Turn a set/reset latch into an astable/monostable multivibrator

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This Design Idea describes a simple way to form a reliable astable or monostable multivibrator from a set/reset latch. You may find it useful because it lets you minimize the number of standard digital ICs your design requires when absolute precision isn't an issue. You can use a set/reset latch either with active-low or active-high inputs, which you can build with two NAND or NOR logic gates. You can also use integrated set/reset latches or any type of flip-flop that comes with asynchronous preset and clear inputs because they have the same function as the set/reset inputs when the clock and data inputs are grounded. This method functions only with CMOS-logic families that offer the benefits of high input impedance; a quasi-ideal voltage-transfer characteristic with a threshold voltage, V_{TH}, typically equal to the drain-to-drain voltage, V_{DD}, divided by two; and low power consumption. This concept has undergone testing with a 74HC00 quad NAND, a 74HC02 quad NOR, a CD4001 quad NOR, a CD4011 quad NAND, and a CD4013 dual-D-type flip-flop.

Connecting two RC networks between the complementary outputs Q and $\overline{Q}$ and set and reset inputs enables astable operation (**Figure 1**). Due to complementary outputs, the circuit has no stable state, and it toggles continuously, generating an output clock. The time constants R_2C_2 and R_1C_1 set the high and low time periods, T_H and T_L, respectively, and also the duty cycle. Diodes D_1 and D_2 quickly discharge capacitors C_1 and C_2 so that, on the next

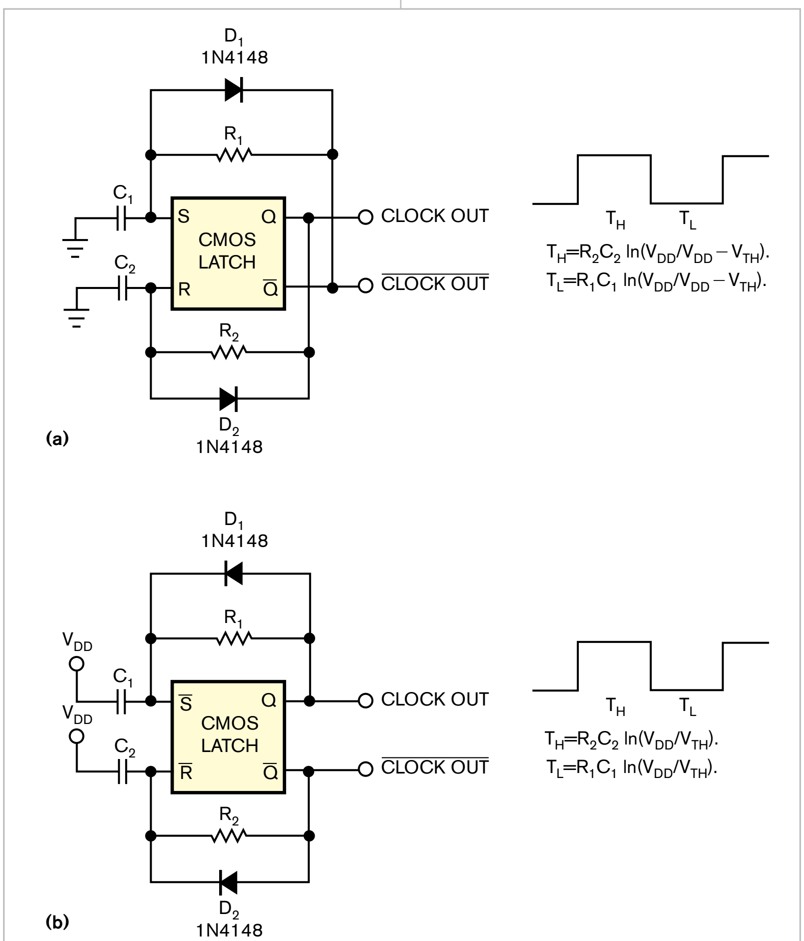

Figure 1 Capacitors that connect to ground or V_{DD} depend on active-high (a) or active-low (b) inputs.

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cycle, they will recharge from 0V.

In monostable mode, connect one RC network (**Figure 2**), depending whether you need a positive-pulse or a negative-pulse trigger. When an input trigger pulse occurs, it sets the output pulse, T_W, which remains in this state until the RC network activates the reset pin. The RC time constant sets the output-pulse width. For correct operation, the trigger pulse must be shorter than the output pulse. Diode D_1 reduces recovery time.

