Project

One-Button Digital Timer

Accurately controls the time-on interval for rechargeable cells and batteries to prevent damage due to overcharging

By Dennis Eichenberg

For many electrical and electronic devices, rechargeable cells and batteries have eliminated the inconvenient umbilical line that draws power from the ac line. Unfortunately, many recharging systems provide no automatic monitoring facilities. If you do not constantly monitor the charger, you run the risk of overcharging and destroying a battery power source. This is especially true of lead-acid cells and batteries but is also an important factor with popular nickel-cadmium and other rechargeable devices. One way to eliminate this risk is to use the "One-Button Digital Timer" described here.

Our Timer is fully automatic in operation. It applies ac line power to your battery charger for a preselected period of time, after which it disconnects power from the charger. Thus, it prevents overcharging any battery or cell in the charger it controls. The Timer is also useful for controlling power to a lamp, coffee maker and any other electrically-operated device that must be powered for a single interval of time.

Designed for simplicity and fail-safe operation, our Timer connects between the ac power line and the charging system. To operate it, you simply set a for an 8-, 10- or 12-hour charge cycle and press à single button to begin the countdown. At the end of the timed cycle, the Timer automatically disconnects line power from the charger. The Timer is built around readily available and inexpensive components and is the ideal accompaniment to any charger.

About the Circuit

The complete schematic diagram of the circuitry used in the One-Button Digital Timer is shown in Fig. 1. As you can see, this circuit was designed to use a minimum number of components and as little power as possible from the ac line. The latter is achieved through use of low-power CMOS integrated circuits that have minimal current requirements and operate over a wide range of power-supply voltages.

One side of the ac line is tied directly to one side of ac receptacle *SO1* (into which the battery charger or other device to be controlled plugs) and one end of the primary winding of power transformer *T1*. The other side of the ac line connects to one side of normally open START pushbutton switch *S1* and the armature lug of contacts K1A and K1B of relay *K1*.

The remaining contact of *S1* and the other normally-closed K1A contact connect to the remaining end of the primary winding of *T1*. With this arrangement, false starts are eliminated and no ac power is applied to the primary side of the transformer until *S1* is momentarily closed to complete the circuit from the ac line.

Timer current requirements are quite small. Hence, the contact rating of *S1* can be 1 ampere. The contact rating of *K1*, on the other hand, must be hefty enough to handle any load that may be plugged into *SO1*.

The secondary winding of *T1* provides 12.6 volts ac to bridge rectifier *RECT1*. The bridge rectifier should have a rating of not less than 50 volts.

The negative (−) terminal of *RECT1* serves as ground reference for the circuit, while the pulsating dc at the positive (+) terminal is coupled through isolating diode *D1* to filter capacitor *C1*, which converts the pulsating dc to pure dc. Use of *D1*

