

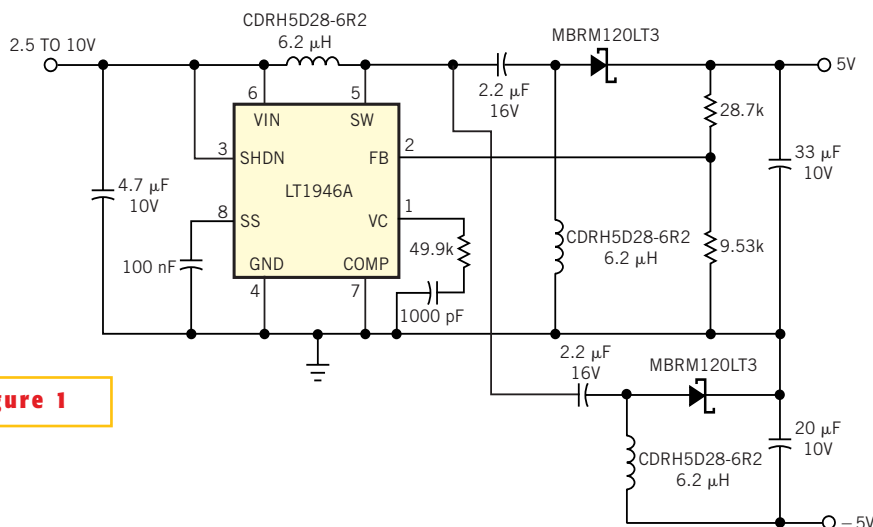


Edited by Bill Travis

## Transformerless dc/dc converter produces bipolar outputs

David Kim, Linear Technology Corp, Milpitas, CA

THE CONVENTIONAL way to produce dual (positive and negative) outputs from a single positive input is to use a transformer. Although such designs are relatively simple, the transformer inherently introduces the problem of size. It can be challenging to fit a transformer into an application in which it's important to minimize the circuit footprint and height. The circuit in **Figure 1** generates  $\pm 5V$  from a 3 to 10V input and fits into applications that lack the room to accommodate a transformer. The circuit uses a topology that allows the disconnection of both outputs when the dc/dc converter is in shutdown mode; thus, the quiescent current is low during shutdown (standby) mode. The circuit also produces a regulated positive and negative 5V, regardless of whether the input is higher or lower than 5V. Therefore, the circuit can operate from various input sources, such as a 3 to 4.2V lithium-ion battery or a 3.3 to 10V wall adapter. By slightly modifying the circuit, you can increase the input range to 2.5 to 16V and the output range to 3 to 12V.



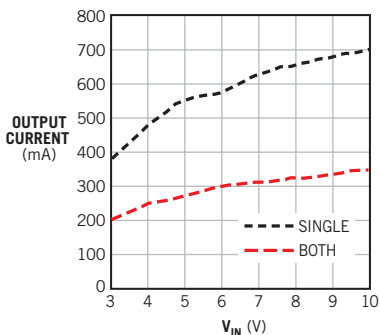
**Figure 1**

A simple circuit produces  $\pm 5V$  from a single positive input without the need for a transformer.

The 2.7-MHz switching frequency of the dc/dc converter allows the use of small, low-profile external components (input/output capacitors and inductors). Using three small inductors instead of one bulky transformer not only reduces the size and height of the converter, but also evenly distributes the power dissipation over the board, thus eliminating concentrated hot spots. The output-current capability of the circuit increases as the input voltage increases (higher input voltage, lower input current). **Figure 2** shows the maximum output current versus the input voltage. The “both” curve represents the maximum allowable output current of both  $\pm 5V$  outputs when you load them with the same current. The “single” curve represents the maximum allowable output current of each output when you load either output alone. When the current from one output decreases, the current capability of the other output increases, as long as you do

not exceed the current rating of the dc/dc converter.

