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High-speed op amp enables IR-proximity sensing

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IR (infrared)-proximity sensors can sense the presence of an object, its distance from a reference, or both. Applications include speed detection, sensing of the hand in automatic faucets, automatic counting or detection of objects on conveyer belts, and paper-edge detection in printers. The latest-generation smartphones, for example, can turn off the LCD touchscreen to prevent the accidental activation of buttons when you press the screen against your chin or your ear.

To sense an object, a proximity sensor transmits IR pulses toward the object and then "listens" to detect any pulses that reflect back. An IR LED transmits the IR signals, and an IR photodetector detects the reflected signal. The strength of this reflected signal is inversely proportional to the distance of the object from the IR transceiver. Because the reflected IR signal is stronger when the object is close, you can calibrate the output of the photodiode detector to determine the exact trigger distance of an object. The trigger distance indicates the threshold for making a decision on whether an object is present.

The photodiode detects IR not only that the object reflects, but also from the ambient conditions. You must filter out this IR noise to prevent false detections. A common method is to modulate the LED's IR signal with a convenient frequency and then detect only the IR with that modulation, which identifies it as a reflection from the object.

This Design Idea describes an IR-proximity sensor with simple transmitter and receiver sections (**Figure 1**). The transmitter consists of an Everlight (www.everlight.com) 940-nm IR11-21C IR LED, which turns on and off using a 10-kHz oscillator frequency. By varying the LED's current, you control the level of transmitted power and, hence, the detection range. To save power, the transmitting pulses have a typical duty cycle of only 10%.

The receiver circuit demodulates and amplifies the IR signals that the Everlight PD15-22C photodiode detects; the photodiode's peak sensitivity occurs at 940 nm. The photodiode output ac couples to the op amp's noninverting input. This coupling allows the 10-kHz signal to pass, but the coupling capacitor sets a 300-Hz cutoff frequency that prevents dc noise and background IR from reaching the amplifier.

Low noise, high bandwidth, and rail-to-rail-I/O capability make the op amp a good choice for demodulation and amplification in this circuit. In addition, its RF immunity prevents the annoying 217-Hz audio buzz that you commonly find in GSM (global-system-for-mobile)-communications cell phones. For the IR receiver, the op amp acts as a gain-of-100, second-order bandpass fil-

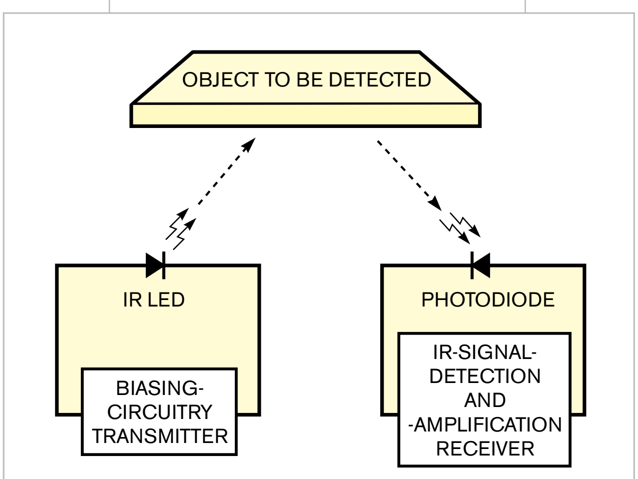

Figure 1 An IR-proximity sensor detects an object by receiving reflected light.

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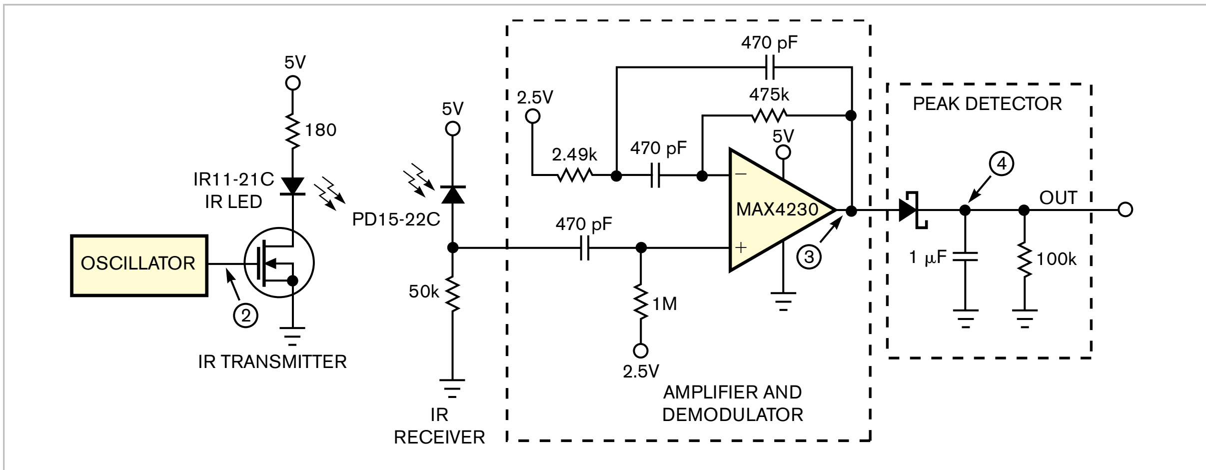

