# SPECIAL FOCUS: TEST INSTRUMENTS

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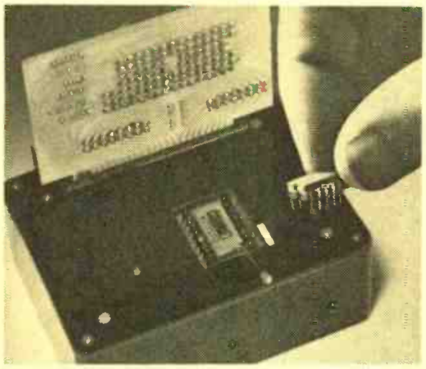
- A 40-MHZ FREQUENCY COUNTER PROJECT
- ACCURATE MILLIAMMETERS ON A BUDGET



# BUILD A DIGITAL IC TESTER

***Inexpensive project tests DTL and TTL IC's.***

BY R. M. STITT

TESTING digital integrated circuits has posed a problem to experimenters ever since the devices were made available at the hobbyist level. After all, many hobbyists were not about to spend thousands of dollars for a commercial, general-purpose digital IC instrument. The tester presented here, however, can be constructed for just a few dollars and provide quick and accurate checks of 14- and 16-pin DTL and TTL IC's.

The operating principle is simple. Logic states of the questionable IC are compared to one of the same type that's known to be good. A testing program is set up via patch cords and the IC's are plugged into their respective sockets, at which time the unit automatically runs through the program. Even the most complicated test program will be performed about 40 times per second.

A good/bad LED indicates the overall status of the device. Furthermore, 16 LED's (one for each pin) isolate faults to specific pins so that bad sections or functions can be detected. These fault LED's are also useful for debugging test programs.

