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## Obtain a lower dc voltage from a higher voltage power supply

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 You can use the circuit in **Figure 1** to obtain a low regulated voltage, such as 5V dc, from a higher voltage, rectified, sinusoidal voltage source without resorting to an electrically noisy dc/dc converter or wasting watts in a dropping resistor. This application requires a regulated 5V-dc source, but a transformer supplies 18V rms to a full-wave bridge rectifier. During the charging phase, two equal-value electrolytic capacitors,  $C_1$  and  $C_2$ , receive charging current when connected in series through forward-biased diodes  $D_1$  and  $D_2$ . An enhancement P-channel MOSFET transistor,  $Q_1$ , an International Rectifier (www.irf.com) IRF9530, remains off because its gate

receives a slightly positive reverse-gate-bias voltage due to zener diode  $D_4$ 's forward-voltage drop. Each capacitor charges to approximately one-half the peak value of the rectified voltage minus the forward-voltage drops that  $D_1$  and  $D_2$  present. The full-wave bridge rectifier,  $D_3$ , or Graetz bridge, produces these drops (**Reference 1**).

When the discharge phase begins,  $D_1$  gets reverse-biased, and capacitor  $C_2$  discharges through the load that voltage regulator  $IC_1$  presents. Subsequently, the anode voltage of diode  $D_1$  continues to decrease,  $Q_1$ 's gate-to-source voltage becomes negative, and the transistor conducts, allowing  $C_1$  to discharge into the load through forward-biased diode  $D_3$ . In effect, the two capacitors charge in series and discharge in parallel into the load, halving

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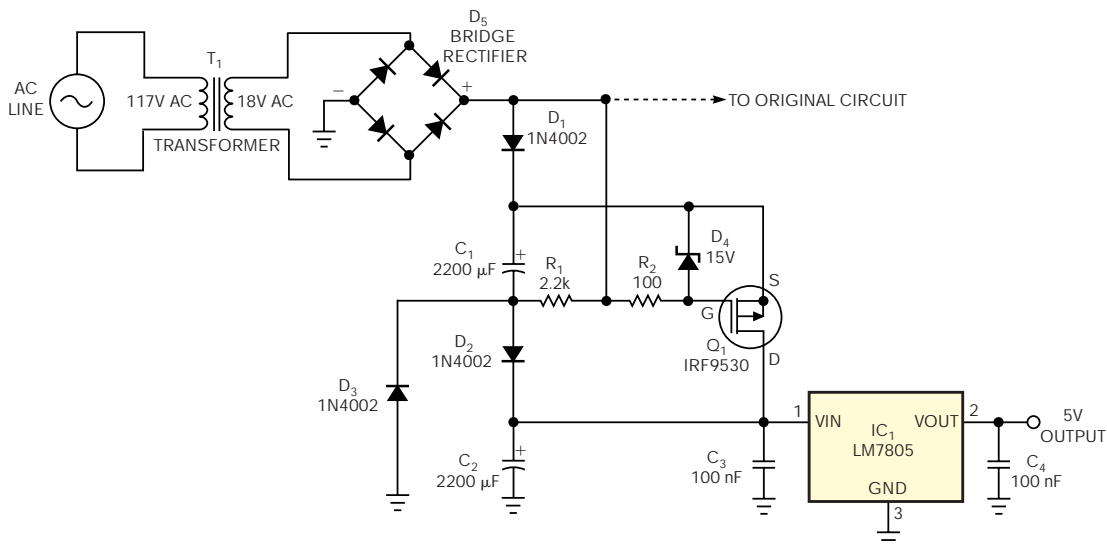
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ward-biased diode  $D_3$ . In effect, the two capacitors charge in series and discharge in parallel into the load, halving



**Figure 1** In this unconventional step-down circuit, capacitors  $C_1$  and  $C_2$  charge in series and discharge in parallel, reducing the voltage applied to regulator  $IC_1$ .

ing the raw rectified voltage and ripple voltage at  $IC_1$ 's input. During  $C_1$ 's discharge, zener diode  $D_4$  protects  $Q_1$  by clamping its gate-to-source voltage within its maximum rating.