Figure 2 An IR transceiver detects the presence of an object and provides an approximate distance from the transceiver.

ter with a center frequency of 10 kHz. Thus, the op amp amplifies the incoming IR signals and demodulates them with a bandpass filter.

With no input IR signal present, the op amp is biased at 2.5V. With a 10-kHz IR signal incident, its output varies around 2.5V with a dynamic range of 5V. The output drives a simple diode detector, which rectifies the 10-kHz signal and provides a dc signal proportional to its amplitude. This analog-output signal is proportional to the distance of the object from the IR transmitter. You can use it as is or feed it to an ADC for further processing.

Figure 2 shows circuit operation at three nodes for objects at 1.2 and 1.4 in. from the IR transceiver. The circled numbers in **Figure 2** refer to the oscilloscope traces in **Figure 3**. EDN

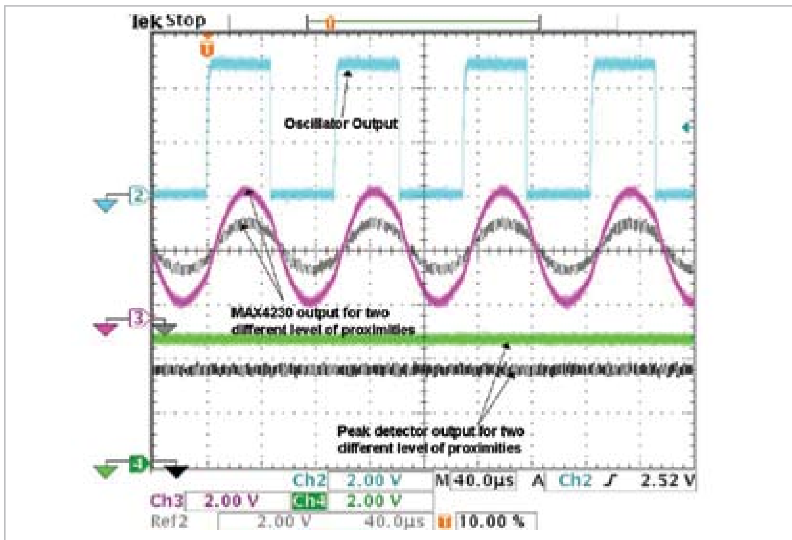

Figure 3 Different distances produce received waveforms of different amplitudes.

Set your lights to music

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As one of many ways you can implement a light show, the circuit in this Design Idea selectively activates various subsets in a group of six strings of lights, causing them to flash on and off according to the level and tempo of music you are playing. The stand-alone circuit requires no microcontroller, no software, and no trimming (**Figure 1**). You apply the audio signal you want to display to IC_1, a 12-bit ADC. The signal ranges from 0 to 2.048V, causing the first string of lights to come on at 2 mV. Although the circuit controls six ac outlets, you can expand it to control 12 outlets.

A short positive pulse at the CNVST pin of IC_1 triggers it to initiate a conversion, which the SCLK signal clocks. Its output (DOUT), which the rising edges of SCLK clock, comprises four leading zeros followed by the 12-bit conversion result, MSB (most-significant bit) first. Thus, one conversion requires 16 clock pulses at SCLK.