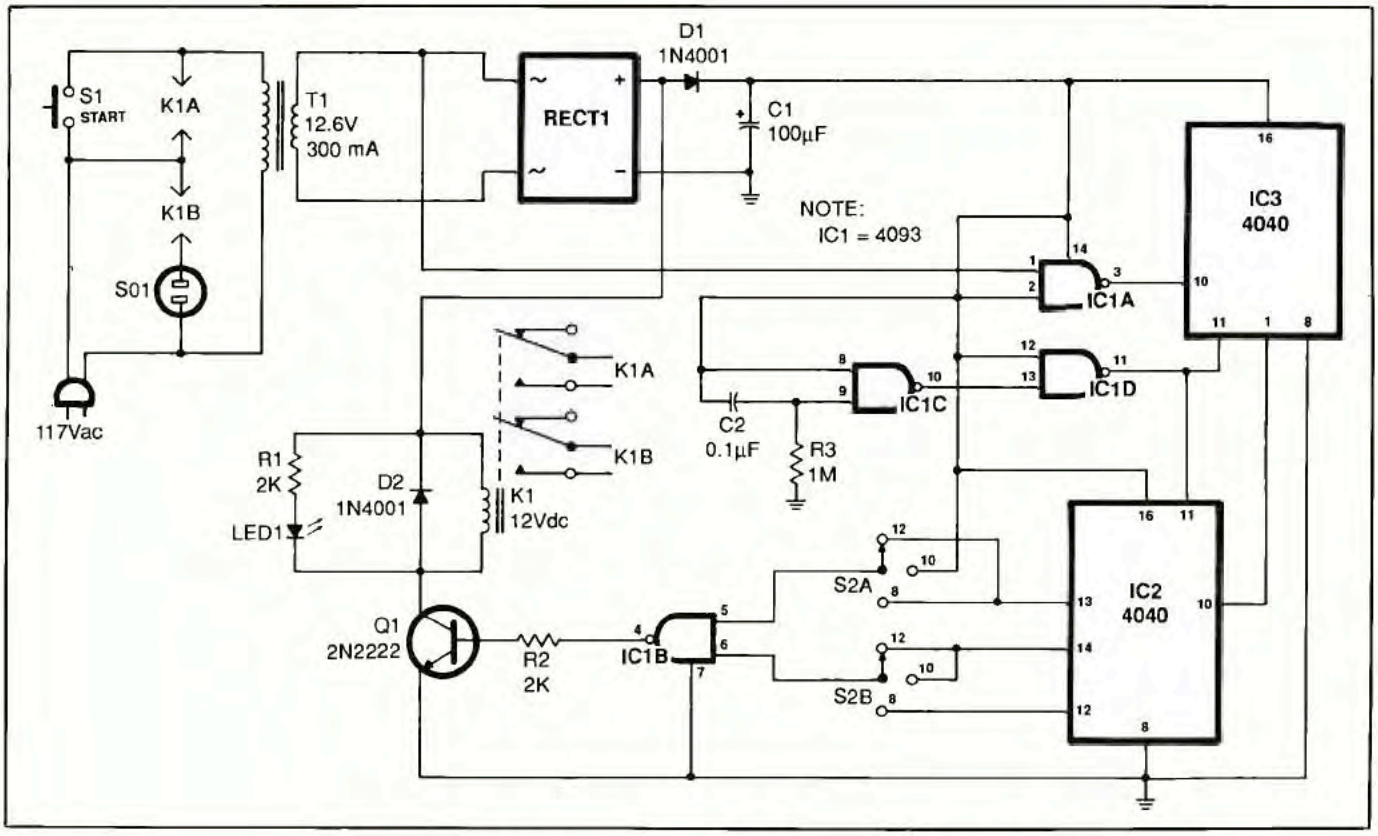

Fig. 1. Complete schematic diagram of the circuitry used in the Timer.

provides isolated unfiltered dc (at the anode) and filtered dc (at the cathode). The unfiltered dc is used to drive the circuitry that does not required filtering and minimizes the physical size of *C1*.

Note that the unfiltered dc voltage is applied to pin 1 of NAND gate *IC1A* and is shown in Fig. 2(A). The output waveform at pin 3 of *IC1A* is a train of square-wave pulses with a period of 1/60 of a second, as shown in Fig. 2(B). This output serves as the system "clock." The period developed by this circuit arrangement is extremely stable because it is synchronized with the frequency of the ac power line.

Cascaded 12-stage binary ripple counters *IC2* and *IC3* permit the clock signal to be divided over a range from 21 to 224. The 220, 221 and 222 outputs are delivered to input pins 5 and 6 of NAND gate *IC1B* by switch sections *S2A* and *S2B*, respectively. This switch is wired to provide periods of 7.28, 9.71 and 12.13 hours, which are rounded out to 8, 10 and 12 hours, respectively, at output pin 2 of *IC1B*.

A buffered power-up one-shot multivibrator circuit consisting of *IC1C* and *IC1D* provide an initial reset signal for *IC2* and *IC3*. The one-shot circuit is triggered by V+. Its period of approximately 0.1 microsecond is determined by the values of *C2* and *R3*.