Cross-load regulation is another important design consideration in this type of circuit. Because the  $-5V$  output does not have control of the dc/dc converter's PWM feedback, the  $-5V$  output voltage



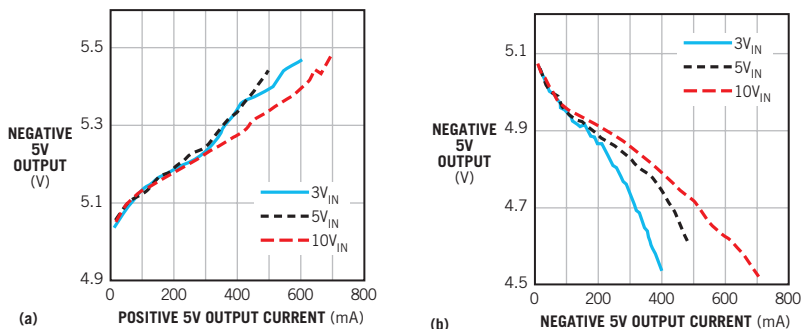
**Figure 2**

This graphic shows maximum output current versus input voltage for both outputs or a single output.

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|--|----|
| Transformerless dc/dc converter produces bipolar outputs .....   | 79 |
| Single processor pin controls on/off function .....              | 80 |
| Isolated MOSFET driver has wide duty-cycle range .....           | 82 |
| Optoelectronic position control simplifies motor movements ..... | 84 |
| Dual-polarity supply provides $\pm 12V$ from one IC .....        | 86 |

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changes with output current. You can greatly improve the cross-load regulation by adding a 10- to 20-mA preload at each output. The preload ensures that the dc/dc converter operates in continuous-conduction mode, in which the inductor current is stable enough to provide constant current. **Figure 3** shows the  $-5\text{V}$  output voltage regulation under different load conditions at the positive (**Figure 3a**) and negative (**Figure 3b**) outputs. In this case, to improve cross-load regulation, both the outputs connect to a 20-mA preload. □



**Figure 3**

These curves show the regulation of the  $-5\text{V}$  supply as a function of the  $5\text{V}$  output current (a), and the regulation of the same output as a function of the  $-5\text{V}$  output current (b).

## Single processor pin controls on/off function

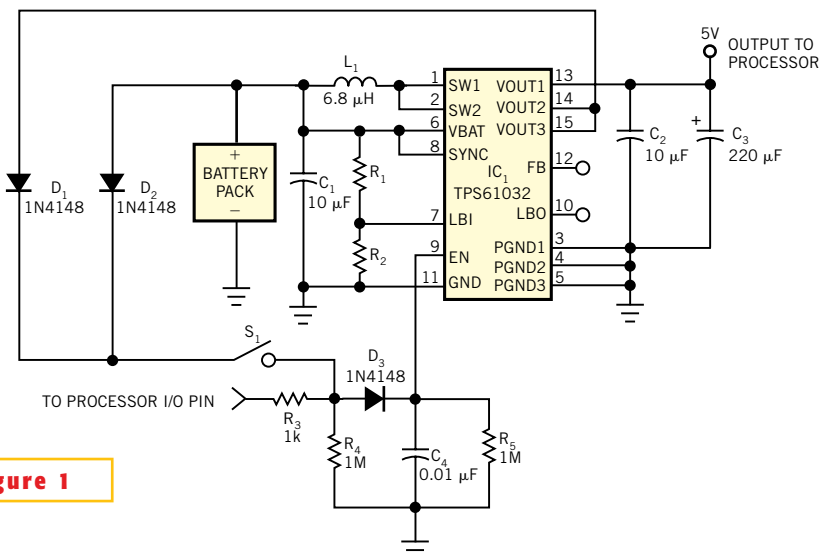
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A RECENT DESIGN IDEA prompted me to offer the simpler solution that I used in a recent project (**Reference 1**). We needed a momentary power switch with processor supervision. This supervision would allow the processor to delay a power-down request from a press of the power switch until all routines exited properly. In addition, in periods of inactivity, the processor could shut down the product to conserve battery life. The project also required a boost converter to convert two or three AA batteries to  $5\text{V}$ . The design uses  $IC_1$ , a Texas Instruments ([www.ti.com](http://www.ti.com)) TPS61032 boost convert-

er (**Figure 1**). It features an enable pin (Pin 9), which, when you pull it low, not only shuts down the converter, but also completely removes the load from the battery. The processor is a PIC16F874. A key element of the design is that you can first configure the processor-I/O pin as an output to keep the converter's enable pin high and then reconfigure it to test the logic level of the power switch.

