MICRO MONITOR

Ease microprocessor design chores with our under-$200 logic-analyzer kit.

JIM COOKE

DEVELOPMENT AND DEBUGGING tools have improved tremendously since the introduction of the microprocessor. Logic analyzers and development systems, widely used by hardware and software developers alike, make child's play of otherwise tough debugging chores. There are several problems with these tools, however: They're processor-dependent, hard to use, and costly to purchase.

It doesn't have to be like that, however. We've designed a universal, easy-to-use, low-cost, yet professional-quality logic analyzer with separate LED displays for sixteen address lines and sixteen data lines, single- and auto-stepping operation, the ability to work with both 8- and 16-bit systems, and more. A complete kit of parts with attractive silk-screened panel is available for well under $200—a fraction of the cost of comparable commercial units. Partial kits as well as a PC board all by itself are also available.

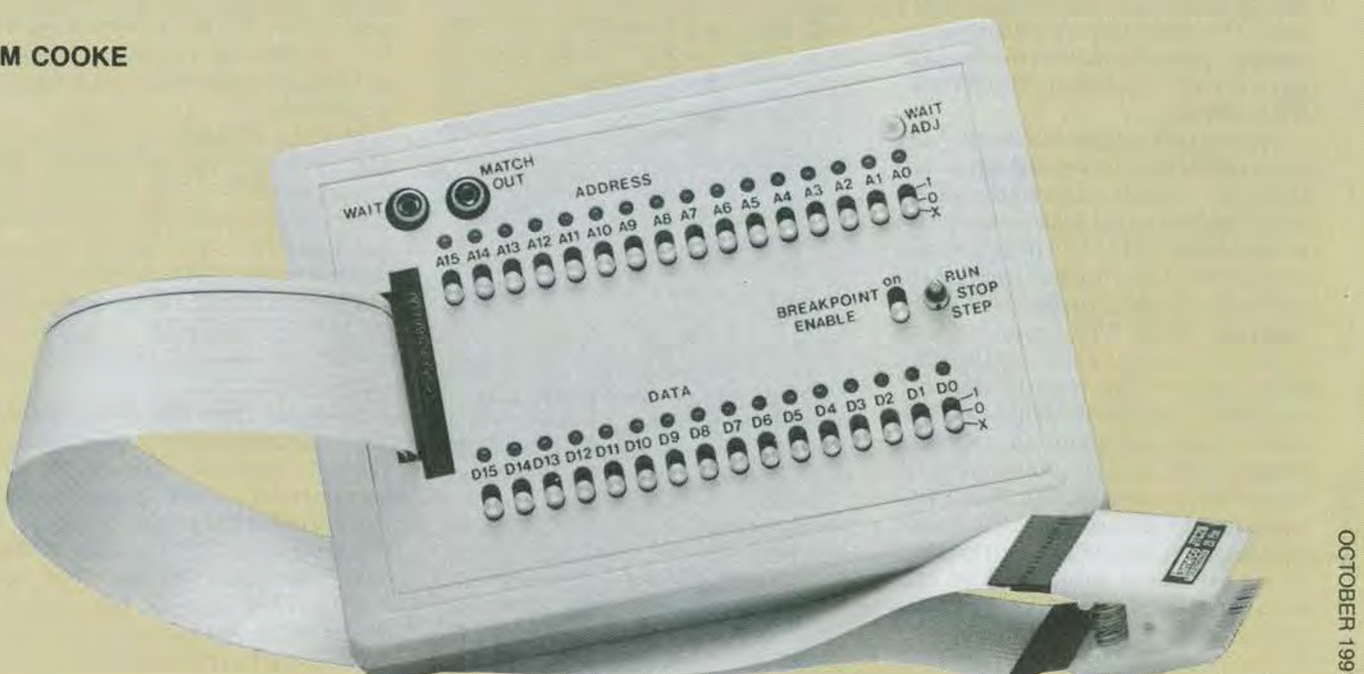
MICRO-MON features

MICRO-MON attaches to any standard ROM or EPROM on the target system via an IC clip. MICRO-MON works with both 8-bit and 16-bit parts with capacities ranging from $2K \times 8$ to $64K \times 16$, in 24-, 28-, 32-, and 40-pin packages. Two conveniently located connectors accept the interface cables. Connector pinout was designed to use standard ribbon cables and standard IC clips.

