EDITED BY MARTIN ROWE
AND FRAN GRANVILLE

designideas

READERS SOLVE DESIGN PROBLEMS

DIs Inside

▶To see all of *EDN*'s Design Ideas, visit www.edn.com/designideas.

Illumination ring provides focused intensities

William Grill, Honeywell Aerospace, Olathe, KS

If you use a camera-based inspection or soldering fixture, you need to see images in a small area. Often, side lighting produces shadows on an image that result in contrasting colors and poor quality. Thus, your monitor views may be difficult to clearly see or interpret. Centering a light ring on the image provides illumination on all sides of the object and may illuminate everything you need to see. In a camera application for controlling a light ring, this implementation not only controls the light, but also enables you to direct the light intensity by maintaining two levels of control. It also lets you maintain and rotate the second-tier levels about the illuminated object.

Based on a seven-LED set, you select three consecutive LEDs; the second-tier settings will define the three LEDs' intensities (**Figure 1**). The remaining displays are maintained at a base-tier-intensity setting. Using four pushbutton switches, the Microchip (www.microchip.com) 16F505 rotates, distributes, and provides PWM (pulse-width-modulation) control of these two power tiers across the seven LEDs. Two of the buttons increase or decrease intensity, or they group or ungroup the tier-intensity settings; the other two buttons rotate the resulting second-tier display clockwise or counterclockwise.

The implementation uses just a few parts, exploiting the controller to provide light level, state maintenance, and PWM control. The application debounces the buttons and indexes the intensity controls. An eighth LED indicates tier-grouped or -ungrouped

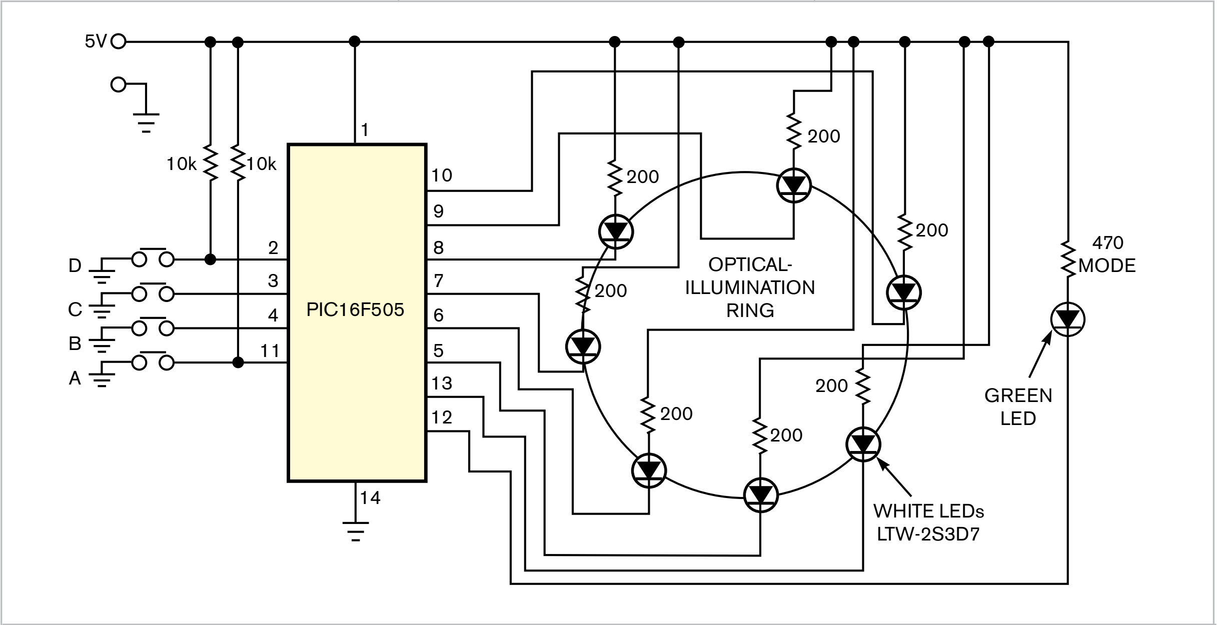

Figure 1 An LED illumination ring provides directed light intensity.

mode. When you group the tiers together, their intensity-setting indexing is common, but their register limits remain independent. You can download **Listing 1**, the assembly code for the circuit, from the online version of this Design Idea at www.edn.com/090709dia.