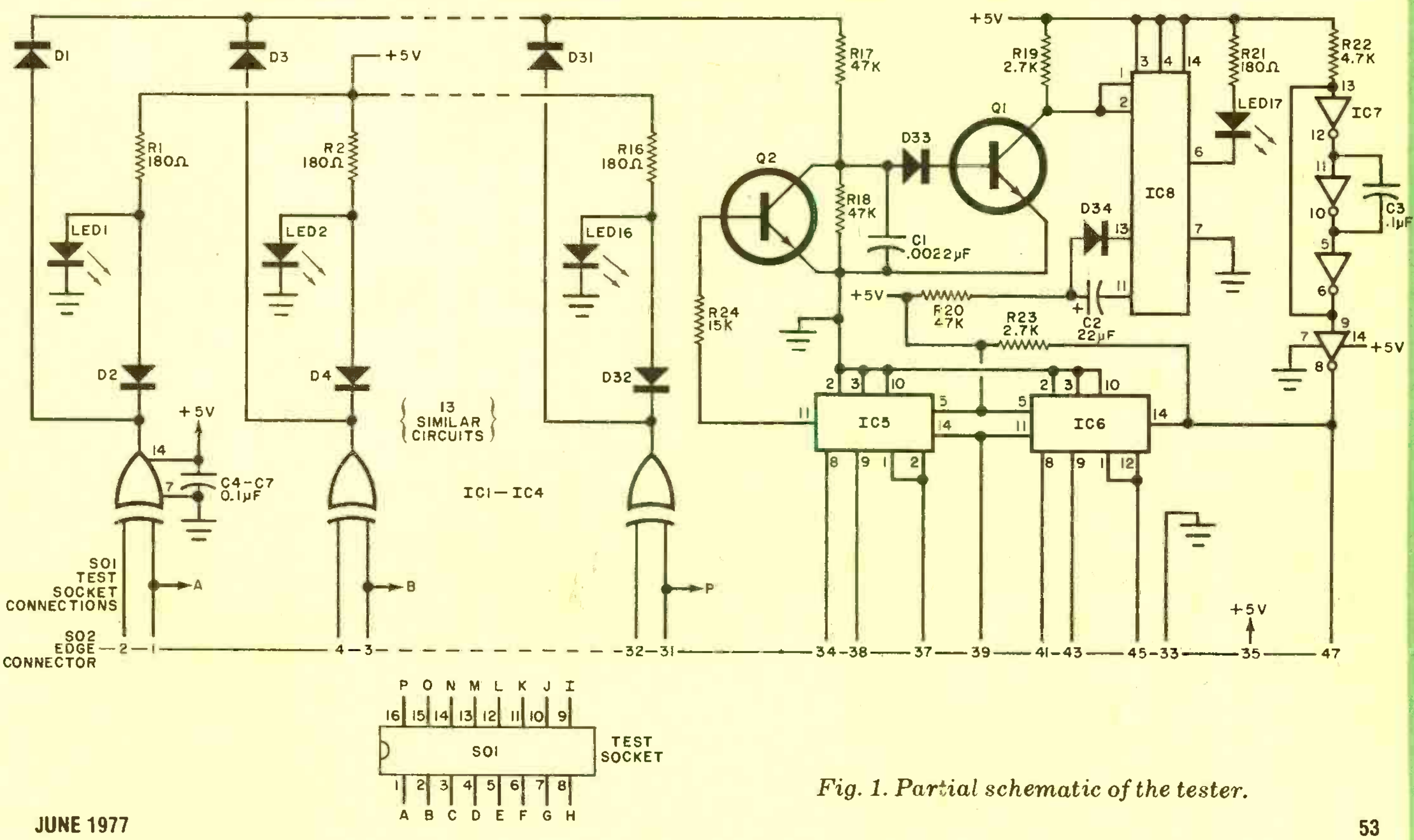



*Fig. 1. Partial schematic of the tester.*

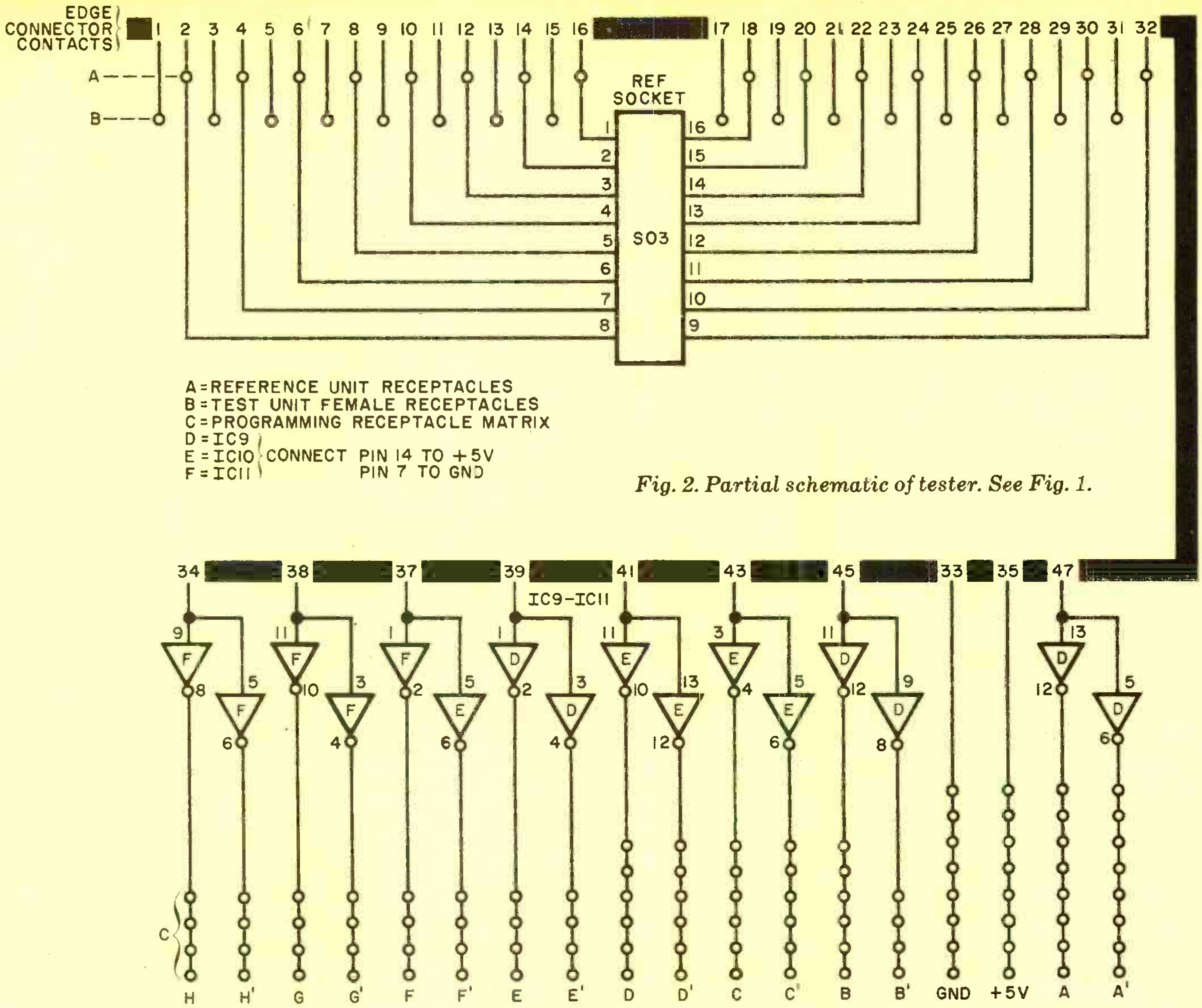



*Fig. 2. Partial schematic of tester. See Fig. 1.*

**About the Circuit.** The tester puts both IC's through their paces in parallel, covering all possible input combinations. The logic state at each input and output pin is continuously monitored and compared to the reference IC. If there is a discrepancy with any input combination, the IC under test is defective and a fault will be indicated by the IC tester.