Each address and data line has its own dedicated LED, so it's easy to identify shorted lines. In addition, MICRO-MON will blink the corresponding LED of any floating or open address or data line.

By attaching a single lead to the target's WAIT or READY line, you can single step or continuously step through microprocessor instructions with the press of a switch. For the stepping function to work, the target system must be static—that means that the WAIT or READY line must be able to stall the microprocessor without adversely affecting system operation.

Continuous stepping works like auto-repeat on a keyboard:



MICRO-MON steps the target system twice per second as long as the Step switch remains depressed. This powerful feature allows you to observe all bus activity, thereby enabling you to easily debug both hardware and firmware.

Another feature allows you to stop the target system on a specific address pattern, data pattern, or combination thereof. MICRO-MON has a three-position switch for each address and data bit, so each bit can be programmed to match on a high, low, or don't care. An external connector carries the MATCH signal, which can be used to trigger a scope or other device. MICRO-MON has its own power supply, so it does not consume power from the target system. Also, to reduce cost, or if the match capability is not required, the unit can be depopulated for 8-bit-only operation.

PARTS LIST

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

R1—150,000 ohms
R2—100,000 ohms
R3—200,000-ohm PC-mount potentiometer
R4—1000 ohms
R5, R10—10,000 ohms
R6—10 ohms
R7—2.2 megohms
R8, R9—47,000 ohms
RN1–RN4—470 ohms × 9 resistor network, pin 1 common
RN5–RN12—47,000 ohms × 9 resistor network, pin 1 common

Capacitors

C1—2.2 µF, 25 volts, tantalum
C2—0.1 µF, 25 volts, tantalum
C3—1 µF, 25 volts, tantalum
C4—33 pF, ceramic disc, with socket (see text)
C6–C15—0.1 µF, ceramic

Semiconductors

IC1–IC4—74HCT240, octal three-state inverting buffer
IC5—74HCT221, dual monostable multivibrator
IC6—74HCT14, hex Schmitt trigger
IC7—74HCT00, quad NAND gate
IC8—74HCT32, quad OR gate
IC9–IC12—74HCT688, eight-bit magnitude comparator
IC13—7805 +5-volt regulator
Q1—2N2222 NPN transistor
D1—1N914 diode
LED1–LED32—red LED (T1-3/4 package)

Other components

J1-a—16 × 2 0.1" header
J1-b—20 × 2 0.1" header
J2—3.5mm coaxial jack
J3–J4—RCA PC-mount phono jack
JU1, JU2, JU4—3-pin 0.1" header
JU3, JU5—2-pin 0.1" header
S1-SPDT toggle, center off, one side momentary (Alcoswitch MTA-106H-PC or equiv.)
SW2–SW33—SPDT slide, middle NC
SW34—SPST slide

Miscellaneous: 6-volt, 300-mA DC adaptor, front panel, enclosure (Hammond P/N A9086265), cables for 28-, 32- and 40-pin ROM's, cable for WAIT line, assembly hardware.

Note: The following items are available from Jim Cooke, P.O. BOX 834, Pelham, NH 03076 (603) 882-4460: Complete kit, $189; PC board only, $29; PC board kit and all components, $99; enclosure with silkscreened front panel, $49; cable assembly with 28-pin chip clip, $49. New Hampshire residents add appropriate sales tax; all orders add 5% for shipping. MC and Visa accepted.

Theory of operation

MICRO-MON consists of three major circuits that we'll discuss separately: Display, Single-step, and Match.

Display Circuit. The display circuit, shown in Fig. 1, consists of inverting buffers IC1–IC4. Address and data lines from the target system feed the buffers via the IC clip. The buffers feed address and data buses used by the rest of the system. In addition, the output of each buffer drives the cathodes of the display LED's via 470-ohm current-limiting resistors (those resistors are contained in resistor networks RN1–RN4).

A unique feature of the display circuit is the Floating Line Indicator, which identifies open and floating lines by blinking the associated LED. Blinking is accomplished by connecting the input side of each buffer to a 2-Hz oscillator via a 47K resistor (contained in resistor networks RN5–RN8). The inputs of HCT buffers IC1–IC4 are high-impedance types, so open or floating inputs will easily allow the 47K resistors to couple the 2-Hz signal into the circuit. On the other hand, if an input is not floating or open, but is high or low, the logic level will override the 2-Hz signal, clamp the buffer either high or low, and display the corresponding state in the appropriate LED.