The controller provides a PWM period of approximately 7.5 msec to all the LEDs. It also controls each LED's duty cycle, according to the registered levels the button sets, in defined and maintained register masks and intensity values. The controller provides six bits of intensity, corresponding to 64 levels of resolution, although 8-bit resolution is available. The operating voltage is 5V. You can reconfigure the controller, the display, and their limiting resistors to operate at voltages as low as approximately 3.1V. High-millicandle, white, 5-mm, T1¾ through-hole LEDs provide the light source. The controller provides about 8 mA of current to each of the LEDs. By constraining the total power, surface-mount or other LED configurations are possible.

You can lay out the four momentary-action pushbutton switches for operation by the left or the right hand. With one representing the pushbuttons' asserted position, the controller's coded sequences provide the button-control functions found in **Table 1**.EDN

TABLE 1 PUSHBUTTON-CONTROL FUNCTIONS

A	B		C	D	
1	1	No function	1	1	Alternate between common-tier mode and second-tier mode
1	0	Select second-tier mode, rotate Tier 2 LEDs counterclockwise	1	0	Increment all or second tier if in second-tier mode with autoindexing
0	1	Select second-tier mode, rotate Tier 2 LEDs clockwise	0	1	Decrement all or second tier if in second-tier mode with autoindexing
0	0	No function	0	0	No function

Digital variable resistor compensates voltage regulator

Jason Andrews, Maxim Integrated Products Inc, Dallas, TX

A variable resistor that integrates a programmable, temperature-indexed look-up table can compensate for the temperature drift of a voltage regulator. In this case, the look-up table can change the resistance every 2°C over a range of −40 to +102°C, thereby nulling any regulator-output changes that would otherwise occur because of temperature. A typical regulator circuit comprises a regulating element, a feedback-resistor divider, and capacitors to provide filtering and regulation against transients and load-switching conditions (**Figure 1**). The ratio of the two feedback-divider resistors sets the regulator-output voltage. The regulator can generate either a preset 3.3V or any user-defined output within its operating range.

For most regulator circuits, the output voltage varies slightly with temperature, from 97.6 to 101.5% of nominal in this circuit. These numbers are respectable, but you can improve them. First, incorporate a digitally controlled variable resistor, such as a DS1859, into the regulator circuit of **Figure 1** by placing it in parallel with R_2 (**Figure 2**). A temperature-indexed look-up table in an internal nonvolatile memory controls the 50-kΩ digital resistor, allowing you to program a different resistance value for each 2°C window.

You can program the look-up table to provide any resistance-versus-temperature profile. In this example, the look-up table flattens the regulator's normal curve over temperature. These look-up tables, therefore, provide a positive resistance slope with respect to temperature. The resistor has 256 programmable resistance settings of 0 to 255 decimal, and each one accounts

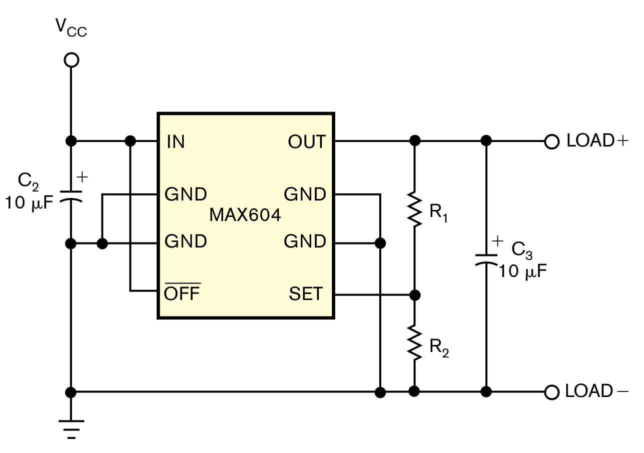

Figure 1 A typical voltage regulator lets you set the regulated output level by adjusting the R_1/R_2 divider.

