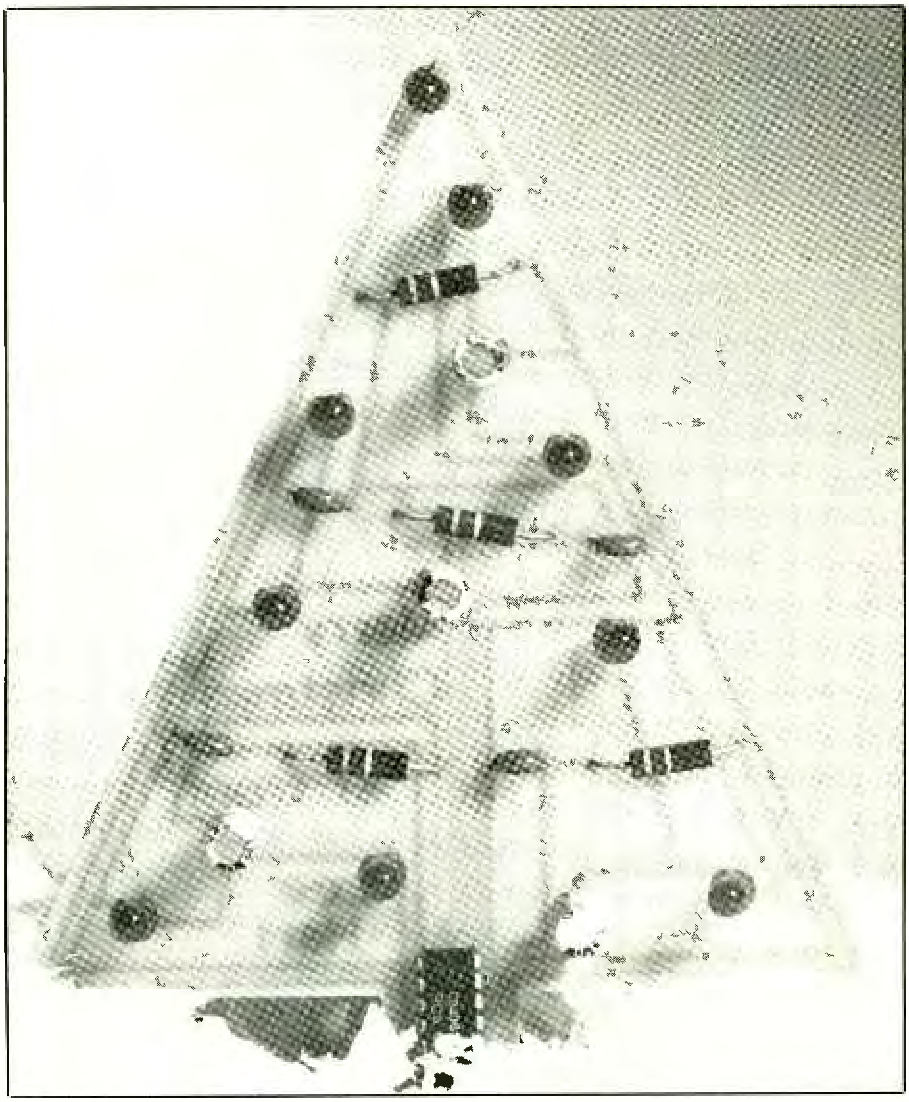
An Electronic Greeting Card

Flashing LEDs and colorful electronic "ornaments" give this different kind of holiday greeting card a high-tech look

