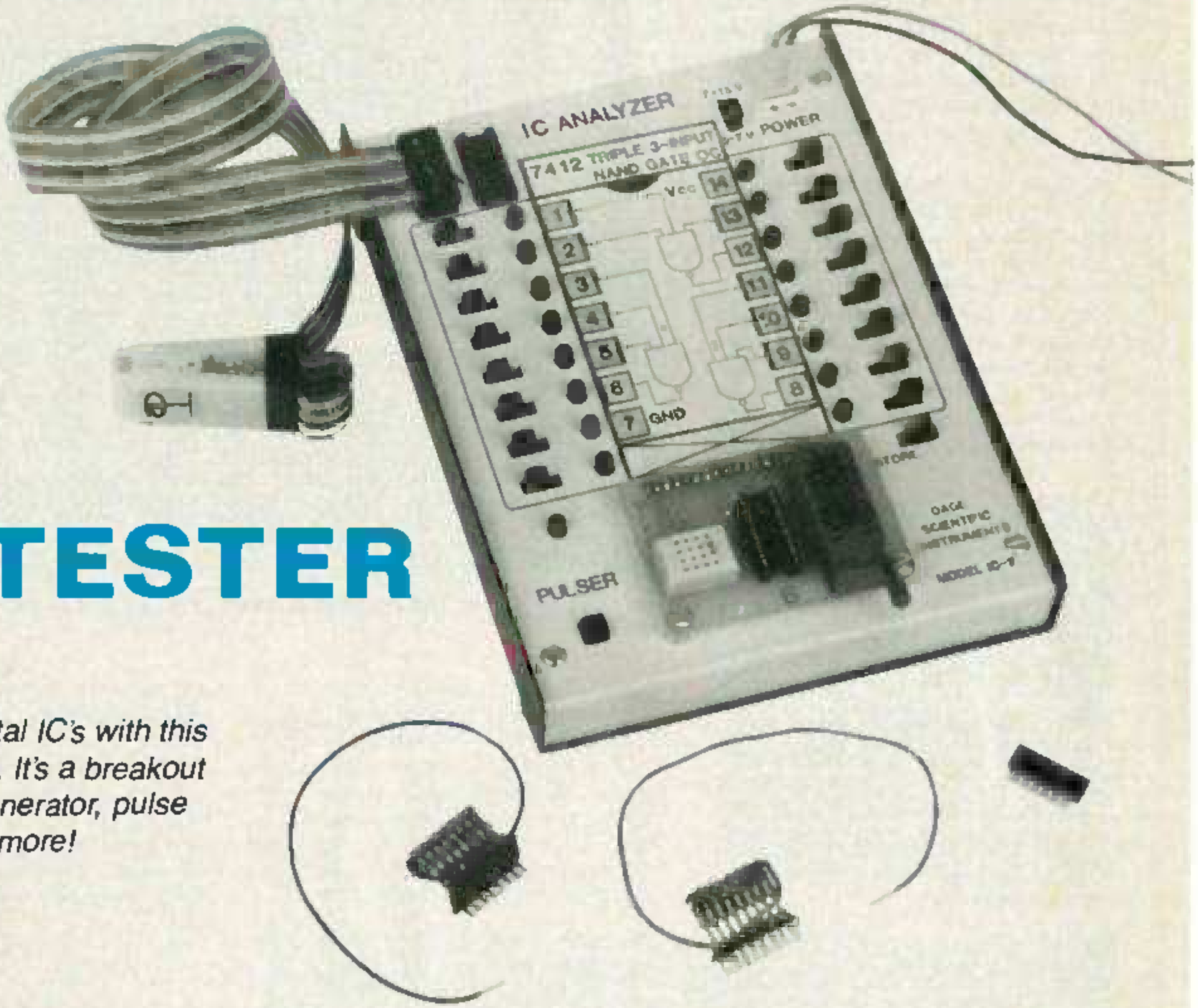


IC TESTER

DAVID H. DAGE

Test your digital IC's with this handy device. It's a breakout box, pulse generator, pulse detector and more!

TESTING DIGITAL CIRCUITS SHOULD BE easy. After all, there are only two voltage levels involved. If the signal isn't high, then it's low. So your voltmeter or oscilloscope should be all that you need, right? How wrong that is! Working with digital circuits requires a whole new generation of test instruments ranging from the indispensable logic probe up to the sophisticated logic analyzers and emulators.

We'll show you how to build a device that's several digital test instruments rolled into one. It's a monitor, breakout box, comparator, pulse generator, and pulse detector. It can be used to troubleshoot digital circuits that contain 14- and 16-pin TTL or CMOS IC's. And it makes a great IC tester and trainer.

To use the analyzer for troubleshooting your digital circuits, you connect the analyzer to the in-circuit IC using ribbon cable and an IC test clip. If the analyzer is being used as a monitor, the logic level of each pin is displayed by an LED right next to a pictorial pinout of the IC. Each pin of the IC is accessible at the analyzer for signal injection or simply for observation. That combination is hard to beat—it's certainly better than tilting your head, holding a databook open with your elbow, and jabbing spasmodically with a logic probe on what may very well be pin 10.

The analyzer gives you a remarkably simple way to troubleshoot an in-circuit IC. You can compare the outputs of the IC operating in-circuit to an IC of the same type that you know to be good. The good IC is inserted in the analyzer, and the power and input pins are connected together using slide switches, while the outputs are compared using EXCLUSIVE OR (XOR) gates. If the LED's remain off, the in-circuit IC is good. It's as simple as that.

The analyzer can also be used to check IC's before installation. Slide switches are used to set logic levels on appropriate pins, while the built-in pulse generator is used to inject single or multiple pulses.

A look at the circuit

The IC analyzer is made up of four main parts: the power feed, a pulse generator, a pulse stretcher, and a set of 16 pin-monitor circuits. To explain the circuit operation as clearly as possible, we will discuss those sections separately.

The schematic of the power feed is shown in Fig. 1. When testing in-circuit IC's, the analyzer gets it power from the circuit under test, through socket SO6. If that input voltage is higher than seven volts, S18 must be switched to supply 5

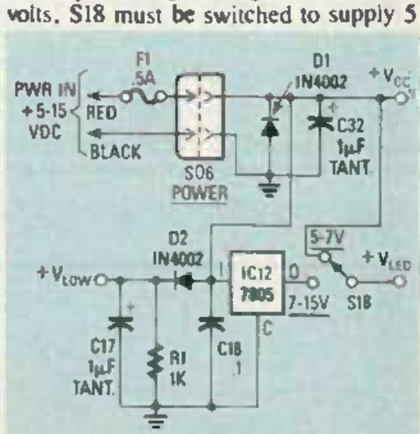


FIG. 1—A POWER-DISTRIBUTION CIRCUIT is used so that the LED's can have their own supply voltage if necessary.

volts to the LED's. Otherwise, the current through them will be too high.

Supply voltage V_{LOW} is 0.8 volt less than V_{CC} and powers the XOR gates and the flip-flops used for the individual pin-monitor circuits. The voltage is derived through D2 and is filtered by C17. This provides a high threshold voltage of 2.1 volts during 5-volt operation (which is necessary for TTL). The rest of the circuits operate between 5 and 15 volts DC.

A block diagram of the pin-monitor logic is shown in Fig. 2, while the schematic is shown in Fig. 3. Since the analyzer can be used to examine 16-pin IC's, it must contain 16 pin-monitor circuits. Instead of showing the circuit 16 times, we have shown it once and have used lettered subscripts. Although that is different from what we normally do in **Radio-Electronics**, it should serve to make the circuit clearer. When referring to those parts, we'll use an "N" subscript. In Fig. 3, of course, N = 1. (Since the XOR gate and S-R flip-flop are *sections* of IC's, we couldn't do that. So we'll mention here that the XOR gates in the pin-monitor circuits are contained in IC1, IC2, IC5, and IC6, while the S-R flip-flops are contained in IC3, IC4, IC7, and IC8.) Just keep it in mind when you go through the Parts List.