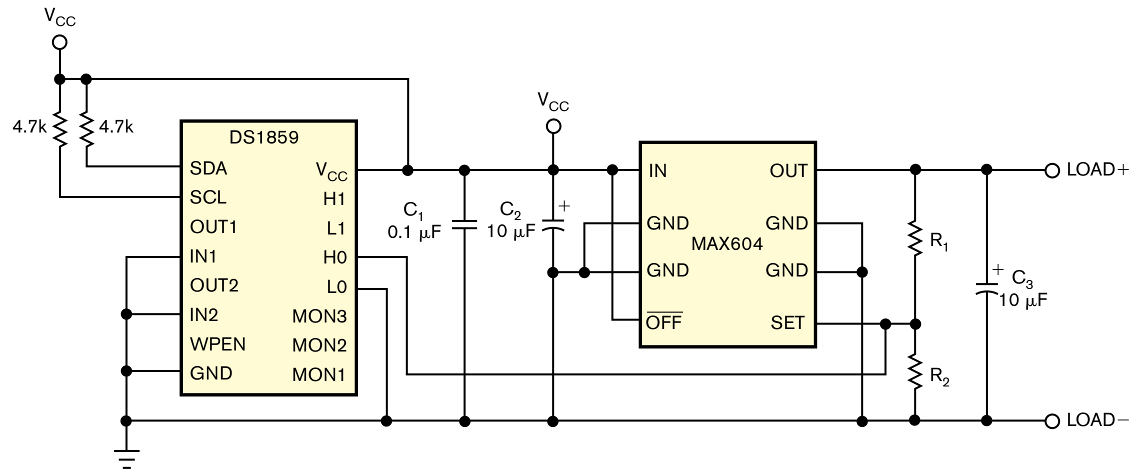

Figure 2 Connecting one-half of a dual variable resistor in parallel with R_2 to the circuit in Figure 1 lets you temperature-compensate the regulated output voltage.

for approximately 192Ω. In this example, the look-up table was programmed with a setting of 143 decimal at −40°C. The settings were incremented by one for every 4 to 6°C change in temperature, resulting in a value of 152 decimal for ambient and 158 decimal for +85°C.

As illustrated in **Figure 3**, the result of this regulated performance over temperature is a drastic increase in precision: The variation from −45 to +85°C is now only ±2 mV. For comparison, note the response of the standard regulator circuit in **Figure 1** (the black curve). The digital-resistor IC of **Figure 2** includes three ADC inputs for monitoring external voltages. An alternative, the DS1847 dual variable resistor, offers similar performance without the ADC monitors and at lower cost. **EDN**

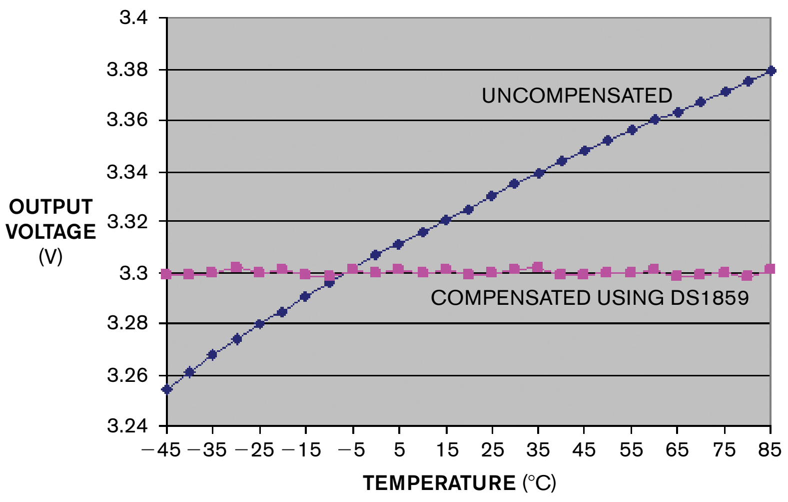

Figure 3 These curves compare regulated outputs versus temperature for the Figure 1 circuit (black) and the compensated Figure 2 circuit (pink).

