design ideas

Edited by Brad Thompson

Dual-output nonisolated SMPS powers appliances

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Modern appliances offer a range of features that rely heavily on microcontrollers and auxiliary circuits. Although conventional iron-core transformers can provide ac line-isolated, low-voltage power for a microprocessor, coupling the processor's control signals to line-side power switches requires yet another layer of electrical isolation, such as optocouplers or pulse transformers.

Designers can avoid the complexity and expense of adding isolation components by powering the microcontroller and its auxiliary circuits from the nonisolated ac line. An offline SMPS (switched-mode power supply) can easily produce a single low voltage, but obtaining multiple voltages can prove more challenging and require a relatively complicated design.

As an alternative, you can use a single-chip SMPS controller, such as STMicroelectronics' Viper22A, IC_1, to derive as much as 3.3W of regulated dual-voltage power over an ac line-voltage range of 88 to 265V ac (**Figure 1**). For the values in the **figure**, this circuit delivers −5V±5% at currents as high as 300 mA and −12V±10% at currents as high as 150 mA.

The Viper22A's internal circuitry includes a 60-kHz clock oscillator, a voltage reference, overtemperature protection, and a high-voltage power MOSFET that can provide several watts of power. Although the Viper22A occupies an eight-lead package, operating requires only four connections: operating power, V_{DD}; feedback, FB; and the MOSFET's source and drain. The remainder of the pins, redundant source and drain connections, help dissipate heat into the pc board.

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Resistor R_4 limits input surge current and doubles as a protective fuse. Diode D_1 rectifies the ac line voltage, providing approximately 160V dc to a filter comprising C_1, R_1, L_1, and C_2. In addition to smoothing dc ripple, the filter reduces

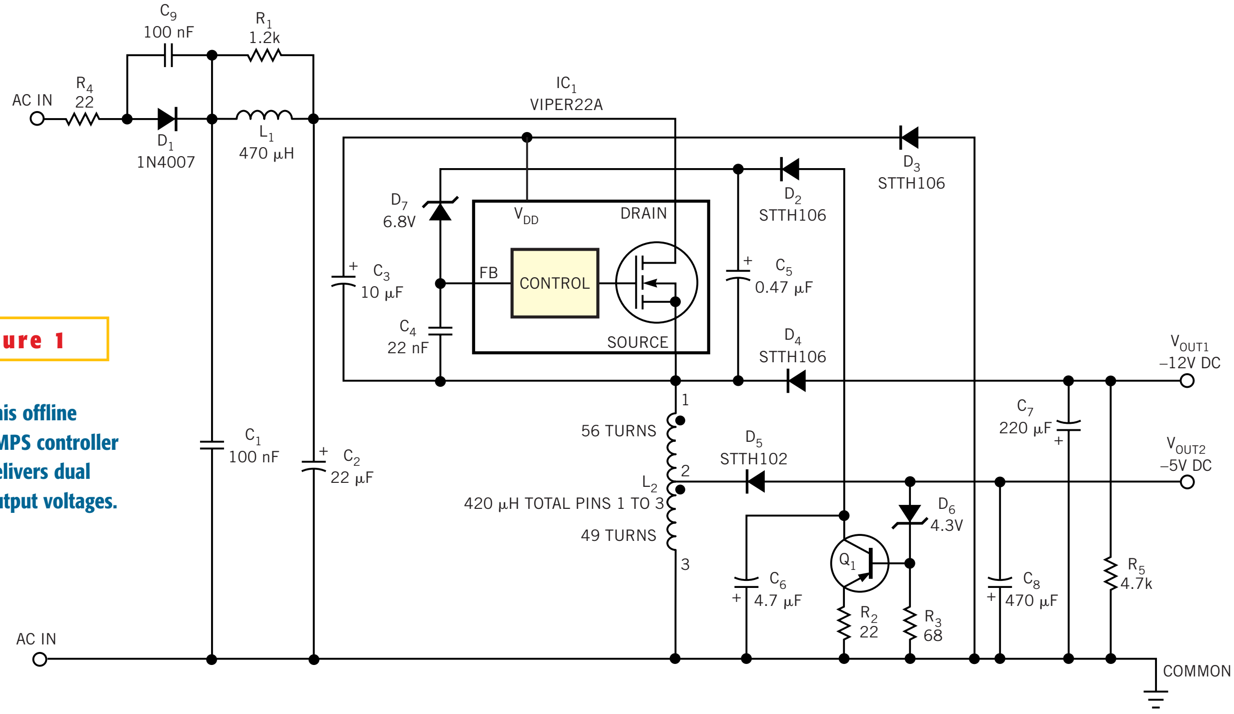

Figure 1

This offline SMPS controller delivers dual output voltages.