To function properly, the circuit requires a minimum load current; the

regulator's quiescent-current drain is usually enough. Otherwise, capacitor  $C_2$  charges to the peak voltage available from  $D_5$ . The values of  $C_1$  and  $C_2$  and the ratings of the remaining components depend on the maximum load current required. The values of resistors

$R_1$  and  $R_2$  are not critical. Note that  $Q_1$  functions as a switch; selecting a device with low on-resistance limits  $Q_1$ 's power dissipation.<sup>EDN</sup>

REFERENCE

[www.answers.com/topic/graetz-ag](http://www.answers.com/topic/graetz-ag).

## Line-powered driver lights up high-power LEDs

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Using LEDs has gained popularity as a method of saving power for general-purpose lighting, but an efficient method for driving them has also become a necessity. For example, Lumileds' ([www.lumileds.com](http://www.lumileds.com)) Luxeon devices create lighting effects or room lighting. Providing power to a few LEDs may require only a current-limiting resistor, but illumination applications need a string of 20 or more LEDs to provide light over an area. Based on On Semiconductor's ([www.onsemi.com](http://www.onsemi.com)) NCP1200A, a 100-kHz

PWM current-mode controller for universal offline power supplies, the circuit in **Figure 1** provides a low-cost, offline constant-current source for powering multiple LEDs. Although designers typically configure it to provide a voltage source, in this application, the NCP1200A provides a constant-current source. **Figures 2** and **3** show close-ups of the circuit.

A full-wave bridge rectifier,  $D_2$  to  $D_5$ , and filter capacitor  $C_1$  provide approximately 160V dc to the conversion circuit,  $IC_1$ , and its associated compo-

nents. Resistor  $R_3$  alters the bias for  $IC_1$ 's current-sense pin and, at 6.2 k $\Omega$ , allows the use of a 1.2 $\Omega$  sense resistor for  $R_6$ . Decreasing  $R_6$  not only reduces costs over a higher wattage sense resistor, but also improves the circuit's efficiency. Capacitor  $C_3$  stabilizes the feedback network's current and carries a 400V rating in case of an open circuit in the LED string. An RC network comprising  $R_5$  and  $C_4$  provides a small amount of lowpass filtering to the CS pin.

Bleeder resistors  $R_1$  and  $R_2$  eliminate any shock hazard across the ac-line plug's prongs when you disconnect it. Although you can use a 1-M $\Omega$  through-hole-mounted resistor, two surface-mounted 500-k $\Omega$  series resistors cost less and provide the required track-

