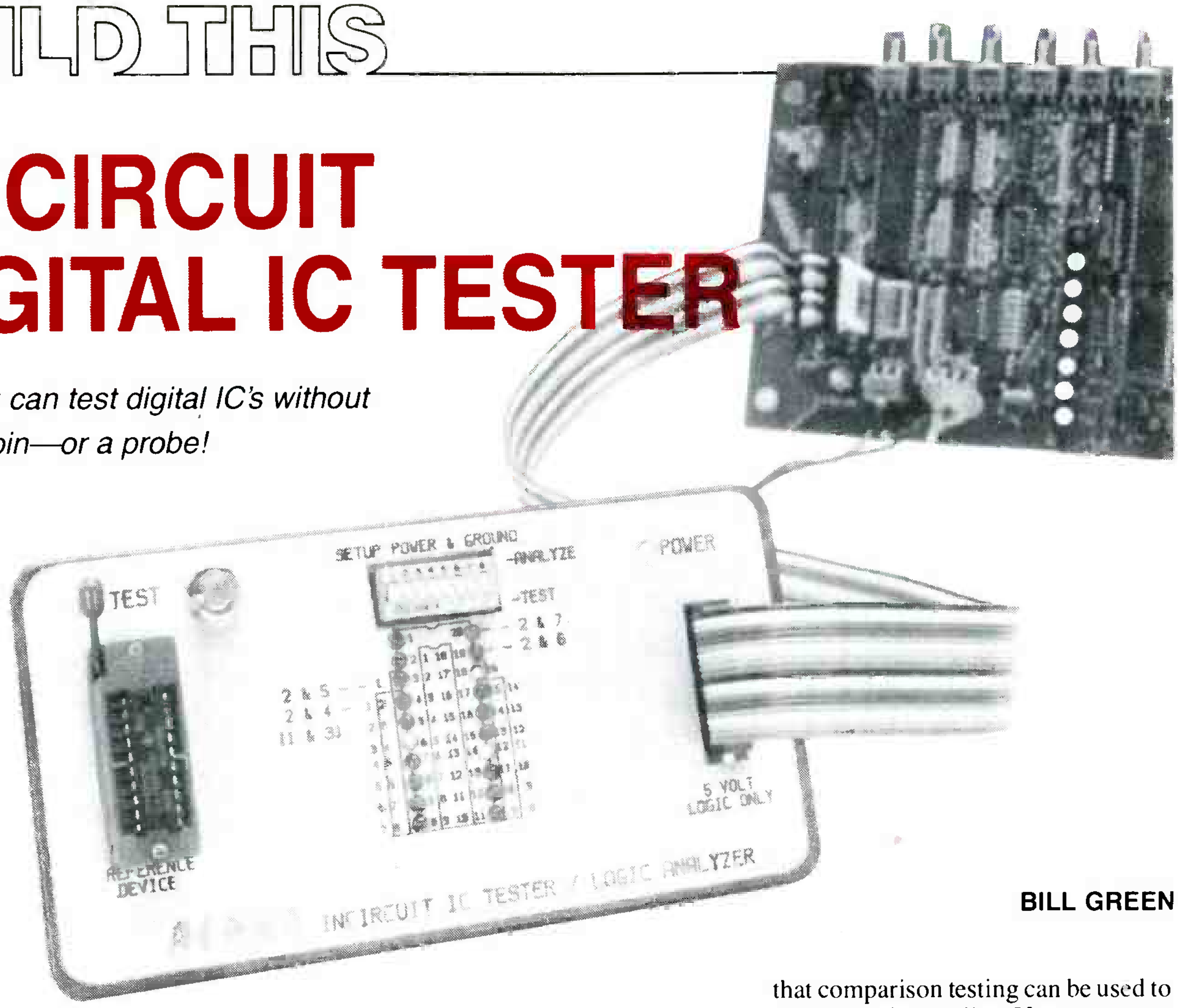
IN-CIRCUIT DIGITAL IC TESTER

Now you can test digital IC's without lifting a pin—or a probe!