The threshold voltage has the typical value $V_{DD}/2$, but it may change from 0.33 to 0.67 of V_{DD} for the CD4000 CMOS family. The parameters of the generated output signals of the circuits in **figures 1** and **2** present variations from unit to unit as a function of threshold-voltage shift. On the other hand, the threshold voltage presents good stability with supply voltage and temperature variations.

For best accuracy, the timing capacitors for both astable and monostable circuits should be nonpolarized, have low leakage, and be much larger than the inherent stray capacitance in the circuit, and the timing resistors for both astable and monostable circuits must be much larger than the CMOS on-resistance in series with them, which typically is hundreds of ohms. In addition, you must decouple the supply voltage for safety to prevent voltage spikes, which may disturb the circuits. EDN

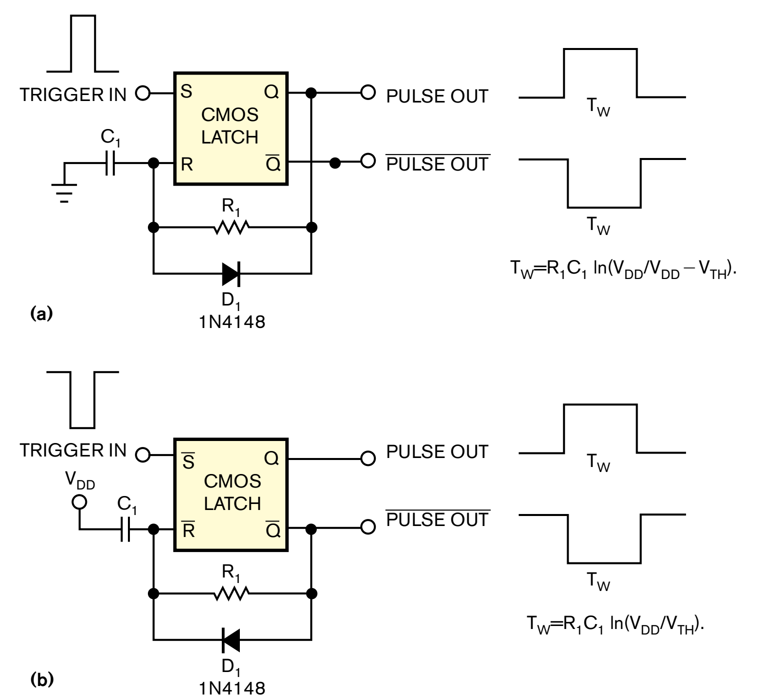

Figure 2 The leading edge of the trigger pulse depends on active-high (a) or active-low (b) inputs.

555 timer eliminates LED driver's need for microprocessor control

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LEDs find their way into applications that range from high-end video displays to low-end lighting applications. Designers often need only some of the functions of a dedicated LED driver but can't afford the cost

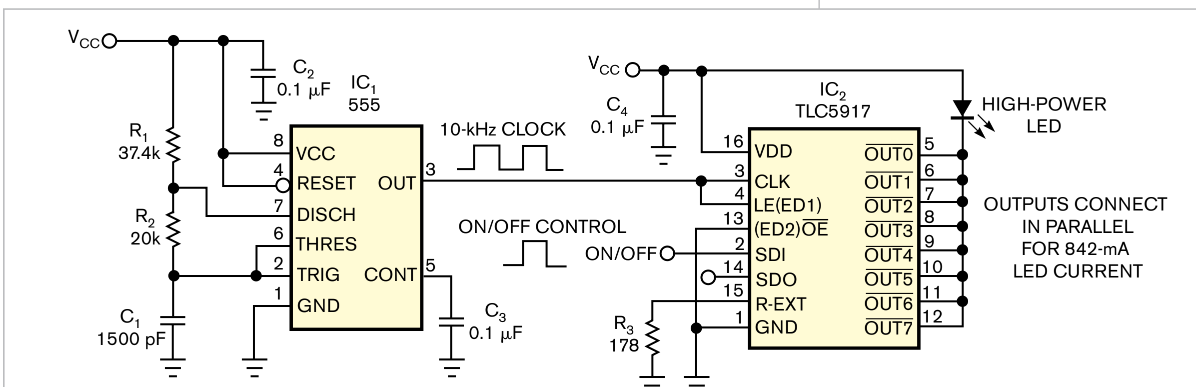

Figure 1 A 555 timer provides the necessary pulses for configuring an LED driver.

of the microprocessor to control them. Microprocessors typically control dedicated LED drivers, enabling features such as analog or PWM (pulse-width modulation) for LED-current control, independent control of each LED, and reading LED status and faults. If your design requires a constant-current LED, such as those in LED lighting or luminaires, then you may not need these advanced features. In these applications, a 555 timer can replace the microprocessor and still allow accurate control of LED current independently of input voltage, temperature, and LED forward-voltage drops.