When the circuit is not running, closing momentary power switch,  $S_1$  (push-on) pulls  $IC_1$ 's Pin 9 high, thereby turning on the converter and providing  $5\text{V}$  to the processor. The processor boots up with its

I/O pin configured as an output and pulled high. This action keeps  $IC_1$ 's Pin 9 high and the converter running after the release of the power switch. Every few milliseconds, the processor's I/O pin reconfigures as an input, and the processor checks the switch for a high (pressed) or low (released) condition. The processor pin then returns to its previous output mode. Capacitor  $C_4$  holds  $IC_1$ 's Pin 9 (enable) high to keep the converter running while the switch undergoes testing. When you release the power switch from power-up and then press it again, the processor begins the push-off sequence. After performing whatever housekeeping it requires, the processor pin configures itself as an input and remains an input. Capacitor  $C_4$  then completely discharges, bringing  $IC_1$ 's Pin 9 (enable) low, thereby shutting down the converter and the rest of the circuitry. Diodes  $D_1$  and  $D_2$  allow the battery voltage to start the converter and the processor to test the power switch using the higher output voltage from the converter. The TPS61032 also features a low-battery comparator whose trip point is a function of  $R_1$  and  $R_2$ . A different processor could read the comparator's output ( $IC_1$ , Pin 10) to perform a safe shutdown when the battery voltage gets too low. □



**Figure 1**

This circuit configuration provides a momentary power switch with processor supervision.

### REFERENCE

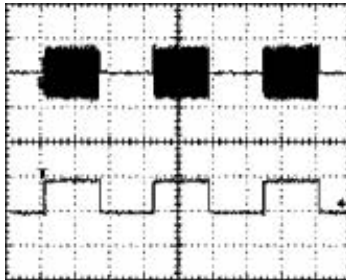
- Gehrke, Dirk, "Microcontroller or DSP circuit controls on/off function," *EDN*, Nov 13, 2003, pg 104.

# Isolated MOSFET driver has wide duty-cycle range

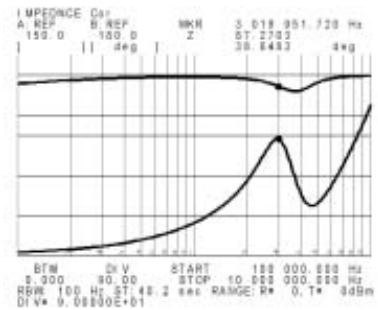
Jesus Doval-Gandoy and Moises Pereira Martinez, ETSI Industriales, Vigo, Spain

**T**HE MAIN APPLICATION for the circuit in **Figure 1** is for driving power MOSFETs with signals ranging in frequency from 1 Hz to 300 kHz and with duty cycles from 0 to 100%. You achieve this goal by using a coreless pc-board transformer. The switching frequency in most power-electronics circuits ranges from a few hertz to a few hundred kilohertz. To design a coreless transformer-isolated gate drive that can switch in the range of frequencies lower than 300 kHz, you implement the modulation of a high-frequency carrier by a low-frequency control signal. The energy transfer from the primary side occurs through the use of a high-frequency carrier signal of 3 MHz. The control-gate signal couples to the secondary output by the modulation process. The binary counter, IC<sub>3</sub>, divides the 24-MHz signal from clock-oscillator IC<sub>2</sub> by eight to obtain 3 MHz. The true/complementary buffer, IC<sub>6</sub>, yields two complementary 3-MHz signals with low delay between them. The NAND gates, IC<sub>5</sub>, implement the modulation process.