Hot-swap switch provides easy thermal protection

Donald Schelle, National Semiconductor Corp, Santa Clara, CA

It is often difficult to design an effective thermal-management scheme that minimizes the risk of meltdown or fire. System orientation, placement, or both complicate matters by generating hot spots at varying locations on a PCB (printed-circuit board). A hot-swap switch and carefully placed temperature sensors mitigate thermal issues by disconnecting system power when a temperature exceeds a safe limit. The circuit in **Figure 1** uses a hot-swap switch to monitor overvoltage, undervoltage, and overcurrent conditions. When the ambient temperature exceeds a preset threshold, a carefully placed temperature sensor, IC_1, forces the hot-swap controller, IC_2, to disconnect system power. You can use multiple tempera-

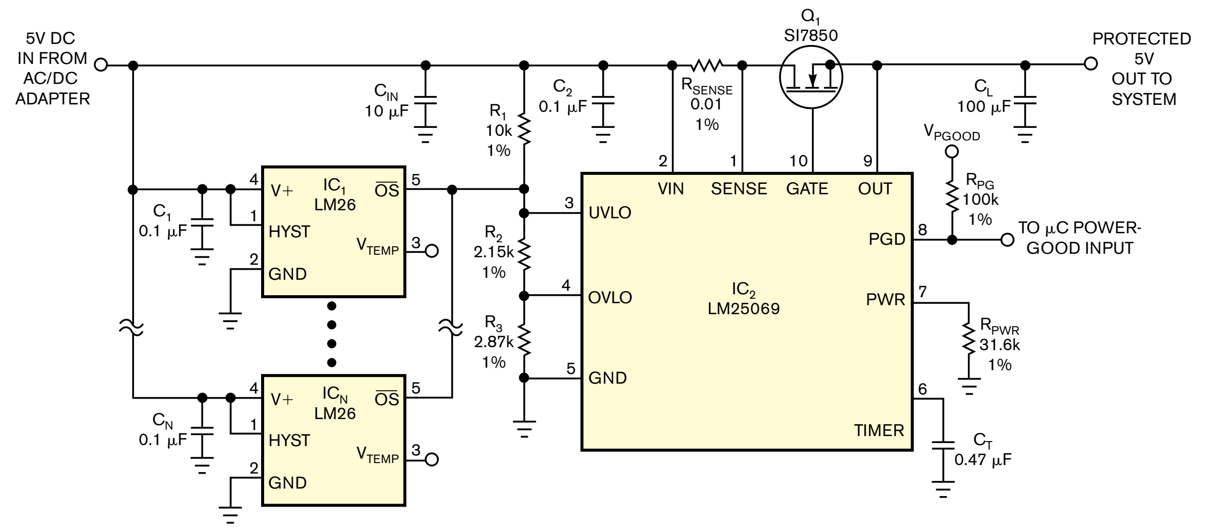

Figure 1 Carefully placed low-cost temperature sensors disconnect system power when an overtemperature thermal event occurs.

ture switches to isolate hot spots when you mount the system in varying orientations. The circuit requires neither a microcontroller nor a costly temperature-monitoring IC. Thermal events cut power to the system using a robust, nondestructive technique.

In a typical overtemperature condition (**Figure 2**), a thermal event (upper trace) causes the LM26 to trip, forcing the LM25069 to disconnect power from the system (middle and lower traces). When the system temperature decreases below the LM26's trip point, system power returns. Incorrect placement or orientation can cause overtemperature events, forcing the system to turn on and off like clockwork; support personnel can easily diagnose this symptom. Inexpensive temperature sensors and an innovative power-limiting hot-swap controller reduce the cost of this circuit to approximately $2 in low-volume applications.**EDN**