IC_2, a TLC5917 dedicated LED driver, controls eight independent constant-current sinks (**Figure 1**). It normally requires a microprocessor to drive four digital-input signals. The command $\overline{OE}$ (output enable) enables and disables the IC. Data on the SDI (serial-data-input) pin clocks into the IC's input shift registers on the rising edge of the clock. The data in the shift registers transfers into internal on/off latches on the falling edge of the LE (latch).

Either the TLC5917 outputs can drive eight independent LEDs, or you can parallel its outputs to increase the current to drive one higher-power LED. Its internal current-setting registers have default values at startup. These values, along with external current-setting resistor R_3, set the LED current. In this application, R_3 sets each output's current to 105 mA: $18.75V/R_3=18.75A/178\Omega$. Connecting all outputs in parallel yields 842 mA of LED current.

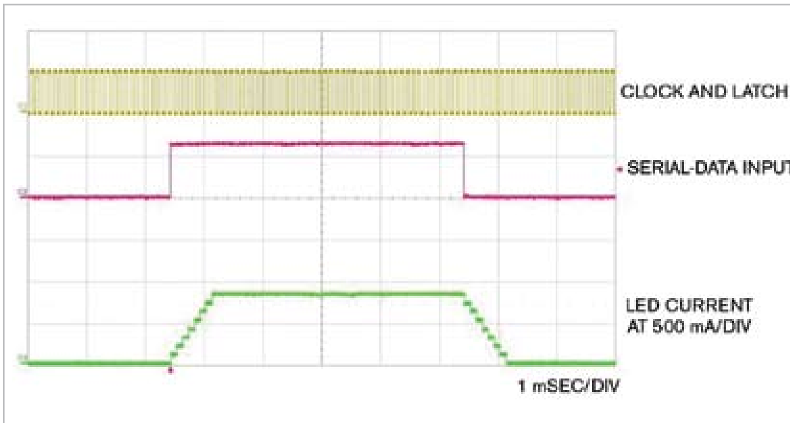

Figure 2 The LED current (lower trace) ramps up and down in eight steps.

At power-up, the internal on/off latches that turn each output on or off default to zero, so you must set these latches to one before the outputs turn on. The 555 timer replaces the microprocessor for this function. The clock and latch lines both connect to the 555 timer's square-wave output. At each rising edge of the clock, the SDI shifts into the TLC5917's input shift register. This data latches into the on/off latch at the falling edge of the latch signal. Because shifting the data and latching the data occur at different clock edges, the clock and latch pins can connect to the same input clock signal. Hard-wiring $\overline{OE}$ to ground permanently enables the IC. You can connect SDI to the power-supply voltage to automatically turn on the LED at power-up. This connection continuously clocks in ones to turn on all outputs. You can also connect SDI to a switch or a digital input to allow for LED on/off control. Then, SDI can pull to the power-supply voltage, which continuously clocks in all ones to turn on the outputs. Alternatively, it can pull to ground, which continuously clocks in all zeros to turn off the outputs.

The 555 timer's clock speed determines how fast the LEDs turn on and off. The LED current ramps from 0 to 100% in eight clock pulses as each falling edge of the latch pin latches the SDI data into another of the eight internal on/off latches, turning on or off another one of the eight outputs. **Figure 2** shows the resulting stair-stepped LED current increasing and decreasing with each successive falling edge of the latch. Even a relatively low clock speed of 10 kHz results in an off/on and on/off transition of only 0.8 msec, which the human eye perceives as instantaneous. You can achieve gradual turn-on and turn-off with low clock speeds. Setting the clock to 0.1 Hz gradually turns the LED on and off in 0.8 sec. EDN

Smart photoresistor timer needs few components

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An application required a photo timer with some unusual functions. It had to switch on the load, a lamp, an hour after sunset. After working for three hours, the timer should turn the load off, which had to remain off until an operator manually reactivated the timer. The timer had to reside between the main 110/220V-ac line and the load. And, as with any other consumer product, it had to be cost-effective. You can achieve these goals by using a voltage comparator and dual timers with an RC-timing network, but an inexpensive, 8-bit microcontroller with a built-in ADC provides a more elegant approach. You can perform all the functions in firmware. **Listing 1**, which is available at www.edn.com/090903dia, contains downloadable source code.