Single-step Circuit. This circuit consists of the logic shown in Fig. 2. Switch S1 selects one of four stepping functions (Run, Stop, Step, Autostep), all of which are executed by controlling the WAIT or READY line of the target microprocessor. Switch S1 is special: It is an SPDT type with a center "off" position, and a spring return on only one side (Step).

Here are the four stepping functions: *Run*—With S1 in the "run" position, the WAIT line is unaffected by MICRO-MON, so the target microprocessor runs at full speed. *Stop*—With S1 in the center "off" position, the WAIT line is asserted, so the target microprocessor halts. In this state, MICRO-MON displays current address and data lines. *Step*—By moving S1 into the "step" position and releasing it, one-shot IC5-a fires once, thus allowing the microprocessor to execute a single operation. The time constant of the one-shot is adjustable and must be set for the particular microprocessor and clock rate. The combination of IC6-a, R2, and C2 form a filter that prevents switch bounce from falsely triggering IC5-a. *Autostep*—If S1 remains depressed, the delay generated by R7 and C3 expires, which in turn allows the 2-Hz oscillator signal (generated by IC6-d, R1, and C1) to feed into the one-shot via IC7-c and IC6-e. Thus the one-shot will be retriggered twice per second as long as step-switch S1 remains depressed.

Match circuit. As shown in Fig. 3, four cascaded octal comparators (IC9–IC12) generate the MATCH signal, which is enabled or disabled by S34, MATCH ENABLE. Each address and data line has a corresponding three-position switch (S2–S33) that is used to specify a match on 0, 1, or X (don't care).

Let's see how the comparators work. Each address or data line is always connected to one leg of a comparator; a switch determines the connection to the other leg of the comparator. For the "don't care" position (down), the two comparator inputs are shorted together, forcing a match. For a match on 1, the switch grounds