The schematic diagram of the IC tester is shown in Figs. 1 and 2. The basic element for the electronic comparison is the exclusive-OR gate. Four two-input, exclusive-OR gates are contained in each SN7486 package (*IC1* through *IC4*), for a total of 16 gates. One input of each gate is hardwired to the test IC socket (*SO1*) for individual pin monitoring. The other gate input is hardwired through programming-board edge connector *SO2* to the corresponding pin on the programming board's reference IC

## PARTS LIST

C1—0.0022-μF disc ceramic capacitor
C2—22-μF, 10-V tantalum capacitor
C3 through C7—0.1-μF disc ceramic capacitor
C8—3000-μF, 25-V electrolytic capacitor
C9—10-μF, 10-V tantalum capacitor
D1 through D34—1N914 switching diode
D35, D36—1N4001 rectifier diode
IC1 through IC4—SN7486 quad 2-input exclusive-OR gate
IC5, IC6—SN7493 4-bit binary counter
IC7—SN7405 open collector hex inverter (do not substitute)
IC8—SN74122 retriggerable monostable multivibrator
IC9 through IC11—SN7404 hex inverter
IC12—LM309K 5-volt regulator
LED1 through LED 17—Light emitting diode (TIL-32 or similar)
Q1, Q2—2N3904 npn silicon transistor
The following are 5% tolerance, ¼-watt carbon composition resistors:
R1 through R16, R21—180 ohms
R17, R18, R20—47,000 ohms
R19, R23—2700 ohms
R22—4700 ohms
R24—15,000 ohms
SO1—Zero-insertion-force 16-pin DIP IC socket (Textool No. 216-330M or equivalent)
SO2—48-pin edge connector (Amphenol No. 2-583660-3 or equivalent)
SO3—16-pin DIP IC socket
T1—20-volt center-tapped, 1-ampere transformer (Burstein-Applebee No. 18A 1626-1 or equivalent)
Misc.—Suitable enclosure (Harry Davies No. 260K with No. 261 cover, or equivalent), printed circuit boards, No. 4 × ¼" standoffs, suitable programming receptacles and patch cords, heat sink, thermal silicone compound, machine hardware, hook-up wire, solder, etc.
Note: See Fig. 4 for information on ordering pc boards.

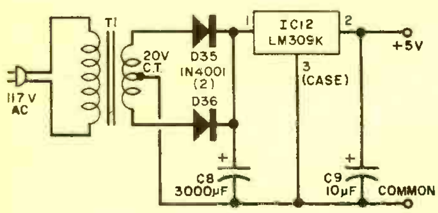
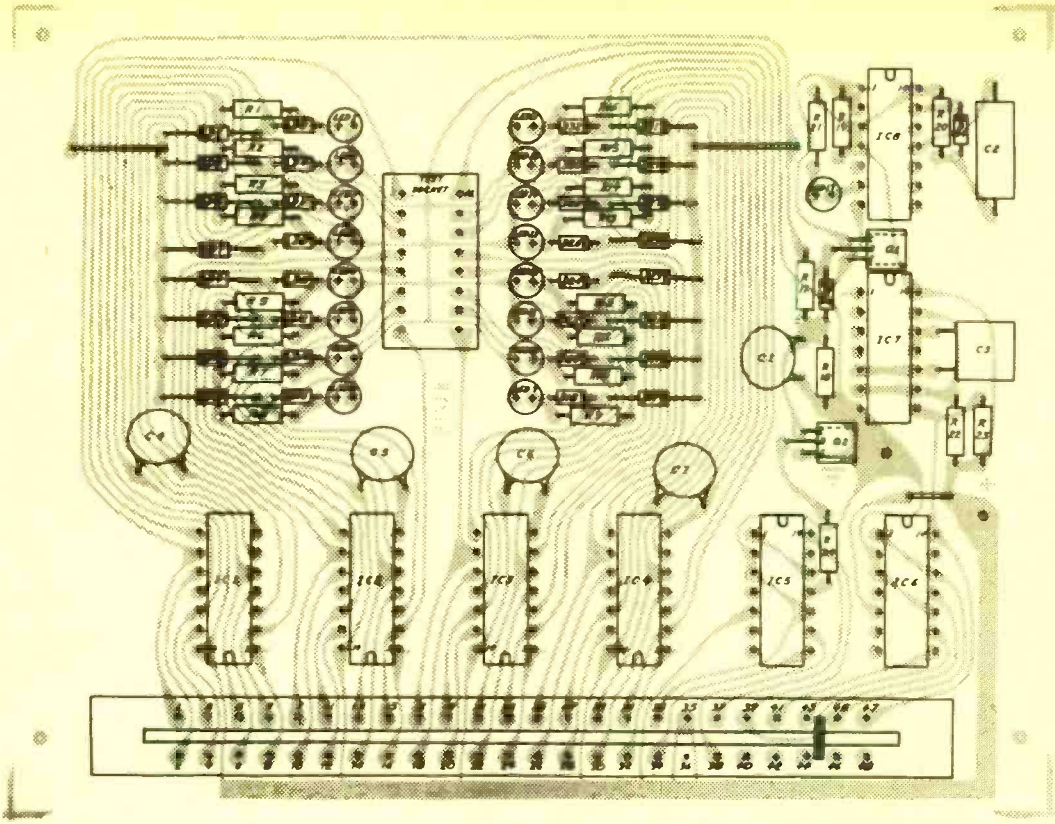