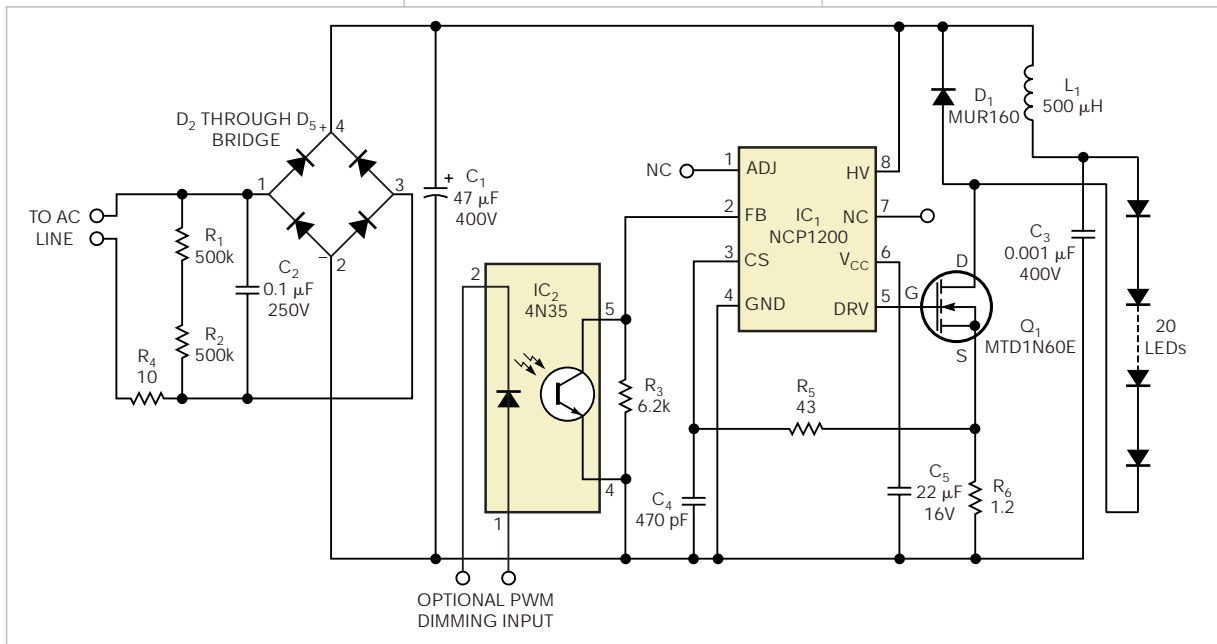


Figure 1 An offline constant-current source drives a string of high-output LEDs.

to-track pc-board spacing for line-voltage applications. Use a capacitor rated for line-bypass service for capacitor  $C_2$ . You can use any power MOSFET with a suitable breakdown voltage and a low on-resistance, such as an MTD1N60E or IRF820, for  $Q_1$ . Inductor  $L_1$ , a 500- $\mu$ H device, should be able to operate at 100 kHz and handle more than 350 mA of continuous current. You can use an inductor from Coilcraft's (www.coilcraft.com) RFB1010 or DR0810 series of surface-mount inductors, or you can experiment with inductors manually wound on suitable core materials. As an option, adding optoisolator  $IC_2$  allows microcomputer-controlled illumination dimming using pulse-width modulation of  $IC_1$ 's feedback terminal, Pin 2.

To understand the economic motivation for using LEDs as illuminators, compare the light output of a string of 20 1W, white Luxeon emitters with a standard incandescent light bulb. Each LED provides 45 lumens, or 900 lumens for a string of 20 LEDs. The average

forward voltage per LED is 3.42V for a power dissipation of 1.197W each at a forward current of 350 mA. Thus, the 20-LED string dissipates 23.94W. Factoring in a conservative 80% efficiency for the power supply, the power the system consumes becomes 28.73W for a light-emission-efficiency value of 900 lumens/29W or 31 lumens/W. The Luxeon emitters also carry a rating for 100,000 hours, or approximately 11 years, of operation.



**Figure 2** A close-up view of the circuit of Figure 1 shows inductor  $L_1$  in the upper right corner.

In contrast, a standard 60W Philips incandescent light bulb produces 860 lumens for 1000 hours, or just over a month, at an efficiency of only 14 lumens/W. From a power-consumption viewpoint, the LED-based design is twice as efficient as the incandescent-bulb-based design and thus reduces power consumption and cost. In addition, the LED design imposes no additional maintenance costs for replacement bulbs and labor. EDN



**Figure 3** This version of the circuit comprises three constant-current driver channels. An LED light-bar assembly is above the pc board.

## Rectifier tracks positive and negative peaks

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Signals ranging from music to complex control-system waveforms may contain unequal positive and negative peak amplitudes. An "envelope-follower" circuit can track unequal peaks, but the ability to select a desired peak can enhance the circuit's performance (**Reference 1**). The circuit in **Figure 1** applies a new twist to a classic absolute-value circuit. Applying an input signal to  $R_1$  (full) produces an output equal to the input's absolute value. Applying an input signal to  $R_6$  (positive) or  $R_7$  (negative) produces outputs of positive or negative half-cycles, respectively. **Figure 2** illustrates all three modes of operation.