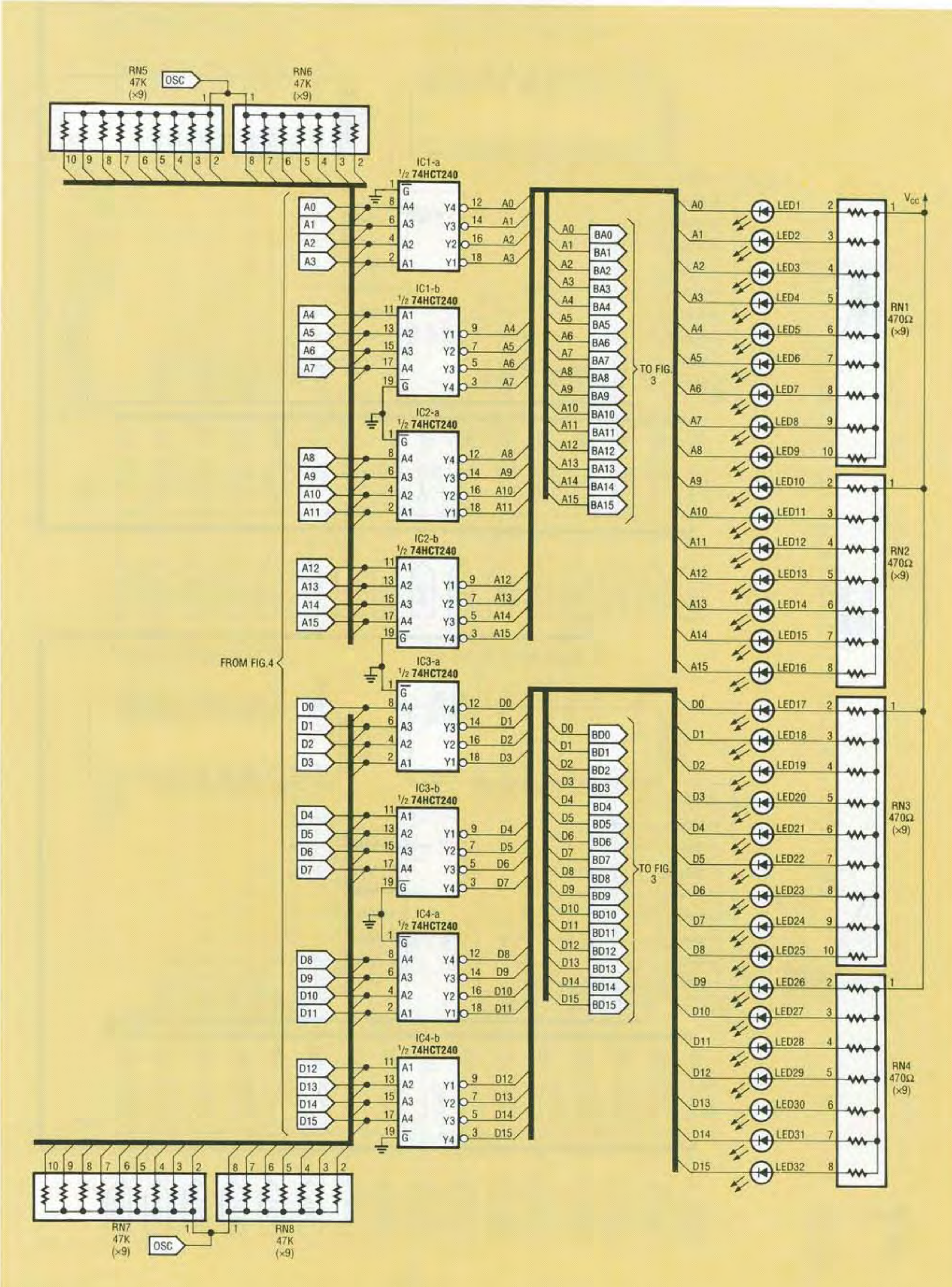


FIG. 1—THE DISPLAY CIRCUIT consists of several octal inverting buffers that drive discrete LED's to display 16 address lines and 16 data lines.