electromagnetic interference to help achieve compliance with EU standard 55014 CISPR14. Snubber capacitor C_9 across D_1 helps further reduce conducted emissions.

Reservoir capacitor C_3 acquires a positive charge via diode D_3 during the MOSFET's off-time and supplies V_{DD} to IC_1 during the MOSFET's on-time. Reverse voltage across D_3 can reach the sum of the peak rectified line voltage plus the magnitude of the maximum regulated dc output voltage, so use a fast-recovery diode rated for 600V peak-inverse voltage for D_3.

The voltage at V_{OUT2} provides feedback to close the regulation loop. The sum of general-purpose PNP transistor Q_1's base-emitter voltage plus D_6's reverse voltage sets V_{OUT2} at -5V. Zener diode D_7 shifts the voltage at IC_1's feedback input terminal into its linear range (0 to 1V). To avoid high-frequency instability in the compensation loop, keep connections to ceramic capacitor C_4 as short as possible. Inductor L_2 comprises a TDK SRW0913 ferrite drum core with two windings whose turns ratio sets the output voltage at V_{OUT1}. To maintain regulation when V_{OUT1} is unloaded and V_{OUT2} is fully loaded, add bleeder resistor R_5 from V_{OUT1} to common ground.□

High-voltage amplifier drives piezo tubes

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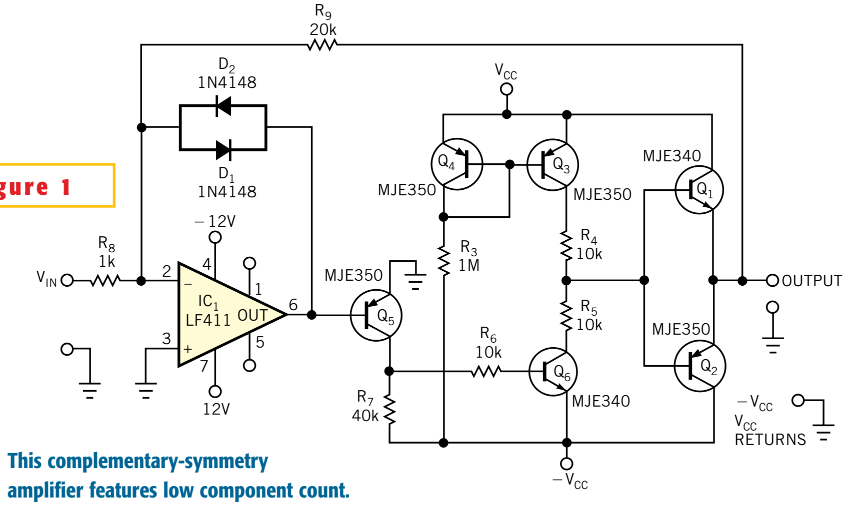
PIEZOELECTRIC TUBULAR positioners that drive manipulators in scanning tunneling microscopes require high-voltage, low-current drive circuits. The circuit in **Figure 1** can drive high-resistance, low-capacitance piezoelectric loads at a -3-dB bandwidth of 6 kHz. It offers a low-cost alternative to commercial drivers. Transistors Q_3 and Q_4 form a current mirror, with R_3 setting Q_4's collector current as the following equation determines: $I_C3=I_C4=[V_{CC}-(-V_{CC})-V_{BE}(Q_4)]/R_3$. Operational amplifier IC_1 provides base drive to Q_5, which in turn drives Q_6. With no signal applied to IC_1's input, the collector currents of Q_6 and Q_3 balance, and the output taken from the junction of emitter followers Q_1 and Q_2 rests at 0V.

Figure 1



This complementary-symmetry amplifier features low component count.