BILL GREEN

ARE YOU TIRED OF HAVING TO CHECK EACH pin of a digital IC using some kind of probe? Do you hate having to look up truth tables in order to compare the inputs and outputs of IC's? Well, now you can stop wasting time troubleshooting IC's that are working in the first place. By using our in-circuit tester, you can check out the whole IC—while it's still on the board and operating—without having to investigate each pin separately. And our tester can do more than check IC's. It can also function as a 19-channel logic monitor.

There are several types of in-circuit IC testers that are now available. Some come equipped with a library of IC parameters stored in their memories, while others require the user to enter the testing parameters. Still others merely compare a known-good IC with an identical one that is operating in a circuit.

The first two types, although expensive and complex, do a superior job. The comparator-type tester, has the important advantage of being less expensive—ours can be built for under $100! But it also has a disadvantage: Because it is passive, it does not provide any stimulation to the IC being tested. As a result, a defective IC may appear to be good. An inverter with an output stuck low will appear bad only when its input is low.

While our tester is of the comparator type, it has both monitoring and testing capabilities. By selectively using its compare and monitor functions, we can determine whether the inputs of an IC are being exercised sufficiently—that is, in a way such that comparison testing can be used to determine its quality. If not, we can move through the circuit using the tried-and-true methods of circuit tracing, along with comparison testing, until we can sort the good IC's from the questionable and obviously bad ones.

Circuit description

The in-circuit IC tester is based on four custom AE013 IC's. Custom IC's were used to make the tester as easy to build as possible. When you consider that each AE013 contains 5 independent comparator/latch/LED-driver

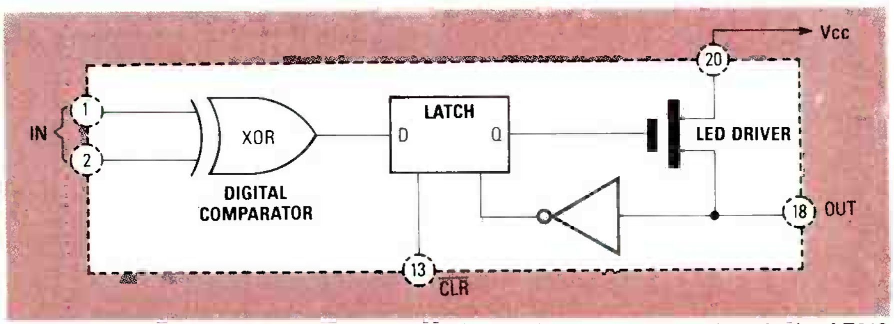


FIG. 1—ONE OF THE DIGITAL-COMPARATOR/LATCH/LED-DRIVER sections in the AE013 custom logic IC. Each IC contains four of these circuits.