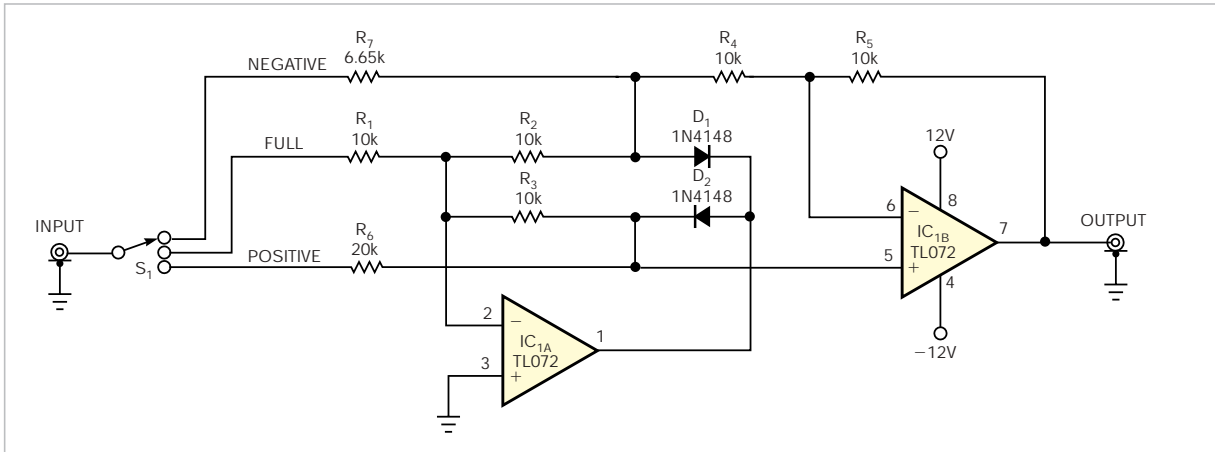
Understanding the circuit is simple if you consider that op amp  $IC_{1A}$  strives

to maintain its inverting input at virtual ground. For example, applying  $-1V$  to the negative input,  $R_7$ , drives the anode of  $D_1$  to  $-333$  mV.  $IC_{1A}$ 's output, Pin 1, drives  $D_2$ 's cathode positive enough to force  $D_2$ 's anode voltage to 333 mV. Because  $IC_{1A}$ 's inputs now rest at 0V,  $D_1$  is effectively reverse-biased and out of the circuit. The 333 mV available at  $D_2$ 's cathode also applies to  $IC_{1B}$ 's noninverting input, Pin 5, and  $IC_{1B}$  must balance its input voltages by driving its output, Pin 7, to 1V.  $IC_{1B}$ 's inverting input, Pin 6, goes to 333 mV. The voltage drop across  $R_4$  thus equals 666 mV. One-third of the input current flows through the series connection of  $R_2$  and  $R_3$ , and two-thirds flows in  $R_4$ . To achieve unity

gain,  $R_7$ 's value equals that of  $R_2 + R_3$  in parallel with  $R_4$ .

Applying a positive input to  $R_7$  causes  $IC_{1A}$ 's output to go negative by a voltage equal to one forward-diode drop and thus holds  $D_1$ 's anode at ground.  $D_2$  is reverse-biased, and both of  $IC_{1B}$ 's inputs rest at 0V. The circuit's output is thus 0V. Applying an input voltage at  $R_6$  yields similar operation. A positive input causes an equal-value positive output, and a negative input produces a 0V output. You can ignore the effects of  $IC_{1B}$ 's high input impedance, which are negligible. To maintain unity gain, the value of  $R_6$  is twice that of  $R_3$ .