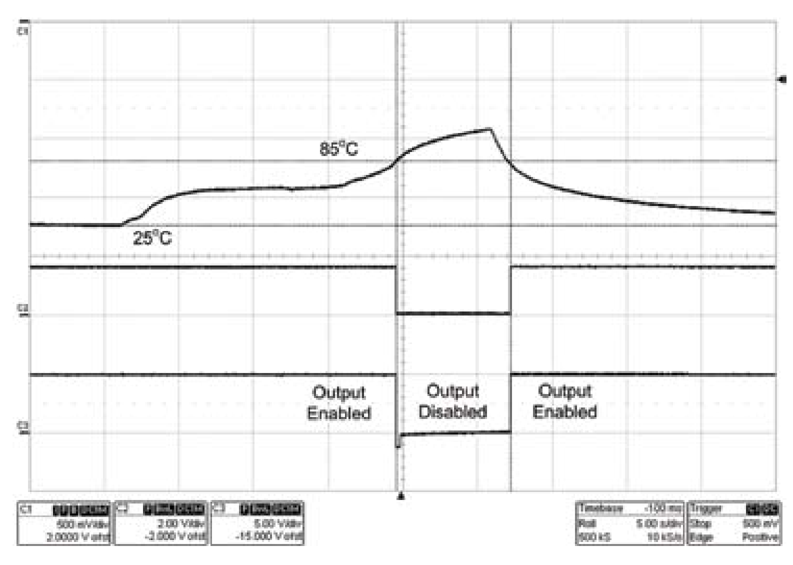

Figure 2 As the temperature rises above the threshold (top trace), the output of the temperature sensor (middle trace) goes low, forcing the hot-swap switch to disconnect power (bottom trace) from the circuit.

Add headphones to a Class D amplifier

Hiroshi Fukushima, Technical Research Center,
D&M Holdings Inc, Kawasaki City, Kanagawa, Japan

The MAX9704 from Maxim (www.maxim-ic.com) is a small and efficient Class D audio power amplifier. Its fully balanced inputs and Class D outputs make it a convenient chip to directly drive speakers. Sometimes, though, you want to have a headphone output to keep the office environment. Class D power amplifiers usually have fully balanced, bridged outputs on each channel. If the amplifier drives separate speakers, you can use an attenuator circuit (**Figure 1**). A problem arises, however, with grounded headphones: Stereo headphones use three-pole plugs with which the negative side of each speaker connects to a common ground. Thus, you may think that you can't directly connect head-

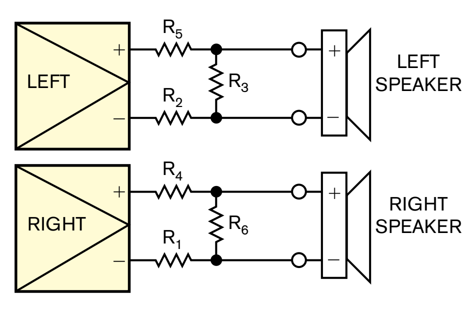

Figure 1 A Class D amplifier has separate drivers for each speaker.

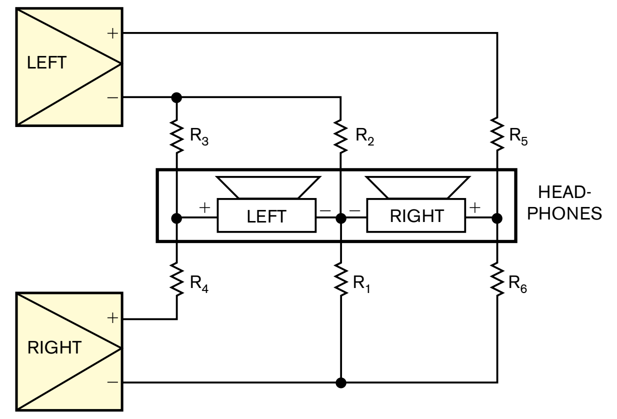

Figure 3 This speaker configuration lets you connect headphones with a common ground to a Class D amplifier.

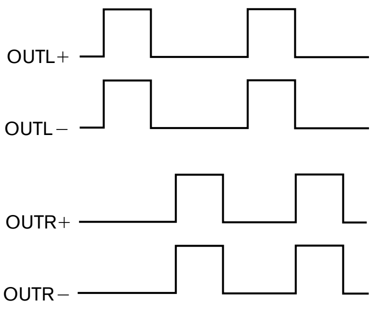

Figure 2 The MAX9704 applies power to one channel at a time.

phones to a Class D amplifier without using a transformer.