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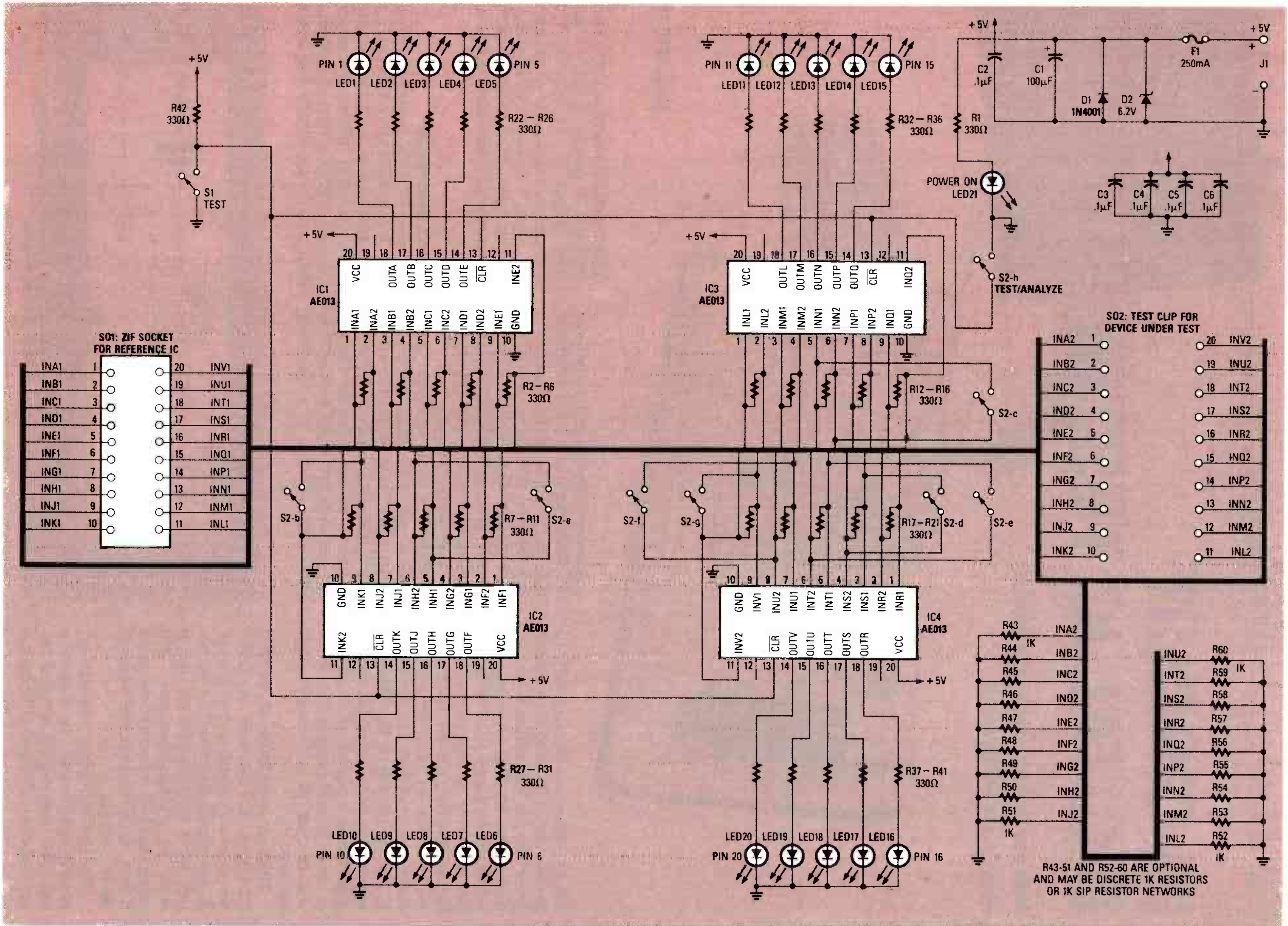

FIG. 2—THE COMPLETE IC TESTER. The reference IC is pluged into the ZIF (*Zero Insertion Force*) socket, SO1, while the test clip, SO2, is attached to the device under test.

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PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1–R42—330 ohms, carbon film
R43–R60—1000 ohms, or 9-pack SIP network
Capacitors
C1—100µF, 10 volts, electrolytic
C2–C6—1µF, 10 volts, ceramic monolithic
Semiconductors
IC1–IC4—AE013 Custom Comparator/Latch/LED Driver
D1—1N4001 rectifier diode
D2—6.2 volt, 1-watt Zener diode
LED1–20—T-1 size, red
LED21—T-1 size, green
Other Components
F1—250 mA, pigtail fuse
SO2—20-pin straight male header
SO1—20-pin wire wrap socket
P1—20-pin DIP header
S1—Normally-open pushbutton
S2—8-section DIP switch
Micsellaneous: PC board, test cables and clips, power cord and clips, IC sockets, 20-pin ZIF socket, and any kind of suitable cabinet and front panel.

Note: The following items are available from W.L. Green, ALPHA Electronics, P.O. Box 541005, Merritt Island, FL 32954-1005, (407) 453-3534. In-Circuit IC Tester kit (does not include DIP header, cables, test clips and ZIF socket): $100.00 plus $5.00 postage and handling. Fully assembled IC Tester with IC test cable, 20-pin and 16-pin DIP clips included, (does not include DIP header, ZIF socket, monitor cable and clips): $169.00 plus $5.00 postage and handling. AE013 custom IC: $18.00 each plus $1.00 postage and handling. PC board and four AE013 IC's: $80.00 plus $4.00 postage and handling. Florida residents must add state sales tax. Canadian sales must add $2.00 additional postage and handling to each order. Foreign sales add appropriate amount for air shipping and insurance.

sections, you can appreciate how much the custom IC's simplify the unit's construction.

