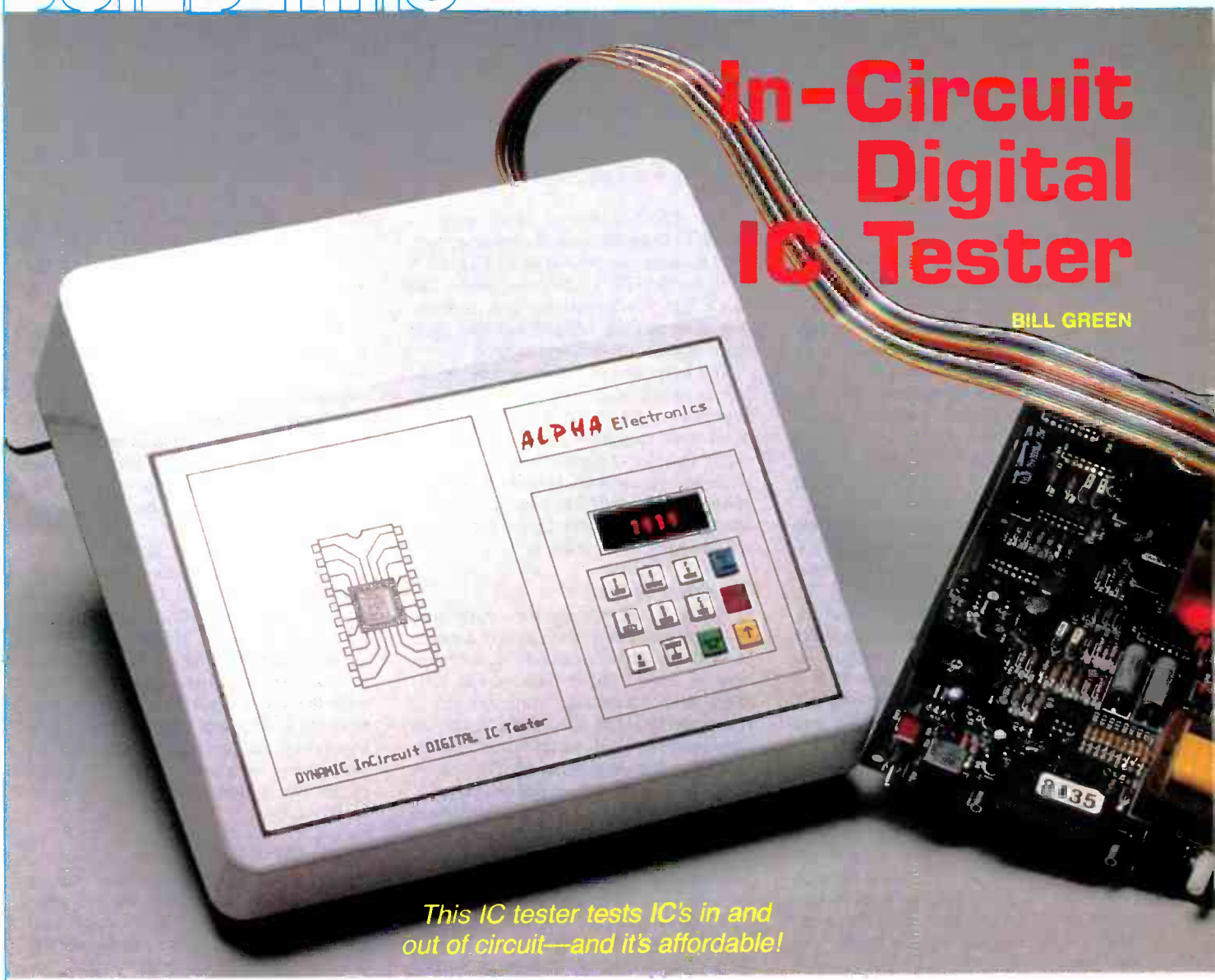
BUILD THIS

In-Circuit Digital IC Tester

BILL GREEN



This IC tester tests IC's in and out of circuit—and it's affordable!

SERVICING DIGITAL ELECTRONIC EQUIPment is seldom easy; difficulties arise from several sources. For example, microprocessors, RAM, and ROM IC's are usually socketed, but digital "glue" IC's (gates, flip-flops, etc.) are seldom socketed, because the sockets may cost as much as the IC's themselves.

Not using sockets reduces manufacturing costs, but causes nightmares for the serviceperson. Often, an inexpensive assembly can be discarded and replaced for less than it would cost to repair it. But when a board must be fixed, the headaches begin. For example, how do you locate a bad IC when most or all are soldered to the board?

One way is to remove IC's one by one, replacing each until the board starts functioning again. However, if two or more IC's are bad, the difficulty of locating them increases tremendously. Defect isolation using logic probes, logic analyzers, oscilloscopes, and other equipment can be performed, but doing so requires a high degree of technical knowledge, which may not always be available. Clearly, a better method is needed.

The in- and out-of-circuit IC tester presented here is such a method. It is a moderately priced device that can test most parts in most TTL families, as well as TTL-compatible MOS and CMOS devices. You use the device by selecting a test routine, clipping a test probe to the *D*evice *U*nder *T*est (DUT), and examining an LED display.

Other IC testers in its price range ($300 for a complete kit, other configurations available) require a known-good IC of the type to be tested for comparison; ours doesn't. In addition, our tester has enough memory to store 105 different IC test routines, and it has a serial interface to upload and download test routines. Those capabilities allow a field-service technician to load different test set-ups depending on the device he or she will be servicing.

Test routines may be entered by hand on the tester's keyboard or downloaded from any computer with an RS-232 serial port. In addition, routines entered via the tester's keypad may be uploaded and saved for future use. Simple BASIC programs allow you to upload and download test routines. Those programs will appear here, and will be available on the RE-BBS; the routines run (or can be adapted to run) on many computers, including IBM's and clones, Radio Shack *Models III* and *IV*, the *Color Computer*, Commodore and Apple computers, etc.

Basic features

The tester has a 12-key keyboard to allow manual entry and editing of test data and commands, and transfer of test data to and from a personal computer. A four-digit sixteen-segment alphanumeric display prompts the user to enter data and displays pin-by-pin test results (both expected and actual data).

External back-up batteries are unnecessary because data and programs are stored in a special non-volatile 32K-byte CMOS RAM IC.

IC's are tested dynamically: inputs are cycled high and low as many as forty times, according to the test routine. That capability allows thorough testing of difficult-to-test parts, including counters, flip-flops, and registers.

Using the tester

Testing an IC out-of-circuit is straightforward: Simply attach the test clip and run the appropriate test routine, which is selectable by part number. The tester then writes data to the device and reads back the results for comparison. (We'll show you how to generate the test data later.) An out-of-circuit IC is not connected to any other devices, so we needn't worry about input pins of the DUT that might be connected to outputs of the same or another device, or to ground or V_{CC}.

To test IC's in-circuit, the tester allows for inputs that may be connected to outputs, ground, or V_{CC} as follows: The tester's output drivers can be floated (i. e., placed in a high-impedance state); in addition, they have enough current drive (both sourcing and sinking) to pull an input high or low (briefly), even if it is connected to an output. Further, you can specify that the test routine ignore any desired pin or pins.

How it works

All circuitry is contained on two PC boards, which are interconnected by a short length of ribbon cable. One board contains the interface circuitry through which the DUT and the on-board microprocessor communicate. The other contains the microprocessor, the RAM, and the support circuitry, including a 5-volt regulated power supply, an RC reset network, and a 2-MHz crystal-controlled clock. Crystal control is required for precise timing of the serial communications channel. A Z80 microprocessor directs all tester operations.

A major design goal of the tester was the ability to store many test routines, so a large amount of nonvolatile storage is provided by a DS1230 32K byte non-volatile static RAM. The lower 4K of the RAM contains the control program.

The tester's schematic is shown in Fig. 1. It uses several custom CMOS gate arrays for various purposes. Part of IC5 (a 75498) provides the write-enable function. It decodes address lines A12–A14 and disables the processor's write enable signal whenever all three address lines are low, thus preventing corruption of the control program. The remainder of IC5 decodes the input and output strobes for the driver board and the display.

Another custom IC (IC6, a 75500) is the input/output port for the keyboard and the display. That IC latches the appropriate keyboard row signals and reads the column signals of the keyboard, and it latches the digit address lines for the display.