To solve the problem, look at the output waveform of the MAX9704 as it swings (**Figure 2**). Each channel output alternates between high and low. You can take advantage of the fact that the channels aren't on at the same time by configuring your circuit like the one in **Figure 3**.

Figure 4 shows the circuit details. Because the MAX9704 alternates the outputs of each channel, the R_3/R_6 combination doesn't affect the channel's drivers. Resistors R_3 and R_2 connect to the left output terminal. Resistors R_4 and R_1 connect to the right output terminal. The inactive channel's output voltage must be the same voltage, which means that R_4, R_1, and R_6 connect to the same voltage when the left-channel output is active. R_3, R_1, and R_5 connect to the same voltage when the right-channel output is active. The values of R_1 and R_2 affect how much crosstalk you get between channels. The values in **Figure 4** provide sufficient channel separation.**EDN**

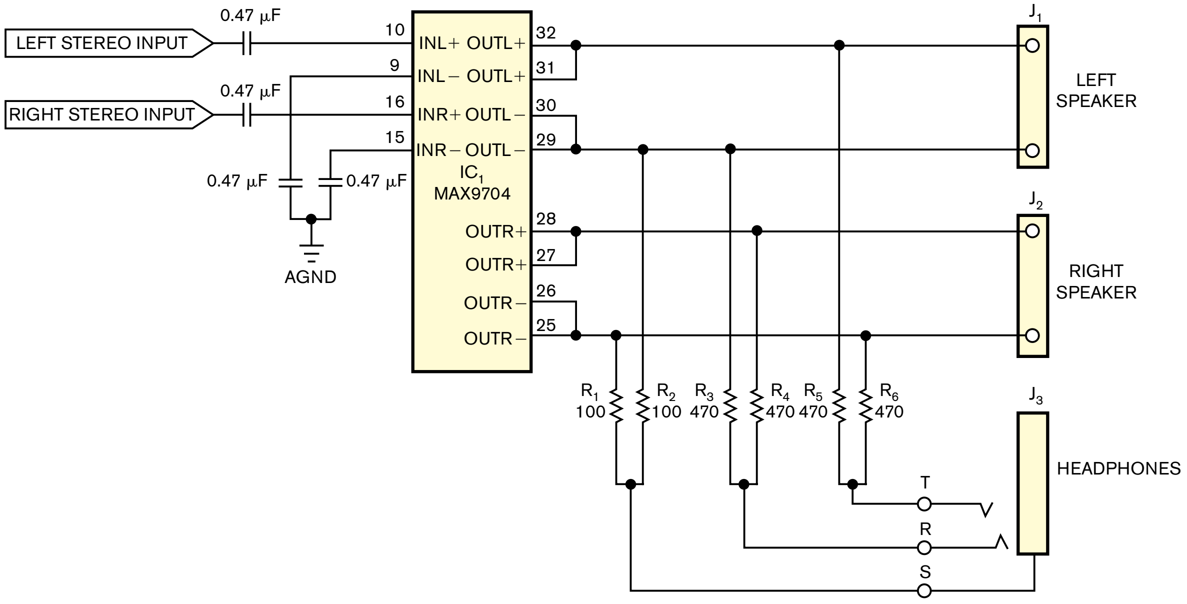

Figure 4 With the resistors in place, you can connect headphones to the MAX9704 amplifier.

Circuit eases power-sequence testing

Goh Ban Hok, Infineon Technologies Asia Pacific Ltd, Singapore

Systems on chip (SOCs) normally require one power supply for the core and another for I/O. To properly apply power to the device, you often need one supply to apply power before the other. The circuit in **Figure 1** lets you test the power sequencing of the SOC. Two TPS75501 linear regulators, IC_3 and IC_4, generate two power supplies. The TPS75501 adjustable regulator provides output voltages of 1.22 to 5V from a maximum input of 6V. The circuit uses 5V as the input source, and it can supply as much as 5A. The SOC requires 3.3 and 1.5V. The following **equations** describe how to set the voltages. $V_{OUT1}=V_{REF}(1+R_4/R_5)$ for IC_3, and $V_{OUT2}=V_{REF}(1+R_6/R_7)$ for IC_4. The reference voltage is 1.22V.