Applying an input signal to IC_1 drives its output toward the positive or the negative 12V supply rail. Allowing IC_1's output to saturate would introduce sufficient slew-rate delay to cause oscillations. Although specifying a relatively fast operational amplifier, an LF411, improves the amplifier's bandwidth and slew rate, antiparallel diodes D_1 and D_2 improve stability by restricting IC_1's output excursion to one diode forward-voltage drop.

You can adjust R_7 to minimize output dc offset voltage and slew rate. As a rule of thumb, select resistor R_7 to be twice the value of R_9. The ratio of R_9 to R_8 sets the amplifier's gain. **Figure 2** shows the input and output waveforms using optimal values for R_7 and R_9. Note that the V_{CEO} ratings for Q_1 and Q_2 limit V_{CC} and $-V_{CC}$ to 300V or less.□

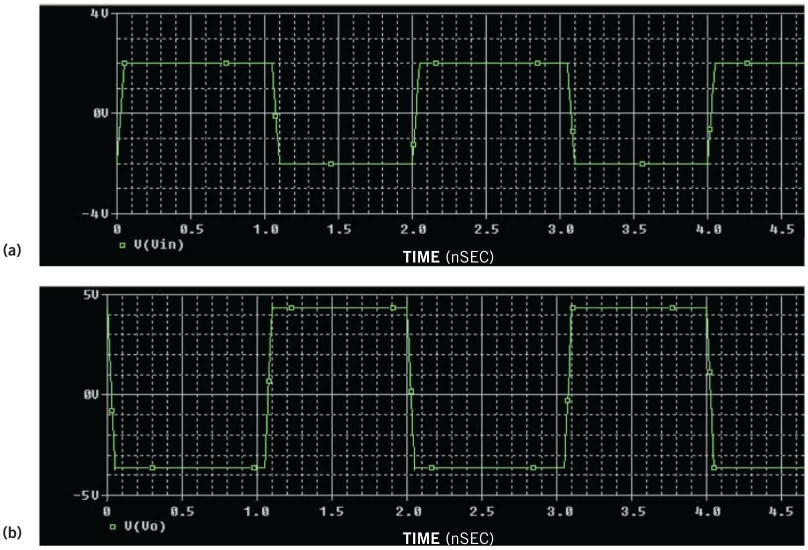


Figure 2 The input waveform show input voltage applied as a pulse of -2 to $+2$V (a). The output waveform shows an amplifier gain of 20 and minimized output offset (b).

Phone wire, RJ-11 jacks and optocouplers build a bus

Ernie Deel, EFD Systems, Marietta, GA

Although cutting-edge technology reaps publicity, the real world often runs on modest hardware that's just "good enough" for home automation, alarm systems, and equipment-monitoring applications. **Figure 1** shows a low-speed, multidrop digital data network that uses inexpensive optoisolators, telephone jacks, and two-pair wiring.

This version of the familiar current loop offers a simplified and somewhat novel implementation in which optocouplers serve triple duty as level converters, isolation/protection devices, and bus interfaces. Galvanic isolation avoids ground loops, increases the effective communications range, and adds a measure of protection for attached hardware.

However, inexpensive optocouplers introduce delays that can cause communications timing errors. Faster optocouplers can minimize errors at the expense of component cost and overall complexity, but using conservatively sized data packets at rates of 4.8 kbps or less allows the use of less expensive components. The H11A-817D optocouplers provide 5-kV isolation and current-transfer ratios of 300 to 600%.

A wall transformer/rectifier provides 12V-dc power for the isolated bus, and devices attached to the bus provide a few milliamperes of 5V power for communicating with isolated-side devices. You can implement RS-232, TTL, or inverted-TTL interfaces by configuring a single jumper and altering connections as appropriate. **Figure 1** illustrates representative examples of each interface.