*Fig. 3. Schematic for a suitable power supply.*



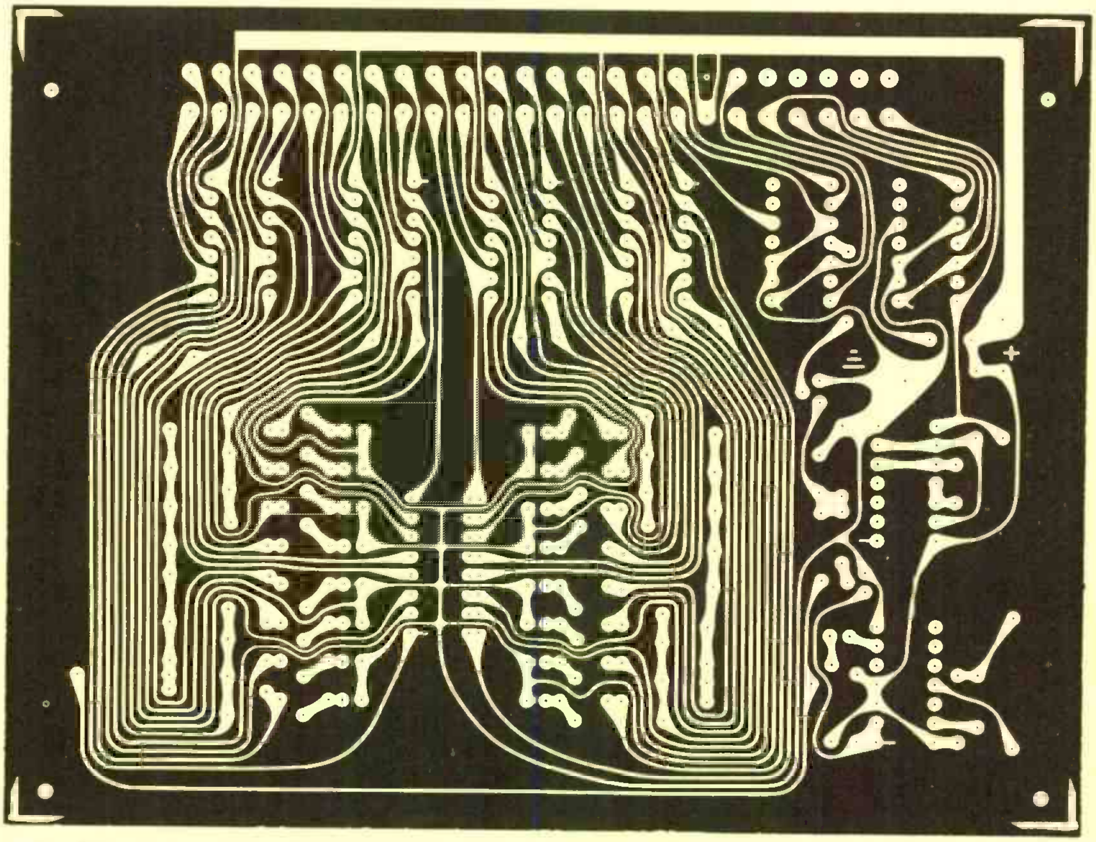
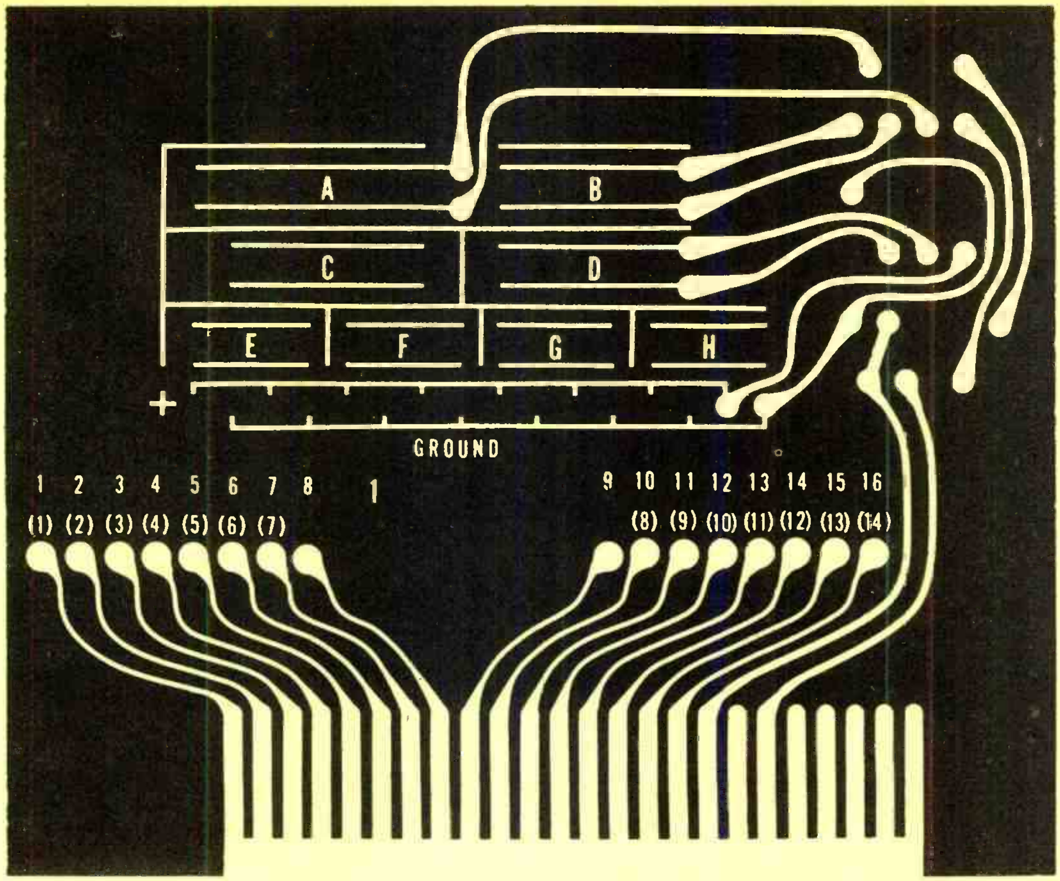