By Lee Hart



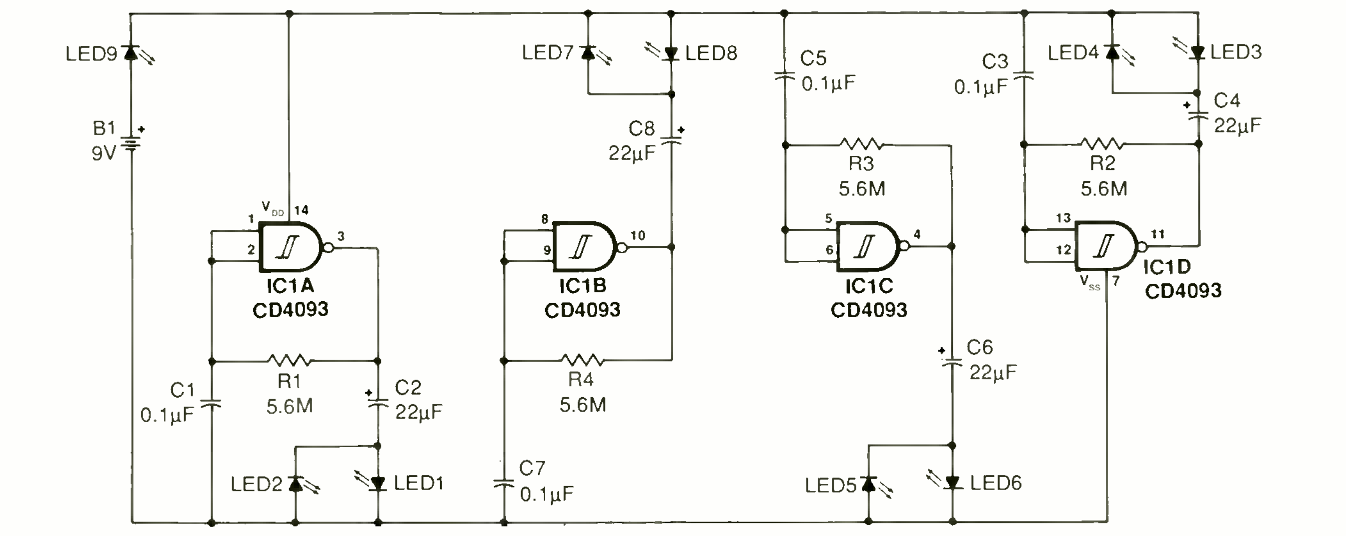
Here's a Christmas "card" that your friends, relatives and business associates won't soon forget. Send them an electronic Christmas tree, decorated with blinking lights and colorful ornaments. Just connect a 9-volt battery (which doubles as a stand to keep it upright), and it will provide weeks of Christmas cheer. Its cost is modest, too.

Not just another 555-timer-based blinker, our "card" uses CMOS technology and a switched-capacitor converter that minimizes power consumption so that recipients can enjoy their card/ornament the entire season long. Drawing just 1 milliampere of current to power its blinking lights, the card can be run for about two weeks on a fresh alkaline battery. (Be sure to include the battery when you send this card off.) The circuit is protected from battery reversal and damage from static electricity, as well!

You can make as many of these "cards" as you wish at a cost of $10 or less per card. You can package it carefully for mailing. The card also lends itself to personal hand delivery, packaged in an attractive gift box. Make your delivery rounds about a week before Christmas so that recipients will have it operating right on up to the New Year.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the project. The heart of this circuit is *IC1*, a CMOS CD4093 quad NAND gate with Schmitt-trigger inputs. The Schmitt-trigger gate was selected for its "split personality." When the gate's output is at logic low, its input switching threshold is about one-third of the supply voltage (called V_{DD} for CMOS components). When the output is high, the input threshold is approximately two-thirds V_{DD}. This peculiar trait makes it easy to configure an oscillator simply by connecting a resistor between the gate's input and output terminals and a capa-



PARTS LIST

Semiconductors
IC1—CD4093 quad 2-input Schmitt-trigger NAND gate
LED1 thru LED9—Jumbo light-emitting diode (any color)
Capacitors
C1,C3,C5,C7—0.1-µF, −20%/+80% disc ceramic
C2,C4,C6,C8—22-µF, 10-volt electrolytic

Resistors (½-watt, 20% tolerance)
R1 thru R4—5.6 megohms
Miscellaneous
B1—9-volt battery
Printed-circuit boards (as many as needed; see text); snap connectors for B1; No. 2 machine hardware (optional; see text); dry-transfer lettering kit (optional; see text); clear spray acrylic; solder; etc.

Note: The following items are available from Lee Hart, 28612 Middle Crossing Rd., Dowagiac, MI 49047 (616-782-3980): etched but not drilled or cut to shape pc board, $3 each; complete kit of parts including etched, cut and drilled pc board and all components, $10. Add $1.50 P&H. Michigan residents, please add state sales tax.