Transistor *Q1* is driven by the output signal at pin 4 of AND gate *IC1B* through current-limiting resistor *R2*. Starting the timer by pressing START switch *S1* sends *Q1* into saturation to energize *K1* and turn on light-emitting diode *LED1*. Resistor *R1* serves as a current limiter for the LED, which turns on when the Timer is started and continues to glow during the entire countdown period. It extinguishes when the countdown period times out and *K1* deenergizes.

Diode *D2* across the coil of *K1* is a protective device. It prevents *Q1* from being damaged by the inductive current spike that is generated when power is removed from the coil and its energy field collapses.

Construction

There is nothing critical about component layout or/and conductor routing. Consequently, you can use any method of construction that suits you to build the One-Button Digital Timer. For example, you can design and fabricate a printed-circuit board on which to mount and wire together the components. Alternatively, you can use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. Whichever way you go, though, it is important that you use sockets for the ICs. These are static-electricity-sensitive devices that can easily be damages by some soldering irons.

Begin construction by installing the IC sockets on your pc or other board. Then install the resistors, bridge rectifier assembly, transistor, diodes and capacitors. Before soldering their leads into place, make certain that the rectifier, diodes and *C1* are properly polarized.

Strip ¼ inch of insulation from both ends of 19 6-inch lengths of stranded hookup wire. Use fairly large gauge wires for the lines that are to go both lugs of relay contacts K1B and the chassis-mounted ac receptacle. These should be of a gauge that will safely handle the current drawn by the load to be controlled. Tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder.

Connect and solder one end of each of 12 these wires to the following points on the circuit-board assembly: one wire at each end of *R1*, one at the toggle of *S2A*, one at the toggle of *S2B*, one to the point to which pin 16 of the *IC3* socket connects, one to the point where pin 12 of the *IC3* socket connects, two to the point to which pin 13 of the *IC3* socket connects, two to the point where pin 14 of the *IC3* socket connects and two to the junction formed by the collector of *Q1* and the anode of *D2*.

Crimp and solder one end of the heavy-gauge wires to the lugs for the normally-open K1B contacts of *K1*. Then crimp and solder two of the lighter-gauge wires to the K1A normally-open contacts of *K1*. Crimp and solder the free end of the wire coming from the *R1/D2* junction to one coil lug of *K1* and the wire coming from the *D2/Q1* junction to the other coil lug. Mount the relay on the circuit-board assembly.

PARTS LIST

Semiconductors
D1,D2—1N4001 or similar 50-PIV, 1-ampere silicon power diode
IC1—CD4093 CMOS quad Schmitt-trigger NAND gate
IC2,IC3—CD4040 12-stage ripple counter
LED1—Red light-emitting diode
Q1—2N2222 or similar general-purpose silicon npn transistor
RECT1—MDA100A or similar 50-PIV, 1-ampere full-wave bridge rectifier

Capacitors
C1—100-µF, 15-volt electrolytic
C2—0.1-µF, 35-volt ceramic disc

Resistors (¼-watt, 10% tolerance)
R1,R2—2,000 ohms
R3—1 megohm

Miscellaneous
K1—12-volt dc relay with dpdt contacts rated to safely handle current that will be drawn by the device being controlled
S1—Spst momentary-contact normally-open pushbutton switch
S2—2-pole, 3-position rotary switch
SO1—Chassis-mount ac receptacle (see text)
T1—12.6-volt, 300-mA power transformer
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for ICs; pointer-type control knob for S2; suitable enclosure (see text); ac line cord with plug; panel clip or rubber grommet for LED1; rubber grommet for ac line cord; ½-inch spacers; machine hardware; stranded hookup wire (including heavy-gauge wire for load circuit); solder; etc.

Crimp and solder a wire to each primary lead of *T1* and insulate both connections with heat-shrinkable tubing. Connect and solder the secondary leads of *T1* into the circuit at the appropriate points. Then mount the transformer on the circuit-board assembly.

Do not wire the ac line cord, switches or chassis-mounted ac receptacle into the circuit until after you have machined the enclosure.

Locate one of the wires coming from the junction formed by the collector of *Q1* and the anode of *D2*. Slip over the free end of this wire a 1-inch length of small-diameter heat-shrinkable tubing. Clip the cathode lead of *LED1* to ½ inch in length. Inline solder the free end of the identified wire to the cathode lead of the LED. Make this connection electrically and mechanically secure.