*Fig. 4. Etching and drilling guide (right) and component layout (above) for main pc board. Note: etched and drilled pc boards for this and Fig. 5 are available from Select Circuits, 1411 Lonsdale Rd, Columbus, OH 43227 for $18.95 a pair.*

socket (*SO3*). Each exclusive-OR gate thus yields a logic-one output signal whenever its two input signals have different logic states. In other words, a logic one appears at the output of each gate when a discrepancy of performance between the test and reference IC's is detected.

Two fault indicator circuits are employed. A LED (*LED1* through *LED16*) at the output of each exclusive-OR gate glows when an error at the corresponding test IC pin is detected. Additionally, a master fault indicator (*LED17*) glows when one or more exclusive-OR gate output is high. Diodes *D1, D3, D5*. . . *D31* are connected to *R17* and to the exclusive-OR outputs to form one large OR gate. A pulse stretcher is included in the master fault indicator circuit to insure that *LED17* will glow at full brilliance no matter what the duty cycle of the fault signal is. This is very important because it's possible for a fault signal to have a



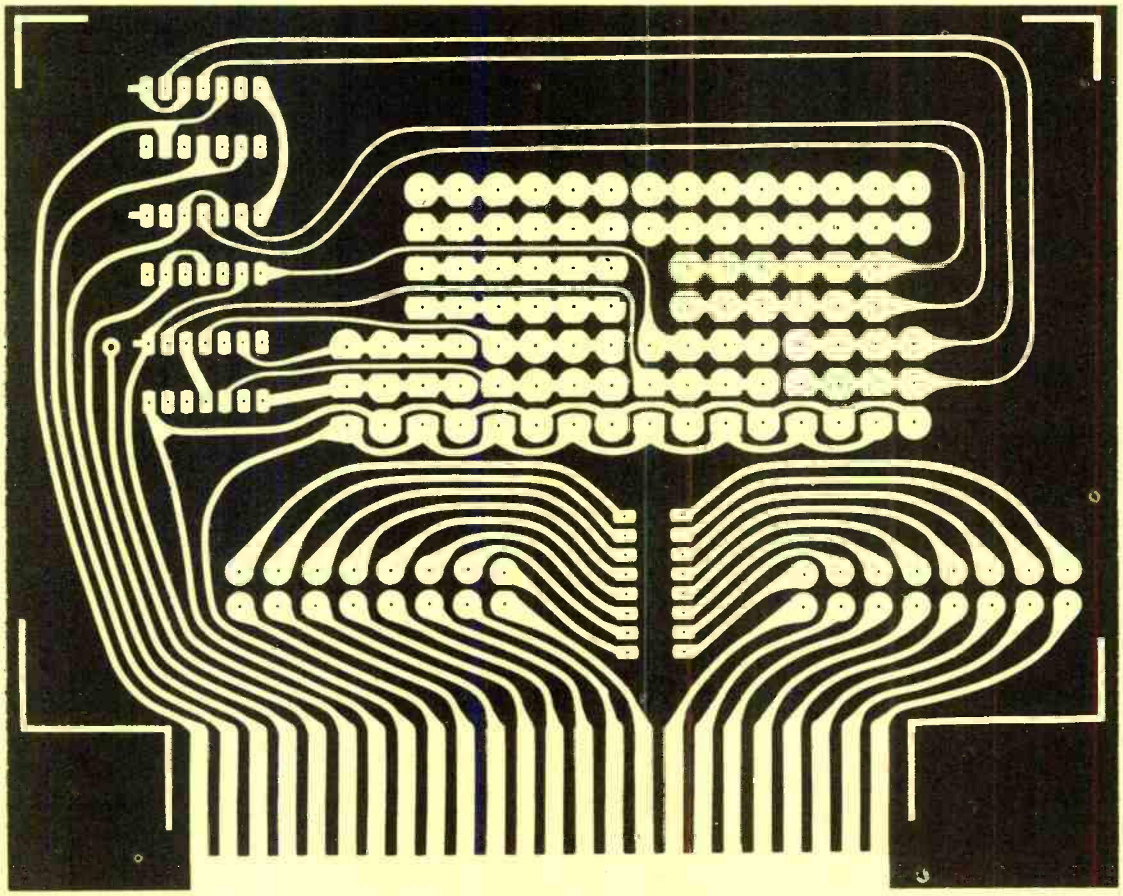



*Fig. 5. Etching and drilling guides for both sides of the programming pc board. See Fig. 4 for ordering information.*

duty cycle as low as 0.4%. It would be difficult, if it were even possible, to detect light output from a LED driven by such a signal. The circuit also includes a low-pass filter (*R17, R18* and *C1*) at the master fault input to reject noise spikes which might otherwise generate a deceptive fault indication.