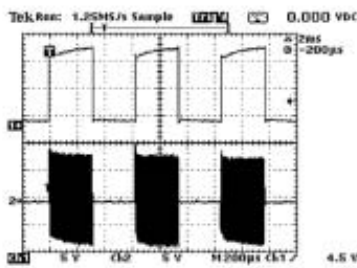
The design uses the value of C<sub>3</sub> to obtain maximum impedance at the working frequency. A voltage doubler (D<sub>1</sub>, D<sub>2</sub>, C<sub>4</sub>) furnishes the gate-drive voltage. This design uses a 555, IC<sub>7</sub>, as a Schmitt trigger because of its low power consumption. D<sub>3</sub> prevents the energy stored in C<sub>6</sub> from discharging into R<sub>1</sub>. As you can see in **Figure 2**, when the control voltage is high, a 3-MHz ac signal appears across



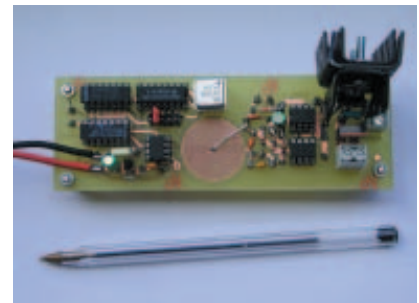
**Figure 2** The top trace is the ac signal across the transformer secondary; the bottom trace is the low-frequency control voltage.



**Figure 4** The input impedance of the transformer peaks at 3 MHz.



**Figure 3** The top trace is the gate-drive voltage to the MOSFET; the bottom trace, the ac signal across the transformer secondary.



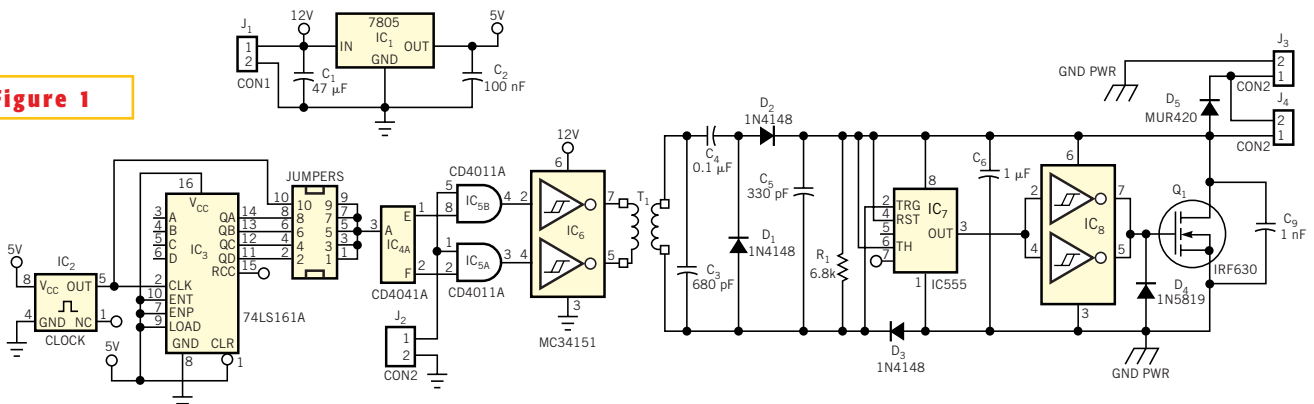
**Figure 5** The prototype of the coreless transformer has a wide duty-cycle range.

the transformer primary, thus charging capacitor C<sub>5</sub> and energy-storage capacitor C<sub>6</sub>. The input to IC<sub>7</sub> goes high, thus turning on the MOSFET. When the control voltage goes low, the voltage across the transformer primary drops to zero,

and the input to IC<sub>7</sub> goes low, thus turning off the MOSFET. **Figures 2 and 3** show the control voltage, the voltage across the transformer secondary, and the gate voltage of the MOSFET.