The third custom IC (IC4, a 75499), is used in the RS-232 I/O channel. The IC decodes the port strobes and latches the serial input and output data and "busy" signals.

The RS-232 driver/receiver is a MAX-233, which provides the necessary level conversions to and from TTL (+5 volts) and RS-232 (±10 volts) levels. The MAX 233 has an internal charge pump that generates the RS-232 voltages from the single-ended five-volt supply.

The keyboard and display provide the human interface. Twelve tactile-feedback keyswitches are arranged in two columns of six rows; they are scanned by the 75500 (IC6). In order to provide legible operator prompts, we use a DL1414 intelligent alphanumeric display. It contains built-in storage, decoders, and drivers for its four red 16-segment LED digits.

The driver board

The IC tester provides for a maximum of 24 test pins. Each test pin may serve as an input or output; as an output, each pin may be forced either high or low. So, functionally, speaking, each test pin is connected to three IC's in the tester: an input latch, a pull-down driver, and a pull-up driver. The outputs, of course, can be three-stated so that the input can be read.

As shown in Fig. 2, that DUT interface circuit is implemented with nine IC's (IC7–IC15) on the driver board, including three each of the NE590, the NE591, and the 74LS373. The 74LS373's are 8-bit data input latches; the NE590's and NE591's are 8-bit addressable latches with open-collector and open-emitter Darlington output transistors, respectively. The NE590's outputs pull to ground and the NE591's pull to V_{CC}. Each of the NE590/1 IC's has three address inputs and one data input. The data present at the latter is routed to the internal latch/output circuit decoded by the former when $\overline{CS}$ and $\overline{CE}$ are low.

We connect those drivers to the pins of the DUT through P3 by way of a test cable and a DIP header clip. There are 24 test connections, plus power and ground, for a total of 26 pins. You can wire up different test cables for IC's with different sizes and shapes.

An additional ground wire in the test cable is terminated with a miniature clip, which should be connected to ground on the circuit board being tested. The V_{CC} pin may be terminated in the same manner to supply power to an IC for out-of-circuit testing. The tester's power supply will not supply much current for external circuitry, so the system being tested must have its own power supply.

Buffer space

Now let's talk about how test data is stored in the tester's non-volatile RAM. First, each test routine takes 256 bytes of memory. In addition to the stored routines, a separate 256-byte buffer is used to store input data.

Next, corresponding to the 24 test pins are 24 "slots" in memory. Each slot consists of five groups; each group contains two bytes. That accounts for 240 bytes (24 × 5 × 2). An additional 16 bytes are reserved for the part number and the number of pins. That makes a total of 256 bytes (240 + 16).

The first byte in each group determines the function of the pin: input, output, indeterminate, or ignore. The second byte constitutes test data for that pin. Each group may have a different pin function (input, output, etc.). That is useful when you are testing an IC that uses the same pins for inputs and outputs at different times (a 74LS245 octal bus transciever, for example.)

One bit of test data is used per test cycle. Each cycle consists of sending a bit of data to each of eight drivers in each of three NE590's and NE591's, starting with the lowest pin. The drivers latch those signals. Then the level on each pin is read in and stored, one byte at a time, starting with the lower eight pins. The cycle is repeated seven more times, for each byte in a group; the procedure is repeated for each group, for a total of 40 (5 × 8) test cycles. We'll present several practical examples later.

Assembly

Start assembly by procuring or making the printed-circuit boards. We will present foil patterns in "PC Service next month." Etch the boards and carefully drill the 700 holes. Several hundred connections are made through the board (via plated-through holes), so you will have to make these connections with short pieces of bare wire soldered on both sides.

As shown in Fig. 3, the display may be mounted in one of two positions, depending on whether the boards are mounted in a case or are allowed to "float." If you are using a case, mount it on the foil side of the PC board in the area outlined with dashed lines in the diagram. Otherwise, mount the display on the component side of the board in the area that is outlined with solid lines.

Similarly, if you use a case, the pushbuttons must also mount on the foil side of the board. In that case, the key legends must be reversed left to right.

If you use a case, install the keyswitches first. Lay the board on a flat surface, foil side up. Orient each switch so that the flat sides on each is toward the Z80. The keyswitches are colored differently: the 0–8 switches are white; the ENTER switch, green; the SHIFT key (').

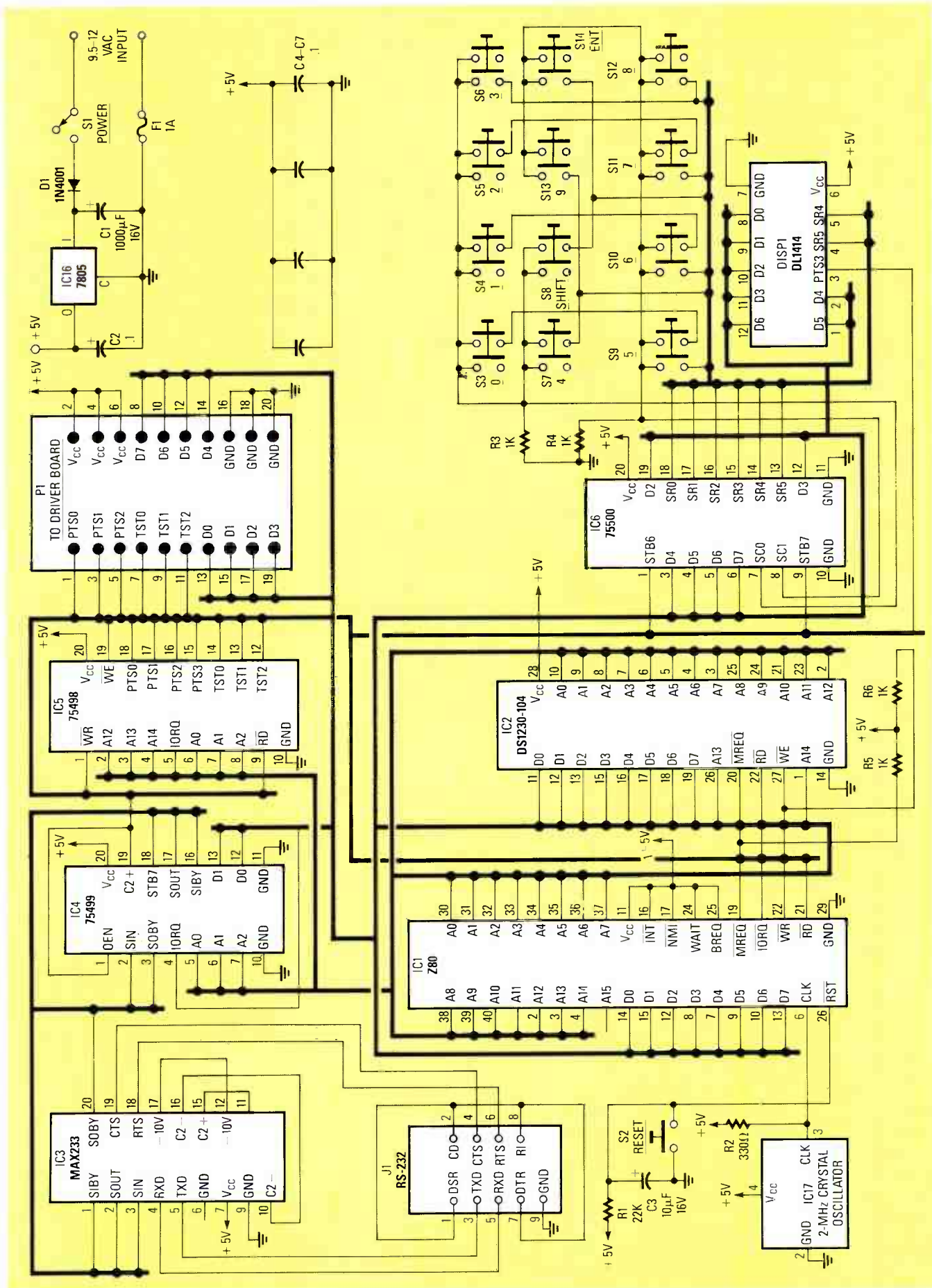


FIG. 1—THE IC TESTER'S MAIN BOARD is built around a Z80 microprocessor running at 2 MHz.