Resistors  $R_1$ ,  $R_2$ ,  $R_3$ ,  $R_4$ , and  $R_5$  are of equal value and close tolerance. Note that  $IC_1$ 's power-supply connections require bypass capacitors (not shown). To minimize errors, use a low-impedance source or buffer amplifier to drive the circuit. You can use a three-posi-

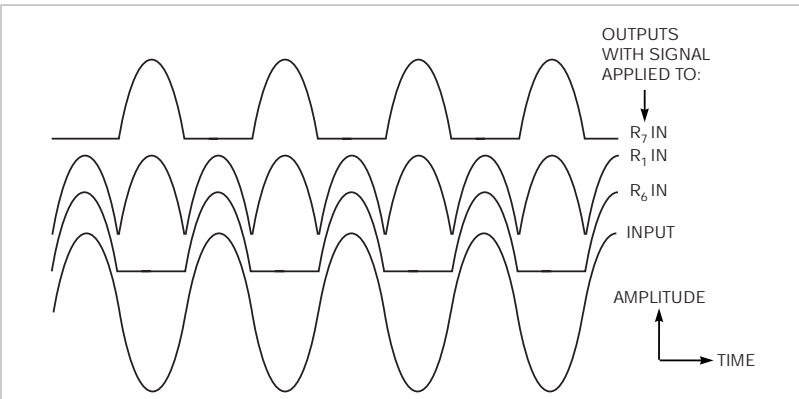


**Figure 1** Use this versatile precision rectifier circuit to recover a signal's positive peaks, negative peaks, or both in full-wave mode.

tion rotary switch for input-mode selection, or an on/on/on toggle switch, such as C&K Components' 7211, available from Digi-Key Corp ([www.digikey.com](http://www.digikey.com)) and other sources, or a similar switch, wired as a three-way selector. (See the manufacturer's data sheet for a connection diagram.) You can also use separate connectors for the inputs, but connect no more than one input at a time.EDN

**REFERENCE**

■ Bissell, Harry, "Envelope follower combines fast response, low ripple," *EDN*, Dec 26, 2002, pg 59, [www.edn.com/article/CA265499](http://www.edn.com/article/CA265499).



**Figure 2** This waveform plot shows the circuit's outputs for a sine-wave input connected to the negative, full, and positive inputs, respectively. Traces are vertically offset for clarity.

## Isolated indicator signals telephone line's status

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Part 68 of the FCC's (Federal Communications Commission, [www.fcc.gov](http://www.fcc.gov)) telecommunications regulations requires that certain signaling equipment connecting directly to the public-telephone network must present a line-to-line resistance of at least 5 MΩ. In addition, status signals that equipment derives from the phone lines must include electrical isolation to pre-

vent interaction between earth grounds from the telephone network and attached control or communications equipment. Although a transformer can provide isolation for voice-frequency signals, the telephone-line-status-indicator circuit in **Figure 1** meets FCC isolation requirements without incorporating a transformer (**Reference 1**). A diode bridge,  $D_1$

through  $D_4$ , and  $R_1$ , a 5.6-MΩ resistor, supply a small amount of dc power from the phone line to a nanopowered combination comparator and a 1.2V voltage reference,  $IC_1$ . The Maxim ([www.maxim-ic.com](http://www.maxim-ic.com)) MAX917 IC draws only 0.75 μA at 1.8V<sub>CC</sub>.

Resistors  $R_2$  and  $R_3$  form the detection-voltage divider, and  $R_4$  provides hysteresis. When  $IC_1$ 's output goes low,  $R_4$  and  $R_3$  form a parallel combination of 3.26-MΩ resistance. To reach the comparator's reference voltage of 1.245V, the voltage across  $C_1$  must reach at least 5.06V. Once  $IC_1$ 's output

goes high,  $R_4$  and  $R_2$  form a parallel resistance of  $6.67\text{ M}\Omega$ , and the voltage across  $C_1$  must reach  $3.37\text{V}$  to deliver a  $1.245\text{V}$  input to the comparator.  $IC_1$ 's output drives a photocoupler,  $IC_2$ , a Toshiba ([www.semicon.toshiba.co.jp](http://www.semicon.toshiba.co.jp)) TLP190B. Unlike other photocouplers,  $IC_2$  includes an array of photodiodes that, when illuminated, delivers a voltage output. Although weak by power-conversion standards, the photocoupler's output can deliver several microamperes at an open-circuit voltage that exceeds  $7\text{V}$ , or enough to drive a MOS-