Figure 1 shows the circuit, which uses an eight-pin MC68HC908QT2 microcontroller from Freescale Semi-

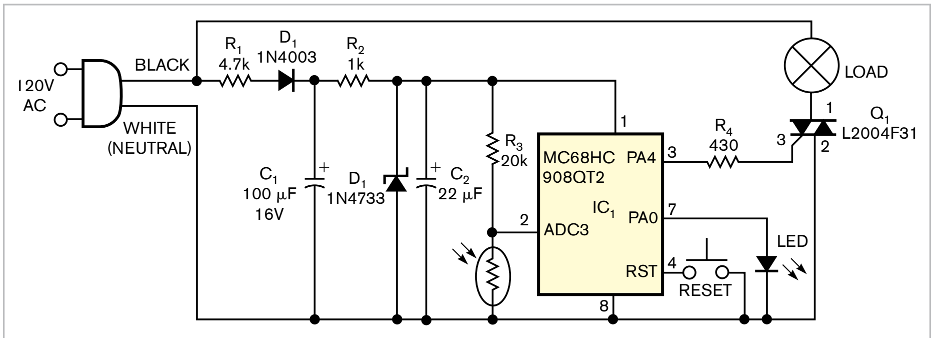

Figure 1 This circuit uses an eight-pin microcontroller and a logic switch to provide a smart photoresistor.

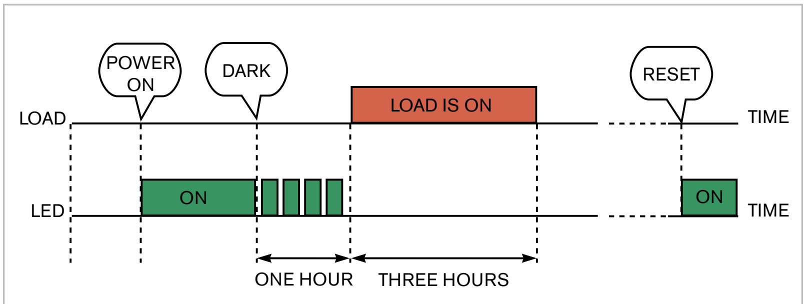

Figure 2 The LED is on when the timer is ready for work and waits for darkness. It blinks during the delay, and it is off when the timer waits for reactivation.

conductor (www.freescale.com). **Reference 1** describes a microcontroller's power supply. Q_1, an L2004F31 logic triac from Littelfuse (www.littelfuse.com), switches the load on and off; the type you use depends only on the load current and main voltage. The L2004F31 requires only 3 mA of dc-gate-trigger current, and it conducts 4A rms at 200V ac. The VT90N1 photoresistor from PerkinElmer (www.optoelectronics.perkinelmer.com) has a dark resistance of 200 kΩ, which drops in light to 10 kΩ or less. The LED indicates the status of the timer: It is on when the timer is ready for work and waits for darkness. It blinks during the delay, and it is off when the timer waits for reactivation (**Figure 2**). The W934GD5V LED from Kingbright (www.kingbright.com) has a built-in resistor that minimizes the number of necessary components. To reactivate the timer, press the pushbutton reset switch. All time delays are set in firmware, and you can easily change them.EDN

REFERENCE

1 Raynus, Abel, "AC line powers microcontroller-based fan-speed regulator," *EDN*, Nov 9, 2006, pg 128, www.edn.com/article/CA6387025.

High-performance adder uses instrumentation amplifiers

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As instrumentation amplifiers become less costly, they can provide improved performance in applications that operational amplifiers traditionally served. The op-amp adder in **Figure 1** has a few shortcomings. First, the inputs have low to medium input impedance, which the input resistor of each signal determines. This arrangement causes gain errors when the source impedance of the driving signal is large or requires the design of low-impedance driving sources. This circuit also has no common-mode-rejection capability, so inputs must be single-ended. The channel with the largest gain limits the performance of the entire system. Higher gain on one channel results in lower bandwidth, higher distortion, and increased system noise on all channels. To limit these effects, even low-performance adders require high-performance, high-bandwidth op amps.