Repeat the entire operation for the anode lead of the LED and the wire coming from *R1*. When both connections have cooled, slide the lengths of heat-shrinkable tubing over the connections and flush against the bottom of the case of the LED. Shrink the tubing solidly into place.

Do not wire the ac line cord, chassis-mounted ac receptacle or switches into the circuit until after you have machined the enclosure.

You can use any type of enclosure that will accommodate the circuit-board assembly, chassis-mounted ac receptacle, switches and LED without crowding. The lead photo shows the author's prototype built into a defunct commercial appliance timer module, which eliminated the need for cutting an opening for the ac receptacle. If you have one of these, by all means use it, especially since it obviates the need for making the receptacle opening and eliminates the need for an ac line cord.

Machine the enclosure as needed. That is, cut the opening for the chassis-mounted ac receptacle and drill

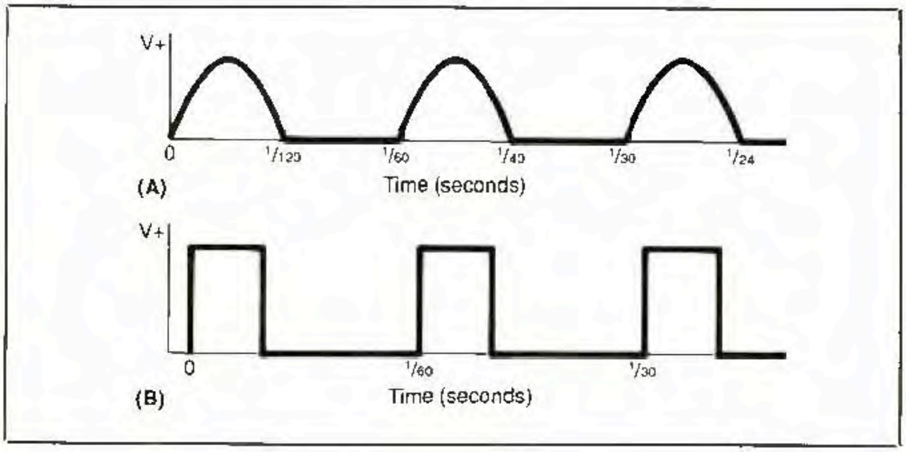

Fig. 2. Half-wave rectified voltage waveform (A) that appears at the + terminal of RECT1 when the project is timing out and the square-wave clock pulses (B) it generates at output pin 3 of IC1A.

mounting holes for the circuit-board assembly, LED and two switches. Also drill a hole for entry of the ac line cord. Make the hole for the LED large enough to accommodate a panel clip or small rubber grommet. If you are using a metal enclosure or have drilled any holes through or cut the slot for the receptacle in a metal panel, deburr all cut edges and line the hole for the ac line cord with a rubber grommet.

Route the line cord into the enclosure and tie a strain-relieving knot in it about 5 inches from the free end inside the enclosure. Tightly twist together the fine wires at the ends of both conductors and sparingly tin with solder. Crimp but do not solder one conductor to one lug of the pushbutton switch and the other conductor to one lug of the receptacle. Locate one of the leads of the primary of *T1* and crimp and solder the free end of it to the same receptacle lug as the line cord is crimped.

Crimp the free ends of one wire coming from the K1A and K1B lugs of *K1* to the same lug of *S1* to which the ac line cord is crimped. Solder the connection. Next, crimp and solder the free end of the other K1B wire to the unoccupied lug of *SO1*. Then crimp and solder the free ends of the remaining *T1* primary and K1A wires to the unoccupied lug of *S1*.

Carefully examine the switch you will be using for *S2* to identify its toggle lugs and its position-lug sequence. Crimp and solder the free ends of the wires coming from pins 5 and 6 of the *IC1* socket to the *S2A* and *S2B* toggle lugs, respectively. Then crimp and solder the free ends of the wires coming from pins 12, 13, 14 and 16 of the *IC3* socket to the position lugs of the switch as illustrated in Fig. 1.