A vertical stack of six switched outlets, in which the top outlet represents the MSB, powers the display. You might, for example, plug a separate string of lights into each outlet. During operation, the circuit scans each conversion result as it is generated (MSB

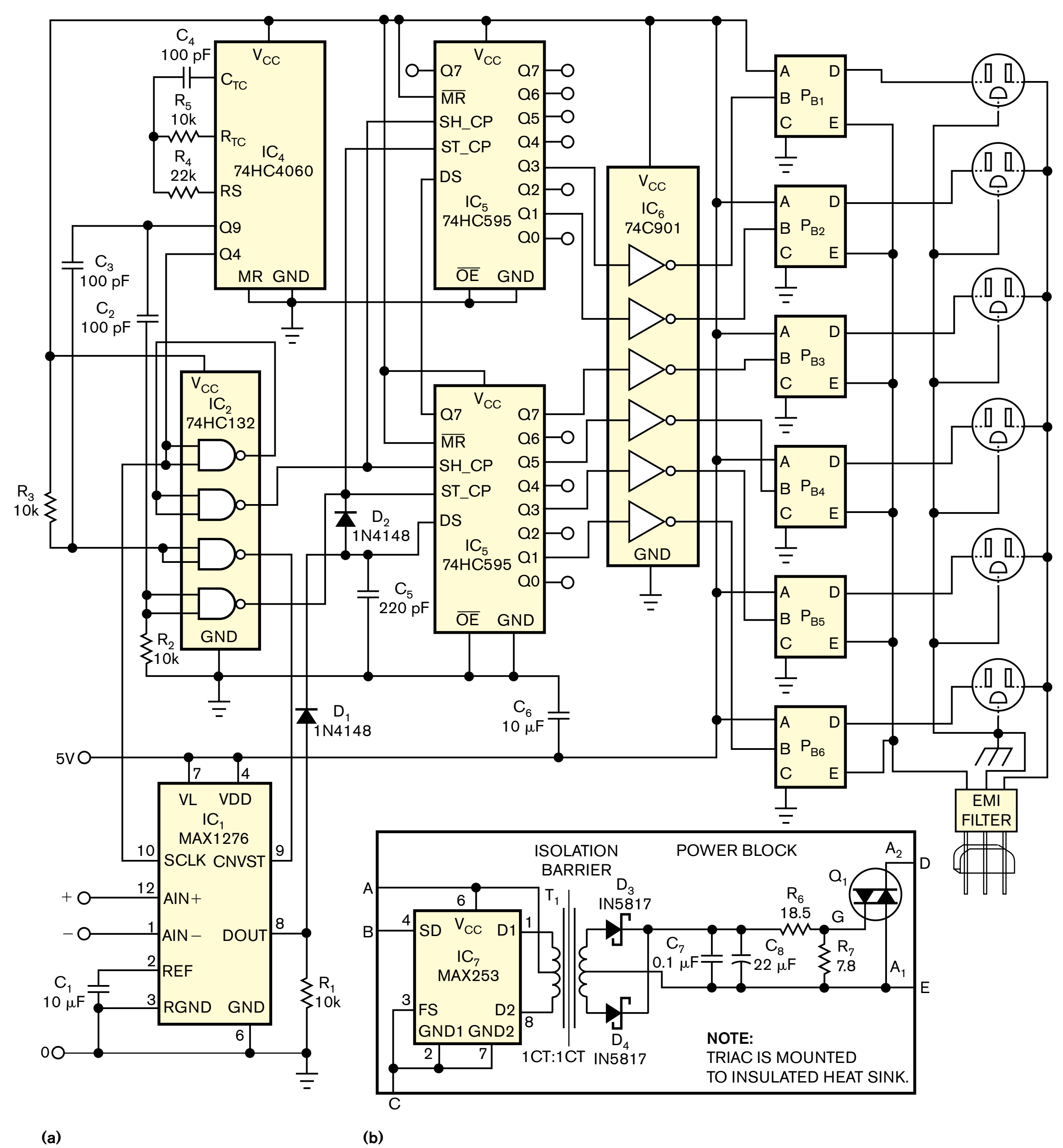

Figure 1 Driven by a 0 to 2.048V music signal at pins 12 and 1 of IC_1, this circuit activates the six ac outlets according to the music amplitude, in a logarithmic thermometer-code format (a). The power block (b) represents each of the power blocks, PB_1 through PB_6.

first, as described previously) and notes the first bit to assume a value of one. It then turns on the corresponding outlet and all those below it in the stack. The result is a logarithmic column, in which the change of input voltage necessary to move the column one step up or down (a 12.04-dB increment) is either quadruple or one-fourth the immediate value. Although the number of steps available equals the ADC's resolution of 12 bits, this circuit uses only every other one to drive the six outlets.