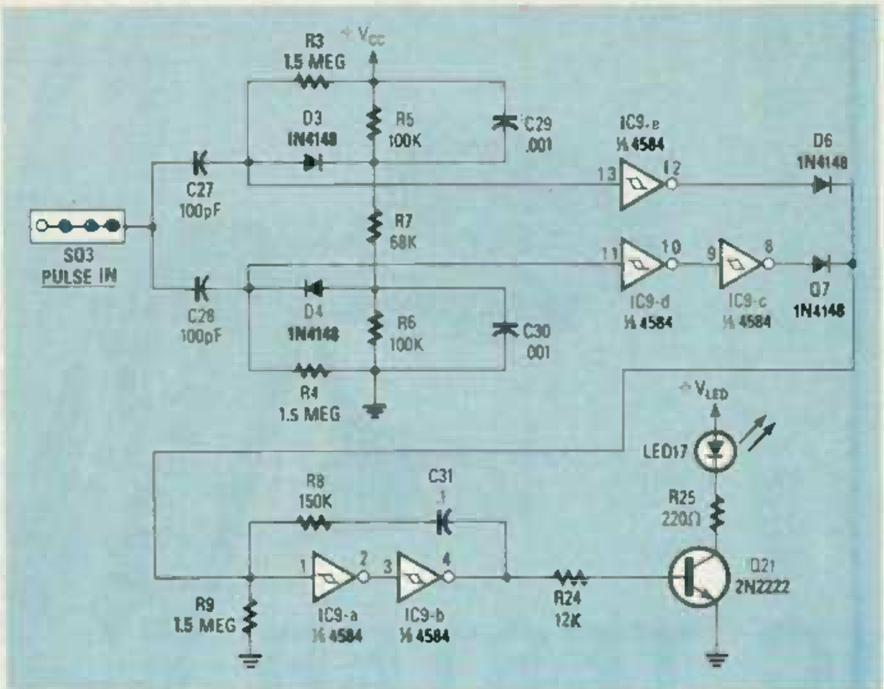


FIG. 5—SCHEMATIC OF THE PULSE STRETCHER. LED17 will light on both positive and negative transitions.

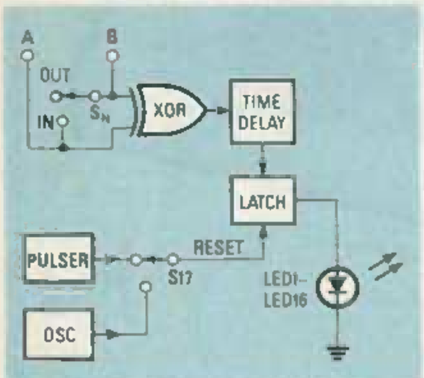


FIG. 2—THE PIN-MONITOR CIRCUIT is shown here in a block diagram.

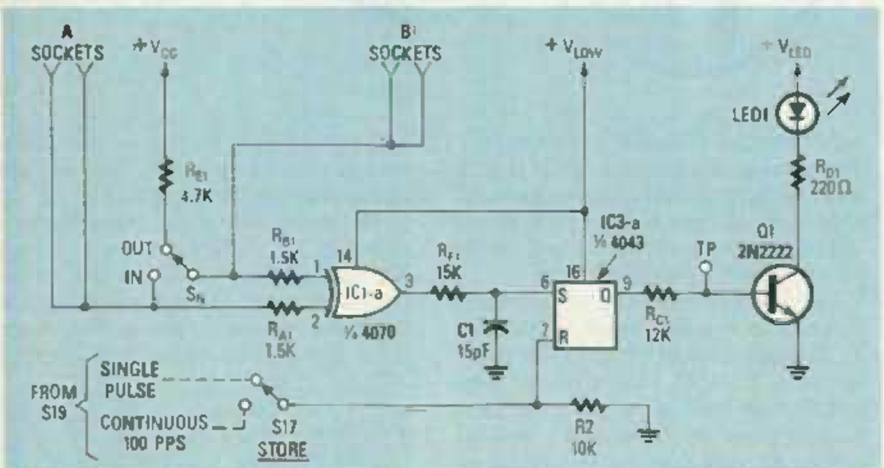


FIG. 3—SCHEMATIC OF THE PIN MONITOR CIRCUIT. Note that because this circuit is repeated 16 times in the analyzer, the part numbers use lettered subscripts.

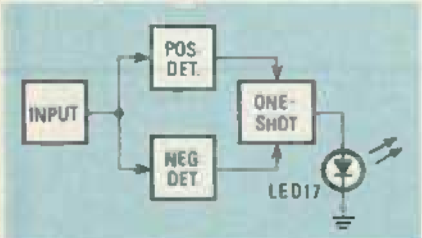


FIG. 4—THE PULSE STRETCHER block diagram.

When switch S_N is in the OUT position, the logic level on pin A_N is compared with logic level on pin B_N by the EXCLUSIVE OR gate. If the two levels are different, the high output will set a 4043 flip-flop. Pulses less than 800 ns are considered glitches and are filtered out by R_{FN} and C_N.

A high output from the 4043 flip-flop will turn on transistor Q_N, and thus the LED. Resistors R_{AN} and R_{BN} isolate and protect the analyzer circuits while R_{CN} and R_{DN} limit current flow.

When switch S17 is in the STORE position, the flip-flop can be reset manually using the PULSER switch, S19. When S17 is not in the STORE position, the flip-flop is continually reset by a 100-pps pulse train.

Placing S_N to the IN position, connects pin A_N to pin B_N, so that an in-circuit IC can be compared to an out-of-circuit test IC.

The analyzer has a built in *pulse stretcher* and *pulse generator*. Both of those functions can be connected independently to any pin on the IC under test. The pulse stretcher will allow a single pulse or a fast pulse train can be caught and displayed on a separate LED. It is highly sensitive to true logic changes but is immune to low-level noise.

A block diagram of the pulse stretcher is shown in Fig. 4, and its schematic is shown in Fig. 5. As you can see, it uses five of the Schmitt-trigger inverters of IC9. The DC level on the input pins 13 and 11 of that IC is held midway between the switching point by R3 through R7, and diodes D3 and D4.

A negative transition discharges C27 and pulls pin 13 low. The capacitor is then charged through R3 until D3 conducts. The time constant of R3 and C27 coupled to the Schmitt trigger, produces a positive pulse of sufficient duration to then trigger the monostable flip-flop made up of R8, R9, C31 and two inverters, IC9-a and IC9-b. When triggered, output from pin 4 of IC9 will go and remain high for approx-

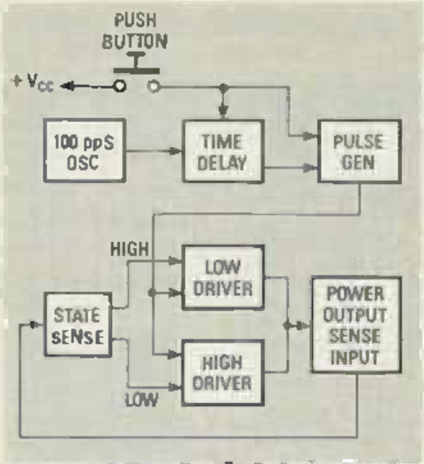


FIG. 6—THE PULSE GENERATOR block diagram.

imately 50 ms. This output drives the LED17.

Positive transitions charge C28 and pulls pin 11 of IC9 high. An output blink of LED17 is produced in a similar fashion. Capacitors C29 and C30 hold the midway reference voltage constant, while diodes D6 and D7 isolate the two outputs from pin 8 and pin 12 of IC9.

The pulse generator can be used to change the logic level voltage to the opposite state for a short time, overriding any logic output that is in control. Injecting pulse(s) to stimulate digital circuitry is indispensable for troubleshooting. The duration of the pulse is so short that no damage is done to the output device. The pulse output can be either a single pulse or a 100 pps (*Pulse-Per-Second*) pulse train.

A block diagram of the pulse generator is shown in Fig. 6, while its schematic is shown in Fig. 7. The logic level of the external circuit is sensed through R16, and is fed to the DATA input of flip-flop IC10-b. When switch S19 is pushed, a single positive pulse is generated by C19 and R13, setting flip-flop IC10-a.