When adding an RS-232 device, you can ensure compliance with the RS-232 standard by using a control line, such as DTR or RTS, to provide pull-up power, and negative voltage from the TX (transmit) line to passively pull the RX (receive) line low. You can devise a suitable master/slave-communication and error-detection protocol to meet your requirements. Using separate transmitter and

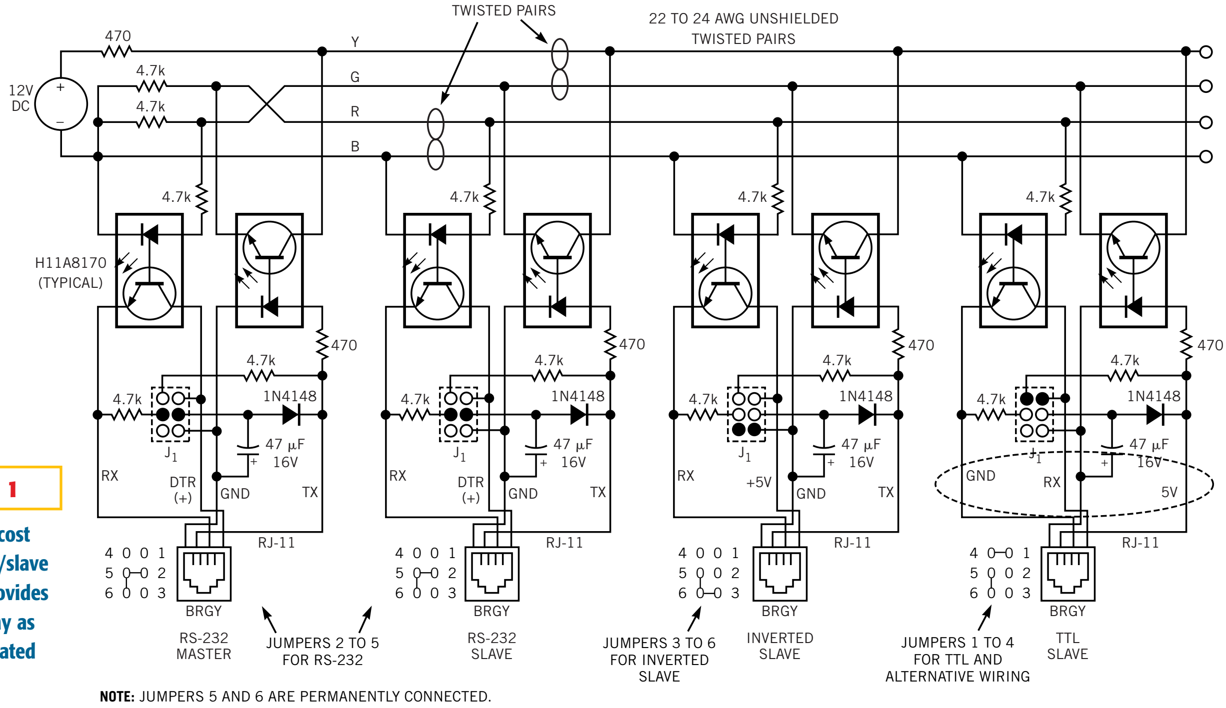


Figure 1

A low-cost master/slave bus provides as many as six isolated nodes.

receiver lines helps simplify the required software. The node-point hardware easily fits inside an ordinary surface-mount telephone jack, thus facilitating quick and easy RJ-11 hookups to master and slave devices. At a 4.8-kbps or lower data rate, the bus can extend as far as 500 ft. Inexpensive dual twisted-pair telephone wire forms the bus.□

Use a PC's parallel port to program a clock source

By William Grill, Honeywell BRGA, Lenexa, KS

THIS DESIGN IDEA shows how you can use Linear Technology's LTC6903 programmable oscillator as a clock source for direct-digital synthesis, data conversion, switched-capacitor filtering, clock, and voltage-controlled oscillator circuits. The LTC6903 operates from 2.7 to 5.5V with modest power consumption and can produce clock signals at frequencies of 1 kHz to 68 MHz. Typical frequency error and resolution over the range are 1.1 and 0.1%, respectively.