A single section of an AE013 is shown in Fig. 1. When both inputs of the comparator are at the same logic level, the driver output will be low, and the LED will be off. When there is a logical difference at the inputs, the driver output will be high, and the connected LED will be on. Therefore, an LED will light when the logic level on a given pin of the DUT (*D*evice *U*nder *T*est) doesn't match the level on the RIC (*R*eference *IC*).

Figure 2 shows the complete schematic for the tester. As we describe the operation of the tester in the test mode, we will assume that the DUT has 20 pins. Since all twenty of the sections are used in essentially the same manner, we will describe only one and point out any exceptions.

Resistor R2 is connected across the input of one of the comparators of IC1. If pin 1 of the RIC is an input, then R2 provides a path for an input signal to flow from pin 1 of the DUT to pin 1 of the RIC. On the other hand, if pin 1 of the RIC is an output, then R2 is unnecessary. When both inputs of the comparator are at the same logic level, a low will be on the driver output and the LED will be off. When a logical difference is present at the inputs, the output and the LED will be on. As explained previously, a lit LED is an indication of a defective IC. The LED indicates at which pin the problem exists.

The CLR pin of IC1 is common to all sections of the IC. When it is high, the latch between the comparator's output and the LED driver's input is active; any disparity at the comparator's inputs will be latched. When low, the latch will be cleared and will appear transparent, meaning that the logic

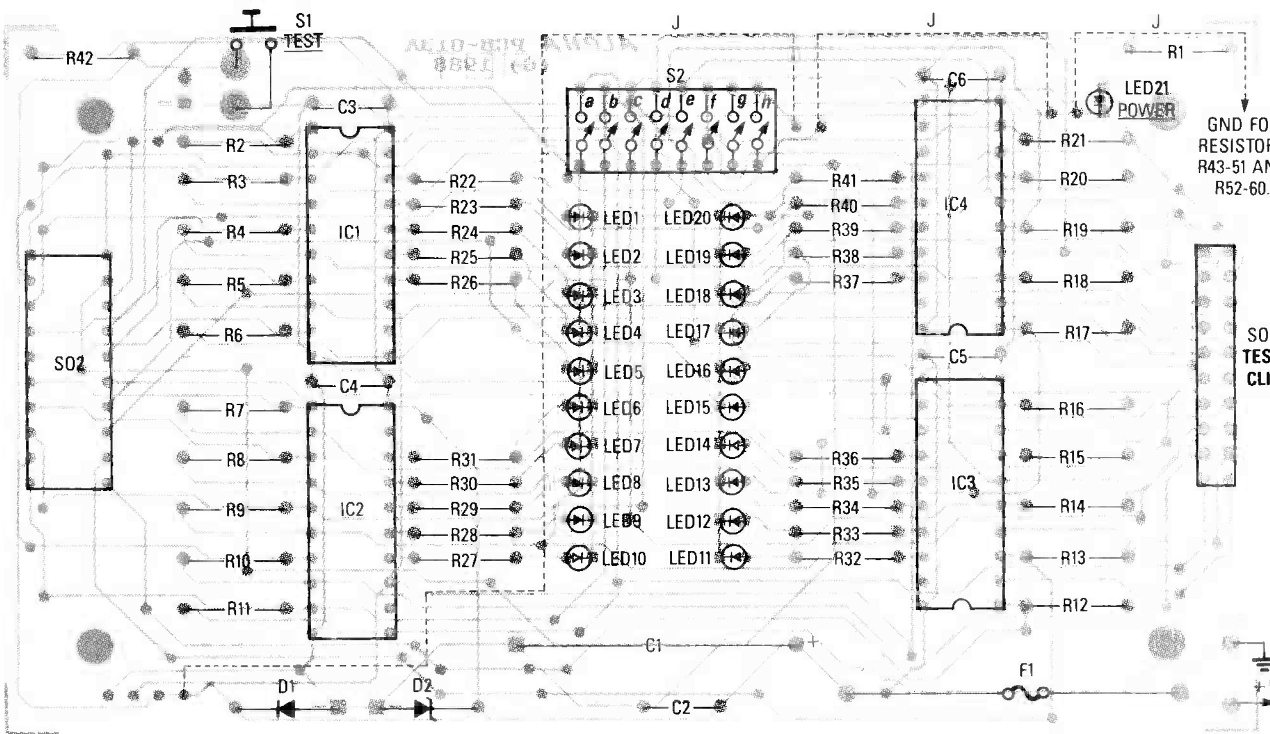

FIG. 3—PARTS-PLACEMENT DIAGRAM. Notice how IC1 and IC2 are facing in the oposite direction of IC3 and IC4.