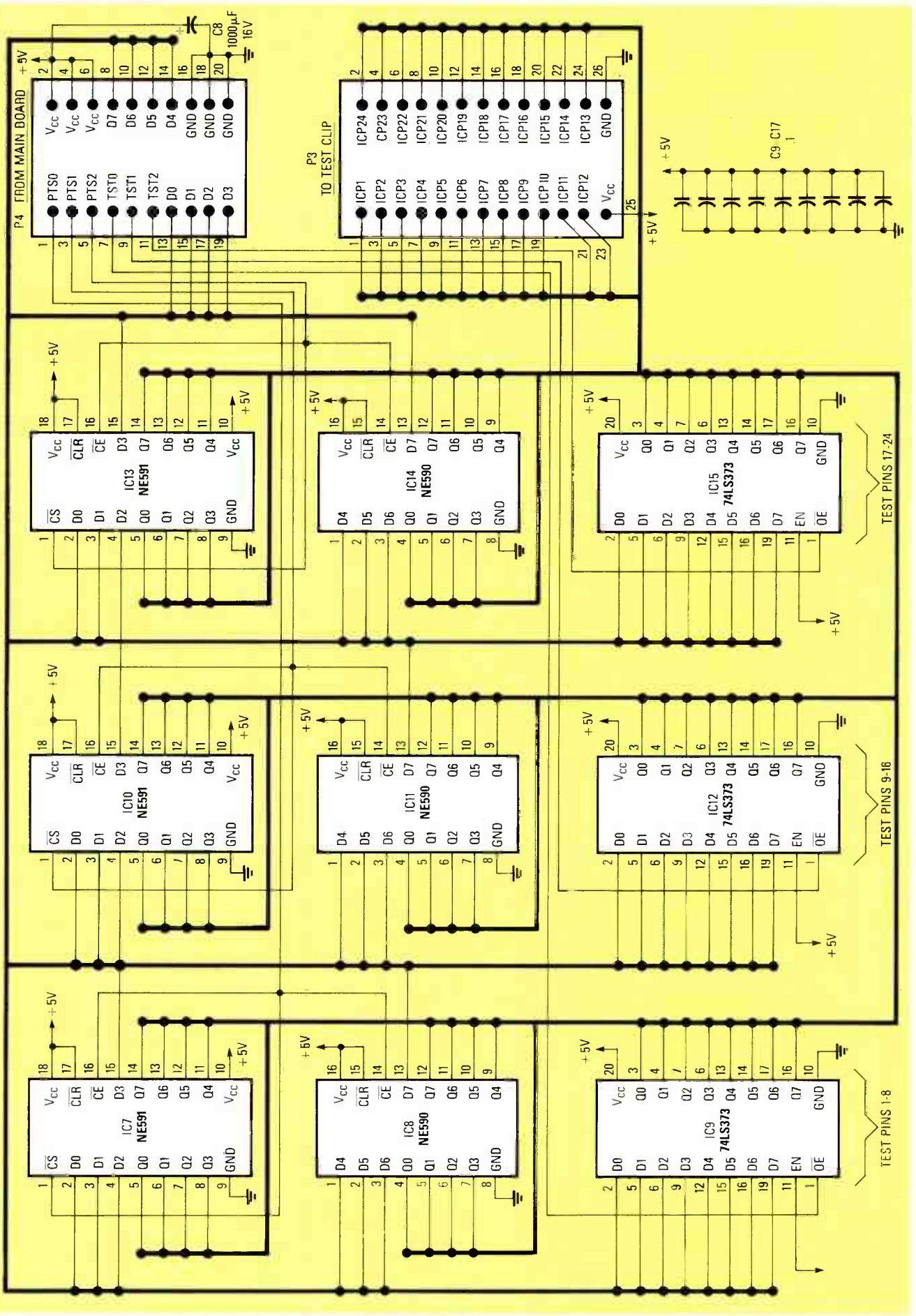


FIG. 2—THE IC TESTER'S DRIVER BOARD provides separate inputs, sourcing outputs, and sinking outputs for each of 24 test pins.

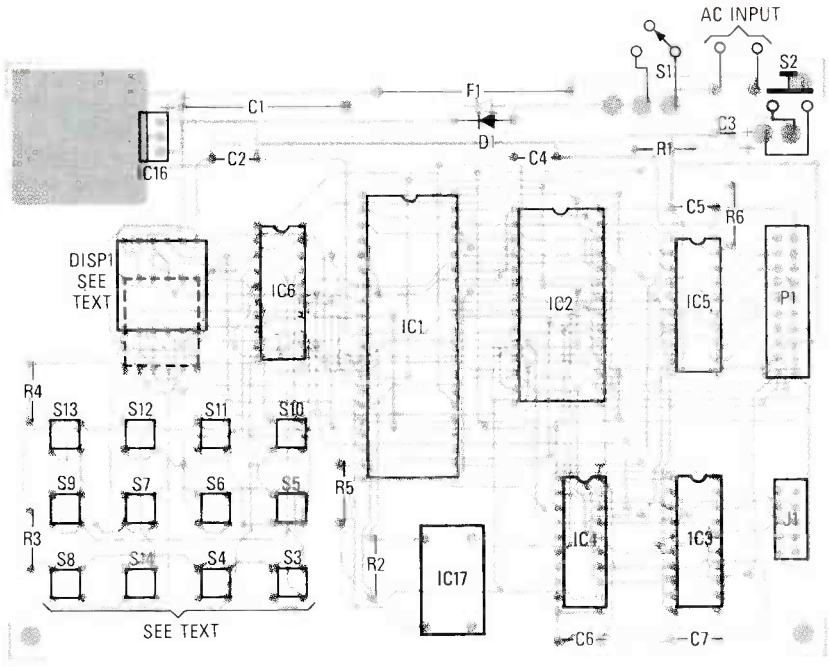


FIG. 3—STUFF THE MAIN BOARD as shown here. Mount the display and switches S3–S14 on the foil side if you will install the tester in a case. Note that the display is oriented differently depending on whether or not the tester is installed in a case.

yellow; the 5 key, red, and the 9 key, blue. Select the proper color and install and solder one pin of each switch from the solder side of the board. Then turn the board over and solder the remaining three pins of each switch from the component side. Mounting the keyswitches that way lifts them off the board enough to protrude through the panel of the case. Now install the 12-pin display socket made from a 24-pin IC socket that has been cut in half.

When not using a case, the keyswitches are installed on the component side of the board and are not spaced away from the board. To mount the power and reset switches on the board, you'll have to enlarge the holes indicated in the parts-placement diagram.

The remainder of the instructions apply to both case and case-less installation. Install the IC the sockets on the component side of both boards next, followed by the remaining components, starting with the low-profile devices.

Be sure to orient the electrolytic capacitors, the diode, the clock module and the voltage regulator (IC16) correctly. It is installed so that its metal tab will contact the foil area of the PC board. To provide extra heatsink capacity, you want to slip a clip-on heatsink on the regulator.

Next mount the male header strips on both boards. (See Fig. 4.) Connect the power and reset switches to the board with 10-inch insulated wires (or directly to the board if you're not using a case). Connect the leads of a 9–12-volt AC, 1-amp wall-mount power transformer to the board. **Do not install any IC's yet.** Connect the driver board to the main board with an 8-inch, twenty-conductor ribbon cable terminated on each end with a twenty-pin female header.

CAUTION! At this point it is possible to erase the control program in the CMOS RAM. For example, if there is a solder short on the board in the right place, the write-protect function of the 75498 will be defeated. Or the write enable pin on the RAM may be shorted to ground, allowing just about anything to be written to the IC. To prevent that from happening, use an ohmmeter or continuity tester to ensure that there are no connections between the following pins and ground, V_{CC}, or any nearby traces on the board: IC5, pins 1, 2, 3, 4, and 19; IC2, pins 20, 27, and all of the address lines, and IC1 pins 20, 21, and 22. Fix any shorts before proceeding.

Measure the output of the regulator; it should be +5 volts, ±0.25 volt. Assuming it's correct, insert the clock module, and check pin 3 for a 2-Mhz squarewave. Now remove power from the board and allow a minute for the filter capacitors to discharge. Being careful to observe proper procedures to avoid static damage to the MOS (Z80) and CMOS (RAM, MAX233, 75498, 75499 and 75500) IC's, install all IC's in their sockets properly oriented. A square foil pad on the board indicates pin 1 of all IC's. Pin one of the display is marked with a small triangle.

When you're certain that all parts are installed correctly, in the correct place, with no pins bent under any of the IC's, and so on, apply power again. The word *COMMAND?* should scroll across the display repeatedly. If it does, you are ready for final assembly. Turn power off and unplug the transformer.

PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.

R1—22,000 ohms
R2—330 ohms
R3–R6—1000 ohms

Capacitors

C1, C8—1000 µF, 16 volts, electrolytic
C2, C4–C7, C9–C17—0.1 µF, 10 volts, ceramic disc
C3—10 µF, 16 volts, electrolytic

Semiconductors

IC1—Z80 microprocessor
IC2—DS1230-104 32K nonvolatile RAM
IC3—MAX233 RS-232 interface
IC4—75499 custom decoder
IC5—75498 custom decoder
IC6—75500 custom decoder
IC7, IC10, IC13—NE591 open-emitter octal driver
IC8, IC11, IC14—NE590 open-collector octal driver
IC9, IC12, IC15—74LS373 octal latch
IC16—7805 5-volt regulator
IC17—2-Mhz crystal oscillator
D1—1N4001 rectifier
DISP1—DL1414 16-segment decoder/driver/display

Other components

F1—1-amp pigtail fuse
J1—9-pin D connector
P1, P2—right-angle double-row 20-pin male header strips
P3—right-angle double-row 26-pin male header strips
S1—minature SPDT toggle switch
S2—momentary SPST pushbutton
S3–S14—momentary SPST keyboard switches
T1—Transformer, 9.5–12-volts, 1-amp, wall-mount

Miscellaneous: One 10-pin, two 20-pin and one 26-pin double-row female IDC header connectors. Two 24-pin single-row female IDC header connectors. Flat ribbon cable. 16-pin, 20-pin and 24-pin DIP test clips, others as desired.

Note: The following are available from: ALPHA Electronics Corporation, P.O. Box 1005, Merritt Island, Florida 32952-1005, (305) 453-3534: Kit of parts for $299.00 + $6.00 P&H. Includes all parts, punched and screened panel, case, and labeled keys. Test cable and clips not included. Completely assembled tester for $399.00 + $6.00 P&H. Includes test cable with 16-, 20-, and 24-pin IC test clips. Partial kit, including all IC's, display, and PC boards for $199.00 + $5.00 P&H. Three custom IC's (75498, 75499 and 75500) for $60.00 + $4.00 P&H. Florida customers please add 5% State sales tax. Canadian customers please add $3.00 additional postage to all orders. All foreign orders add appropriate postage for Air shipping and insurance.

Final assembly

Using the keyboard layout (shown in Fig. 5) as a guide, label the keyswitches. If you plan to use the board without a case, the arrangement of the keys must be reversed from left to right. If you are installing the tester in a case, you will need

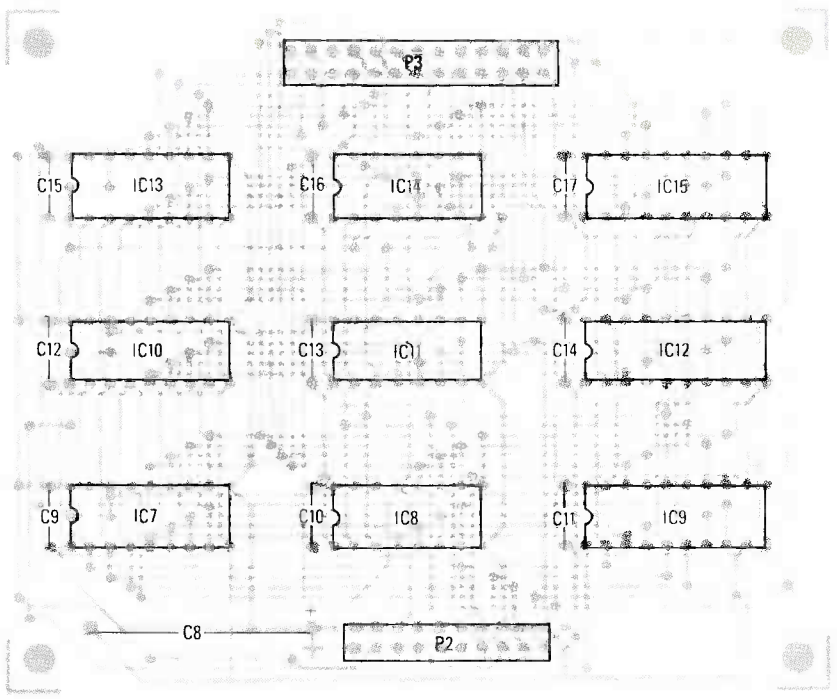


FIG. 4—STUFF THE DRIVER BOARD as shown here. Mount all parts on the component side of the board.

to prepare a front panel for the display and switches; Fig. 6 shows a suitable layout. To protect the display and enhance contrast, install a thin (0.040") plastic bezel inside the panel opening. Then mount the two PC boards to the case.

Using a maximum of three feet of 26-conductor flat ribbon cable, make a test cable. Terminate one end with a 26 pin female header connector. On the other end of the cable separate the 25th and 26th wires. Terminate the 25th wire (+5 volts) with a red test clip, and the 26th wire (ground) with a black test clip. Terminate the remaining 24 wires with two 12-pin single-row female header connectors.

Depending on your needs, you'll want to obtain several IC test clips with different numbers of pins; 16-, 20-, and 24-pin clips will allow you test 14- and 16-, 18- and 20-, and 24-pin IC's easily. When attaching the test clip to the cable, orient the clip so that pin 1 of the cable connects to pin 1 of the test clip.

If you are going to use the serial port to send and receive files, connect a 10-pin female header connector to one end of a 10-conductor ribbon cable, and a DB9 chassis-mount connector to the other. Mount the DB9 connector on the rear of the case. Also mount the power and reset switches on the back of the case. Wire an interface cable to connect the IC tester's port to that of your computer. RS-232 ports come in many configurations, so you will have to determine which pins are needed for your computer. The tester sends and receives serial data at 1200 baud, no parity, 8 data bits, and 2 stop bits. Pin 4 (CTS) is the transmit busy signal, and pin 6 (RTS) is the receive busy

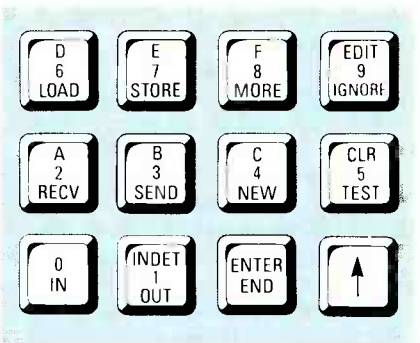


FIG. 5—LABEL THE KEYS as shown here for installation in a case. Otherwise, reverse labels from left to right.

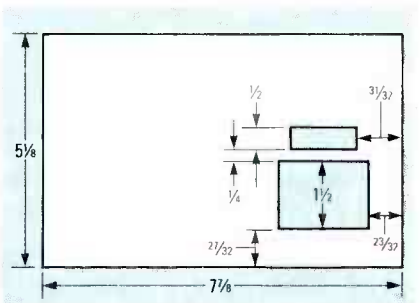


FIG. 6—BASIC DIMENSIONS for the front panel.

signal. The tester requires no other signals to work, but your computer's serial port might. On PC-compatibles, try connecting DSR, CD, DTR and RI together.

Finally, put the case together, plug in the test clip cable and the power transformer, and turn the power switch on.

Basic test procedure

The following commands are available when *COMMAND* is scrolling in the display: Load, Store, Send, Recv, New, Test, and Clr. The Shift key (') is always used to perform the function associated with the upper legend on each key. For example, '6 is a "D," used to enter hexadecimal numbers. The Shift key is a toggle. The first depression causes the shift symbol (') to appear in the display; it will disappear when the Shift key is pressed again, or when any other key is pressed. Shift must be pressed each time you want to use a shifted key function.

As a rule, you should turn the tester on first, followed by the circuit to be tested. Then connect the tester's ground clip, and last the IC test clip. If the test clip has more pins than the IC, "bottom justify" the test clip—when testing a 14-pin IC, for example, connect pin 8 of the clip to pin 7 of the DUT.

Here's how to enter a new test routine. With *COMMAND?* scrolling, press New. The input buffer is cleared of any previous test data. (That also occurs at power up and when the reset button is pressed.) *ENTER PART NO.?* will scroll now. You may enter between one and eight numbers or letters, followed by Enter. *ENTER NO. OF PINS?* appears now. You may enter any even number between 4 and 24 inclusive. Press Enter. *TYPE? PN01* appears. Enter the function of pin 1 by pressing In, Out, Indet, or Ignore, and then the test byte in two hex digits. (We'll show you how to create the test byte later.) For example, 155, OAA, X (no data necessary), or D98.