A multivibrator that generates a 100-pps squarewave is made up of R10, C21, and IC9-f, a Schmitt-trigger inverter. The squarewave is fed to AND gate IC11-c. If S19 is held closed, C20 charges thru R12 and, after about 2 seconds, turns on IC11-c. That allows flip-flop IC10-a to be clocked as long as S19 is pushed. When S19 is released, C20 rapidly discharges thru D5 and R11. Flip-flop IC10-a resets

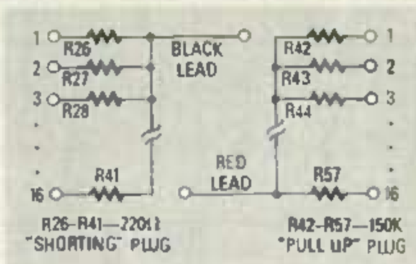


FIG. 8—THE PULL-UP AND SHORTING PLUGS are shown here schematically.

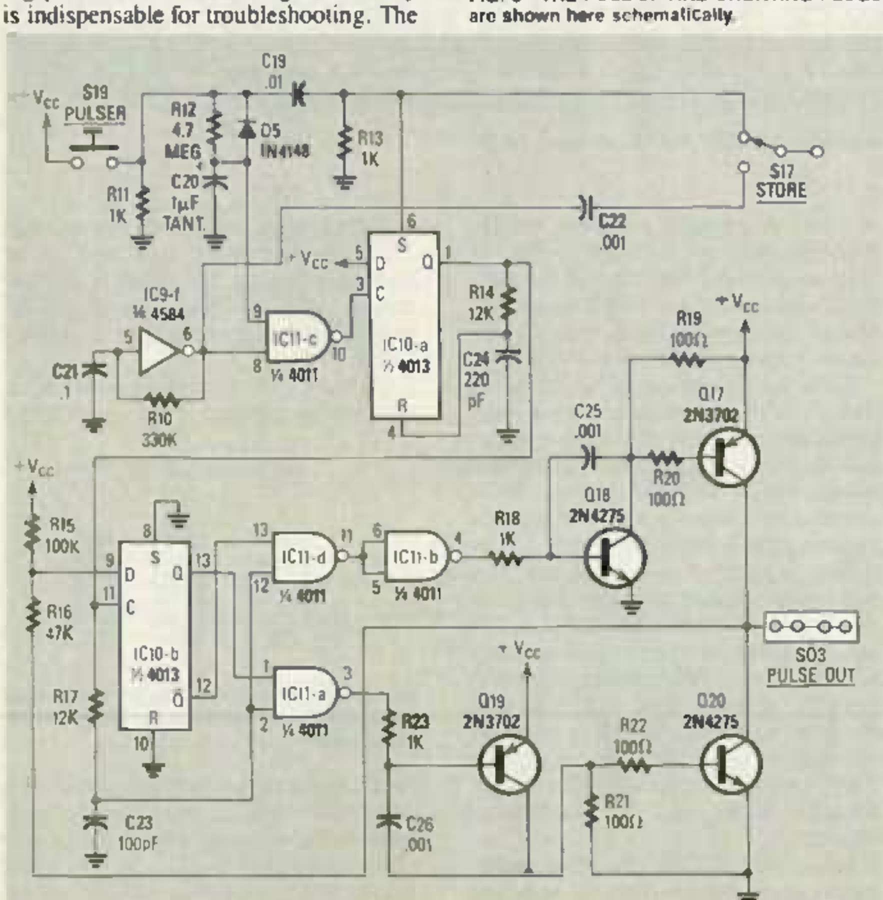


FIG. 7—SCHEMATIC OF THE PULSE GENERATOR. The generator's output is sent to the solderless breadboard socket.

PARTS LIST

All resistors ¼-watt, 5%

R_{A1}–R_{A16}, R_{B1}–R_{B16}—1500 ohms
R_{C1}–R_{C16}—12,000 ohms
R_{D1}–R_{D16}—220 ohms
R_{E1}–R_{E16}—4700 ohms
R_{F1}–R_{F16}—15,000 ohms
R1, R11, R13, R18, R23—1000 ohms
R2—10,000 ohms
R3, R4, R9—1.5 megohms
R5, R6, R15—100,000 ohms
R7—68,000 ohms
R8, R42–R57—150,000 ohms
R10—330,000 ohms
R12—4.7 megohms
R14, R17, R24—12,000 ohms
R16—47,000 ohms
R17—12,000 ohms
R19–R22—100 ohms
R25, R26–R41—220 ohms

Capacitors

C_{A1}–C_{A16}—15 pF, ceramic disc
C17, C20, C32—1.0 μF, 25 volts, tantalum
C18, C21, C31—0.1 ceramic disc
C19—0.01 ceramic disc
C22, C25-C26, C29, C30—0.001 μF, ceramic disc
C23, C27, C28—100 pF ceramic disc
C24—220 pF polystyrene

Semiconductors

IC1, IC2, IC5, IC6—4070 quad EXCLUSIVE OR gate
IC3-IC4, IC7, IC8—4043 quad 3-state latches
IC9—4584 Hex Schmitt trigger inverters
IC10—4013 dual D-type flip-flop
IC11—4011 quad NAND gate
IC12—7805 5-volt regulator (TO-220 case)
Q1–Q16, Q21—2N2222
Q17, Q19—2N3702
Q18, Q20—2N4275
D1, D2—1N4002
D3–D7—1N4148
LED1–LED17—standard red LED

Other components

S1-S18—SPDT slide switches
S19—Pushbutton switch, normally open
SO1, SO2, SO4—wirewrap type, 16-pin DIP sockets
SO3—Solderless breadboard strip (4 × 4)
SO5—ZIF socket
SO6—2-pin power connector
SO7—20-pin single-row female header

Miscellaneous: Main PC board; B-socket PC board; IC sockets, cabinet, DIP headers for plugs, etc.

The following are available from Dage Scientific Instruments, P.O. Box 144, Valley Springs, CA 95252: Plated-thru PC boards, IC pin-out cards and detailed instructions (order number IC-18), $30.00 plus $2.00 shipping. Complete kit of parts less chassis, DIP-clip cable, and sockets (order number IC-20), $79.95 plus $3.00 shipping. Complete kit, includes assembled dip-clip cable, zero insertion force socket, even solder (order number IC-22), $119.00 plus $4.00 shipping. California residents please add sales tax. Countries other than U.S.A. and Canada, please add $8.00.