You can control the programmable oscillator circuit in **Figure 1** via an IBM-compatible PC's parallel port, which also provides power to the circuit. Resistors R_1 and R_2 limit power-supply current drawn from parallel-port data bits DB_3 and DB_4, and resistors R_3 through R_5 isolate programming bits DB_0 through DB_2. A precision micropower voltage reference, IC_1, provides 4.096V of stable power to IC_1 and $IC_{2.}$ For optimal performance, minimize the lead lengths of bypass capacitors C_1 and C_2 with respect to IC_2's power and ground connections. High-speed buffer IC_3 isolates IC_2's output and prevents frequency pulling due to load variations. **Listing 1** on the Web version of this Design Idea at www.edn.com translates a user-supplied input into a 16 bit, SPI-compatible data stream that programs IC_1's output frequency. The LTC6903's output frequency depends on two control coefficients, OCT and DAC. The program derives the closest values for OCT and DAC by solving the equation: $f=(2^{OCT})\times 2078/(2-(DAC)/1024)$. At initial application of power, IC_2's output frequency defaults to 1.039 kHz.□

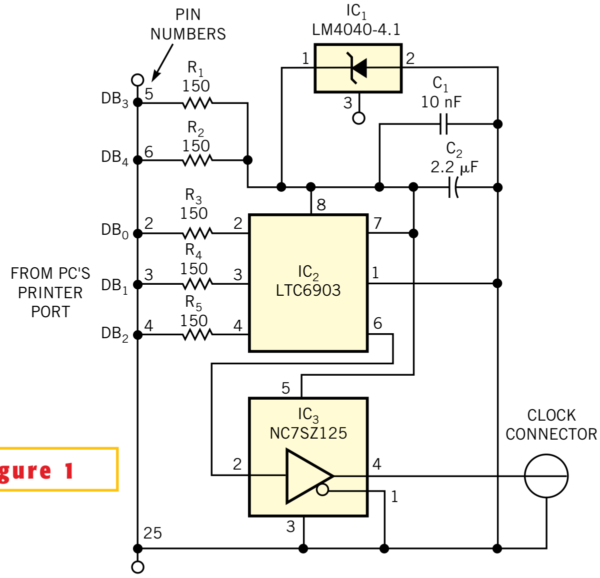


Figure 1

PC-programmable wide-range clock source features minimal component count.

Constant-on-time buck-boost regulator converts a positive input to a negative output

Robert Bell, National Semiconductor Inc, Chandler, AZ

Buck regulators find wide application as step-down regulators for converting large positive input voltages into a smaller positive output voltages. **Figure 1** shows a simplified buck regulator that operates in continuous-conduction mode—that is, the inductor current always remains positive. The output voltage, V_{OUT}, is equal to $D \times V_{IN}$, where D is the duty-cycle ratio of the buck switch, Q_1, and V_{IN} is the input voltage. The duty cycle, D, is equal to T_{ON}/T_S, where T_{ON} is the on-time of Q_1 and T_S is the switching-frequency period.

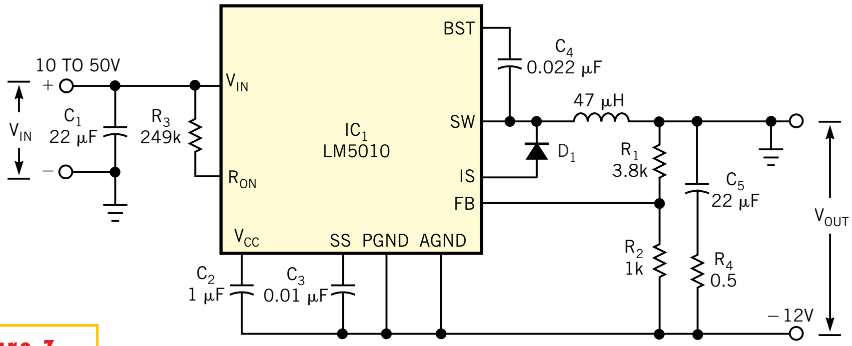


Figure 3

Based on National Semiconductor's LM5010, this buck-boost regulator operates over a wide input-voltage range.

You can reconfigure a buck regulator into a buck-boost circuit to convert a positive voltage into a negative voltage (**Figure 2**). The basic component configurations of both circuits are similar, and the inductor and the rectifier diode are transposed. Because the main switch, Q_1, remains in the same location for both configurations, you can use an IC buck regulator for either topology. Switching on Q_1 applies input voltage V_{IN} across power inductor L_1, and current in the inductor ramps up while Q_1 remains on. When Q_1 switches off, inductor current continues to flow through C_1, the load resistance and D_1, producing a negative output voltage. During Q_1's next on-time interval, the output capacitor supplies current to the load.