The dimensions of the transformer

**Figure 1**



A modulation scheme makes it possible to obtain isolated gate drive for a power MOSFET over a wide duty-cycle range.

and the carrier frequency yield a good relationship between the secondary and the primary voltages and minimize the input power of the gate drive. The transformer has a circular spiral primary winding on the bottom of the pc board. The primary winding has 20 turns of

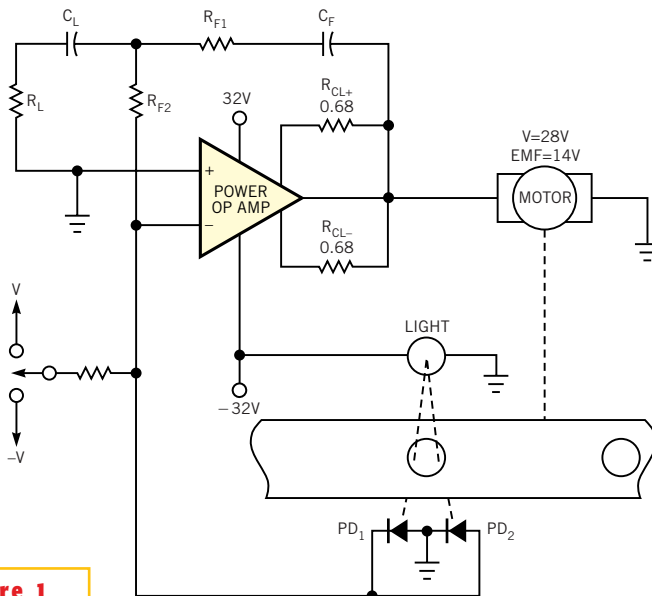
0.3-mm-wide conductor. The circular spiral secondary winding is on top of the pc board. It has 15 turns and a 0.4-mm-wide conductor. For both windings, the conductor thickness is 35 microns, and the outermost radius is 25 mm. The pc board is 1.54 mm thick. **Figure 4** shows

a frequency plot of the input impedance of the transformer with the secondary winding terminated by  $C_3$ . The network analyzer shows that the maximum impedance occurs at approximately 3 MHz. **Figure 5** is a photograph of a working prototype. □

## Optoelectronic position control simplifies motor movements

Marie Rivera, Apex Microtechnology Corp, Tucson, AZ

**T**HE optoelectronic technique for achieving position control provides an inexpensive, easy-to-design method of achieving simple, repeatable movement using fixed index points with linear- or rotary-motion components. The simple, basic design in **Figure 1** for sequential position control exploits the quick response time of a power op amp, working in tandem with a pair of photodiodes. The result is a low-component-count system that provides high reliability, accuracy, and repeatability when you use it in well-defined operating conditions. The circuit in **Figure 1** achieves sequential position control by using a power op amp to integrate the differential



**Figure 1**

An optoelectronic circuit uses a power op amp to achieve sequential position control.

output of a pair of photodiodes to drive the motor in the proper direction until the photodiode currents are equal. Movement between index points occurs when you momentarily switch a fixed input current to the amplifier's input, causing the amplifier to drive the motor in the desired direction. The charge on  $C_F$  maintains motor drive as the input current switches off before reaching the index point.

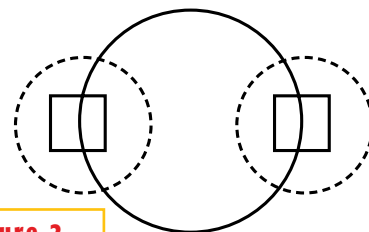
To ensure continued motion in the desired direction, the motor drive receives reinforcement by the output from the first photodiode as it illuminates. As the second photodiode illuminates, its cur-

rent reverses the motor drive, causing the system to lock to the index point. The use of a differential configuration eliminates errors from temperature and time instability in the optoelectronic devices. The entire system uses a simple switch, as **Figure 1** illustrates, to generate both forward and backward motion. Because motor response time and system inertia vary greatly in different applications, you achieve proper damping by selecting  $C_F$  and  $R_F$  based on the application.  $C_F$  needs to be small enough to allow drive reversal before the index point passes the second photodiode; otherwise,

the system continues on to the next index. If the value of  $C_F$  is too small, severe overshoot or oscillation can occur, resulting in drive-train failure or motor burnout.