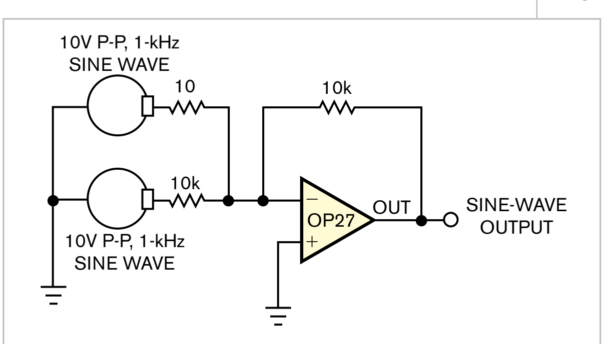

Figure 1 A typical adder configuration uses a single op amp.

The noise gain of this op-amp adder is 1+10,000/(10||10,000). The input signal with the highest gain and 10Ω input dominates the noise gain, but all inputs suffer increased offset voltage, gain error, noise, and distortion. You can increase input impedance and improve common-mode rejection by using instrumentation amplifiers. The output voltage of an instrumentation amplifier is proportional to the voltage difference between the positive and the negative inputs. You can amplify this signal by connecting a resistor, R_{GAIN}, to the R_G pins (**Figure 2**). The output voltage is generated between the reference pin and the output pin. This arrangement allows you to use the reference pin to cascade multiple signals together in an adder configuration. You can set each instrumentation amplifier to a different gain.

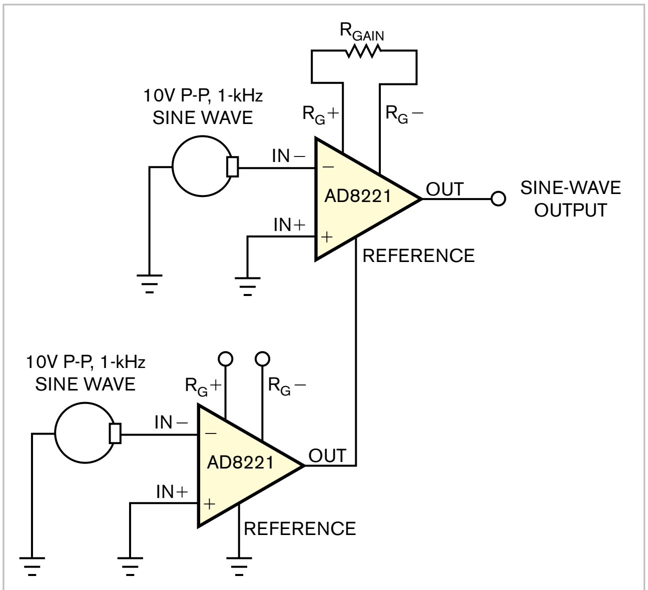

Figure 2 Two instrumentation amplifiers provide increased input impedance in this adder circuit.

This system has several advantages over the simple op-amp adder. For example, each input has extremely high input impedance and has independent common-mode rejection, which the instrumentation amp connected to that channel determines. The higher the channel gain, the higher the common-mode rejection, and the smaller the resulting error. You can also easily add or subtract signals by using the inverting or noninverting terminals of the instrumentation amplifier, and the amplifier enables the use of differential input signals if you wish. Further, the distortion, noise gain, and bandwidth of each signal are independent of the other signals, leading to lower offset voltage, gain error, noise, and distortion. **Figure 3**'s THD+N (total-harmonic-distortion-plus-noise) plot demonstrates five times less distortion for the instrumentation-amplifier adder than that of the op-amp adder, even though the instrumentation amplifier has 1-MHz bandwidth and operates at 1 mA, whereas the op amp has 8-MHz bandwidth and operates at 4.5 mA. EDN

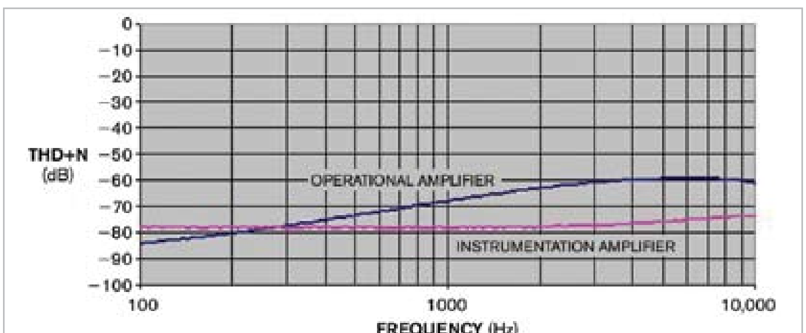

Figure 3 The instrumentation-amplifier configuration shows improved THD+N at frequencies greater than 300 Hz.