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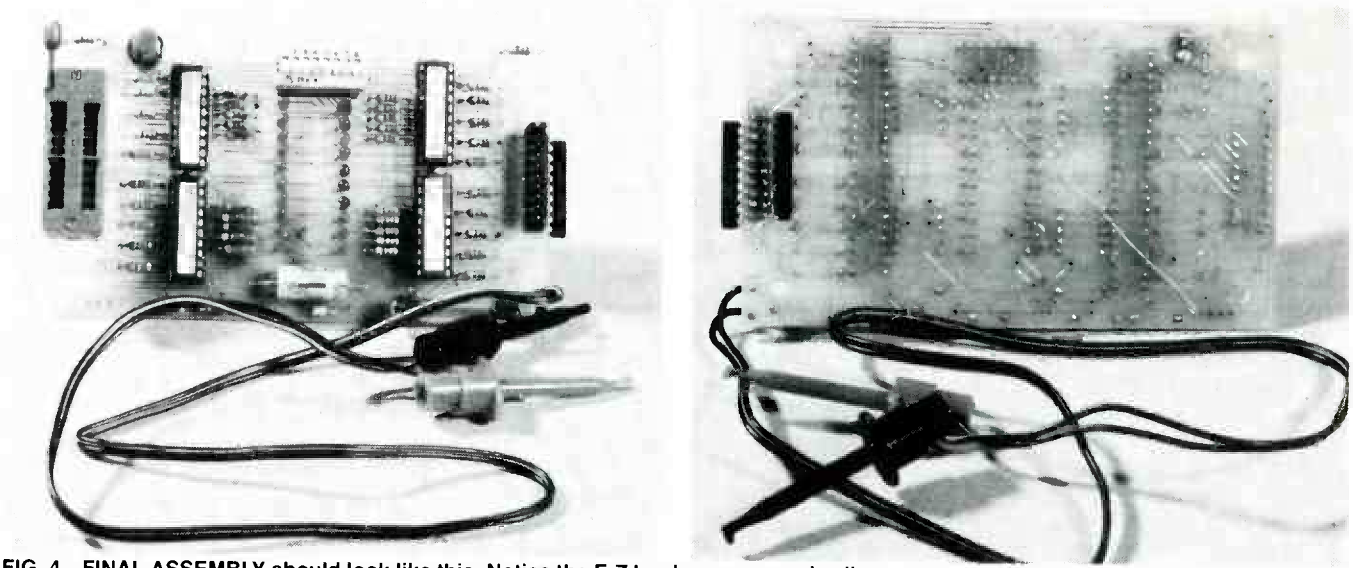

FIG. 4—FINAL ASSEMBLY should look like this. Notice the E-Z hook power-supply clips and the ZIF socket on the left.

level at the latch's input will appear at its output. When test-button S1 is pressed, the $\overline{CLR}$ input of each AE013 is grounded; that clears all latches in preparation for a new test.

IC's can have 14, 16, 18, or 20 pins. Notice that each switch contained in S2 (DIP switch) is connected in parallel with an input resistor. Depending on how many pins the DUT has, and which pins are power and ground, the appropriate switches should be closed. In other words, we will short out two of the resistors to provide a direct path for power and ground from the DUT to the RIC.

Resistors R1, and R22–R41 limit the current through the LED's to less than 10 mA. LED's 1–20 indicate the level at the output of the drivers, and the green LED (LED21) is the power indicator. All capacitors are used to filter the power bus. Rectifier-diode D1, Zener-diode D2, and fuse F1, provide power-supply polarity and short-circuit protection. Because power for the tester is supplied from an external source—usually the circuit board under test—you must protect it against overvoltage and reverse voltage. Rectifier-diode D1 will conduct with reverse polarity and blow the fuse because there's no current limiter. Also, Zener-diode D2 will conduct at greater than +6.2 volts and also cause the fuse to blow.