In the circuit, R_5 and R_7 are 30 kΩ. Variable resistor R_4 is 7 kΩ for the 1.5V supply, and R_6 is 50 kΩ for the 3.3V supply. Green LED D_2 lights when the 3.3V supply is present, and red LED D_1 lights for the input-supply voltage. Pin 1 of the TPS75501 is the enable pin. When low, it enables the output voltage at Pin 4. Switch S_2 selects the sequence of the power supplies. IC_1 is a 555 timer operating as a monostable circuit. It provides the delay between the two power supplies. You can adjust the delay by using the time constant of R_3 and C_3: $\text{Delay}=1.1\times R_3C_3$.

C_3 is 33 μF and R_3 is 11 kΩ for a 400-msec delay between powering the two supplies. The timer triggers with a negative pulse at Pin 2 of IC_1. It produces a positive pulse at Pin 3 of IC_1. The output becomes inverted at IC_{2A} before passing to IC_6's Pin 11. IC_5 and IC_6 are the latched circuits. The set pin, S, connects to the 5V supply, and the reset pin, R, connects through resistors R_2 and R_{10} and capacitors C_4 and C_7 to ensure that the Q output is high during the initial power-up stage. Regulators IC_3 and IC_4 are initially off.

When analog switch S_2 is in the on position, the sequence of the 1.5V power supply starts first, and the 3.3V supply follows. To start the power-sequence testing, press and release trigger switch S_1 to momentarily produce

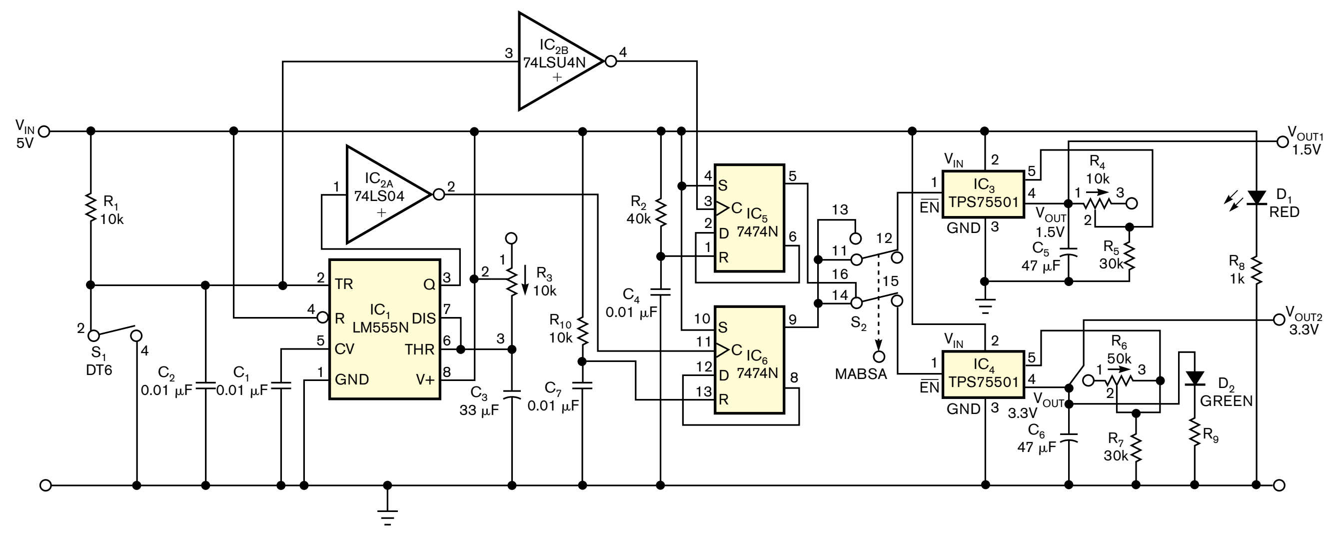

Figure 1 A configurable sequencing circuit uses a 555 timer to delay one power supply.