The diode OR gate drives pulse stretcher *IC8* (an SN74122 monostable multivibrator) and its associated components (*C2, D34,* and *R20*) through input conditioners *D33* and *Q1*. Because a continuous fault indication at the pulse stretcher input would trigger the one

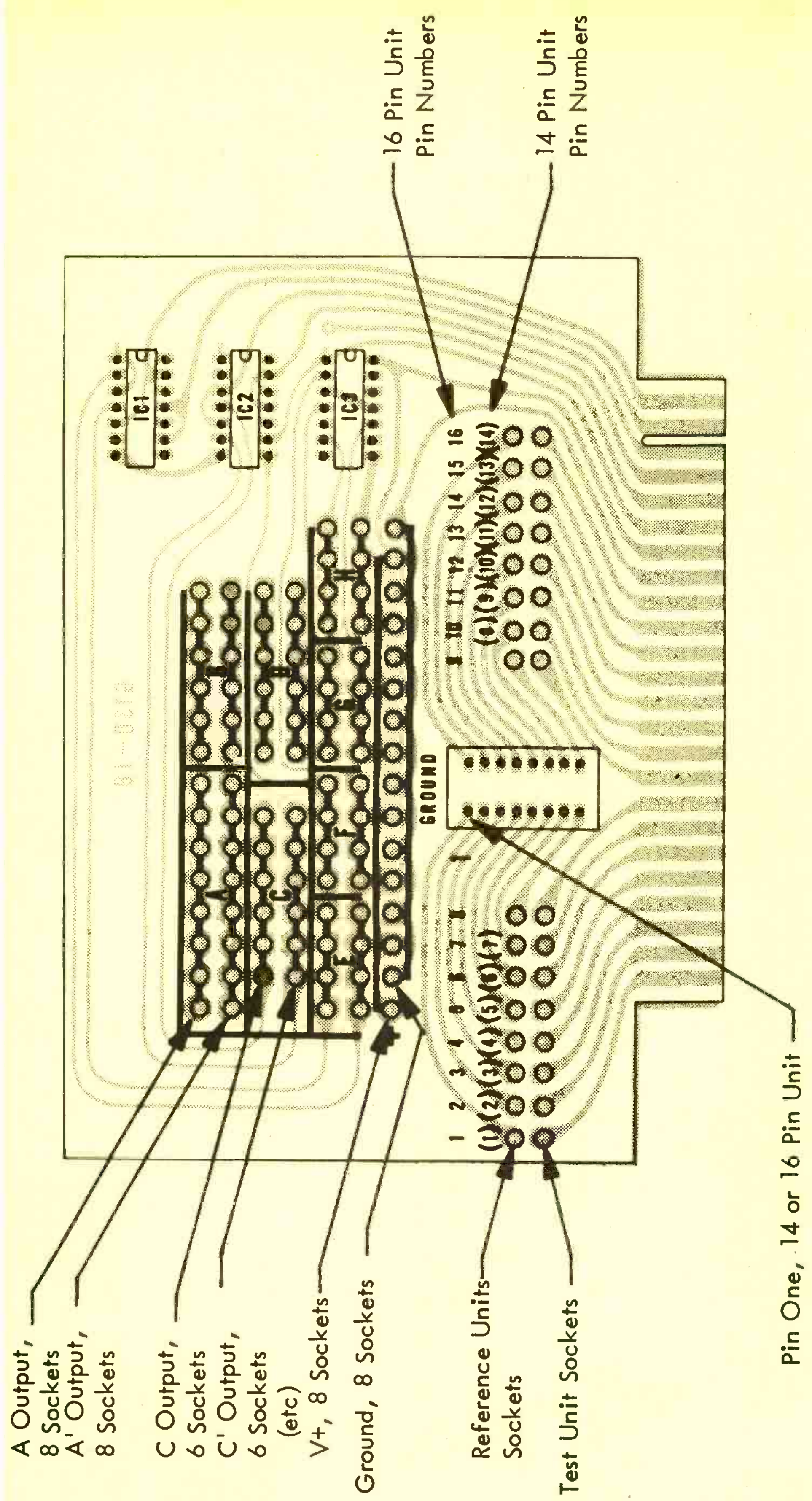



*Fig. 6. Component placement guide for programming pc board.*

shot for but one test cycle, the input must be periodically reset. This is accomplished by transistor *Q2*, which is driven by the last stage of a binary code generator.

To provide all possible test input combinations, an eight-stage binary code generator (*IC5* and *IC6*, SN7493 4-bit counters) is incorporated. It is driven by a free-running square-wave generator consisting of *C3*, *R22*, and *IC7*, an SN7405 hex inverter. The square-wave generator provides a clock signal at about 5000 Hz. The clock output and the outputs from the first seven stages of the binary code generator are available at edge connector *SO2*. Thus there are eight independent test input signals present on the programming board. The eighth stage of the binary code generator is used to reset the master fault indicator, as mentioned earlier.

The programming board interfaces with the main tester board via 48-pin edge connector *SO2*. This allows prewired program cards to be kept on hand and simply plugged into the tester for quick checks of common IC's. Each bit of the binary code is independently buffered by sections of *IC9* through *IC11* (SN7404 hex inverters) to drive both the reference and test IC inputs. Separate buffering for all inputs of each IC ensures that such logic-overriding faults as input short circuits will be detectable.