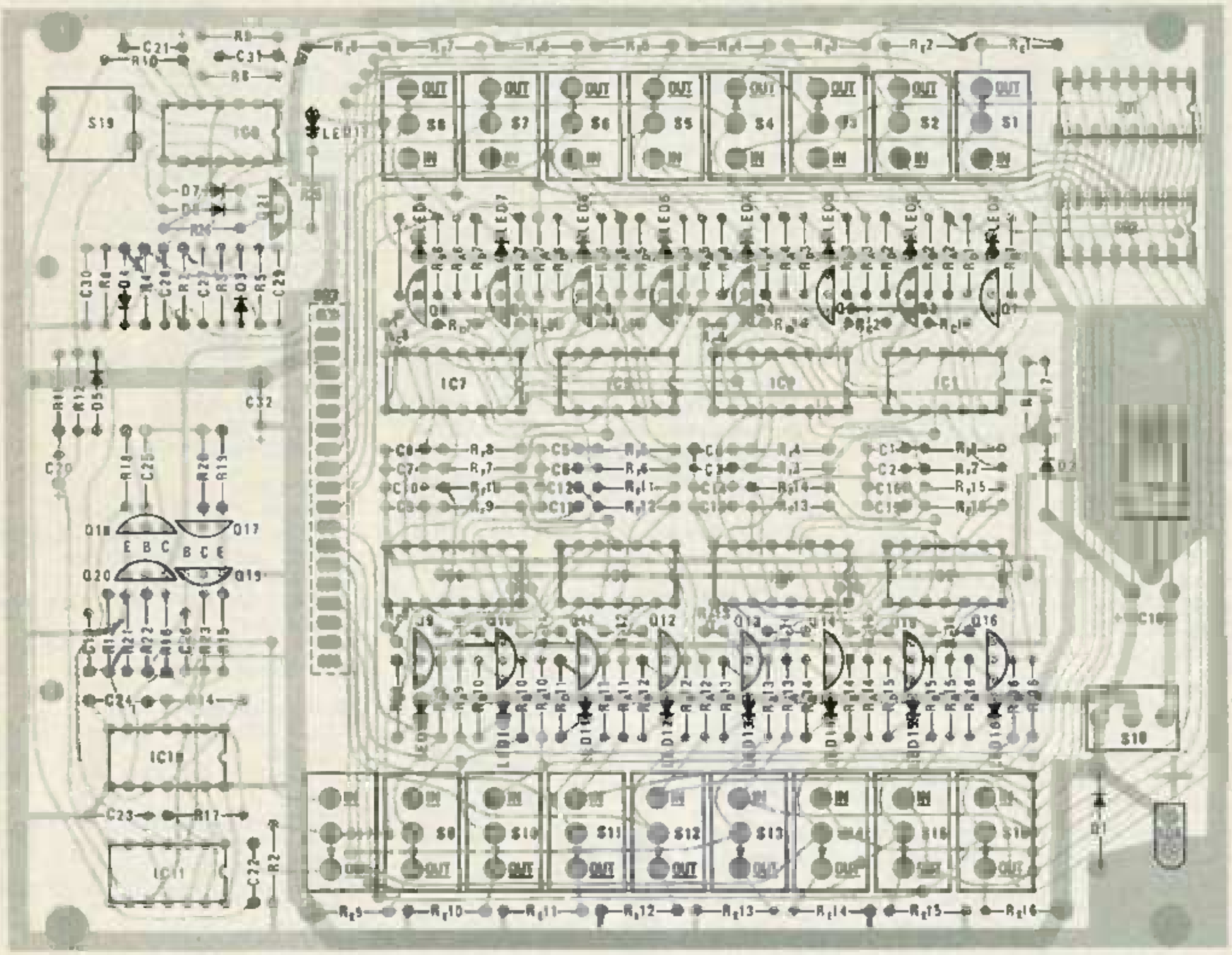


FIG. 9—PARTS PLACEMENT DIAGRAM FOR THE MAIN BOARD. Note SO7, the connection to the B-socket board.

itself by R14 and C24 producing a positive pulse of a few microseconds. That positive pulse latches the external circuit level sensed by IC10-b and, after a slight delay produced by R17 and C23, drives NAND gates IC11-a and IC11-d

If the external circuit is high, the Q output of IC10-b will be high allowing IC11-a to turn on the negative-drive circuit containing Q19 and Q20. Conversely, if the external circuit is low, $\overline{Q}$ will be high which will turn on gates IC11-d and IC11-b, and then the positive drive circuits containing Q17 and Q18.

The final part of the analyzer's circuit are two plugs, each of which contains 16 identical resistors mounted on a header with all resistors connected to a common lead. The "shorting" plug uses 220 ohm resistors while the "pull-up" plug uses 150K resistors. The schematics of the plugs are shown in Fig. 8.

Building the IC analyzer

The easiest way to build the analyzer is to use printed-circuit boards. See our new "PC Service" section starting on page 81 for foil patterns for a double sided board. A parts-placement diagram for the 5×6½-inch board is shown in Fig. 9. That main board contains all the analyzer's active circuitry. (We'll also need a second board, called the B-socket board, but we're getting ahead of ourselves.)

In the author's prototype, the 18 IN/OUT slide switches determined the front panel height above this board. Mount a switch and measure this distance. For the unit shown, the distance is 0.35 inch. Make sure that all components that are not suppose to extend above the panel, are installed no higher than the switches. This will require careful assembly and selection of parts. Keep in mind, however, that you can mount switches to the front panel and use point-to-point wiring to connect them to the board. That will make your component sizes less critical. A cover for the analyzer is not absolutely necessary, but you must find some way to protect the circuitry from shorts or mechanical damage.

Install the 17 LED's first. They should extend above the panel by ⅛ inch, and their height should be as even as possible. That can be accomplished by making a mounting jig. A simple strip of aluminum 3¼ inches long and ¼ inch high can be placed between the LED leads before soldering. After soldering, the strip is removed, leaving the LED's at a uniform height.

The two "A" sockets, SO1 and SO2, must also be installed about ¼ inch above

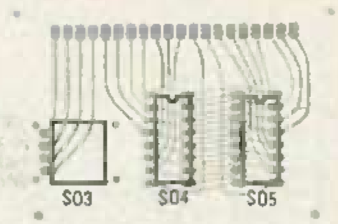


FIG. 10—THE B-SOCKET BOARD parts placement. Note that SO3 is a small solderless breadboard socket.

the PC board so that they protrude about ⅛ inch above the panel. Wire wrap IC sockets have the necessary pin length for such above-board mounting. Excess pin length should be trimmed even with the bottom side of the board.

continued on page 101

IC TESTER

continued from page 62

All of the resistors are mounted horizontally on 0.4-inch centers except for R_{C1} to R_{C16}. Mount those resistors vertically with the resistor body down and the bare lead toward the top of the board. (The bare lead will be used as a test point for checking the LED circuitry.) Be sure that the resistors do not extend high enough to touch the top panel when installed. The finished PC board should look something like that shown in Fig. 9.

A second PC board, the B-socket board, contains a small solderless breadboard socket (SO3), a standard 16 pin DIP socket (SO4), and a zero-insertion-force or ZIF socket (SO5). It sits above the main board and the cabinet top and mates to the

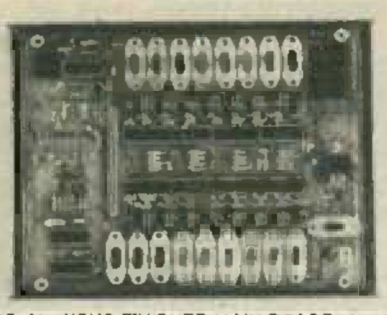


FIG. 11—YOUR FINISHED MAIN BOARD should look like this before you install a top cover.

main board with a 20-pin connector. The foil patterns for that double-sided board are shown in our special "PC Service" section, and the parts-placement diagram is shown in Fig. 10.

The 16-pin resistor plugs can be assembled by using a standard 16 pin header as shown in Fig. 11. The common connection can be made with a tiny PC board or simply by tying the leads together. The shorting plug uses 220-ohm resistors while the pull-up plug uses 150K resistors.

Power is supplied from the circuit under test using a 2-pin connector with leads, mini clips and an in-line fuse. Connection to the IC under test is via an IC test clip, which we'll call a DIP clip. The plugs, DIP clip, and power connector are shown in Fig. 11.

Circuit checkout

Before applying power, check over the entire assembly for solder bridging, poor solder connections or missing solder points. Verify that all 11 DIP IC's are oriented with pin 1 up toward the top of the board. Check all LED's and transistors for polarity, and correct any mistakes now.

Mount the main PC board on the bottom chassis, but don't install the top cover until we're done testing. Plug the small PC board into the main board (through SO6) and place all of the IN/OUT slide switches to the OUT position (toward the outside). Put the power switch in the 5–7-volt position and apply 5 volts from a regulated external DC source.

To check the pulse detector, connect a 1K resistor between the pulse input (PULSE IN) and V_{CC} on the solderless connector, SO3. Short PULSE IN to ground with a wire lead. The pulser LED must blink each time the short is made or broken. That verifies that either a rising or falling edge will trigger the pulse detector. Remove the resistor and lead.

Immediately to the left of the solderless connector is IC9. Connect pin 6, a square wave output, to PULSE IN using a short piece of wire. The pulser LED should pulse on and off rapidly. Remove the wire. If you have a pulse generator, feed a 25-ns pulse to PULSE IN. The pulser LED should blink for each pulse. Do that with both positive- and negative-going pulses.

To check the output pulser, use a short length of wire to connect PULSE OUT to PULSE IN on the solderless connector. Then connect a 22-ohm resistor from PULSE OUT to V_{CC}. When you momentarily press the pulser button, the pulser LED (LED17) should blink. Next, connect the 22-ohm resistor from PULSE OUT to ground. Once that is done, when you momentarily press the pulser button, the LED17 should blink. Depress and hold the pulser button again. In about 2 seconds the pulser LED should start and keep pulsing on as long as the button is depressed. Remove jumper and resistor.