When the tester is used as an analyzer/monitor, one side of all of the comparators are connected to ground. The other side of the comparators are connected through the test cable to various points in the circuit that we wish to analyze. When any one of those points is high, the corresponding LED will light. Whether S1 is open or closed will determine if those LED's will be latched or non-latched, respectively.

Assembly

Refer to the parts-placement diagram in Fig. 3 for correct orientation of all components on the PC board. (Space does not allow us to print the board pattern in this month's issue. It will appear in next month's PC Service section. We apologize for the inconvenience.)

Begin by installing resistors R1–R42 on the board. Next, install the two diodes D1 and D2, and filter-capacitors C2–C6. Install the sockets for the IC's and switch S2, noting that IC1 and IC2 face one direction while IC3 and IC4 face in the other direction. Install C1 with its negative lead in the hole marked by a "–," and then install the fuse F1.

In the author's model, the LED's are installed with their bottom edges spaced ⅜-inches from the board; that way each LED will protrude through the front panel when the PC board is installed. Of course, the amount that the LED's will protrude above the front panel depends on the length of the stand-offs that you use to mount the PC board. As with most LED's, the cathode lead is shorter than the anode lead, however, our experience tells us that it's a good idea to check each LED before installing it—especially if you're using "grab-bag" parts. Each LED is installed so that the cathode lead is soldered to the square pads, which are the ground points.

Use a 20-pin wire-wrap socket for SO1 so that the socket will be flush with the top of the case when the board is installed. If you fail to do that, you will never be able to plug the ZIF socket into SO1. Seat a socket for DIP-switch S2 against the board and solder it in. (Use a wire-wrap socket as a pin extender if necessary.) Next, install connector SO2, a 20-pin double-row straight male header strip.

For the power cord, use a piece of zip-cord, about 18–24 inches long. On the free end of that cord, attach a red and a black hook clip. The black clip goes to the ground side of J1,

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TABLE 1—IN-CIRCUIT IC TESTER

Number of IC Pins	DIP-Switch S2 Sections Turned-On
20 pins	a and g
18 pins	b and f
16 pins	b and e
14 pins (pin-7 ground, pin-14 power)	b and d
14 pins (pin-10 ground, pin-5 power)	a and c

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DRAWING BOARD

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In actual fact, that is really sloppy programming. The game it was protecting (no names) is a really slick piece of work and is obviously that of a gifted programmer. Finding that kind of garbage in the middle of it is evidence that someone else modified the source code in order to make it difficult for people like us to examine and understand.

If you go through the corrected listing carefully, you'll realize that the second programmer forgot to put everything back the way it was in the beginning, because executing the instruction at $59EA will leave the listing looking like:

```
      59E4  CE E7 59  DEC $59E7
      59E7  CE EA 59  DEC $59EA
      59EA  EF        ???
      59EB  EA        NOP
      59EC  59 AD 51  EOR $51AD,Y
----> 59EF  etc., etc.
```

That's not the same as the original listing. In order to do the job properly, the code should have looked like:

```
      59E4  CE E7 59  DEC  $59E7
      59E7  CE EA 59  DEC  $59EA
      59EA  EE EA 59  INC  $59EA
----> 59ED  EE E7 59  INC  $59E7
      59F0  AD 51 etc. LDA $??51
```

The instruction I added at $59ED would make the code go back to its original garbage appearance as soon as it was finished.

Hey, if you want to throw people off the scent at least do the job properly!

Several people who worked out the listing also picked up the fact that there was some unnecessary code as well. It showed up as:

```
      5A07  A9 00     LDA #$00
      5A09  8D EB B7  STA $B7EB
----> 5A0C  A9 00     LDA #$00
      5A0E  8D F0 B7  STA $B7F0
```

You can see that the instruction at $5A0C is a waste of space since the accumulator was already loaded with $00 at $5A07 and hasn't been changed. It's only a couple of bytes and doesn't really mean much in the great scheme of things, but it's surprising to see it there since the game was such a neat bit of programming.