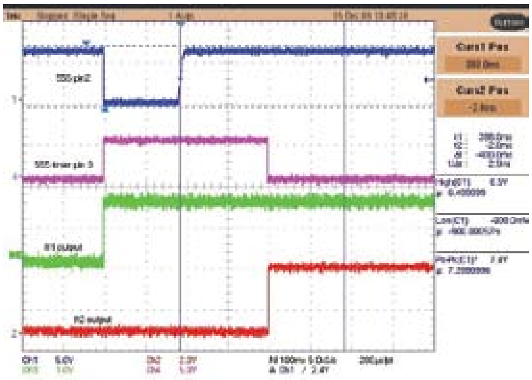

Figure 2 The 1.5V power supply (green trace) comes on first, and the 3.3V supply (red trace) and 555 timer follow.

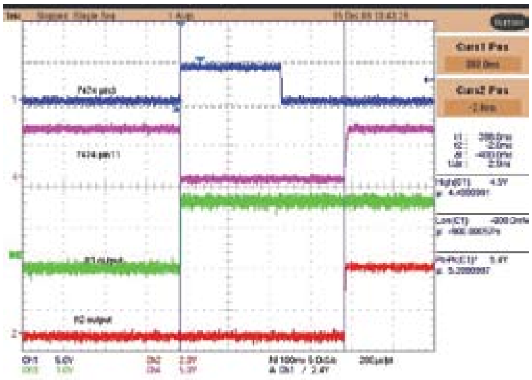

Figure 3 The 1.5V power supply (green trace) comes on first, and the 3.3V supply (red trace) and 7474 latch-circuit input follow.

a low pulse. This pulse triggers the 555 timer, IC_1, which produces a positive pulse. This pulse in turn produces a delay before enabling IC_4's power 3.3V supply. When you press and release S_1, another signal goes to inverter IC_{2B} before passing to the latch pin, Pin 3 of IC_5. There is no delay for the 1.5V regulator that connects to this pin. It enables IC_3's 1.5V power supply. Because IC_3's enable pin immediately receives the enable signal, it produces the 1.5V without delay. IC_4's enable pin, which receives a signal after the delay by the 555 timer, later produces the 3.3V, thus achieving the power sequence. The 1.5V power supply comes first when you press S_1, and the 3.3V power supply comes on only after the 555 timer delay (**figures** 2 and 3).

Switch S_2 connects to pins 13 and 16. When S_2 is off, the power sequence changes. In this case, the 3.3V supply powers up first, and the 1.5V supply follows (**figures 4** and **5**). When you press S_1, the 3.3V power supply comes first, and the 1.5V supply follows after the 555 timer delay.**EDN**

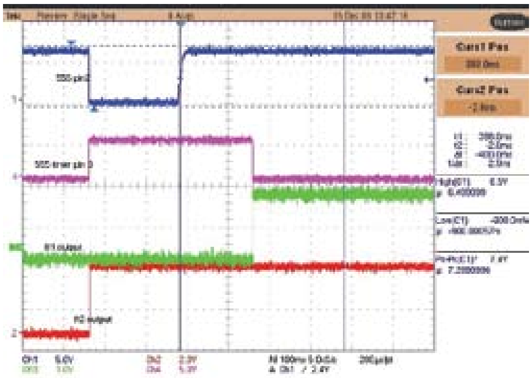

Figure 4 The 3.3V power supply (red trace) comes on first, and the1.5V supply (green trace) and 555 timer follow.

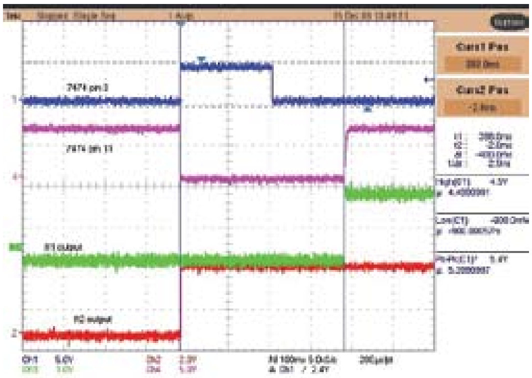

Figure 5 The 3.3V power supply (red trace) comes on first, and the 1.5V supply (green trace) and 7474 latch-circuit input follow.