Fig. 1. Complete schematic diagram of electronic Christmas "card."

citor from the input terminal to circuit ground.

To understand how this circuit works, let's examine the stage built around *IC1A*. Since both inputs of this gate are tied together, this gate operates as a simple inverter. When the output is high, resistor *R1* charges capacitor *C1* on the input to the gate. After a short time, the input voltage reaches the $0.67V_{DD}$ threshold. At this point, the gate's output suddenly switches low. Resistor *R1* discharges *C1* until the input voltage reaches $0.33V_{DD}$. Now the output switches high, and the cycle repeats. As you can see, this is the action of a simple oscillator operating at a frequency of approximately 1/(1.4RC). A sawtooth waveform cycling between $0.33V_{DD}$ and $0.67V_{DD}$ appears at the input of the gate, while the output is a square waveform.

Power consumption of this arrangement is very low. The CMOS gate uses almost no current. The resistor, the only power-dissipating element in the circuit, has a value that is so large that the oscillator runs on just a few microamperes of current.

You could connect a light-emitting diode to the output of the *IC1A* gate through a suitable value of series resistance. However, this would negate the low-power nature of the circuit. A LED requires just 1 volt to light but at least 10 milliamperes of current to generate a reasonable brightness level. With a 9-volt battery, 8 volts gets used up as heat dissipated by the series resistor. So, since battery-powered heaters in circuits have never been popular, there is a far better way to go.

Suppose you use a capacitor in series with the LED at the output of the gate. It's a well-known fact that capacitors don't dissipate power; rather, they store power that they yield later on demand to the circuit load. The rub is that if you try a capacitor/LED series arrangement, the LED will blink just once, lighting as it discharges the capacitor. After this, the LED acts like a blocking diode that prevents the capacitor from discharging.

Connecting a second LED in reverse polarity across the first (as illustrated by *LED1*, *LED2* and *C2*) offers an elegantly simple solution. Now, when the gate's output goes high, *C2* charges and the charging current lights *LED1*. Once *C2* is fully charged, the current goes to zero and the LEDs extinguish. When the output of the gate goes low, *C1* discharges its stored energy through *LED2*, generating a brief flash.

In engineering jargon, the double LED/capacitor arrangement is called a switched-capacitor current-mode downconverter. It converts a high-voltage, low-current source (the battery) into a low-voltage, high-current pulsed output, which causes the LEDs to briefly flash. Thus, the nine LEDs used in this circuit can be made to blink at high brightness while reducing battery current by a ratio of about 10:1.

As you can see in Fig. 1, there is no resistor to limit the capacitor's charge/discharge current. Theoretically, the current would be infinite and so turn the LEDs into DEDs (dark-emitting diodes). In practice, however, the CMOS gate has an output resistance of a few hundred ohms. This limits peak current to about 50 milliamperes, which works out very well. LEDs are more efficient light producers at high currents, and the human eye tends to overestimate the brightness of flashing objects.

You will note in Fig. 1 that the three remaining oscillators in the circuit are similar but not identical to the *IC1A* oscillator arrangement. If all were the same, all four oscillators would tend to run at exactly the same frequency. Since they share an unregulated power supply, battery *B1*, they would blink in lock-step, with groups of four LEDs flashing in unison. This would make a very monotonous and uninteresting project.

A slight rearrangement of the components yields equivalent but not identical oscillators. This exaggerates the differences between the gates and component values to keep the oscillators from synchronizing with each other.

Two purposes are served by *LED9*, which is directly in series with the battery. The LED serves as a blocking diode to protect *IC1* should battery power be connected in reverse polarity of what it should be. Secondly, *LED9* lights with each pulse of battery current as any capacitor in any oscillator gate circuit charges. Thus, *LED9* does not exactly blink; it "twinkles" like a star, which is the reason why this LED is located at the top of the tree-shaped printed-circuit board used for the project.