To check the individual pin logic, insert the 220-ohm shorting plug into one of the A sockets (SO1 or SO2) and connect its common lead to ground. Place the STORE switch to the not-stored position, and cycle each of the individual pin slide switches to verify that the corresponding LED is on when the switch is in the OUT position and off when in the IN position. If an LED does not perform properly, a simple check can determine if the LED and drive transistor are working.

The test is done as follows. To turn off the LED, connect one end of a 1K resistor to ground. With a clip lead or jumper wire, connect the free end of the resistor to the top of R_{CN}. (R_{CN} is the vertically mounted resistor; there's one for each pin). To turn on an LED, connect one end of a 1K resistor to V_{CC} and repeat the above.

To check the STORE function, place the STORE switch to the STORE position. Turn each LED on by placing its switch to the OUT position, then place all IC switches to the IN position. The LED's should remain on until either the store switch is moved "out" or the pulser is pulsed.

Do not continue if the analyzer is not operating as described. Correct any problems before you go on. Next time, we'll see how to use the analyzer. R-E

DIGITAL IC's

continued from page 80

Other shift registers

A recirculating shift register is a special type of shift register whose output is fed back to its input. A block diagram of such a circuit is shown in Fig. 11.

In that circuit, as data is clocked out of the serial output, it is re-entered into the register via the serial input. The result is that after every n + 1 clock pulses, where n is the number of stages, or "bits", in the register, the contents of the register is reset to its original state.

One application for that type of shift register is in a digital storage oscilloscope; a block diagram of such a device is shown in Fig. 12. In such a scope, the analog input is converted to digital form by the A/D converter and then stored in the shift register. The section of that register denoted as the "cache" is four to eight bytes of parallel data that are used to update the stored waveform. The serial output of the register is re-converted to analog form by the D/A converter for display on the scope's CRT, and also fed back to the register's input for reinsertion.

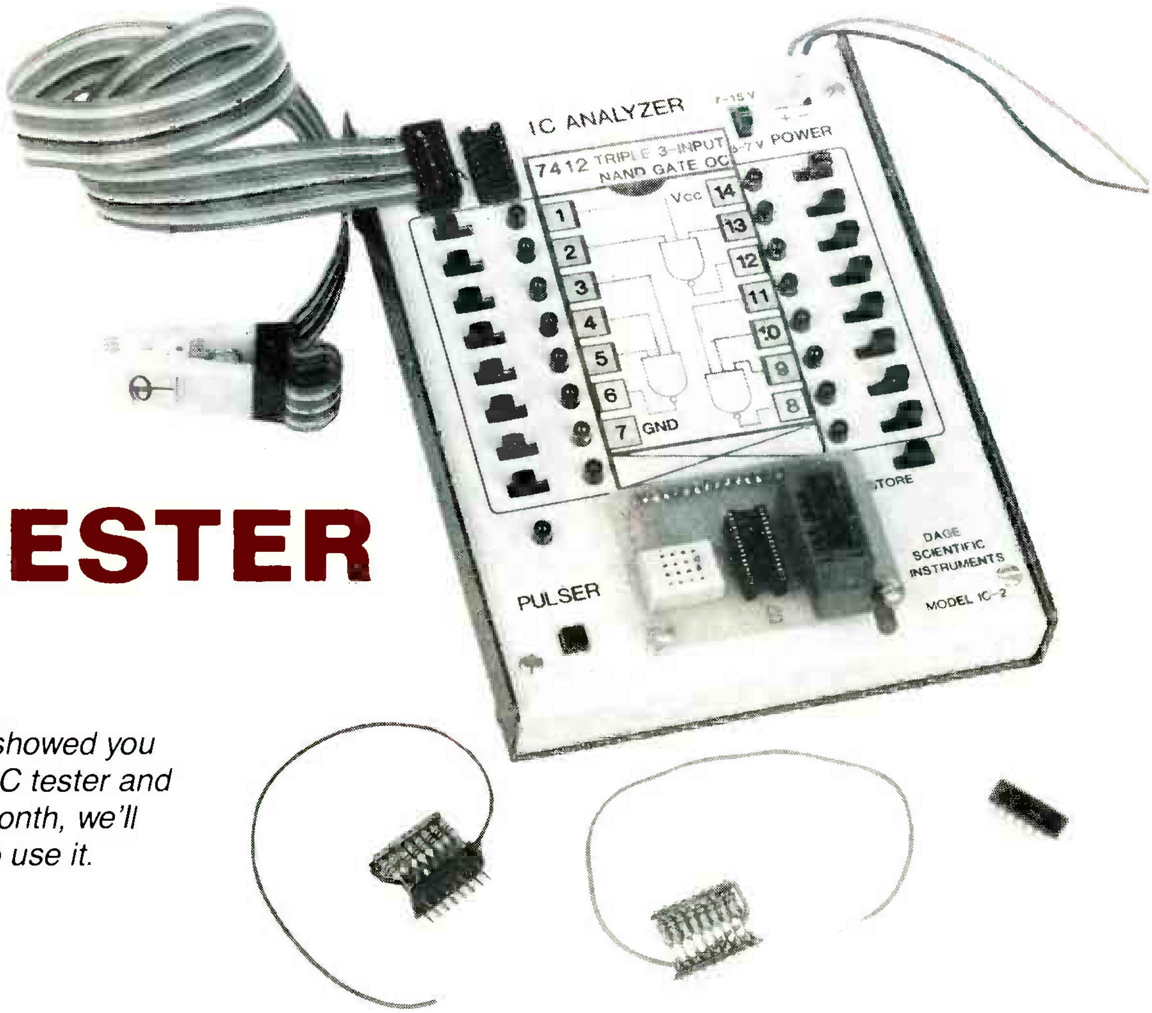
Figure 13 shows a bucket brigade device, or stepper; the timing diagram for that circuit is shown in Fig. 14. That circuit is an electronic version of the electromechanical stepper, where a voltage is applied sequentially to a series of contacts.

In that type of shift register, J-K flip-flops are connected so that the J inputs are always high and the K inputs are always low. In that state, the Q outputs of each flip-flop are usually high. However, if a reset pulse is applied, it will force the Q output of the first stage low. As shown in Fig. 14, that low will be passed, in "bucket-brigade" fashion, to each succeeding stage of the register on negative-going transitions of the clock signal.

Figure 15 shows a pseudo-random sequencer. The output of that circuit is a pseudo-random signal (i.e., noise). Such a signal can be used to test a variety of equipment, such as audio amplifiers and radio receivers.

The pseudo-random sequencer can output $2^n - 1$ (where n is the number of stages in the device) different states. The particular state output on a given clock pulse appears to be random. We say "appears" because the outputs do repeat in a sequential manner; however, that sequence is not apparent over a "short" period of time. (Short is a relative term; a 64 stage pseudo-random sequencer will repeat only after $2^{64} - 1$, or 1.84467×10^{19}, clock pulses.)

Next time, we will look at another circuit in which flip-flops are used—the counter. R-E



IC TESTER

DAVID H. DAGE

Last month, we showed you how to build an IC tester and analyzer. This month, we'll show you how to use it.

Part 2

WHEN WE LEFT OFF last month, we had put the IC analyzer or tester together and had just finished checking its various functions. This month, we'll show you how to put the tester to work. Before we get started, we should mention that the foil pattern for the solder side of the main board was not shown in the "PC Service" section because of space restrictions. It does, however, appear this month. (See page 83)

IC pinout cards

When using the IC analyzer as a monitor or tester, you must know how the IC is supposed to function, i.e., how the input pins affect the output pins. The IC pinout cards supply that information.

While the pinout cards cannot supply all the information that you would expect to find on data sheets, they can come surprisingly close. For example, see Fig. 12-*a*, which shows the pinout card for a 7400 quad NAND gate. To use the IC tester in its comparator mode, set each switch either IN (for an input) or OUT (for an output). Setting up the analyzer can be done quickly and easily if each pin on the card is marked appropriately.

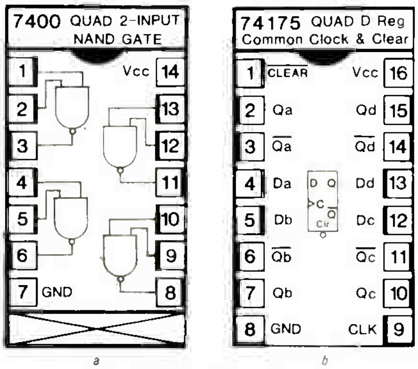


FIG. 12—THE PINOUT CARDS should contain as much information as possible.