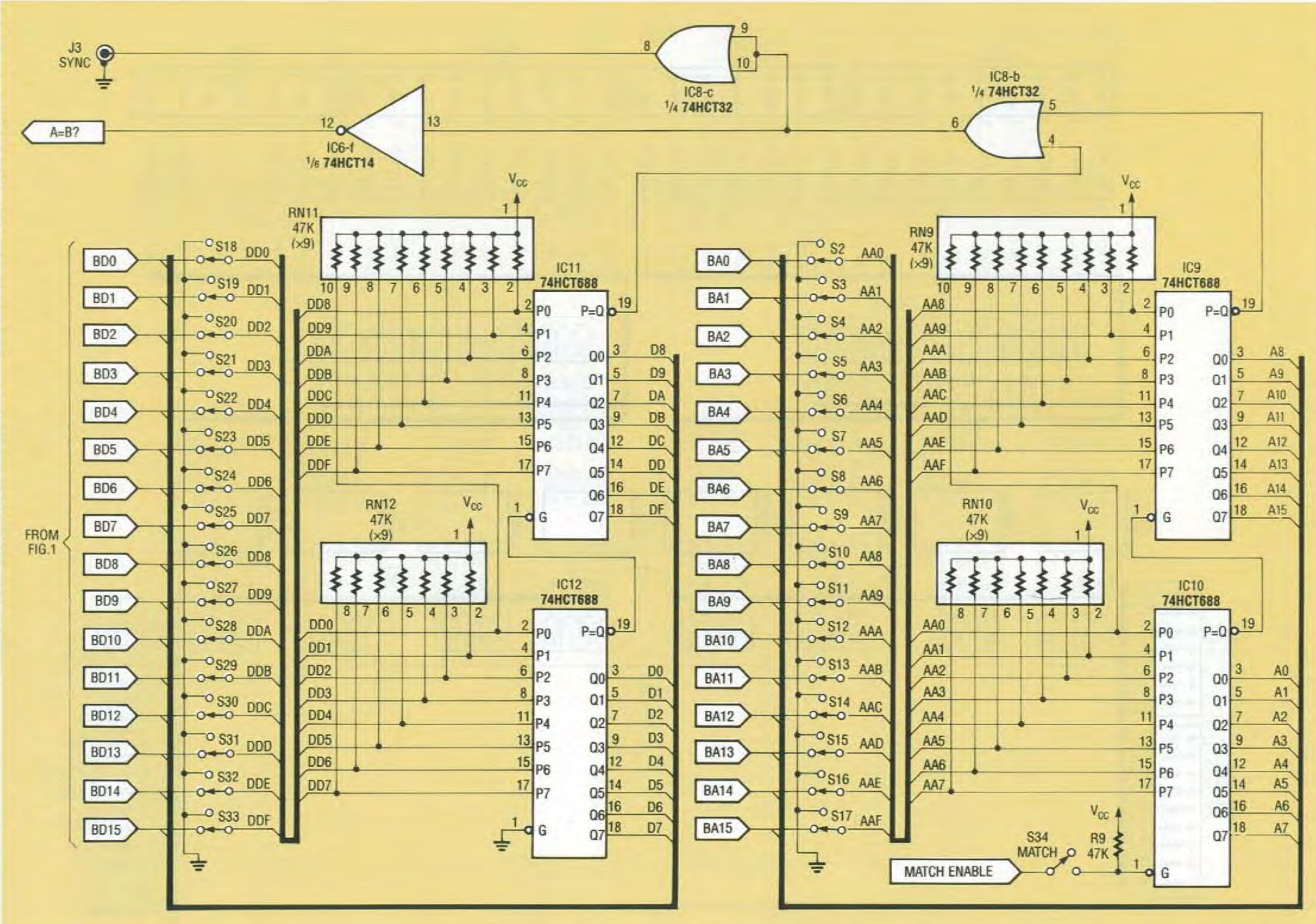


FIG. 3—THE MATCH CIRCUIT compares all address and data lines to the values set on switches S2–S33. If there is a match, IC6-f goes low, and a pulse appears at J3.

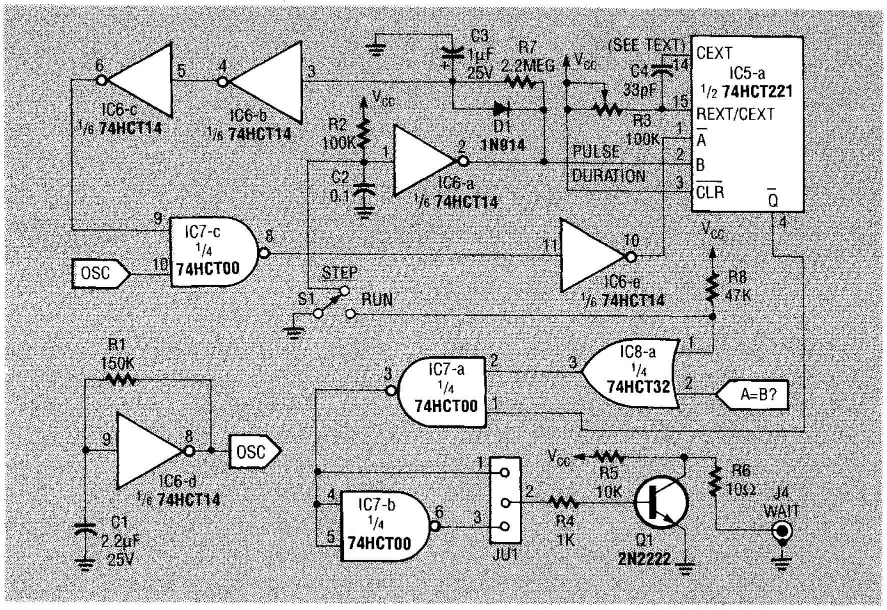


FIG. 2—THE SINGLE-STEP CIRCUIT provides four modes: Run, Stop, Step, and Autostep.