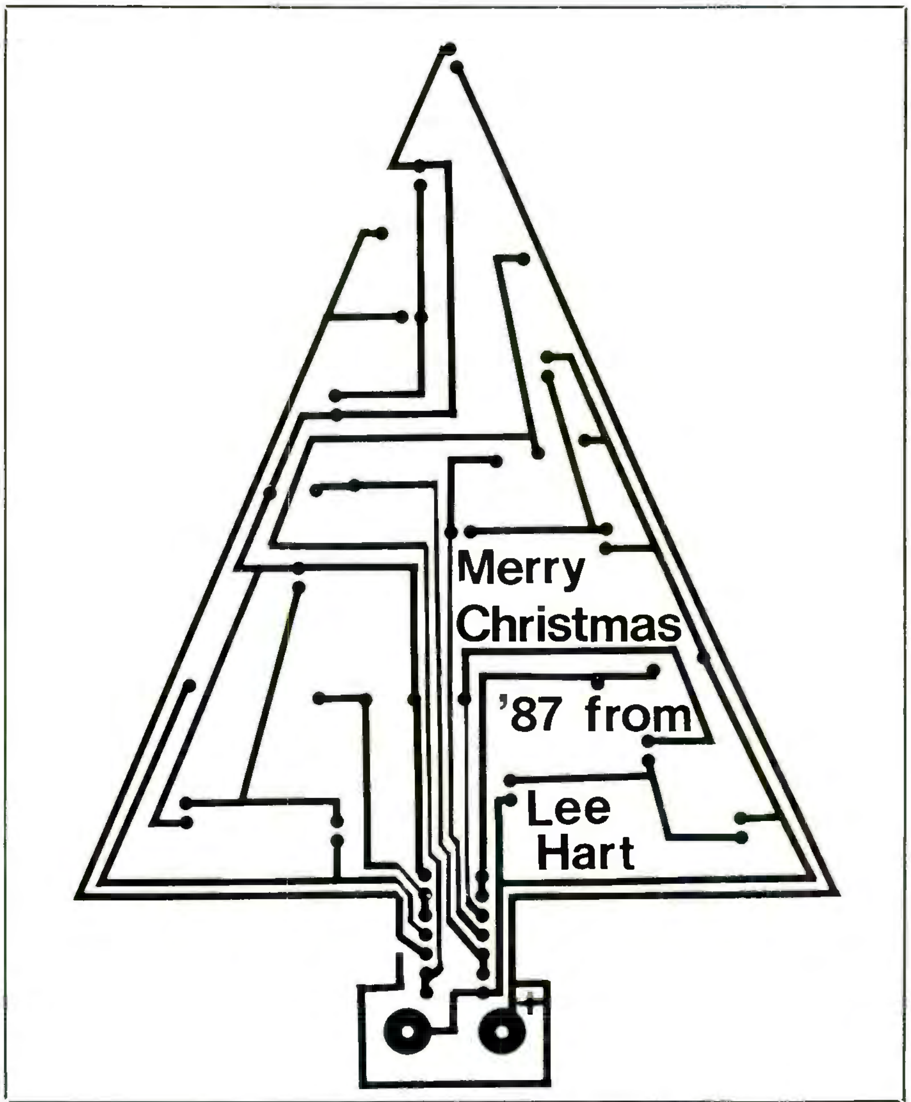


Fig. 2. Actual-size etching-and-drilling guide for Christmas-tree card's printed-circuit board. Other shapes are possible, as discussed in text.

Construction

Because of its intended use, the only construction approach for this project should be a printed-circuit board, preferably using G-10 Fiberglas pc blank. This material is green (for the Christmas season, of course.) However, if you cannot obtain G-10 blank, you can use any other, but paint its component side green just before component installation.

Fabricate as many of your own boards as needed using the actual-size etching-and-drilling guide shown in Fig. 2. If you wish, you can work into the blank areas a Christmas message that will personalize the "card." For example, you might