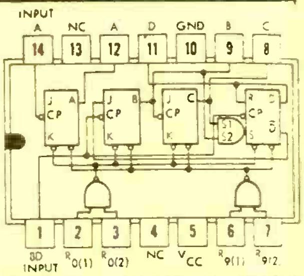
The tester is powered by a simple 5-volt, 1-ampere regulated supply (Fig. 3). Ac from *T1* is converted to pulsating dc by a full-wave rectifier (*D35* and *D36*) and filtered by *C8*. Unregulated dc is then applied to *IC12*, an LM309K 5-volt regulator, which is essentially blow-out proof. Current limiting is built in to the IC, as is thermal shutdown. Output bypass capacitor *C9* provides increased stability and improved transient response.

However, other power supply configurations can be used. For example, *T1* could be a 12.6-volt, 2-ampere transformer driving a bridge rectifier. The output of the bridge would then be filtered and regulated as in Fig. 3.

**Construction.** Assembly of the tester is not critical. However, the use of pc boards will simplify the task. Etching and drilling guides for the main and programming boards are shown in Figs. 4, 5, and 6. The main pc board contains most tester components mounted in a conventional manner. It in turn is mounted on four ¼-inch (6.4-mm) No. 4 standoffs behind the front panel of a molded plastic box. Holes are cut in the front panel for the test socket, the sixteen indicator

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Reference Unit Connection | A' | NC | NC | NC | COM | NC | NC | X |
| Test Unit Connection | A | NC | NC | NC | COM | NC | NC | X |
| Pin Number | (14) 16 | (13) 15 | (12) 14 | (11) 13 | (10) 12 | (9) 11 | (8) 10 | X |

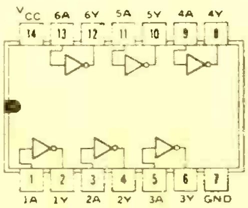
DEVICE TYPE: **CIRCUIT TYPES SN5490, SN7490 DECADE COUNTERS**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pin Number | 1 (1) | 2 (2) | 3 (3) | 4 (4) | 5 (5) | 6 (6) | 7 (7) | X |
| Test Unit Connection | B | C | D | NC | V+ | E | F | X |
| Reference Unit Connection | B' | C' | D' | NC | V+ | E' | F' | X |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Reference Unit Connection | V+ | B' | NC | B' | NC | B' | NC | X |
| Test Unit Connection | V+ | B | NC | B | NC | B | NC | X |
| Pin Number | (14) 16 | (13) 15 | (12) 14 | (11) 13 | (10) 12 | (9) 11 | (8) 10 | X |

DEVICE TYPE: **CIRCUIT TYPES SN5404, SN7404 HEX INVERTERS**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pin Number | 1 (1) | 2 (2) | 3 (3) | 4 (4) | 5 (5) | 6 (6) | 7 (7) | X |
| Test Unit Connection | A | NC | A | NC | A | NC | COM | X |
| Reference Unit Connection | A' | NC | A' | NC | A' | NC | COM | X |

NOTES: All inputs could have been tied in parallel to A & A' for example, but it is not necessary to do so.

*Fig. 7. Sample programming sheets for testing decade counters (above) and hex inverters (below).*

LED's, the master fault indicator and the edge connector.

Before mounting any components on the main board, use it as a template to locate holes and cutouts on the front panel. It can be clamped to the front panel and used as a drilling guide for the four standoff mounting holes. The locations of the master fault indicator, the test socket, and edge connector can be specified by marking the corners of each cutout. Components which do not protrude through the front panel must be mounted flush to the main pc board so that they will not interfere with the fit of the board to the front panel. If LED's with base diameters larger than 0.200" (5.08 mm) are used for the sixteen fault indicators, their bases must be filed so that a proper fit is obtained. The author recommends the use of a 16-pin zero-insertion-force (Textool No. 216-330M or equivalent) IC socket for the test IC location. A conventional DIP socket can be substituted, of course, but is much less convenient to use for many IC's.

The programming board is double-sided. Because most builders will not be able to produce plated-through holes, IC and socket pins, as well as programming receptacles must be soldered (where applicable) to both sides of the board. The programming receptacles and jumpers (patch cords) are a matter of preference. The solder pads on the pc board are large enough to accept eyelet sockets for the 0.040" (0.916-mm) pin terminated type of patch cords. The most economical programming patch cord is simply a length of No. 22 or 24 solid insulated hookup wire. The wire should be cut to the desired length and about ½" (1.27 cm) of insulation stripped from each end. If diagonal cutters are used to trim wire length, position the cutters so that their hollow side faces the body of the jumper when the wire is clipped. Then a point will be formed on the wire, making it easier to insert the jumper into a programming receptacle.

A solid wire jumper is best accommodated by a 0.020" (0.458-mm) receptacle. No. 24 wire is approximately 0.020" (0.458 mm) in diameter and fits such a receptacle exactly. No. 22 wire is about 0.005" (0.127 mm) larger in diameter and thus makes a more secure fit in some 0.020" (0.458-mm) receptacles. Probably the most inexpensive 0.020" (0.458-mm) receptacle available is the Molex Soldercon, which is sold in quantity by many dealers in the Electronics Marketplace in this magazine.

You might want to solder wire jumpers to appropriate points without using any receptacles at all. This can be done if you desire a permanent testing board for a specific IC type. You could even make one "deluxe" programming board with patch cords and receptacles for testing any TTL IC, and at the same time fabricate a number of prewired boards set up for frequently tested IC types.