A set of pinout cards for the 74xx series of ICs is available from the source mentioned in the Parts List. If you make up your own set, you'll want to include on the cards an easy way to distinguish between inputs and outputs. Our convention is to mark inputs with a bold line toward the inside of the card, and outputs with a bold line toward the edge. You'll also want to indicate which inputs and outputs are numerically weighted, etc.

To monitor and check an IC, we need to know how its inputs affect its outputs. For the most part, that information will be obtained from reading the IC cards, and using a little prior knowledge. The 7400 card is an example of simple gates shown in symbols. Prior knowledge of gate operation is necessary in order to know that when pins 1 and 2 are high, the output at pin 3 will be low.

As another example, look at the 74175 quad D flip-flop with common clock and clear shown in Fig. 12-*b*. You may already know that a D-type flip-flop stores the data on its D input when clocked and that it may be preset (set) or cleared (reset). The data stored is available at the Q output, and it's complement is available at the $\overline{Q}$ output. The 74175 flip-flop can be cleared, but no preset is available. To clear the flip-flop, a low level signal is required (as indicated by the tiny circle). The flip-flop is clocked with a rising edge.

The title "quad D flip-flop with common clock and clear" indicates that there are four separate flip-flops that are clocked and cleared together. The four inputs, the four true outputs, and the four complimented outputs are designated with subscripts a, b, c, and d.

Putting all that together in words and using the pin designations on the card we have: data on pins 4, 5, 12, and 13 will be stored when pin 9 (clock) goes high providing pin 1 is high and remains high. This data will be present on pins 2, 7, 10, 15 and its compliment on pins 3, 6, 11, 14 respectively. After pin 1 goes low, outputs on pins 2, 7, 10, and 15 will go low and pins 3, 6, 11 and 14 will go high.

Using the analyzer

The IC analyzer requires an external source of between 5 and 15 volts DC. It draws approximately 300 mA with all LED's lit. If possible, you should power the analyzer from the circuit under test. For safety's sake, first connect the power cable to the circuit, and then measure the voltage magnitude and polarity at the cable connector. Place the power switch to the proper range, and only then connect the cable to the analyzer.

If the external circuit cannot supply the 300 mA needed, you'll have to use a separate power source. If you do that, *it is important that the two supplies have a common ground (or that the individual grounds remain within 1/2 volt of each other).*

The pinout card corresponding to the IC under test should be inserted in the analyzer, and all switches should be initially in the OUT position, as shown in Fig. 13. However, if you're testing 14-pin IC's, you may want to switch the two bottom (unused) switches to the IN position so that the LED's will stay off and won't be distracting.

The DISPLAY STORE switch should also be left in the OUT (not stored) position until needed. When installing IC's or the DIP clip, always orient pin 1 correctly. Pin 1 is always at the top left—even when installing 14 pin devices.

Be aware of the voltages present on an in-circuit IC before connecting the DIP clip. Many IC's operate as input or output buffers and their pins may not be at logic voltage levels. Any IC with open-collector outputs should be suspect. Remember to orient the DIP clip to pin one.

Using the pulse stretcher

Connection to the pulse stretcher is made at the second row of SO3, the solderless breadboard. Any transition from high to low (or low to high) greater than 20 ns will cause the pulse-stretcher LED to

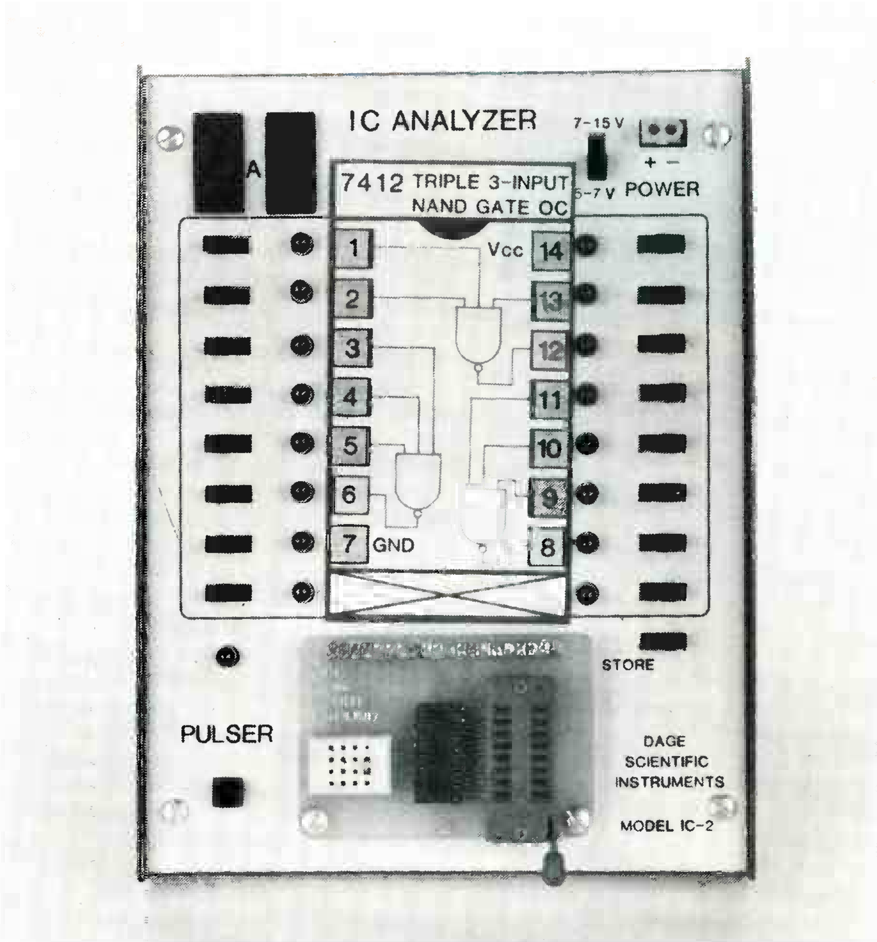


FIG. 13—WHEN THE PINOUT CARD is mounted on the front panel, the function of each switch becomes apparent. And since each IC has its own card, no numbering confusion exists between 14 and 16 pin IC's.

blink on for about 50 ms. Rapid pulse activity below 50 MHz will cause the LED to blink continually. Connecting the pulse stretcher to an in-circuit IC is usually made by connecting the IC to one of the A sockets (using the DIP clip) and connecting the pulse stretcher input from socket B to socket A using an 8-inch length of 24-gauge solid wire stripped at both ends.

The pulser

The pulser or pulse generator is accessed at the third row of the solderless connector, SO3, and it can be connected to an in-circuit IC in the same manner as described for the pulse stretcher. The pulse generator senses the external logic level, and when the PULSER pushbutton (S19) is pressed, it will drive the circuit to the opposite state. If S19 is held closed for more than 2 seconds, the generator will deliver a 100-pps pulse train as shown in the oscilloscope photograph of Fig. 14.

Let's see how we would use the pulse generator to troubleshoot the circuit shown in Fig. 15. Suppose we want to verify that the AND gate IC1-a is operating properly, and suppose that an initial check shows that pin 2 is high and pin 1 is low. In order to see if the gate is operating correctly, we have to override the low level output from IC1-c. The pulse generator output is connected to pin 1 of IC1-a and is activated. If the circuit is operating properly, pin 3 should change state. If it doesn't, both pin 1 and pin 3 must be monitored.

If pin 1 is shorted to ground (and therefore cannot be pulsed), monitoring pin 3 is useless. So let's assume at this point that pin 1 did go high when pulsed, but pin 3 stayed low. One of the internal components of the gate could be faulty, holding pin 3 low. Let's label this a "logic short," which is typically several ohms. Pin 3, on the other hand, could be shorted externally by a solder bridge or an unetched PC trace. Let's label this kind of a short as a "hard short," which is typically less than an ohm.