After entering data for all pins (or all pins you want to enter data for) press End. The display will ask *MORE OR END?*. Unless you wish to enter data for another test group (remember, there are five possible), press End again to indicate you are finished entering data.

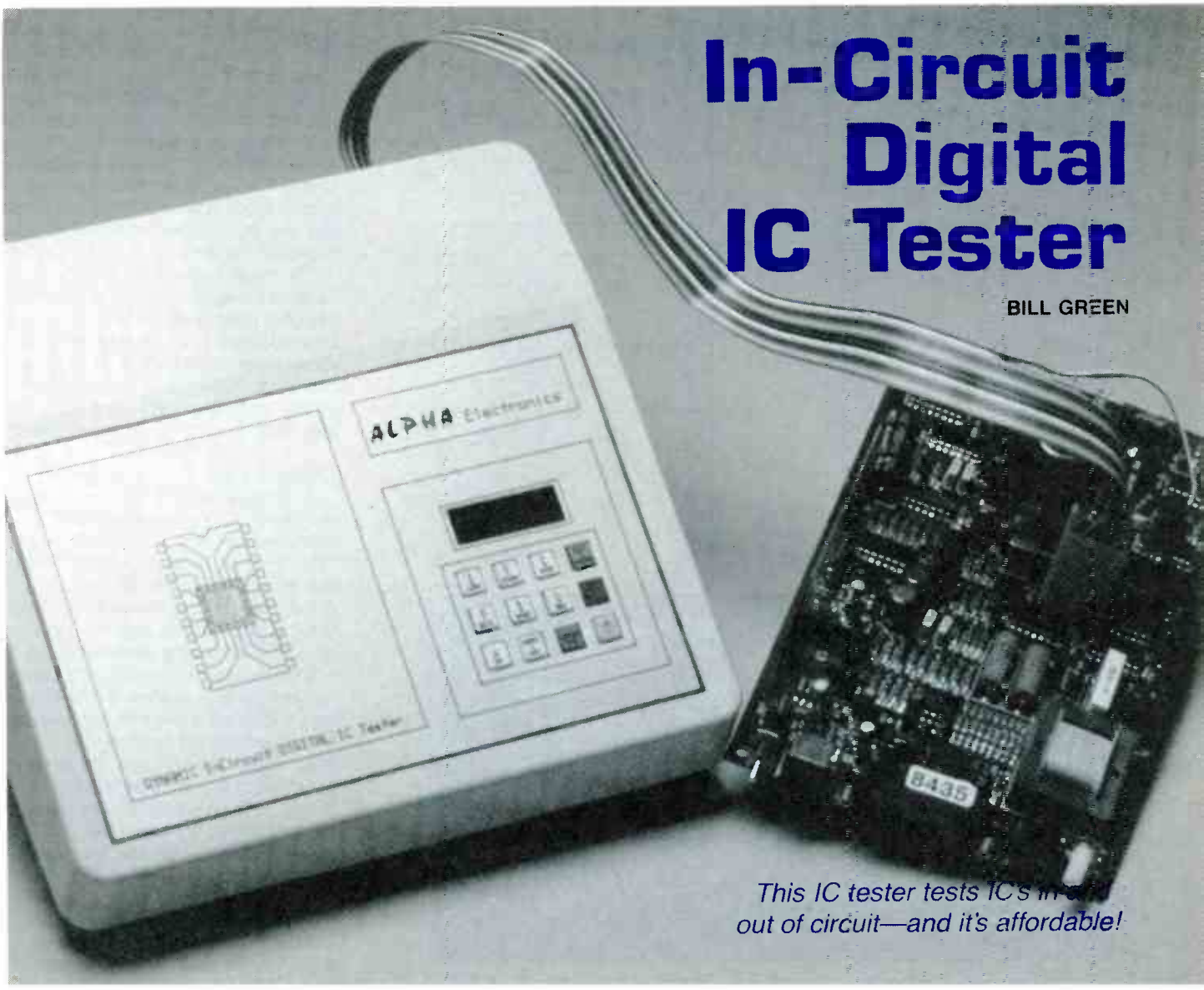
The Edit key allows you to back up one pin if you make an error after entering the three (or one if a pin is set for IGNORE) of the test data characters. Each time you press Edit, you back up one pin. The Clear key works any time the tester is expecting a keyboard entry, and pressing that key is functionally the same as pressing the reset button.

Press the Test key after all data has been entered. The IC will then be tested. If it is good, the display will read *IC TESTS GOOD*. Otherwise, *ERROR PN?? GRP? EXP/RD ????* will scroll across the display for each pin in error, showing the pin number, the group, and the expected and read data. Each question mark in the preceding message will be replaced by a numeral. For example, *ERROR PN01 GRP 01 EXP/RD 0100* would indicate a problem with pin 1 in test group 1; a "1" was read where a "0" was expected.

Next time we'll show how to send data to and receive data from an external computer. In addition, we'll give several specific examples of how to generate test data for various kinds of IC's. **R-E**

In-Circuit Digital IC Tester

BILL GREEN



This IC tester tests IC's in and out of circuit—and it's affordable!

Part 2 LAST MONTH WE BUILT the tester and discussed basic test methodology. Now we'll go on and provide specific examples showing how to set up your own test routines on paper and by computer, and how to send those files to and from your desktop computer.

Before we get started, lets correct a few errors from last month. The schematic of the driver board incorrectly identified P2 and P4. Also, the ordering information should have noted that IC16 and IC17 are not included in the partial kit.

7404 test data

Here is how to generate test data. This procedure applies whether data is entered via external computer using the data-entry routine discussed later, or is entered via the tester's keyboard.

Our first example illustrates the process for a 7404 hex inverter. First, obtain the pin numbers for inputs, outputs, V_{CC}, and ground, and the functional description (or truth table) from the device's data sheet.

To ease the process of generating the test data, make a copy of the template shown in Fig. 7; then fill in the blanks for the part number, number of pins, and group number. You must make a template for each test group if you need more than one. You may also sketch the part's logic diagram in the box on the template.

Next fill in the data blanks, leaving room to write eight binary digits at each pin that must be tested. If we put a 1 into an inverter, we should get a 0 out of it. So put a 1 in the blank for pin 1, and a 0 by pin 2. Repeat the procedure with the remaining five inverters. Then put an X at pins 7 and 14 to indicate that they will be ignored. Now we have all data for the first test cycle.

There is a total of eight test cycles, so now place a 0 at each input and a 1 at each output. (The X's should remain by pins 7 and 14.) That accounts for two of the eight bits in this test group's byte, so duplicate the bit pairs four times. Then convert the eight-bit data, four bits at a time, to two hexadecimal digits using the binary/hexadecimal chart at the bottom of the template. The completed test form is shown in Fig. 8.

The test information, along with the part number and the number of pins, is then stored in the tester's memory using the procedure outlined last time. There is no need for more than one test group to test a 7404 completely.

In-circuit example

The data for an in-circuit IC depends on how the IC is connected. For example, input pins may be tied to V_{CC} or to ground, so we tell the tester to ignore those pins. Or, if the IC's input is connected to one of its outputs, ignore the input, because its data will be supplied by the output it's connected to. A sample chart is shown in Fig. 9.

TEST ROUTINE TEMPLATE

PART NUMBER (8 Alphanumeric Digits Maximum: ____________
NUMBER OF PINS (2 Digits Maximum, Even Numbers 4 to 24): ____________
GROUP NUMBER (1 to 5): ________
REMARKS: ____________

Binary Data		Hex	Funct	Pin#		Pin#	Binary Data		Hex	Funct

BINARY TO HEXADECIMAL CONVERSION TABLE			
BINARY	**HEX**	**BINARY**	**HEX**
0000	0	1000	8
0001	1	1001	9
0010	2	1010	A
0011	3	1011	B
0100	4	1100	C
0101	5	1101	D
0110	6	1110	E
0111	7	1111	F

FIG. 7—COPY THIS TEMPLATE to simplify generating your own test routines.

Multiple test groups

IC's with pins that can function as both inputs and outputs can be tested as follows. We'll use a 74LS245 octal bus transceiver for illustration. That IC is commonly used to buffer data into and out of a microprocessor; direction of data flow is controlled by a single DIR input (pin 1).