Figure 3 shows a low-cost buck-boost converter based on the LM5010 buck-regulator IC that converts a 10 to 50V positive supply voltage into −12V. Although many applications use a fixed switching frequency and modulate the output pulse width, this design features a constant-on-time approach in which the IC's internal output transistor turns on for an interval that's inversely proportional to the difference between the circuit's input and output voltage.

Inside IC_1, a regulation comparator monitors the output voltage from voltage divider R_1 and R_2 and a 2.5V internal reference, and, if the output voltage falls below the desired value, the comparator switches on IC_1's output transistor for an interval that an on-timer determines:

$$T_{ON} = K \times \frac{R_{ON}}{V_{IN} + V_{OUT}},$$

where K represents a constant, R_3 sets the buck switch's on-time interval, V_{IN} is the input voltage, and V_{OUT} is the magnitude of the output voltage. Substitute $T_{ON} = 1/F_S$ and then solve for F_S to yield:

$$F_S = \frac{V_{OUT}}{K \times R_{ON}}.$$

Providing that current through L_1 remains continuous, V_{OUT} remains regulated. Because R_3 and K are constants, switching frequency F_S remains constant. This relationship holds true provided that the current through the inductor remains continuous. At lighter loading, the current in the inductor becomes discontinuous—that is, the inductor current drops to zero for a portion of the switching cycle. At the onset of discontinuous operation, the

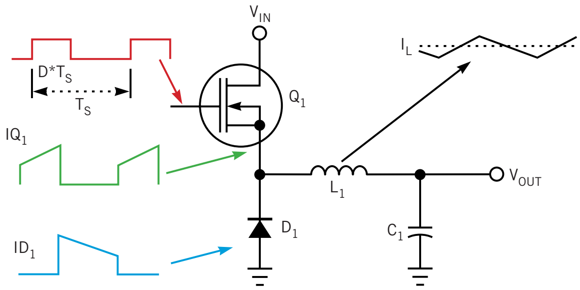


Figure 1

In the basic buck-regulator circuit, current flows continuously through inductor L_1.

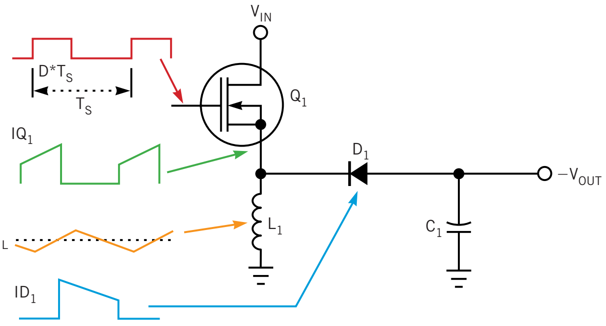


Figure 2

The buck-boost regulator circuit produces a negative output voltage.

switching frequency begins to drop and thus brings V_{OUT} back into regulation.

Operating a buck-boost regulator in fixed-frequency mode without an oscillator eliminates loop compensation and stabilization components and, as a bonus, offers fast transient response unlimited by feedback-network lag time. With the component values in **Figure 3**, the regulator operates at approximately 400 kHz, delivering 12V at approximately 0.5A for 10V input and approximately 1A of output current for 50V input. Resistor R_4 ensures that the minimum amount of output-ripple voltage necessary for regulation—approximately 25 mV—is available.

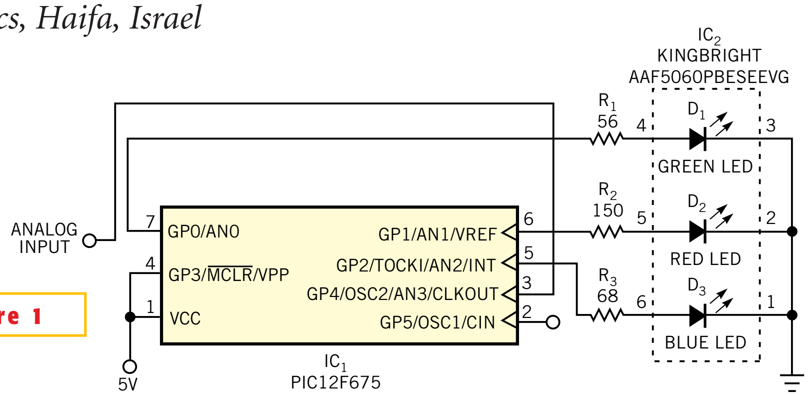
Fixed-frequency operation without an oscillator offers a low-cost, easily implemented regulator with no loop-compensation or stability issues to worry about. The transient response is fast, because there are no bandwidth-limiting feedback components. The regulator operates at approximately 400 kHz. The output-current capability varies with the input voltage. When you apply 10V input voltage, the output-current capability is approximately 0.5A, and, at 50V input, the output current is approximately 1A.□