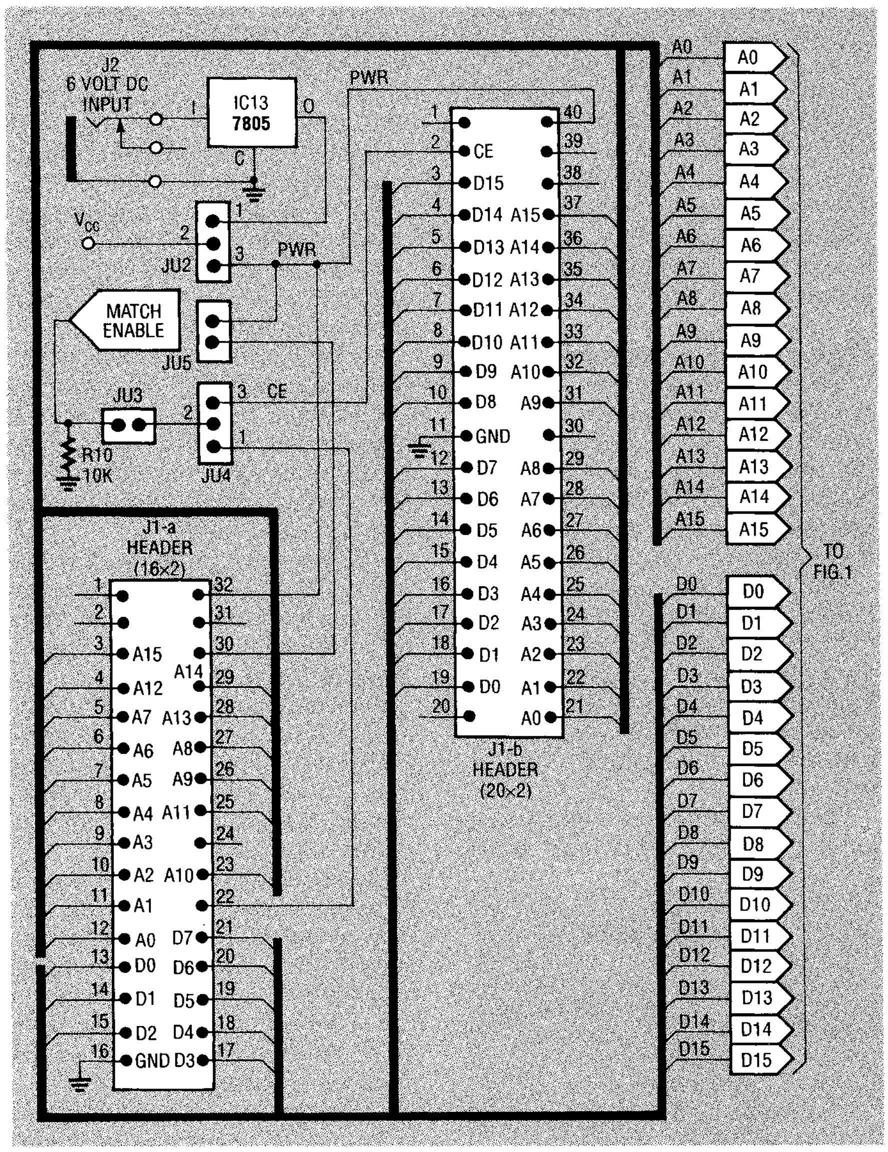


FIG. 4—CABLE AND CONNECTOR WIRING diagram; J1-a accepts 8-bit devices, J1-b accepts 16-bit devices.

the corresponding input. For a match on 0, the switch is not connected at all, so the input is pulled up through a 47K resistor (contained in RN9–RN12). (Remember, the buffered data is inverted, which explains the negative logic.)

The output of the cascaded match logic feeds into the single-step circuit (shown back in Fig. 1) and, when enabled by S34, can be used to stop the microprocessor on a specific pattern. Note also that the *MATCH* signal is buffered by IC8-c and delivered to J3 for use as a sync or trigger signal.

That completes the description

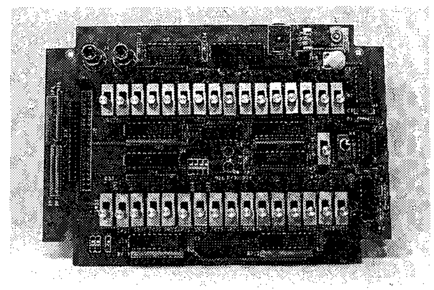


FIG. 5—THE FINISHED BOARD will look something like this. We'll start building the Micro Monitor next month.

of the logic portion of the circuit. Figure 4 shows wiring details for the power supply and the test connectors. The power supply consists of a 6-volt DC wall transformer feeding a 7805 regulator. Header J1-a is a dual-row 32-pin connector for 28- and 32-pin IC's, and J1-b is a 40-pin unit for 40-pin IC's.

Next month

Unfortunately we've run out of space. Therefore the rest of this story is going to have to wait until next month. We have finished our discussion on how the circuitry works, so next month we'll start right in with building the Micro Monitor. (By the way, a photo of what the finished board looks like is shown in Fig. 5.) In the meantime, we've given you the parts list and a source for the parts and PC boards. So if you're anxious to being building the Micro Monitor, we recommend that you start gathering together all of the parts and a PC board. We'll provide foil patterns for the double-sided board next month if you want to make your own. **R-E**

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LAST MONTH WE FINISHED OUR DIScussion on the circuitry. Now let's build the unit.