At DOUT, the first output bit with a value of one charges C_5 through D_1 to the logic-one level. The voltage on C_5 connects to the data input (DS) of the first of two cascaded 74HC595 ICs, which together form a 16-bit shift register. The signal that clocks the ADC, slightly delayed, also clocks this shift register through the NAND gates in IC_2 and thereby inserts into the shift register the value present at its input. At the end of a conversion, the voltage stored on C_5 forces to one all the bits following the first one that exhibits a value of one.

At the completion of each conversion, a negative pulse applied to the ST_CP inputs of both 74HC595 ICs transfers these shift-register contents to a parallel-output register, IC_6. The same pulse discharges the storage capacitor through diode D_2, leaving the circuit ready for the next conversion scan. The parallel-register outputs then serve as drivers for the 12-bit logarithmic column, with the MSB driving the top outlet.

IC_4, a 74HC4060, serves as a clock and timing-sequence generator, and IC_2, a 74HC132, provides some necessary glue logic. For each connected 74HC595 output, the signal, which IC_6 inverts, activates the corresponding MAX253 transformer driver, IC_7 in one of the six power blocks. A 1-to-1 transformer isolates this driver signal, which then triggers solid-state TRIAC (triode for alternating current), Q_1, to its on state. For the component values in the **figure**, the circuit has a display-sampling rate of about 2.5 kHz and uses the 12th, 10th, eighth, sixth, fourth, and second bits to control the six outlets. The resulting light show adds an extra dazzle to the music you are playing.

This circuit operates at lethal voltages and requires proper handling. Note that the transformer must withstand a line level of 120V ac. It operates with incandescent light bulbs; you should not use any other type of light bulb. Even though the outlets are standard 120V-ac outputs for use with commercial incandescent lights, fast switching in the TRIACs makes them unsuitable for driving other types of loads, such as appliances, electronics, or ac adapters. Transformer T_1 is a TGM-350NA from Halo Electronics Inc (www.haloelectronics.com), and TRIAC Q_1 is a T1235-T from STMicroelectronics (www.st.com). For a video of this circuit in action, go to www.edn.com/090806dia. EDN

Current limiter allows large USB bypass capacitance

Daniel Morris, Group IV Technology, Renton, WA

The USB (Universal Serial Bus) specification requires a connected USB device to present a load to the host or hub of no greater than 10 μF in parallel with 44Ω, including the effects of any bypass capacitance visible through the device's voltage regulator. This limit avoids excessive voltage drop at the device as inrush current charges its capacitance. Occasionally, a bus-powered device needs more than 10-μF bypass capacitance to provide an adequate reservoir for current spikes. The circuit in this Design Idea repurposes a Linear Technology (www.linear.com) LTC6102 precision current-sense amplifier, IC_1, to limit inrush current below the specified maximum, allowing the device to use more capacitance when necessary.

The LTC6102 usually translates the voltage across a current-sense resistor to a larger ground-referenced voltage in an output resistor. The part features an amplifier with low offset voltage, letting you use low-value sense resistors. In the usual circuit configuration, output current flows through an onboard FET whose source connection connects to a force pin separate from the amplifier input pin to minimize errors across trace and pin resistances.

This circuit grounds the LTC6102's output pin and uses the onboard FET as a source follower to drive the gate of an external current-limiting FET (**Figure 1**). The feedback loop around the LTC6102 maintains equal voltages at the positive and negative inputs of the amplifier, pins 8 and 1 of IC_1. Resistor divider R_2/R_4 sets the positive input of the amplifier, IC_1's Pin