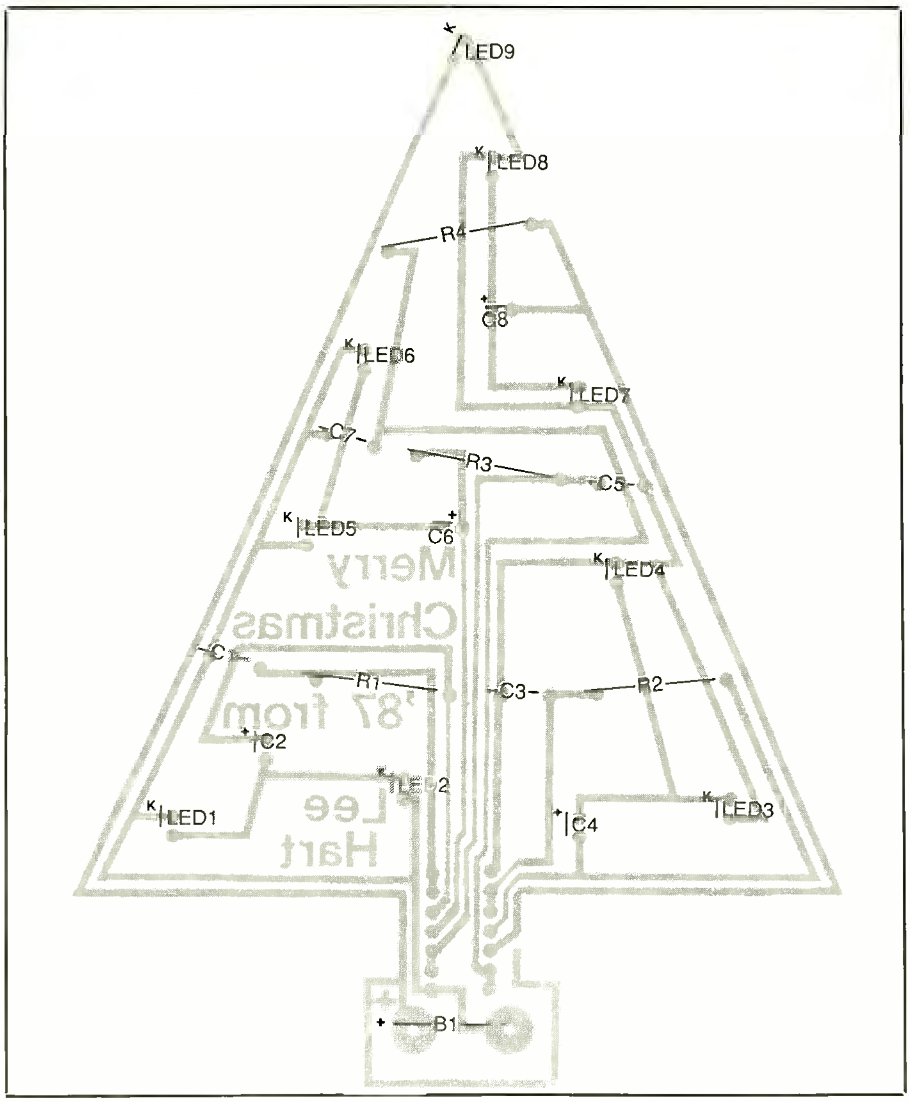


Fig. 3. Wiring guide for pc board.

place the legend "Christmas 1988" in one free area and your name in another free area, using dry-transfer lettering in the appropriate pc guide areas. When the boards are etched, your message will appear in bright copper. When making the boards, begin with rectangular single-sided pc blanks that are approximately the same height as the pc guide and at least as wide as the widest point of the tree shape.

After preparing the boards, etch and drill them. Then carefully trim the boards to shape. The odd Christmas-tree (arrow-head?) shape of the boards can be a bit of a problem to manage. If you're making just one board, you can rough out the shape with tin snips, trim it to final shape with a nibbling tool and smooth its edges with a fine file or emery cloth.

If you're making a number of boards to use as the wiring medium for your "cards," a faster approach would be to sandwich together five to ten boards in a vise or C clamp and use a saw to cut them all to shape and emery cloth to finish the edges. When making the sandwich, make sure to align all boards before clamping them together. An easy way to do this is to pass a thin wire brad through two or three holes (say, at the three points of the triangular shape of the main tree) in one board and then lowering onto the ends of the brads the remaining boards that will make up the sandwich in the *same* orientation. This way, all boards in the sandwich can be cut to shape simultaneously without danger of slicing through traces.