The data for testing the IC in send mode is shown in Fig 10; the data for testing it in receive mode is shown in Fig. 11. Notice that the data in both cases is identical except for the setting of the direction line.

The enable line of a registered (latched) IC must be toggled to ensure that the IC responds when it is enabled, and does not respond when it is not enabled. Fig. 12 shows the test pattern for a 74LS373 octal data latch. The outputs should follow the inputs when the enable line (pin 11) is high, and shouldn't change otherwise.

Clocked logic

A clocked IC that has no means of setting or clearing its outputs will have an indeterminate state before it is clocked. Therefore, all outputs must be listed as indeterminate (D). The first state of a pin defined as indeterminate will be cleared to zero. (Only outputs can be indeterminate.) The remaining 7 states of the group will be processed normally. If more than one test group is needed, the first state of each additional group will not be indeterminate and should be defined as Output. Note in the test data that the clock line goes high in the odd-number cycles (1, 3, 5, and 7). The outputs will only change on those cycles, because the 74LS374 changes state during the leading clock edge. Test data is shown in Fig. 13.

Multiple-output-state devices

An IC with many inputs or outputs may require more than one test group. (Remember that there is a maximum of five test groups per part number). For exam-

PART NUMBER (8 Alphanumeric Digits Maximum: 7404
NUMBER OF PINS (2 Digits Maximum, Even Numbers 4 to 24): 14
GROUP NUMBER (1 to 5): 1
REMARKS: HEX INVERTER

Binary Data	Hex	Funct	Pin#	Pin#	Binary Data	Hex	Funct
0101 0101	55	I	1	14			X
1010 1010	AA	O	2	13	0101 0101	55	I
0101 0101	55	I	3	12	1010 1010	AA	O
1010 0101	AA	O	4	11	0101 0101	55	I
0101 0101	55	I	5	10	1010 1010	AA	O
1010 1010	AA	O	6	9	0101 0101	55	I
		X	7	8	1010 1010	AA	O

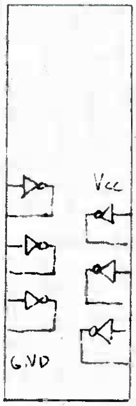


FIG. 8—TEST DATA FOR A 7404 hex inverter. All states are redundantly checked four times.

PART NUMBER (8 Alphanumeric Digits Maximum: 7404
NUMBER OF PINS (2 Digits Maximum, Even Numbers 4 to 24): 14
GROUP NUMBER (1 to 5): 1
REMARKS: IN-CIRCUIT

Binary Data	Hex	Funct	Pin#	Pin#	Binary Data	Hex	Funct
0101 0101	55	I	1	14			X
1010 1010	AA	O	2	13			X
		X	3	12	0000 0000	00	O
0101 0101	55	O	4	11	0101 0101	55	I
		X	5	10	1010 1010	AA	O
1010 1010	AA	O	6	9	0101 0101	55	I
		X	7	8	1010 1010	AA	O

FIG. 9—TEST DATA FOR AN IN-CIRCUIT 7404. Input pins 3, 5, and 13 are marked X, for "ignore." Those pins might be hard-wired to ground, V_{CC}, or elsewhere in an actual circuit.

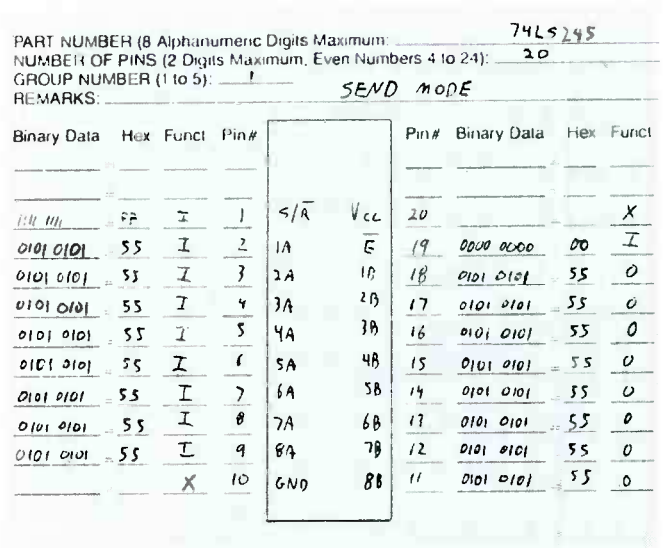


FIG. 10—TEST SETUP FOR A 74LS245 octal bus transceiver in send mode.

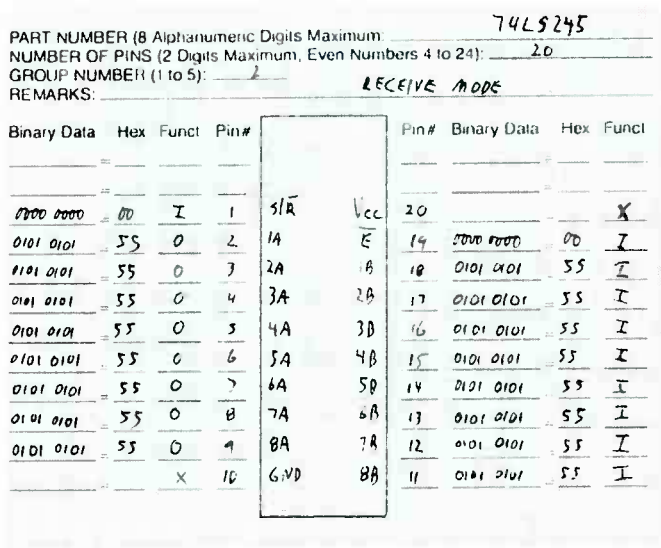


FIG. 11—TEST SETUP FOR A 74LS245 octal bus transceiver in receive mode.

ple, the 74154 4-to-16 line decoder has four address inputs (pins 20–23), two active-low gate inputs (pins 18 and 19), and 16 outputs, one of which goes low when both gate inputs are low, depending on the state of the four address inputs. Figures 14, 15, and 16 show the data required to test the IC completely.

Advanced commands

After generating test data you'll probably want to store it in your desktop computer. The tester provides storage for as many as 105 test routines, which you may upload to and download from the tester's internal memory.

After entering test data, if you wish to store it, press the Store key, and the data will be stored in memory for future use under the part number that is entered with the data.

To load a test routine from the tester's local memory, press Load and then enter the part number. If a corresponding routine is in memory, *CLEAR OR ENTER?* will appear on the display. Press Clr to erase the entry from memory, or press Enter to leave the data in the test buffer for testing or transfer to the external computer. To upload the data, press Send. To download it, press Recv. If you wish to retain a received file, press Store. Use the BASIC programs shown in Listings 1 and 2 to send and receive programs.

Remote data generation

The BASIC program shown in listing 3 can be used to create test patterns somewhat more conveniently than on the tester itself. It is important to note that when using the program to generate test files, only hex characters (0–9, A–F) may be used in the part number (TF$) if the file is to be stored in the Tester's memory. The reason for this is that the Tester's keyboard has no other characters to access the test routine in its memory. Therefore you would not be able to load or delete the test routine. For example, a part entered as 74LS138 would be inaccessible because there is no L or S on the Tester's keyboard.

Usage hints

First a few words of caution. Never connect the test clip to an IC that has power on it unless the tester is on and *COMMAND?* is scrolling in the display. Conversely, never shut the tester off when the clip is connected to a powered IC. And always make sure when testing in-circuit IC's that the tester and the DUT (*D*evice *U*nder *T*est) share a common ground. Connect the black test hook clip to a ground on the board near the IC's to be tested.

The test drivers (IC7–IC15) are rated at 7 volts maximum, so be careful what you connect the test clip to. A powered RS-232 driver might have ±12 volts, or even more, and voltages at those levels

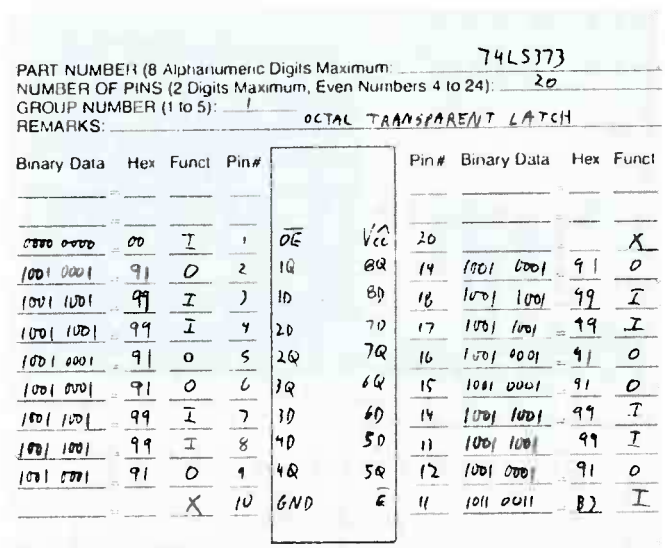


FIG. 12—TEST SETUP FOR A 74LS373 octal transparent data latch. Whenever the enable line (pin 11) is high, each output follows the corresponding input.