FET's gate or a microprocessor's input pin. In addition, the TLP190B carries a  $2500\text{V}$ -rms emitter-to-detector isolation-voltage rating.

When a telephone is not in use, the on-hook voltage across its line of approximately  $-48\text{V}$  produces a current of  $7$  to  $8\text{ }\mu\text{A}$  through  $R_1$ , which imposes a low-leakage requirement on  $C_1$ . The prototype version of the circuit uses an X5R-characteristic ceramic capacitor. When the voltage across  $C_1$  exceeds  $5.06\text{V}$ ,  $IC_1$ 's output goes high and drives  $IC_2$  through  $R_3$ , discharging

$C_1$ . When the voltage across  $C_1$  decreases to  $3.37\text{V}$ ,  $IC_1$ 's output goes low, and  $C_1$  recharges. The output from  $IC_2$  comprises a  $1.4\text{-msec}$ -wide voltage pulse with a repetition period of approximately  $240\text{ msec}$ . When the phone is off the hook, the voltage across its lines drops to a few volts, which don't sustain pulse generation. EDN

## REFERENCE

1 [www.fcc.gov/wcb/iatd/part\\_68.html](http://www.fcc.gov/wcb/iatd/part_68.html).

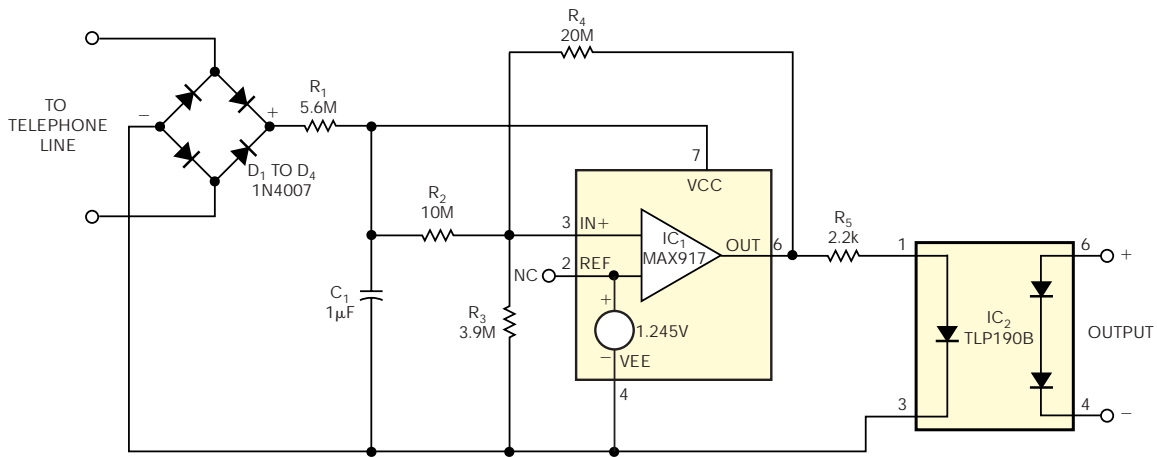


Figure 1 Drawing minuscule amounts of power from a telephone line, this isolated-output circuit indicates whether the line is in use.