Power supply construction is not critical. Point-to-point wiring is adequate. Connections from the IC tester to the power supply should be made directly at the voltage regulator's terminals. If the project is mounted in a plastic, rather than aluminum, enclosure, a heat sink must be provided for *IC12*. In any event, heat sink compound such as Dow Corning No. 340 silicone heat-sink compound should be used when mounting the IC on a heat dissipating surface.

Worst-case maximum power dissipation for the regulator will be approximately (in watts) the unregulated supply voltage minus five volts, because maximum current is about one ampere. The maximum dissipation of the regulator must be kept in mind when selecting the power supply transformer and heat sink. The rectified voltage across the filter capacitor will be about 1.4 times the rms voltage from the center tap to one end of the secondary in a full-wave circuit. If a bridge rectifier is used, the dc voltage across the filter capacitor will be about 1.4 times the rms voltage across the entire secondary winding (no center tap is needed). In any event, the unregulated dc applied to the input of *IC12* should never drop below 8 volts at full load. Otherwise the output will not be regulated. Also, the input to the regulator must not exceed 35 volts or the integrated circuit will be damaged.

**Programming.** All that's required to program the tester is patching input signals to the reference and test IC's. Each individual input of the test IC should be connected to a different binary code bit (*A* through *H*). In multiple section IC's, corresponding inputs can be wired in parallel. For example, when programming a test of a quad two-input NAND IC (SN7400), one input of each gate can be connected to the *A* output of the binary code generator and the other input of each gate to the *B* output. Thus there would be four gates with their inputs wired in parallel to the *A* and *B* bits.

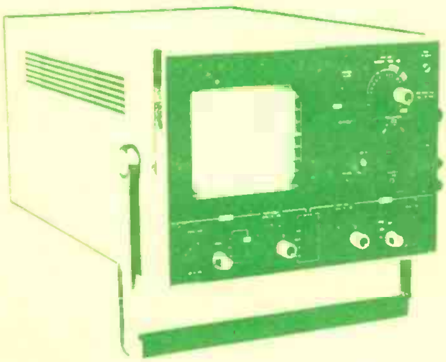
When specific binary code generator outputs (*A* through *H*) are patched to the test IC inputs, the corresponding separately buffered outputs *A'* through *H'* must be patched to the corresponding reference IC inputs. Programming is completed by patching +5 volts and grounds to the appropriate pins of both IC's.

The foil on the component side of the programming board is etched to provide clear labelling. Binary code generator outputs are boxed in and identified by the letters *A* through *H*. Separately buffered outputs are shown bussed together on the component side. This bussing is done for appearance's sake only and the programming receptacles need not be soldered on this side of the board. Actual bussing is done on the other side. Note, however, that the right-most receptacles in areas A, B and D must be soldered on both sides of the pc board.

The choice of which binary code outputs are used to drive either the reference IC or test IC inputs is unimportant so long as only one set (*A* through *H* or *A'* through *H'*) is used with one of the two IC's. The +5 volt supply is identified by a "+" and is shown bussed on the component side of the board. Similarly, the ground is so labelled and bussed. Again, this bussing on the component side of the board is for appearance only and the receptacles need not be soldered on the component side. But the right-most receptacles must be soldered on both sides of the board for proper connection to the power supply.

Receptacles tied to the test and reference IC sockets parallel each other along the edge of the board just above the edge connector contacts. They are labelled with pin numbers for 14- (in parenthesis) and 16-pin DIP's.

Two programming examples are shown in Fig. 7. It is desirable to make up similar programming sheets for each IC you test. Then you can use them as check-off sheets to verify proper programming and as a permanent record of the test program. Similar tests can then be performed at a future date by quickly referring to the appropriate programming sheet. ◇



# GUIDE TO OSCILLOSCOPES

***How to weigh the functions and performance that you need for your application in choosing this instrument.***

BY CLAYTON HALLMARK

EVERYONE who gets into electronics, either vocationally or as a hobby, hopes to own an oscilloscope. This isn't surprising, considering that the scope is one of the most versatile test instruments ever to become available. Not only can an oscilloscope display a "picture" of the actual signal in a circuit under test, it can also measure the signal's amplitude, frequency, and time period.

The oscilloscope represents a sizable investment, but it is worth every penny you invest if you buy what you need and use it wisely. Here are some basic scope guidelines you should know before buying the instrument, including operating principles and specifications.

**Curves and Measurements.** The oscilloscope's usefulness in measuring time and voltage is illustrated in Fig. 1. Horizontal distances on the screen represent time by a fixed amount per graticule square, while vertical distances represent voltage, also by a fixed amount per square.

A TIME/DIV (typical) control on the scope can be used to set the width of the displayed image. The calibration markings on this control permit the elapsed time between any two points on the display to be determined by mutliplying the horizontal spacing in divisions by the numerical value of the TIME/DIV control setting. For example, the horizontal division between points A and B in Fig. 1 is five divisions. If the TIME/DIV setting is 100 μs/division, the elapsed time between A and B is 100 μs × 5 = 500 μs.

The VOLTS/DIV (typical) control on the scope is used to set the height of the display. The vertical distance tells the magnitude of the voltage of the displayed waveform in much the same manner as the horizontal distance tells the time be-