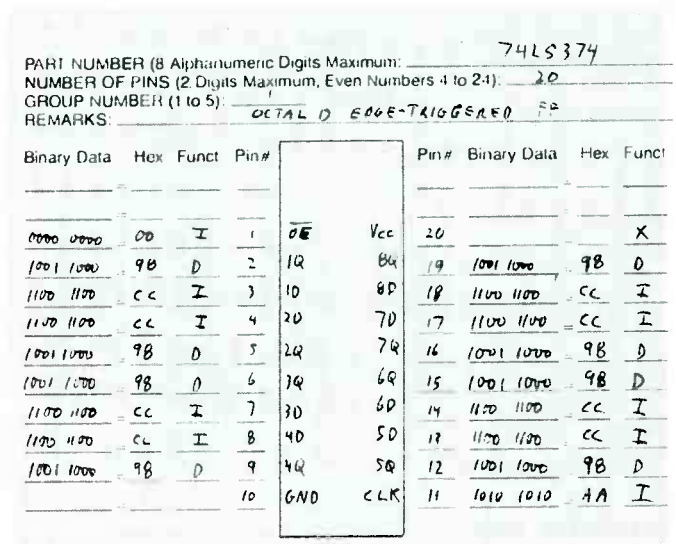


FIG. 13—TEST SETUP FOR A 74LS374 octal D flip-flop. Data on each input is clocked into the corresponding output on the leading edge of each clock pulse. Clock pulses are applied to pin 11.

PART NUMBER (8 Alphanumeric Digits Maximum): 74154
NUMBER OF PINS (2 Digits Maximum, Even Numbers 4 to 24): 24
GROUP NUMBER (1 to 5): 1
REMARKS: 4-TO-16 LINE DECODER

Binary Data	Hex	Funct	Pin#			Pin#	Binary Data	Hex	Funct
1111 0111	F7	0	1	Q0	Vcc	24			X
1110 1111	EF	0	2	Q1	A	23	0101 0111	57	I
1101 1111	DF	0	3	Q2	B	22	0110 0111	67	I
1011 1111	BF	0	4	Q3	C	21	1000 0111	87	I
0111 1111	7F	0	5	Q4	D	20	0000 0111	07	I
1111 1111	FF	0	6	Q5	G2	19	0000 0011	03	I
1111 1111	FF	0	7	Q6	G1	18	0000 1001	05	I
1111 1111	FF	0	8	Q7	Q15	17	1111 1111	FF	0
1111 1111	FF	0	9	Q8	Q14	16	1111 1111	FF	0
1111 1111	FF	0	10	Q9	Q13	15	1111 1111	FF	0
1111 1111	FF	0	11	Q10	Q12	14	1111 1111	FF	0
		X	12	GND	Q11	13	1111 1111	FF	0

FIG. 14—A 74154 demultiplexer has six inputs and 16 outputs, so it requires three test groups to test all combinations. Group 1 is shown here.

PART NUMBER (8 Alphanumeric Digits Maximum): 74154
NUMBER OF PINS (2 Digits Maximum, Even Numbers 4 to 24): 24
GROUP NUMBER (1 to 5): 2
REMARKS: 4-TO-16 LINE DECODER

Binary Data	Hex	Funct	Pin#			Pin#	Binary Data	Hex	Funct
1111 1111	FF	0	1	Q0	Vcc	24			X
1111 1111	FF	0	2	Q1	A	23	0101 0101	55	I
1111 1111	FF	0	3	Q2	B	22	0110 0110	66	I
1111 1111	FF	0	4	Q3	C	21	1000 0111	87	I
1111 1111	FF	0	5	Q4	D	20	1111 1000	F8	I
1111 1110	FE	0	6	Q5	G2	19	0000 0000	00	I
1111 1101	FD	0	7	Q6	G1	18	0000 0000	00	I
1111 1011	FB	0	8	Q7	Q15	17	1111 1111	FF	0
1111 0111	F7	0	9	Q8	Q14	16	1111 1111	FF	0
1110 1111	EF	0	10	Q9	Q13	15	1111 1111	FF	0
1101 1111	DF	0	11	Q10	Q12	14	0111 1111	7F	0
		X	12	GND	Q11	13	1011 1111	BF	0

FIG. 15—GROUP TWO OF THE 74154 TEST set is shown here.

PART NUMBER (8 Alphanumeric Digits Maximum): 74154
NUMBER OF PINS (2 Digits Maximum, Even Numbers 4 to 24): 24
GROUP NUMBER (1 to 5): 3
REMARKS: 4-TO-16 LINE DECODER

Binary Data	Hex	Funct	Pin#			Pin#	Binary Data	Hex	Funct
1111 1111	FF	0	1	Q0	Vcc	24			
1111 1111	FF	0	2	Q1	A	23	1111 1101	FD	I
1111 1111	FF	0	3	Q2	B	22	1111 1110	FE	I
1111 1111	FF	0	4	Q3	C	21	1111 1111	FF	I
1111 1111	FF	0	5	Q4	D	20	1111 1111	FF	I
1111 1111	FF	0	6	Q5	G2	19	1111 1000	F8	I
1111 1111	FF	0	7	Q6	G1	18	1111 1000	F8	I
1111 1111	FF	0	8	Q7	Q15	17	1111 1011	FB	0
1111 1111	FF	0	9	Q8	Q14	16	1111 1101	FD	0
1111 1111	FF	0	10	Q9	Q13	15	1111 1110	FE	0
1111 1111	FF	0	11	Q10	Q12	14	1111 1111	FE	0
1111 1111	FF	X	12	GND	Q11	13	1111 1111	FE	0

FIG. 16—GROUP THREE OF THE 74154 TEST set is shown here.

could damage the drivers easily. The display will probably dim if you inadvertently connect the test clip to an IC incorrectly, or if you have entered test data incorrectly. If the display does become dim, disconnect the test clip and remove power immediately.

In addition to testing IC's both in and out of circuit, the tester can also be used as a simple logic analyzer to test as many as twenty four points in a digital circuit. Simply replace the DIP clip with individual test-hook clips. Some lines would be used as outputs to stimulate the circuit, and others would be used as inputs to read the results. **R-E**

PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.

R1—22,000 ohms
R2—330 ohms
R3–R6—1000 ohms

Capacitors

C1, C8—1000 µF, 16 volts, electrolytic
C2, C4–C7, C9–C17—0.1 µF, 10 volts, ceramic disc
C3—10 µF, 16 volts, electrolytic

Semiconductors

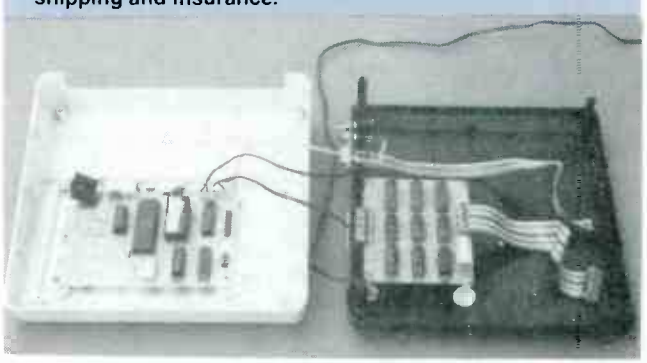
IC1—Z80 microprocessor
IC2—DS1230-104 32K nonvolatile RAM
IC3—MAX233 RS-232 interface
IC4—75499 custom decoder
IC5—75498 custom decoder
IC6—75500 custom decoder
IC7, IC10, IC13—NE591 open-emitter octal driver
IC8, IC11, IC14—NE590 open-collector octal driver
IC9, IC12, IC15—74LS373 octal latch
IC16—7805 5-volt regulator
IC17—2-Mhz crystal oscillator
D1—1N4001 rectifier
DISP1—DL1414 16-segment decoder/driver/display

Other components

F1—1-amp pigtail fuse
J1—9-pin D connector
P1, P2—right-angle double-row 20-pin male header strips
P3—right-angle double-row 26-pin male header strips
S1—minature SPDT toggle switch
S2—momentary SPST pushbutton
S3–S14—momentary SPST keyboard switches
T1—Transformer, 9.5–12-volts, 1-amp, wall-mount

Miscellaneous: One 10-pin, two 20-pin and one 26-pin double-row female IDC header connectors. Two 12-pin single-row female IDC header connectors. Flat ribbon cable and test clips.