To help minimize overshoot,  $R_{F1}$  and  $R_{F2}$  in **Figure 1** stabilize the control loop at the unity-gain point. You can also improve response time by applying a braking force, which you create by using  $R_L$  and  $C_L$  to form a lead network, which enables the amplifier to modify the motor drive based on a change in the sensor output. The motor in **Figure 1** has EMF (electromotive force) of 14V and can apply a 46V stress across the conducting output transistor when you reverse it. This power dissipation is

a worst-case scenario; you need to check it against the SOA (safe operating area) of the amplifier. **Figure 2** shows optimum

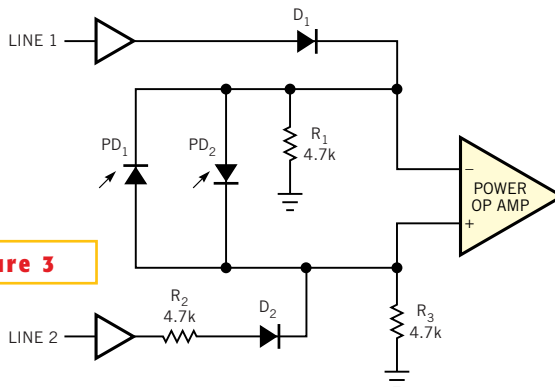


**Figure 2**

With optimum beam-sensor alignment, the light beam illuminates half the photosensitive area of each diode.

alignment for the beam sensor. You achieve optimum alignment by centering the light beam in relationship to the active areas of each photodiode. The light beam needs to illuminate half the photosensitive area of each diode. When sizing the “hole,” consider the distance between the location of the light beam and the photodiodes. If the beam is too large, the sensors do not produce any change for a range of positions. Too small a beam produces a nonlinear transfer function along the center line between the photosensitive areas. This nonlinearity can create difficulty in selecting the value of  $C_F$  for dampening the circuit and requires a

**Figure 3**



This circuit imparts digital-interface control to the circuit in Figure 1.

light source with higher intensity. **Figure 3** illustrates how you can use a nonbipolar signal without digital-to-analog conversion for systems that inte-

grate digital control. When logic lines are low, the signal diodes do not conduct. This condition allows the photodiodes to control the circuit. A high level on Line 2 causes current to flow to the summing junction and swing the amplifier negative. A high level on Line 1 raises the summing junction voltage above ground and swings the amplifier positive. By selecting a resistance value that allows a logic-level supply high enough to provide at least

twice the maximum current from each photodiode, the circuit maintains system control regardless of the photodiode signals. □

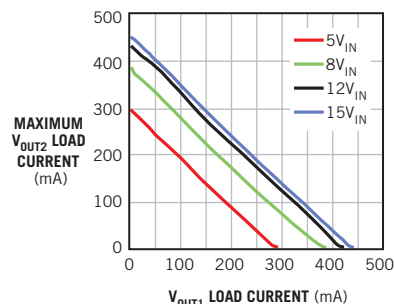
twice the maximum current from each photodiode, the circuit maintains system control regardless of the photodiode signals. □

## Dual-polarity supply provides $\pm 12V$ from one IC

Keith Szolusha, Linear Technology Corp, Milpitas, CA

**W**ELL-REGULATED, dual-polarity power supplies find wide use in disk-drive, handheld-device, automotive, and notebook-computer applications. In these applications, board space and allowable component heights are continually shrinking. So, power-supply designers face the challenge of providing split rails with as few parts as

possible, thus saving board space and cost. Some dual-polarity dc/dc-converter topologies—for example, overwindings and flyback converters with multiple-winding transformers—require excessive board space, component height, or both; offer poor load regulation; or provide limited load current. **Figure 1** shows an alternative approach that uses