Before proceeding to final assembly, use a dry-transfer lettering kit or tape labeler to label the switches and LED (see lead photo). If you use the former, protect the lettering with two or more light coats of clear acrylic spray. Allow each coat to dry before spraying on the next.

Before proceeding to final assembly, check all component installations for proper value or type and orientation. Carefully check all wiring, especially wherever ac line power will appear in the circuit. Then carefully examine all soldered connections. If you missed any connection, solder it. If you find a connection that appears to be suspicious, reflow the solder on it and add solder if needed. If you locate any solder bridges, use desoldering braid or a vacuum-type desoldering tool to remove them. Do not proceed to final

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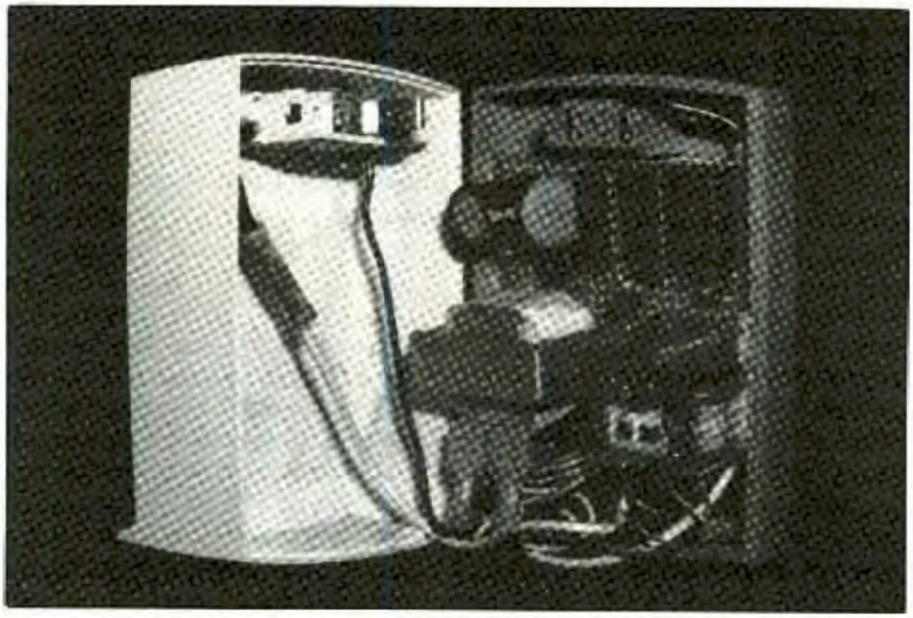

Fig. 3. Interior view of author's prototype showing perforated-board construction inside a commercial appliance timer.

One-Button Digital Timer

(from page 45)

assembly until you are certain that everything is okay.

Now, practicing safe handling procedures for MOS devices, install the ICs in their respective sockets. Make sure each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets. When you are done, double check to make sure of orientations.

Mount the circuit-board assembly in place using ½-inch spacers and 4-40 × ¼-inch machine hardware, including lockwashers. Plug the domed case of the LED into its panel clip or rubber grommet. Next, mount the switches in their respective holes using the hardware supplied with them. Place a pointer-type control knob on the shaft of *S2* and check switch positioning. If the pointer does not line up with the panel markings, remove the knob and adjust the positioning. Then mount the ac receptacle in its cutout.

Using the Project

Use of the project is as simple as plugging it into an ac receptacle, plugging the device to be controlled into the chassis-mounted ac receptacle, setting the device's power switch to "on," selecting the timing interval you desire and pressing and releasing the START button. At this point, the LED on the Timer will light to signal that the project is counting down. The project will continue to count down until it times out and extinguishes the LED and removes power from the device being controlled.

You select the correct timing interval by referring to the data sheet published by the manufacturer of your rechargeable cells and batteries. Select the interval nearest that recommended by the manufacturer. Remember that a power failure terminates the timing period. To restart the timing period when power is restored, you must press and release the START switch. **ME**