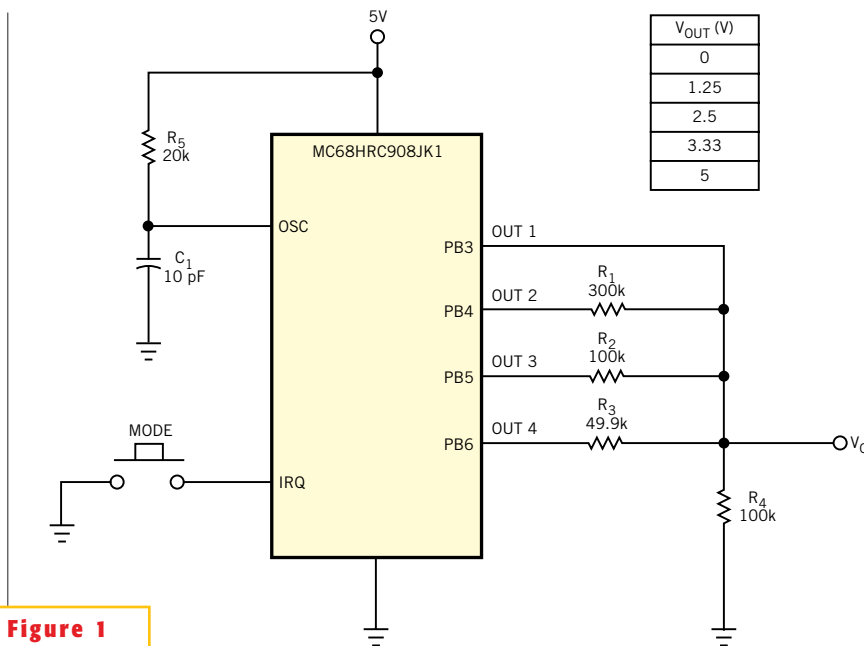


Figure 1

A microcontroller can generate analog outputs for motor-control purposes.

no effect on output voltage. **Figure 1** shows a circuit example.

The circuit needs no external components, except for a few resistors. You can set the output-voltage levels during the main program execution or by an external interrupt. For testing purposes, using an external interrupt is preferable (see **Listing 1** at www.edn.com). A pushbutton-mode switch triggers the external interrupt, the service routine of which consequently sets all the predetermined voltages. This design uses 0, 1.25, 2.5, 3.33, and 5V levels. Resistors R₁ to R₄ determine the intermediate levels. The circuit uses the inexpensive, 8-bit MC68HRC908JK1 flash microcontroller from Motorola (www.motorola.com), but this method applies to almost any kind of microcontroller. You can download the microcontroller software from the Web version of this Design Idea at www.edn.com. □

Single transistor provides short-circuit protection

Keith Szolusha, Linear Technology Corp, Milpitas, CA

IN CERTAIN dc/dc-converter applications, on-chip, cycle-by-cycle current limit may be insufficient protection to prevent a failure during a short circuit. A nonsynchronous boost converter provides a direct path from the input to the short circuit through the inductor and the catch diode. Regardless of current-limit protection in the IC, when a short circuit exists in the load, extremely high currents that flow through the load path can damage the catch diode, the inductor, and the IC. In a