Once the boards have been cut to shape, refer to the wiring guide shown in Fig. 3 for component installation. You'll note in this illustration that not all components are arranged in the traditional horizontal and vertical orientations. The reason for this is that the LEDs serve as the Christmas-tree lights, the colorful capacitors and resistors as the "ornaments" and the black integrated circuit as the tree "trunk."

Note in the Parts List that the resistors are specified at a tolerance of 20 percent and that a −20%/+80% tolerance is given for the capacitors. This is a radical departure from the norm in modern solid-state circuits, but it's one of those rare cases in which wide-tolerance components works to your benefit. While having no effect on the basic operation of the oscillator circuits, low-quality, off-tolerance resistors and capacitors virtually assure that the LEDs won't blink in lock-step, as would be the case if precision components were used.

If you painted the component side of the boards, use the point of a needle or straight pin to clear all holes of paint. Then, referring to the wiring guide shown in Fig. 3, install and solder into place the resistors in the specified locations. Then do the same with the capacitors, making sure that you properly polarize the leads of the electrolytics before soldering them to the copper pads on the bottom of the board.

Next, install the LEDs in their re-

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spective locations. Make sure their leads go into the appropriate holes before doing any soldering. If you examine the molded plastic cases of the LEDs, you'll note a flat on the perimeter of their bases. This flat is near the cathode leads in all cases. Alternatively, if there's no flat, the cathode will be the shorter of the two leads. Note in Fig. 3 that all LEDs mount on the board in the *same* orientation, their cathode leads plugging into the holes nearer the top of the "tree."

Do *not* mount the LEDs with the bottoms of their cases flush against the surface of the pc board. Instead, leave at least ⅛ inch of space between the LEDs and board. Also, use soldering heat sparingly to avoid heat damage to the LEDs. Either clip a heat sink onto each lead as you solder it into place or solder only one lead of each LED to its copper pad at a time, returning to solder the other lead when you are done with the first lead of all nine LEDs. This way, the LEDs will have time to cool off between soldering operations.

Snap-on battery connectors for *B1* can be salvaged from old dead 9-volt batteries or can be purchased new. If you salvage the connectors, cut away the plastic parts, since all you need are the metal connectors themselves. Once you have as many connectors as needed, you can use No. 2 machine hardware to fasten them to the boards and make the required electrical connections. The alternative is to solder the connectors directly to the appropriate copper pads on the solder side of the boards. Once again, observe polarity! If you're in doubt as to which snap connector goes to which pad on the circuit boards, check polarity against a 9-volt transistor battery.

Finally, install and solder into place the integrated circuit. This is a CMOS device and should be handled with the same precautions you would use for any other MOS device. Use a grounded soldering tip to solder its pins to the copper pads on the bottom of the board. (Note: Though you can use a socket for the IC, it's not necessary and will only add unnecessarily to the cost of your "card.")

Snap a 9-volt battery into the connectors at the bottom of each circuit-board assembly in turn and note LED activity. If one or more pairs of LEDs do not blink, the problem can usually be traced to a reversed LED or electrolytic capacitor. Make any corrections to get the boards operating as they should. Once your "cards" are functioning properly, spray a coat of clear acrylic over the entire solder side of the boards to keep the copper bright and shiny.

A project like this invites artistic license. In fact, the components for this project were chosen for their appearance rather than values. For example, red LEDs, red/green/red-coded 2.7-megohm resistors, bright green 0.1-microfarad capacitors and light and dark blue electrolytic capacitors really stand out as lights and ornaments on the green trees.

Any color light-emitting diodes can be used in this project for variety. Two-color LEDs are particularly interesting because they can be wired to blink alternately red and green. A CD40106 or 74C14 hex Schmitt-trigger inverter can be substituted for *IC1* with suitable component additions to blink six pairs of LEDs instead of the four described above and shown in Fig. 1.

As an alternative to the tree shape shown in Figs. 2 and 3, you might want to fashion a star, octagonal ornament or other shape suitable to the holiday season. In fact, a variety of shapes can be given to different people as "personalized" gifts. Here's an idea for the basic tree-shape card festooned with red LEDs: when the holiday season is over, the project can be turned on its side and hung near a door or stairway where it will serve as an "exit" sign that can be seen at night!