A special thanks to D. H. Evett, Steve Z, James Swindell, Raymond Zapp Jr., Philip Albro, Alan Wilson, Isaac Molho, Michel Kronowit, and David Andrus, for sending in the correct listing. You've all earned 17 cracking points and a gold star.

I was happy to see that a lot of you share my interest in working out puzzles in general and snooping around software in particular. If you'd like to see more of that kind of thing, drop me a note and let me know. The next time I do it, however, I'm going to make it *really tough!*

There isn't really enough room in this column to go into a heavy discussion of copy protection, but I can certainly pass along any tips and suggestions that look interesting. One thing though: Software is machine-specific—an elegant code on an Apple is just garbage to an IBM. If you want to see more on that subject, let me know what kind of computer you have and what peripherals you have connected to it.

In order to deal with copy protection you have to have a working understanding of assembly-language programming. There's no easy way to get into it—you just have to make up your mind and do it.

The more experience you have with dealing with the CPU on a gut machine-code level, the more success you'll have in dealing with the ins and outs of copy protection. When I get a better idea of what kind of computers you own, I'll be able to make some recommendations of programming books and tutorials. If you know of any good ones for your hardware, put them on the note and I'll be sure to pass them along.

Z-80 Reset

On a completely different subject, John Gruszynski dropped me a note with a question about the Z-80 series we did a few months ago. He wants to know what happens to the registers when the Z-80 is reset. Here it is:

IC TESTER

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while the red clip goes to the positive side. Make or purchase an IC test cable and test clips (one 20-pin and one 16-pin test clip should be adequate), and use a 20-pin cable with multi-colored micro-hook probes for the analyzer cable.

After checking for good solder joints and proper component location, install the four AE013 IC's observing proper handling precautions for CMOS devices. As shown in Fig. 3, pin 1 of IC3 and IC4 is oriented 180 degrees from pin 1 of IC1 and IC2. If the IC's are installed backwards, they will be damaged. Put an 8-section DIP switch in the S2 socket; the switch marked "1" goes toward the pin-1 end of the socket.

Checkout and final assembly

For the preliminary checkout you will need a +5-volt supply, capable of outputting at least 250 mA. (DO NOT connect the tester to anything greater than +5.5 volts.) Plug the 20-pin header, P1, to SO1, and connect a jumper from any pin of the header to ground. Now wrap a thin piece of bare wire around each pin of the header, so that all of the pins are connected together. Wrap a thin piece of bare wire around each pin of DIP-clip SO2, so that all the pins are connected together. Now connect a jumper from any pin to ground. Turn off all sections of S2, and then connect the power leads to the +5-volt supply and then press and release S1. If the tester is working properly, all of the LED's should be off except LED21.

With S2-h open, connect the P1 header jumper to +5 volts, and then remove it and connect it to ground. All of the LED's should turn on and stay on. Now, with S2-h closed, connect the jumper to +5 volts, and then to ground. All the LED's should turn on when 5 volts is applied, and then go off when the jumper is grounded (holding S1 will have the same effect). Now remove the power, the P1 header from SO1, and the SO2 test clip.

Now get your enclosure, and label the front panel using the photographs as a guide. Drill and/or punch holes as necessary, and be sure to make a hole in the bottom of the case for the power

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AMPLIFIER

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shown. After that, install an RCA plug on the other end for PL1. Then install two short wires at the pads marked SPKR for the speaker. Continue by connecting a 6-inch wire between S1 and the power pads (unmarked). Finish up by connecting transformer T1 and fuseholder between S1 and the other unmarked pad. Snap a 1-amp slow-blow fuse into the holder when you are finished.

Note that if you substitute a standard filament transformer for T1, the wiring is a somewhat different, as shown in Fig. 6. Wire the transformer's secondary directly to the unmarked pads, then wire the primary to S1 and F1 as shown. Also, be sure to use a ¼-amp fast-blow fuse for F1.

All that is left to do now is to install the board in the cabinet with 4-40 hardware, using spacers between the cabinet and the board, as shown in Fig. 5. Now connect the speaker wires, attach the knobs.