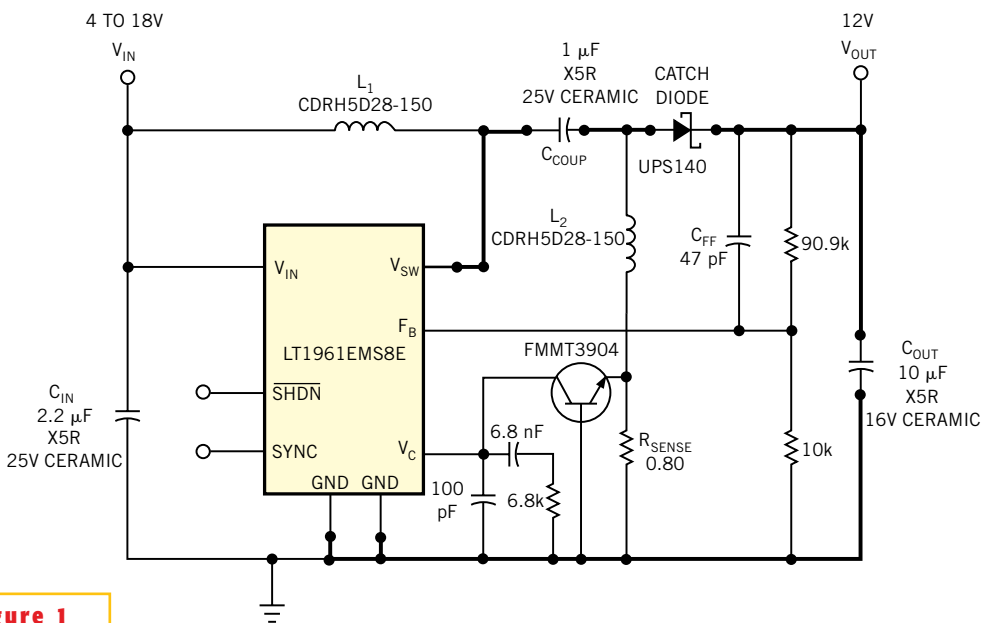


Figure 1

This 4 to 18V-input, 12V-output SEPIC has short-circuit protection.

primary-inductance-converter) circuit, the coupling capacitor breaks this path. Thus, when a short circuit exists in the

load, no direct path exists for current to flow from input to output. However, if the required minimum on-time is less

than the application-specific duty cycle, the inductor and, thus, the switch current can rapidly increase, causing IC fail-

ure, input-supply overload, or both. Even in certain buck-regulator applications, duty-cycle limitations sometimes keep the switch on too long to maintain control during an output short-circuit condition, especially at very high input

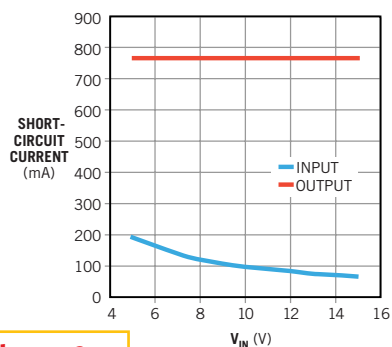


Figure 2

The short-circuit input and output current for the circuit of Figure 1 differ at different voltages.

voltage with extremely high-frequency ICs. A single-transistor approach protects the SEPIC circuit from short-circuit fault conditions by pulling down the V_C pin (the output of the error amplifier) when the inductor current starts to run away during an overload or short circuit in the load (Figure 1).

Pulling the V_C pin low forces the IC to stop switching, skipping minimum on-time switch cycles, and allowing the current in each inductor to ramp down. During a short circuit, the peak current in L_1 , which decreases because of the limited number of switch cycles, and the peak current in L_2 sum up to equal the peak current in the switch, which is less than the 1.5A limit of the LT1961EMS8E. Figure 2 shows the short-circuit input and output currents at different input voltages. Figure 3 shows the maximum load current versus input voltage. The average current in L_2

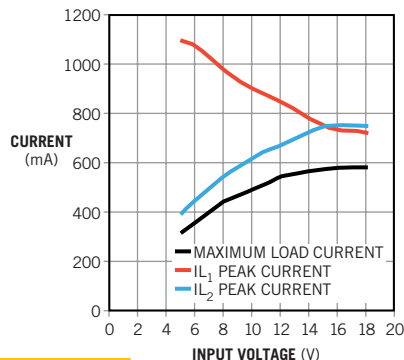


Figure 3

These curves show the maximum load current under normal load conditions.

is equal to the load current and is a maximum of 600 mA under all load conditions. If the sense resistor sees 800 mA, it knows that an overload condition has occurred and tells the transistor to protect the circuit. □