## Circuit converts DAC's outputs from single-ended to differential mode

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High-speed DACs, such as Analog Devices' AD9776/78/79 TxDAC family, offer differential outputs, but, for low-end ac applications or high-precision level-setting applications, a single-ended current-output DAC with a differential-conversion circuit provides a novel approach to generating differential-waveform-control functions. The basic circuit in **Figure 1** combines a current-output DAC,  $IC_1$ , such as the 8-bit

AD5424 DAC, with a single-ended-to-differential op-amp stage— $IC_2$ ,  $IC_{3A}$ , and  $IC_{3B}$ —to generate the desired outputs. For dual-power-supply applications, you select the DAC's unipolar mode of operation to achieve optimum performance from the DAC. Using a single op amp, the DAC provides two-quadrant multiplication or a unipolar output-voltage swing. The DAC's output requires a buffer because changing the code applied to the DAC's input

varies its output impedance.

This equation defines the circuit's output voltage:  $V_{OUT} = -V_{REF} \times (D/2^N)$ , where  $N$  defines the number of input bits,  $V_{REF}$  is the reference voltage, and  $D$  is the decimal equivalent of the binary code. To generate a positive common-mode voltage, you use a negative voltage for the DAC's reference voltage. The DAC's internal design accommodates ac reference input signals of  $-10$  to  $+10\text{V}$ . In this mode, the DAC provides a  $5\text{M}$ -sample/sec maximum update rate for one-quarter full-scale code changes when you operate it from a  $5\text{V}$  power supply. Use resistors  $R_1$  and  $R_2$  only if your application requires adjustable gain.



imum update rate to 1.5M samples/sec. You can use sections of a dual op amp to buffer the DAC's input and to amplify the DAC's output voltage (Figure 3). The circuit's intended application determines your choice of supporting amplifiers. For lower speed, precision applications, the op amp requires low input-bias currents and low input-offset voltage to avoid degradation of the DAC's DNL (differential-nonlinearity) performance. For example, the AD8628 offers 100-pA maximum bias current at room temperature and 5- $\mu$ V maximum input-offset voltage. The op amp's low-frequency noise is important in precision level-setting applications, and the AD8628 specifies 0.1- to 10-Hz noise of less than 0.5  $\mu$ V p-p. Its rail-to-rail inputs and outputs make it ideal for use in single-supply circuits.

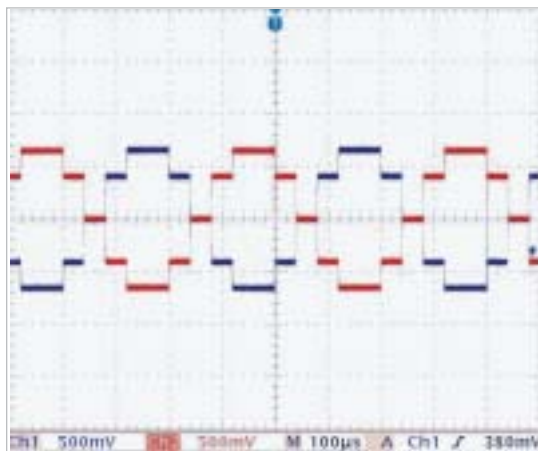


Figure 3 The single-ended-to-differential conversion of a digitized, eight-point sine wave produces differential outputs.

For high-speed-system applications, the op amp's slew rate must not dominate the DAC's slew rate. The op amp's bandwidth must be large enough to drive the feedback load and must not limit the circuit's overall bandwidth, and the DAC's output-voltage settling

time should determine the circuit's maximum update rate. The AD8042 in figures 1 and 2 offers 170-MHz bandwidth and a 225V/ $\mu$ sec slew rate, allowing it to easily achieve these results. Other high-speed op amps, such as the AD8022, AD8023, and AD8066, also work well in this application.

The DAC consumes only 0.4  $\mu$ A of power-supply current, and the op amps thus dominate the circuit's power consumption. To minimize the area for the circuit on a pc board, you can replace all four op amps in Figure 2 with a single AD8044 quad op amp. The single-ended-to-differential conversion of a digitized, eight-point sine wave in the presence of a 1.4V common-mode voltage and a 0.6V differential signal produces differential outputs (Figure 3).EDN