Note: The following are available from: ALPHA Electronics Corporation, P.O. Box 1005, Merritt Island, Florida 32952-1005, (305) 453-3534: Kit of parts for $299.00 + $6.00 P&H. Includes all parts, punched and screened panel, case, and labeled keys. Test cable and clips not included. Completely assembled tester for $399.00 + $6.00 P&H. Includes test cable with 16-, 20-, and 24-pin IC test clips. Partial kit, including all IC's (except IC16 and IC17), display, and PC boards for $199.00 + $5.00 P&H. Three custom IC's (75498, 75499 and 75500) for $60.00 + $4.00 P&H. Florida customers please add 5% State sales tax. Canadian customers please add $3.00 additional postage to all orders. All foreign orders add appropriate postage for Air shipping and insurance.



INSIDE THE IC TESTER. Last time we showed you how to build the project; this month we show you how to use it.

IN-CIRCUIT DIGITAL IC TESTER

BILL GREEN

Three BASIC listings, some corrections, and more!

Part 3 DUE TO SPACE LIMitations, we were unable to publish the three BASIC listings mentioned in Part 2 of this series. Those are shown on this page.

Corrections

We have a couple of corrections to the first part of the article (November, 1987). First of all, the end of the third paragraph on page 48 should read, "When installing the test clip on the cable, orient the clip so that the connector on the end of the cable connects to the side of the test clip with pin 1 on it. When using a clip with less than twenty-four pins, align the connectors so that the pins on the right end of the clip—the end furthest from pin 1—are even with the right end of the connectors."

Second, on page 48 the next to last paragraph should read, "For example, ERROR PN01 GRP 1 EXP/RD 0100 would indicate a problem with pin 1 in test group 1: a "1" was expected where a "0" was read.

New kit

Alpha Electronics (P.O. Box 1005, Merritt Island, FL 32952-1005, 305-453-3534) has decided to offer a minimum parts kit for the IC Tester. It includes the PC boards, the nonvolatile RAM with code, and the three custom IC's—75498, 75499, and 75500. The cost is $140.00, postpaid in the U.S.; FL residents must add appropriate sales tax. R-E

LISTING 3

```
000 'THIS PROGRAM (ENTERTST.BAS)
015 'ALLOWS GENERATION OF TEST FILES
020 'ON AN EXTERNAL COMPUTER
025 'FOR TRANSFER TO THE IC TESTER.
030 'by ALPHA Electronics Corporation,
035 'PO Box 1005, Merritt Island, FL. 32952
100 CLS
105 PRINT"ENTER INFORMATION AS PROMPTED FOR GENERATING 'part number.FIL'"
110 DIM A$(256):DIM TF$(8):GRP=1
120 FOR X=1 TO 256:A$(X)="00":NEXT:PRINT 'initialize array to 0
130 PRINT"PART NUMBER MUST BE HEX (0-9, A-F), 8 DIGITS MAX."
140 INPUT"ENTER PART NUMBER ";TF$
150 IF TF$="" OR LEN(TF$)>8 THEN  140
160 IF LEN(TF$)<8 THEN TF$=TF$+"0":GOTO 160 'stretch to 8 digits
170 PRINT"NUMBER OF PINS MUST BE EVEN NUMBER(S) FROM 4 TO 24"
180 INPUT"ENTER NUMBER OF PINS ";NP$
190 IF NP$="" THEN 180:IF LEN(NP$)>2 THEN 180
200 IF LEN(NP$)<2 THEN NP$="0"+NP$ 'stretch to 2 digits
210 NP=VAL(NP$):OFFSET=(24-NP)/2 'offset when less than 24 pins
220 IF NP<4 OR NP>24 THEN 180
230 NP=NP-2:IF NP=0 THEN 250
240 IF NP=-1 THEN 180 ELSE 230
250 NP=VAL(NP$):X=OFFSET+1
260 PRINT"ENTERING DATA FOR GROUP ";GRP:PN=1
270 PRINT"FUNCTION MUST BE I,O,D OR X"
280 PRINT"ENTER FUNCTION OF PIN  ";PN;:INPUT;PF$:PRINT
290 IF PF$="I" THEN A$(X)="02":GOTO 340
300 IF PF$="O" THEN A$(X)="01":GOTO 340
310 IF PF$="D" THEN A$(X)="03":GOTO 340
320 IF PF$="X" THEN A$(X)="F0":PD$="00":GOTO 350
330 GOTO 270
340 PRINT"ENTER HEX DATA FOR PIN ";PN;:INPUT;PD$:PRINT
350 A$(X+24)=PD$
360 X=X+1:PN=PN+1:IF PN<NP+1 GOTO 280
370 GRP=GRP+1:IF GRP=6 THEN 420
380 INPUT"DO YOU WISH TO ENTER ANOTHER GROUP (Y/N) ";Q$
390 IF Q$="N" OR Q$="n" THEN 420
400 IF Q$="Y" OR Q$="y" THEN 410 ELSE 380
410 X=(OFFSET+1)+((GRP-1)*48):CLS:GOTO 260
420 CLS:PRINT"TEST DATA FOR ";TF$;" HAS BEEN ENTERED.  ";
425 PRINT"CREATING FILE ";TF$+".FIL"
430 FOR N=1 TO 8:TF$(N)=MID$(TF$,N,1):NEXT
440 FOR N=1 TO 8:PART$=PART$+"0"+TF$(N):NEXT 'stretch to 16 ASCII digits
450 PINS$="0"+LEFT$(NP$,1)+"0"+RIGHT$(NP$,1) 'stretch to 4 ASCII digits
460 OPEN TF$+".FIL" AS 1 LEN=512
470 FIELD 1, 480 AS B$,16 AS BPART$,4 AS BPINS$,12 AS BFILL$
480 C$=""
490 FOR X=1 TO 240
500 C$=C$+A$(X)
510 NEXT
520 LSET B$=C$
530 LSET BPART$=PART$
540 LSET BPINS$=PINS$
550 LSET BFILL$="000000000000" 'stretch to 512 bytes
560 PUT 1
570 CLOSE
```

LISTING 1

```
010 'THIS PROGRAM (SENDTEST.BAS)
015 'SENDS TEST FILES TO THE IC TESTER
020 'by ALPHA Electronics Corporation,
025 'PO Box 1005, Merritt Island, FL. 32952
100 INPUT"ENTER NAME OF TEST FILE TO SEND ";TF$
110 IF LEN(TF$)<8 THEN TF$=TF$+"0":GOTO 110
120 PRINT"SENDING ";TF$;" TO COM1"
130 OPEN TF$+".FIL" AS 1 LEN=1
140 FIELD 1, 1 AS B$
150 OPEN "COM1:1200,N,8,2,CS3000,BIN" AS 2 LEN=1
160 FIELD 2, 1 AS C$
170 FOR X=1 TO 512
180 GET 1,X
190 LSET C$=B$
200 PUT 2,1
210 NEXT X
220 CLOSE
```

LISTING 2

```
010 'THIS PROGRAM (RECVTEST.BAS) RECEIVES
015 'TEST FILES FROM THE IC TESTER
020 'by ALPHA Electronics Corporation,
025 PO Box 1005, Merritt Island FL. 32952
100 INPUT"ENTER NAME OF TEST FILE TO RECEIVE ";TF$
110 IF LEN(TF$)<8 THEN TF$=TF$+"0":GOTO 110
120 PRINT"RECEIVING ";TF$;" FROM COM1"
130 OPEN TF$+".FIL" AS 1 LEN=1
140 FIELD 1, 1 AS B$
150 OPEN "COM1:1200,N,8,2,CS3000,BIN" AS 2 LEN=1
160 FIELD 2, 1 AS C$
170 FOR X=1 TO 512
180 GET 2,1
190 LSET B$=C$
200 PUT 1,X
210 NEXT X
220 CLOSE
```