Operation

Now set all controls fully counterclockwise. Plug the unit into a nearby AC outlet, then turn it on by advancing the treble control. You will hear a brief "pop" from the speaker, then silence if all is well. Turn up the volume and touch the center terminal of PL1. You should hear a hum. If you are successful so far, you should connect a signal source, such as a tuner, and adjust the controls.

If you have any problems, check some voltages. From ground, you should read about 17 volts on C22, 15 volts on C23, and 9.1 volts on D1. The collector of Q1 should read about 4.9 volts. Start troubleshooting where the voltages are seriously off. Integrated circuit IC1 is more difficult to check, but start by measuring the voltages on the SPKR pads with the speaker disconnected; expect 7.5 volts on each pad, and if that voltage is not present, try replacing IC1.

The project also works well from a 12-volt battery. Simply short out diodes D2, D3, and D4 with a jumper wire, and then connect the +12 volts through fuse F1 and switch S1 directly to the positive terminal of BR1. Wire the negative side of the battery to the negative terminal of BR1. **R-E**

NANOELECTRONICS

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lower than those used in conventional logic circuits. Therefore, quantum-effect devices will have to have current- and voltage-translation devices built into them to make the signal levels compatible with more conventional devices. Similarly, signals input to a quantum-effect device will have to be reduced to levels compatible with its operation. And, presumably, signals routed from one quantum-effect device through a PC trace to another quantum-effect device on the same board will also have to go through a translation process to push them along.

Tooling up for a new generation of quantum-effect devices will not be easy or cheap. However, in the end, the benefits will outweigh whatever obstacles may presently stand in the way. Future integrated circuits will permit us to place as many as a hundred switching devices in the space that is now required for just one. Power requirements will be reduced significantly, and switching speeds will increase. Indeed, sometime in the next decade, we may truly see the advent of the "supercomputer on a chip." **R-E**

IC TESTER

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cord. Install the completed board in the case, and make sure that the wire with the black clip goes to the "–" pad of J1.

Tester operation

Table 1 shows the settings of S2a–h. The settings depend on the pinout of the IC being tested, and whether the in-circuit tester is in the testing or analyzing mode.

Connect the power leads to the power supply of the board to be tested. Set the DIP switches to the in-circuit test position, as shown in Table 1. Install a known-good reference IC in SO1, and connect the IC test clip to the DUT. Now, press and release S1; if any LED's light, the IC is bad. Remove and replace any bad IC's that you find, and then observe the board's operation. If the board works properly, we are now finished, and if not, we will need to use the monitor/analyzer feature to check the circuit.

To set the tester for analyzing, set S2-b on, and S2-h either on or off as your experience dictates. Also, install the 20-pin header in SO1 (with all pins shorted together). Closing S2-b provides a ground to the header in most cases. If, however, you are analyzing an IC with pin 10 grounded, open S2-b, and close S2-c.

Let's call upon your experience and knowledge of logic circuits to determine which IC's would be most likely to cause the symptoms that the circuit exhibits. A schematic and IC data sheets would, at this time, be helpful. The in-circuit tester is an instrument that can separate IC's that are definitely good from those that might not be. Remove and replace suspected IC's as necessary, but keep in mind, that it may be something other than an IC that's causing the problem.

As mentioned earlier, resistors R43–R60 may or may not be necessary. It depends on the type of circuit that is being tested. They may be needed when testing circuits with three-state outputs connected to a common bus, such as the data bus of a microprocessor, but not always. In fact, those resistors are so rarely required, that they are optional. LED's on the tester corresponding to these outputs may turn on during the time when the bus is floating. If that occurs, it can be overcome by using the resistors, or by holding S1 down during testing. If needed, they can be discrete resistors or resistor networks. Mount them on the pins of SO2 on the bottom side of the PC board. The ground for those resistors is provided by the jumpers through S2-h.

To use the tester as a logic monitor/analyzer, plug the 20-pin DIP header into SO1, and close S2-b. Connect the cable with the hook probes to SO2. The hook probe connected to pin 10 of SO1 is to be connected to a ground point on the board we are monitoring. That connects one side of all the comparators to ground. Now, connect the other probes to the points in the circuit that you wish to examine.

As mentioned earlier, S2-h will select the latched or non-latched mode. Generally, use the non-latched (S2-b closed) mode because the latched mode is used mostly to capture very short pulses. **R-E**

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