Nonvolatile standby/on switch remembers its state

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You can use the standby/on switch in **Figure 1** for industrial or telecom applications in which the circuitry must somehow "remember" its state—standby or on—after a power failure that occurs when no operator is present. An alternative approach uses a battery or a supercapacitor and a flip-flop. This approach is less reliable, however, because the circuit can lose its state if leakage current drains the battery. Another alternative involves the use of a microcontroller and EEPROM, but that approach requires software plus a provision for start-up time. Also, a stand-alone EEPROM for this application has an awkward interface.

You can use an electronically programmable voltage reference, IC_4, as a single-bit nonvolatile-memory cell. To remember the state of the standby/on switch, this circuit programs IC_4's output voltage high or low and can reprogram it at least 50,000 times. IC_1 is a low-dropout linear regulator with reset output and a wide input-voltage range that extends to 72V. A microprocessor supervisor, IC_2, debounces the standby/on pushbutton and supports the programming of IC_4 by increasing the pause length between pulses. IC_4's output drives IC_5, an inverter with Schmitt-trigger input, which in turn drives the gate of transistor Q_2 to control the main power supply.

Flip-flop IC_3 helps to change the standby/on state with each press of the control button. At the end of IC_4's programming cycle, a low-to-high edge at IC_3's clock input sets the flip-flop to its opposite state, thanks to the feedback from the inverter. IC_2's reset triggers this action at power-up to ensure that the switch is ready to change state. Transistor Q_{1B} and IC_1's reset output prevent the programming of incorrect states by blocking IC_4's adjust input during start-up and power-fail conditions.

You must block the effect of IC_2's power-up or -down reset pulse on IC_4's adjust input; C_2 therefore sets IC_1's reset time-out to be longer than IC_2's reset time-out. The threshold voltage of IC_2, 2.9V, is also lower than that of IC_1, 4.6V. The worst-case 1.32V input-threshold voltage of IC_5 guarantees the standby position at first power-on because the factory-preset output for IC_4 is only 1.2V. EDN

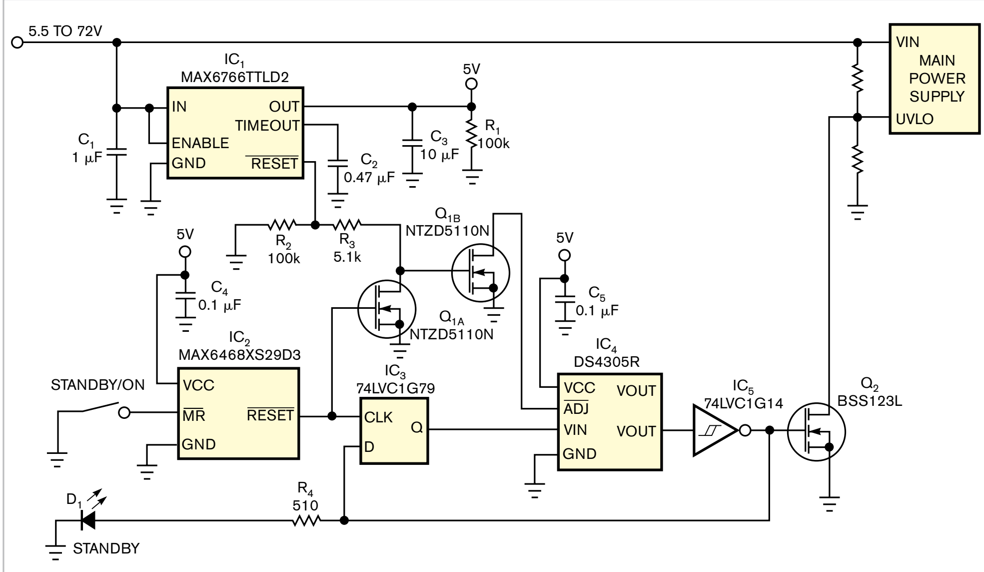

Figure 1 The circuit remembers its standby or on state if power fails with no operator present.