Rainbow LED indicates voltage with color

David Prutchi, Impulse Dynamics, Haifa, Israel

Meters that indicate analog levels via a moving-pointer meter, a numeric display, or a column of LEDs typically occupy considerable panel area and require more than a casual glance to read. An indicator lamp or LED takes little space but indicates only an on or off condition. However, an unobtrusive LED that changes color as a function of a measured value would enable an observer to easily assess the measurement.

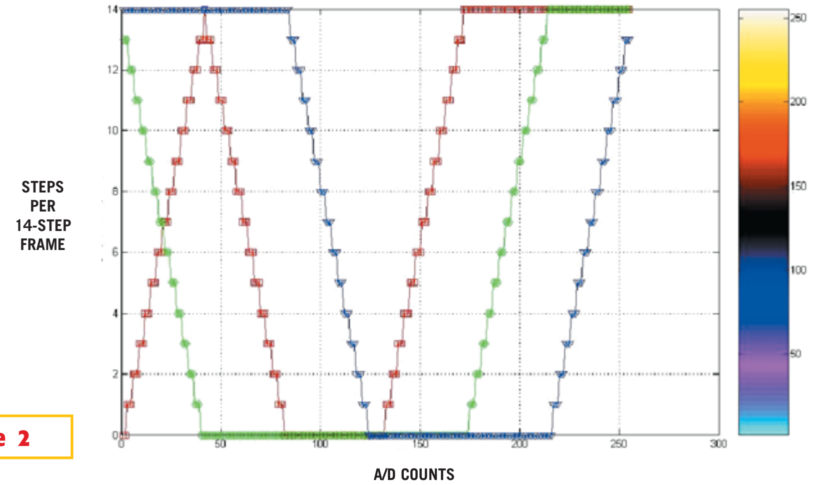
Figure 1



Using a minimal number of components, this voltage-to-color converter uses a single rainbow LED to monitor an analog voltage level.

The circuit in **Figure 1** comprises IC_1, a Microchip PIC12F675 microcontroller driving IC_2, a Kingbright AAF5060PBESEEVG "rainbow" indicator that contains three ultrabright LED chips (red, green, and blue) within one package. Modulating each LED's duty cycle produces all of the perceivable colors of the visible spectrum, including white light. **Listing 1** at the Web version of this Design Idea at www.edn.com contains a PIC program for the PicBasic Pro compiler, which is available from MicroEngineering Labs Inc (www.melabs.com). This program converts a 0 to 5V input applied to Pin 3 of IC_1 to an 8-bit digital value that corresponds to a perceived color containing certain amounts of red, blue, and green.

Figure 2



You can alter the color versus input-voltage palette by modifying the firmware.

Under control of a PWM routine, each LED flashes for an interval proportional to its corresponding content of red, green, or blue. During each PWM frame, an LED die receives power for as many as 14 steps per frame as the color map of **Figure 2** shows. (You can view the color map at the Web version of this Design Idea at www.edn.com.) Although not all LEDs are necessarily simultaneously illuminated, the eye's slow response integrates their output to create the illusion of a change in intensity proportional to the duty cycle. The RGB-encoding function in **Listing 1** assumes that the analog input to IC_1 has a zero-signal offset of 2.5V, which switches all LEDs off. "Cool" colors (shades of blue, purple, and aqua) denote an input in the 0 to 2.5V range, and "hot" colors (shades of red, orange, yellow, and white) denote an input in the 2.5 to 5V range. You can create different palettes by changing the primary-color proportions stored in the RGB encoding table.□