The pulser can change the level of a logic short but not of a hard short. If you verify that pin 1 pulsed high but pin 3 did

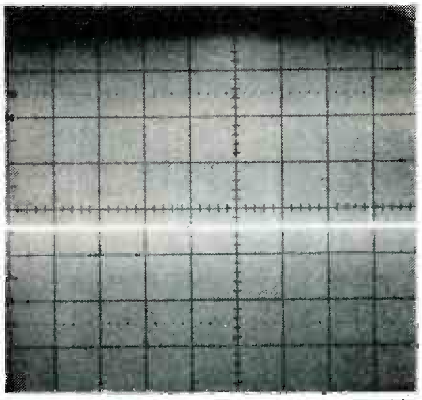


FIG. 14—THE PULSER OUTPUT is shown on this oscilloscope photograph. (Courtesy Tektronix.)

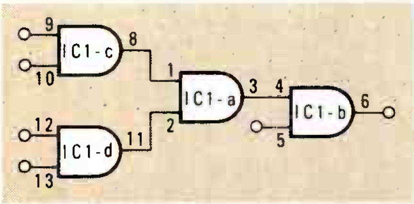


FIG. 15—TROUBLESHOOTING THIS CIRCUIT is easy using the IC tester.

not, the pulser should then be connected to pin 3 and pulsed. If pin 3 can't be pulsed with the pulse generator, look for an external short first before replacing gate A. By using the pulse generator in this manner it is possible to distinguish between logic shorts and hard-wire shorts.

While hard shorts can occur in IC devices, they are not as common as logic shorts. To complicate matters, shorts may exist between inputs (pin 1 and 2), between outputs, outputs to inputs, and circuits shown here to circuits on the other side of a schematic. When using the pulse generator along with the monitor, observe any input or output that changes.

If both pins 1 and 2 are low, they could be connected together and pulsed. The pulse generator has plenty of power to pulse several inputs at once. By tying pins 1 and 2 together, output pins 8 and 11 are also tied together. Should pin 11 change state, it would be shorted through output pin 8. Diodes can be used to pulse more than one input while maintaining output isolation. Use diodes with a low forward drop, such as germanium or Schottky diodes.

Using the in-circuit monitor

To use the IC analyzer as an in-circuit monitor, it should be set up as follows:

- Connect power from circuit under test (or a separate supply)
- Connect jumper cable to socket "A".
- Connect shorting plug to socket "B" and ground at solderless connector.
- Place all IC switches, including the DISPLAY STORE switch, to the OUT position.

Select the appropriate IC card, insert it into the IC analyzer, and connect the DIP clip to the in-circuit IC. If an LED is off, then the corresponding pin is at a low logic level. If the LED is on, then the pin is either at a high logic level or it is pulsing rapidly. A blinking LED indicates slow pulse activity.

The A sockets (SO1 or SO2) are directly connected to the IC under test. Voltage measurements can be made at that point with an oscilloscope or voltmeter. The built-in pulse generator and pulse stretcher can also be connected there.

When an LED is on, its meaning is ambiguous—it can mean that the pin is at a steady state or that it is pulsing rapidly. However, you can determine which state it's really in by using the pulse stretcher.

To determine pulse activity, the built in pulser detector could be connected to one pin at a time at socket "A". That's the recommended procedure when tracing logic or using the pulser. However a much faster method is available. With the shorting plug grounded, the LED will be on if the logic voltage is high or rapid pulse activity is present. If you lift the shorting plug's ground and the LED remains on, rapid pulse activity is present. If the LED goes off, the voltage level is high with no pulse activity. Lifting the ground on the shorting plug to observe pulse activity can be accomplished very quickly. The monitor circuit alone is capable of detecting single pulses greater than 1 µs. They are stored in a flip-flop until reset by the internal 100-pps generator.

If you remove the shorting plug from ground, the LED's will display the complement logic, i.e. on for low, off for high. That is useful when observing complemented inputs or outputs. As an example, the 7447 decoder that is driving a 7 segment display will have active low output when displaying a segment. By using the compliment a lighted LED will correspond to a display segment that is on.

Pull-up plugs

For TTL devices, a floating input is considered to be high. However, depending on internal leakage, its voltage could fall into the undefined area of 1.7 volts or so. Since many designers choose to leave unused TTL inputs floating, incorrect monitoring may result.

That problem can be eliminated by using the pull up plug. Insert it into the A socket and connect its lead to $+V_{CC}$ at the solderless connector.

CMOS devices have very high input impedances, and their inputs must not be left unconnected (floating). A floating CMOS input can, and will, switch from one state to the other. For new designs, that can make troubleshooting difficult.

The pull-up plug can be installed in one of the A sockets and alternately connected from $+V_{CC}$ to ground at the solderless connector. Any input which changes

ORDERING INFORMATION

The following are available from Dage Scientific Instruments, P.O. Box 144, Valley Springs, CA 95252: Plated-thru PC boards, IC pin-out cards and detailed instructions (order number IC-18), $30.00 plus $2,00 shipping. Complete kit of parts less chassis, DIP-clip cable, and sockets (order number IC-20), $79.95 plus $3.00 shipping. Complete kit, includes assembled dip-clip cable, zero insertion force socket, even solder (order number IC-22) $119.00 plus $4.00 shipping. California residents please add sales tax. Countries other than U.S.A. and Canada, please add $8.00

when the pull up plug is changed should be examined more closely. The pull-up plug is not needed for normal CMOS operations, and should be removed from the circuit after checking the inputs.

The in-circuit comparator

To use the in-circuit comparator:

- Connect power from the above circuit.
- Connect the jumper cable with DIP clip to socket A.
- Place all switches in the OUT position.

Select the proper card and insert it in the tester. Then connect the DIP clip to the in-circuit IC and install a good IC in socket B. You are then ready to put the switches for ground, power, and the inputs to the IN position.

All the LED's should remain off if the in-circuit IC is operating properly. If an output LED blinks or stays on, something is wrong. If an input LED blinks or stays on, the input is probably floating and should be ignored. To catch and hold single momentary faults, switch S17 to the STORE position. To clear, press S19, the PULSER switch.

Output LED's will go on if an output pin on one IC changes more than 800 ns before the same pin on the other. The old style CMOS outputs called A-Series do not have the drive capabilities that the newer B-Series devices have. It is possible that the A-Series device is driving a large capacitive load and may take longer than 800 ns to switch. The analyzer's good IC is driving practically no load at all and therefore switches very rapidly. Viewing the output on a scope should reveal such timing problems.

For the comparison test to work, both IC's must be synchronized. As an example, assume that a 4060, 14-stage ripple counter is used as a simple divider and that the circuit does not require the divider to be reset or start from zero. To reset this device, pin 12 must be made high. If pin 12 is held low with a resistor, the pulse generator can reset both the in-circuit and the known good IC. They will now run in