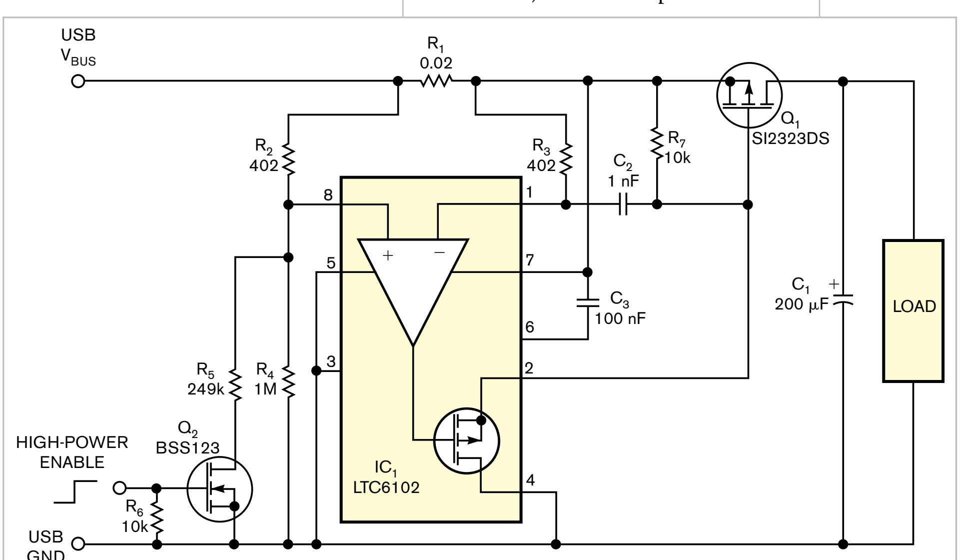

Figure 1 This circuit limits USB-device current both at connection and after configuration.

8, approximately 2 mV below the 5V USB-voltage rail. With Q_1 initially off at device connection, the negative amplifier input, IC_1's Pin 1, is higher than the positive input, causing the amplifier's output to go low. As the amplifier's output drops, the onboard FET follows, pulling the gate of Q_1 low and turning it on. Current increases in Q_1 until the voltage drop across sense resistor R_1 matches the drop across resistor R_2.

Resistor R_3 and capacitor C_2 compensate the feedback loop against oscillation and slow the turn-on of Q_1, preventing an initial current spike when the device connects to the bus. Capacitor C_3 bypasses a regulator on IC_1. Resistor R_7 meets the allowed maximum 1-mA current through the FET on IC_1. Q_1 turns on at a gate voltage low enough that it does not exceed the input range of 4V positive voltage to IC_1's Pin 7 to Pin 2.

Instead of the large capacitive load of C_1, the circuit presents a resistive load to the USB host equal to $R_1(R_2+R_4)/R_4=49.8\Omega$, lighter than the 44Ω maximum requirement. After C_1 charges, the circuit continues to limit current below the 100-mA maximum permitted to a low-power USB device. Upon configuration, the device can raise the current limit to the 500-mA maximum permitted to a high-power device by turning on FET Q_2 to place R_5 in parallel with R_4, increasing the voltage maintained across sense resistor R_1. EDN

High-speed pulse modulator retains signal envelope

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The circuit in **Figure 1** enables you to convert an arbitrary, relatively slowly varying voltage waveform to a new waveform in which the instantaneous values of the original waveform alternate with positive and negative signs. The new waveform retains information about the original waveform, and its mean value approaches zero. This situation holds true for any input waveform, even a dc voltage. The nearly zero dc component of the output of the circuit in conjunction with the upconversion of the frequency band lets the modulated waveform pass easily through a transformer (**Figure 2**).