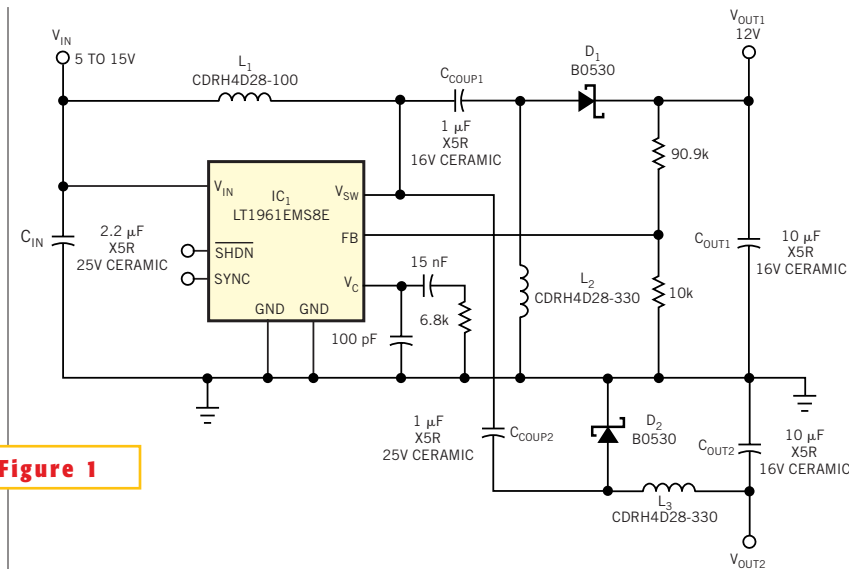


**Figure 2**

This graph shows the maximum load current at the  $V_{OUT2}$  terminal versus the  $V_{OUT1}$  load current.

a single boost regulator using a dual-polarity SEPIC (single-ended, primary-inductance-converter) architecture. The circuit saves space and offers good regulation and current-handling capability. The boost regulator,  $IC_1$ , usually figures in step-up-converter configurations, but the low-side power switch in  $IC_1$  allows the use of the IC in both SEPIC and negative-SEPIC circuits.

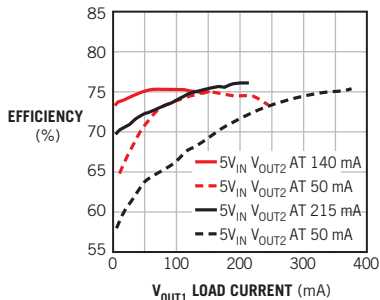
The combination of the two topologies creates a dual-polarity SEPIC, an excellent source for multiple-rail bias power. The circuit provides well-regulated



**Figure 1**

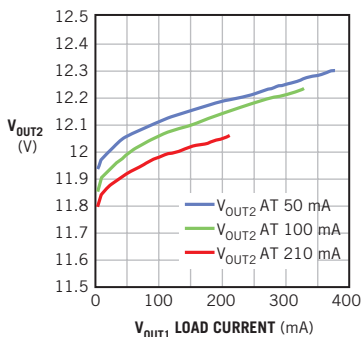
This circuit uses a single boost-regulator in a dual-polarity SEPIC architecture.

$\pm 12V$  outputs at varying load currents (5W power with 12V input and 3.6W with 5V input). **Figure 2** shows the maximum available current at  $V_{OUT2}$  as a function of the load current at  $V_{OUT1}$ . **Figure 3** shows the efficiency of the converter as a function of the load current at  $V_{OUT1}$ . Although the positive feedback



**Figure 3**

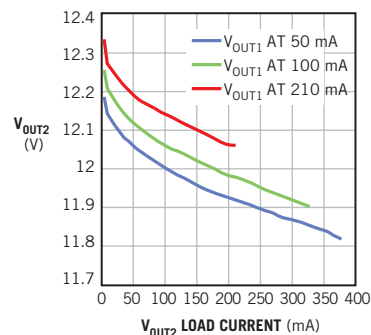
Efficiency of the circuit in Figure 1 is more than 70% for most of the range of load-current values.



**Figure 4**

Regulation of the  $V_{OUT2}$  voltage as a function of  $V_{OUT1}$  load current is reasonably tight.

comes from  $V_{OUT1}$ ,  $V_{OUT2}$  maintains excellent regulation (**figures 4 and 5**). The circuit maintains the regulation as long as each load draws a minimum of 5-mA current. The SEPIC topology accommodates input voltages both above and below the output voltage. The use of three



**Figure 5**

Regulation of the  $V_{OUT2}$  voltage is within  $\pm 200$  mV over almost all of the range of  $V_{OUT2}$  load currents.

small power inductors as opposed to a transformer keeps the component height below 3 mm, reduces board space, and allows layout flexibility. The high-frequency, current-mode boost-regulator IC uses all ceramic capacitors, thus minimizing ripple and overall cost. □