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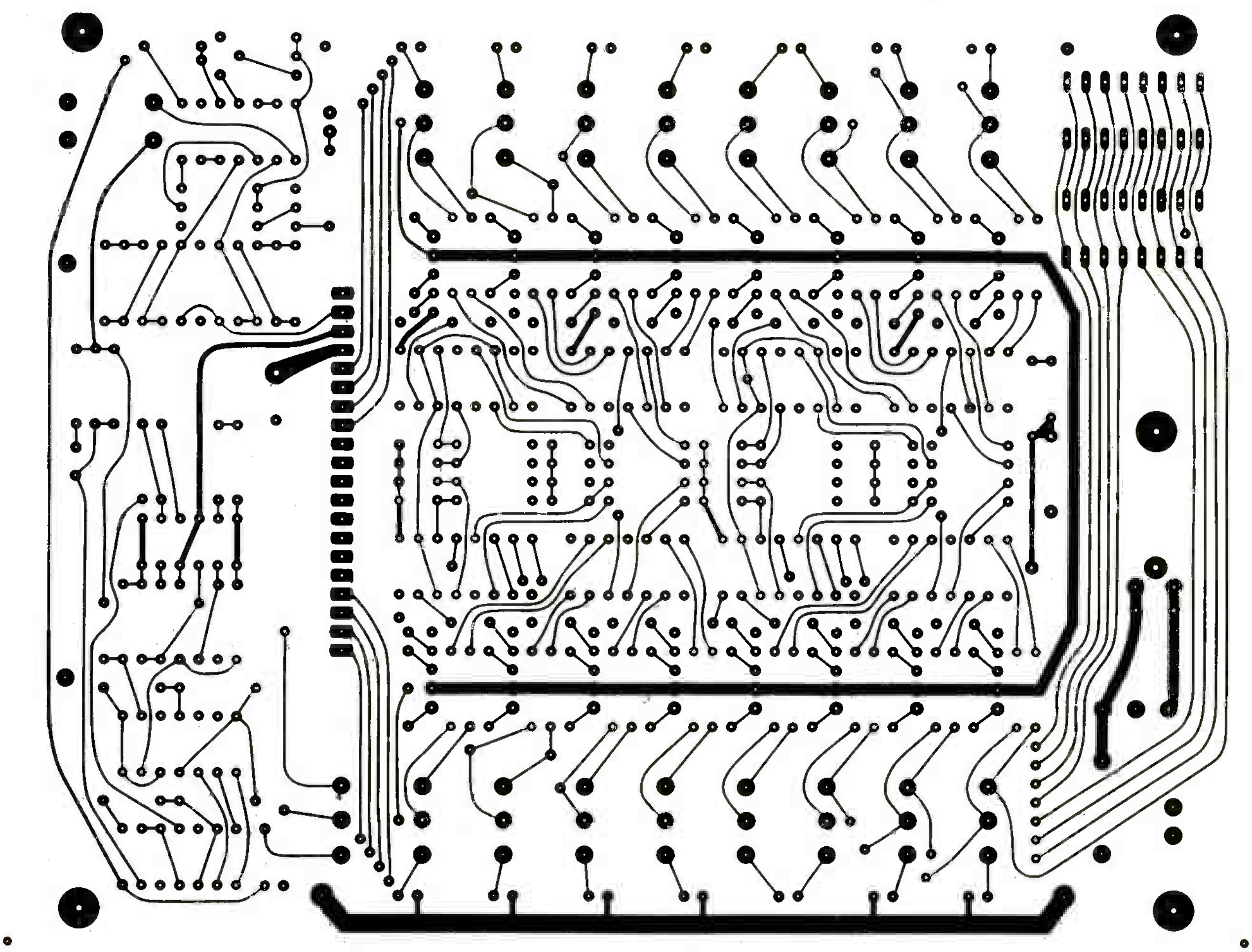
PC SERVICE

One of the most difficult tasks in building any construction project featured in **Radio-Electronics** is making the PC board using just the foil pattern provided with the article. Well, we're doing something about it.

We've moved all the foil patterns to this new section, where they're printed by themselves, full sized, with nothing on the back side of the page. What that means for you is that the printed page can be used directly to produce PC boards!

In order to produce a board directly from the magazine page, remove the page and carefully inspect it under a strong light and/or on a light table. Look for breaks in the traces, bridges between traces, and, in general, all the kinds of things you look for in the final etched board. You can clean up the published artwork the same way you clean up you own artwork. Drafting tape and graphic aids can fix incomplete traces and doughnuts, and you can use a hobby knife to get rid of bridges and dirt.

An optional step, once you're satisfied that the artwork is clean, is to take a little bit of mineral oil and carefully wipe it across the back of the artwork. That helps make the paper transluscent. Don't get any oil on the front side of the paper (the side with the pattern) because you'll contaminate the sensitized surface of the copper blank. After the oil has "dried" a bit—patting with a paper towel will help speed up the process—place the pattern front side down on the sensitized copper



6½ INCHES

THE SOLDER SIDE OF THE IC TESTER BOARD. See page 80 for more information.

PC SERVICE

blank, and make the exposure. You'll probably have to use a longer exposure time than you are used to.

We can't tell you exactly how long an exposure time you will need because we don't know what kind of light source you use. As a starting point, figure that there's a 50 percent increase in exposure time over lithographic film. But you'll have to experiment to find the best method to use with the chemicals you're familiar with. And once you find it, stick with it. Don't forget the "three C's" of making PC boards—care, cleanliness, and consistency.

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MULTIPATH RECEPTION

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nal and the direct signal are amplified by the same gain factor and then rectified to produce DC voltages.

The comparator/control circuit compares the levels of the DC voltages derived from the two IF signals and immediately selects the antenna and tuner combination with the lowest DC voltage from the AM component of a multipath signal. The control circuit switches the input of the audio amplifier to the output of the tuner providing the better signal. Switching occurs as rapidly as necessary to ensure that the listener gets the signal with the least interference and distortion.

Other manufacturers use different techniques to reduce multipath distortion in automotive FM receivers. One such technique makes use of the fact that, for a given signal strength, a stereo FM signal is inherently noisier than a mono one. For adequate reception, a receiver requires a signal that is above a given threshold level. As the signal drops toward that level, interference and distortion is first noticed as noise and hiss in the treble range. A further drop causes garbled sound and random dropouts. Mono signals have a higher high-frequency content than stereo signals, which results in better masking of noise and hiss.

Some car stereo makers use that fact to reduce multipath distortion. When multipath reception causes the incoming signal to fall below a given level, control circuits automatically switch the receiver from stereo to mono. In some sets, the switching from stereo to mono is rather abrupt and quite noticeable. In others, such as Pioneer's (5000 Airport Plaza Dr., Long Beach, CA 90815) receiver models *KE-A630*, *KE-A430*, and *KE-A330* (see Fig. 10) the transition from stereo to mono is achieved by a gradual blend of the left- and right-channel signals. As the FM signal gets stronger, the effect is gradually reversed.

In some receivers multipath distortion under weak-signal conditions is made less noticeable by rolling-off the high-frequency response when the incoming signal does not have enough treble content to over-ride hiss and noise. Usually that is done by feeding the recovered audio signal through a highpass filter and rectifier to a logarithmic amplifier that develops a DC voltage that is proportional to the high-frequency content of the signal. That DC voltage controls the bandwidth and roll-off of a variable highpass filter—cutting the high-frequency response so noise and hiss are eliminated. **R-E**

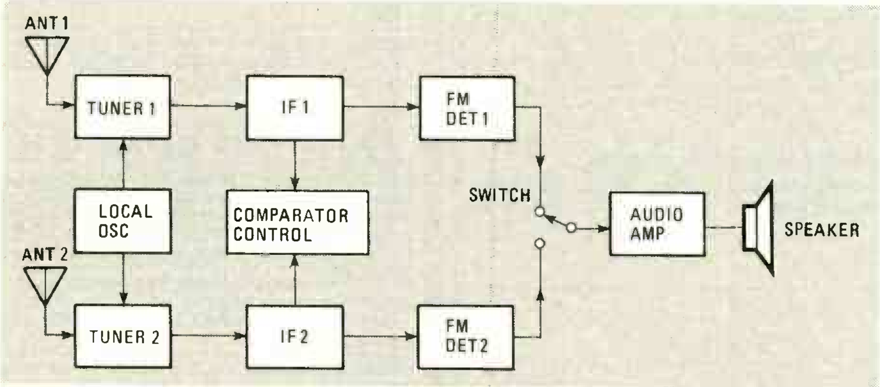

FIG. 8—BLOCK DIAGRAM of a stereo diversity reception stereo receiver. Note that it has two independent front ends.

FIG. 9—THE AUDIA *DXT-1000* diversity receiver from Clarion.

FIG. 10—THE *KE-A330* stereo receiver from Pioneer automatically switches to mono when the signal strength drops below the level required for acceptable stereo reception.

IC TESTER

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unison. More than likely, the circuit will tie pin 12 directly to signal ground. In that case, there is no easy way to get the two devices synchronized, and the comparison test will not work.

Testing IC's

To test out-of-circuit ICs:

- Connect power from external source
- Connect a grounded shorting plug to socket A
- Place all IC switches in the OUT position.

Select the appropriate IC card and insert it into the IC analyzer. Then insert the IC in the right-hand B socket (SO5). Use short jumpers of 22-gauge solid wire to make power and ground connections from the solderless connector to one of the B sockets.

The inputs can be tied low by putting the switches to the IN position. Do not switch the outputs, power, or ground pins. The pulser can be connected at the B socket, and should be used to test clocked logic. The pulse generator pushbutton is not debounced, so occasionally a double output pulse may result. **R-E**