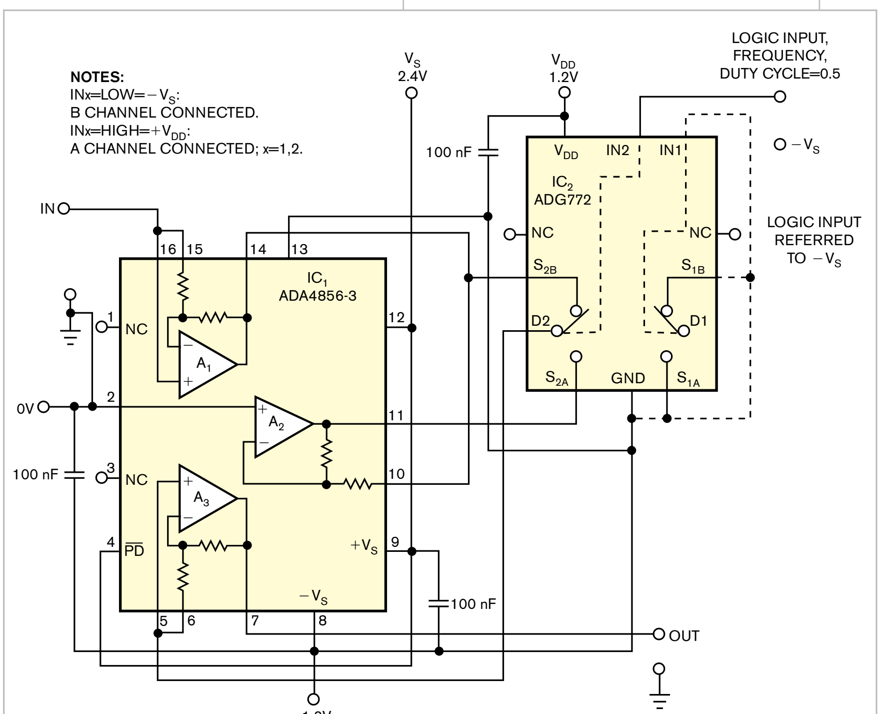

Figure 1 Video amplifiers and a switch pulse-modulate analog waveforms.

The circuit uses just one and one-half ICs from Analog Devices (www.analog.com). IC_1 is a triple video amplifier, the ADA4856-3 with a gain of two (**Reference 1**). Amplifier A_1 acts as a voltage follower, which gives a maximally smooth and flat frequency response. Amplifier A_2 acts as an inverter, having a voltage gain of negative one, and A_3 serves as an impedance converter with a voltage gain of one.

IC_2, an ADG772 high-speed 2-to-1 multiplexer (**Reference 2**), alternately switches the outputs of A_1 and of A_2 to the input of A_3. You must keep the duty cycle of IC_2's logic-control signal, IN2, close to 0.5 to ensure the "zero" mean value of the output voltage, even at a nonzero input voltage. At a modulation rate, or the frequency of the logic-control signal, of approximately 6 MHz, the output voltage's dc component shifts negligibly only from the low-frequency mean-offset voltage of the circuit, which is less than 4 mV.

Experiments have confirmed this value for an input voltage of 0V and for the precise reference dc voltage of 0.8188V. At a frequency of 60 MHz, the dc component of the output voltage remains at about 4 mV for an input voltage of 0V and rises to approximately 175 mV for an input voltage of 0.8188V. This result is still remarkable because the ADG772 is a BBM (break-before-make) type of multiplexer/switch. During time interval t_{BBM}, which is typically 5 nsec, both the S_{2A} and S_{2B} switches are temporarily off. Thus, the corresponding switch is on for approximately 8.2 nsec within a half-period of a 60-MHz control signal, yielding an on-state duration of only 3.2 nsec. An eventual 320-psec difference of the turn-on times of switches S_{2A} and S_{2B} would cause a shift in the dc component of 81.88 mV. The corresponding dc components of output voltages for an input voltage of 0V and an input voltage of 0.8188V differ by about 175 mV as a result of the difference in turn-on times of S_{1A} and S_{1B}. You can estimate this difference using the following **equation**:

$$320\ \text{psec}\times\frac{175\ \text{mV}}{81.88\ \text{mV}}\cong 684\ \text{psec}.$$

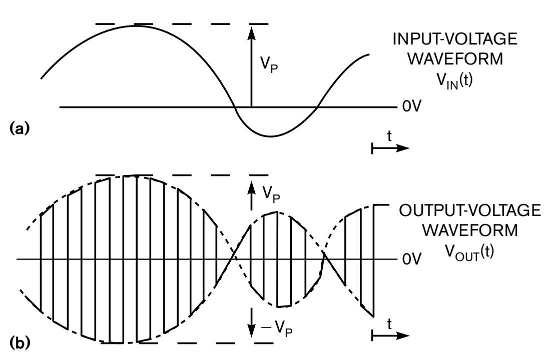

Figure 2 The pulse-modulated waveform can pass through a transformer, providing signal isolation. Comparing the input waveform, $V_{IN}(t)$ (a) with the output waveform, $V_{OUT}(t)$ (b) shows that the frequency spectrum of the output waveform upconverts while its dc component becomes zero.

Thus, this application calls for an analog multiplexer having the speed and bandwidth of the ADG772, and it should operate as an MBB (make-before-break) type. At a switching rate of 60 MHz, the channels of such a multiplexer will conduct almost three times longer, and the difference in turn-on times of the A and B channels will be less significant. To prevent short overloading of amplifiers A_1 and A_2, you can place SMD resistors of about 20Ω to the outputs of A_1 and A_2 when using an MBB multiplexer. EDN

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