Construction notes

This is a simple project conceptually, but the wiring is complex, hence we recommend use of a PC board. Foil patterns are provided to make your own board; etched, drilled, and silk-screened boards are available from the source mentioned in the parts list.

Using Fig. 5 as a guide, mount all parts, except those mentioned below, on the component side of the board. The LED's should be shimmed so their domes are level with or slightly above S1.

DC power connector J2, a 3.5mm coaxial jack, mounts on the foil side of the board, as do several configuration options (capacitor C4 and option-select jumpers JU1–JU5).

Mount in the position for C4 (on the foil side of the board) a two-pin header socket, and insert a 33-pF ceramic disc. Then mount three-position header pins at JU1–JU4, and a two-pin header at JU5. Insert header jumpers according to the information shown in Table 1. Check for and correct any wiring errors, but don't mount the board in the case yet.

Initial checkout

Before installing the PC board in the enclosure, perform the following tests:

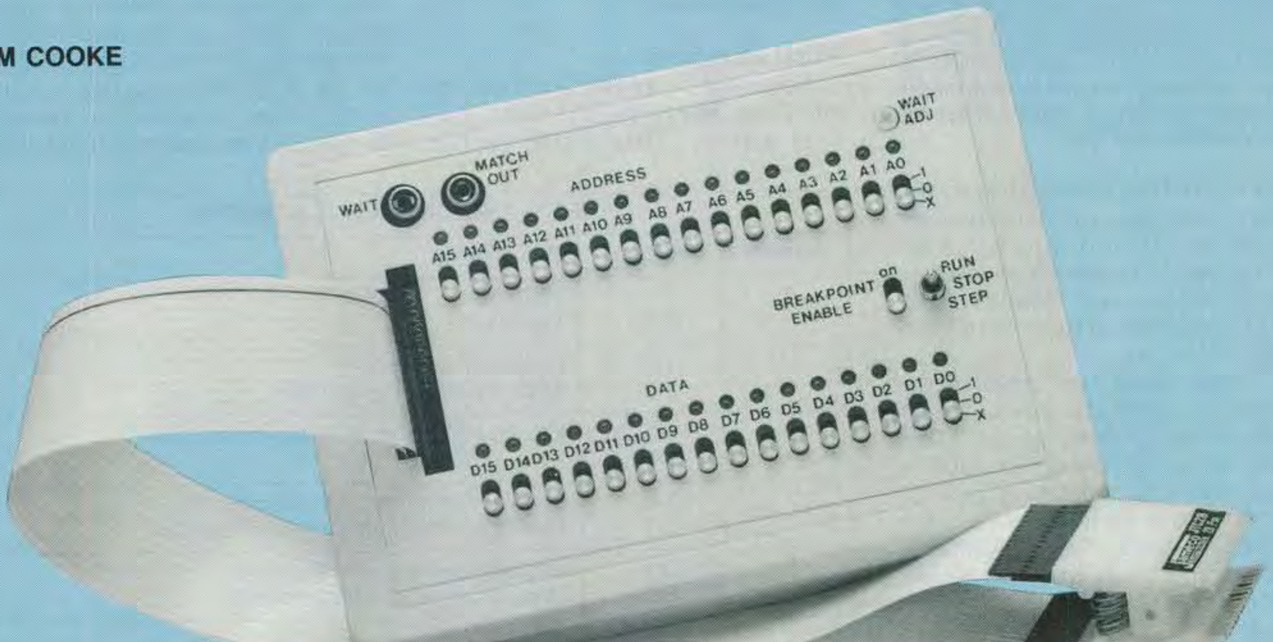
1) Use an ohmmeter to verify that the reading between +5V and ground is greater than 20 ohms.

2) Plug in the wall-mount power transformer and ensure the presence of +5 volts between pin 20 and pin 10 of IC1.

3) With no test clip installed, verify that all LED's are blinking. If not, check whether pin 8 of IC6 is oscillating at about 2 Hz.

4) With one side of a test clip attached to ground, momentarily touch the other side to each address and data input. Verify that the corresponding LED goes out, and that the remaining LED's continue to blink.

5) Verify the correct logic level for the WAIT or READY line.



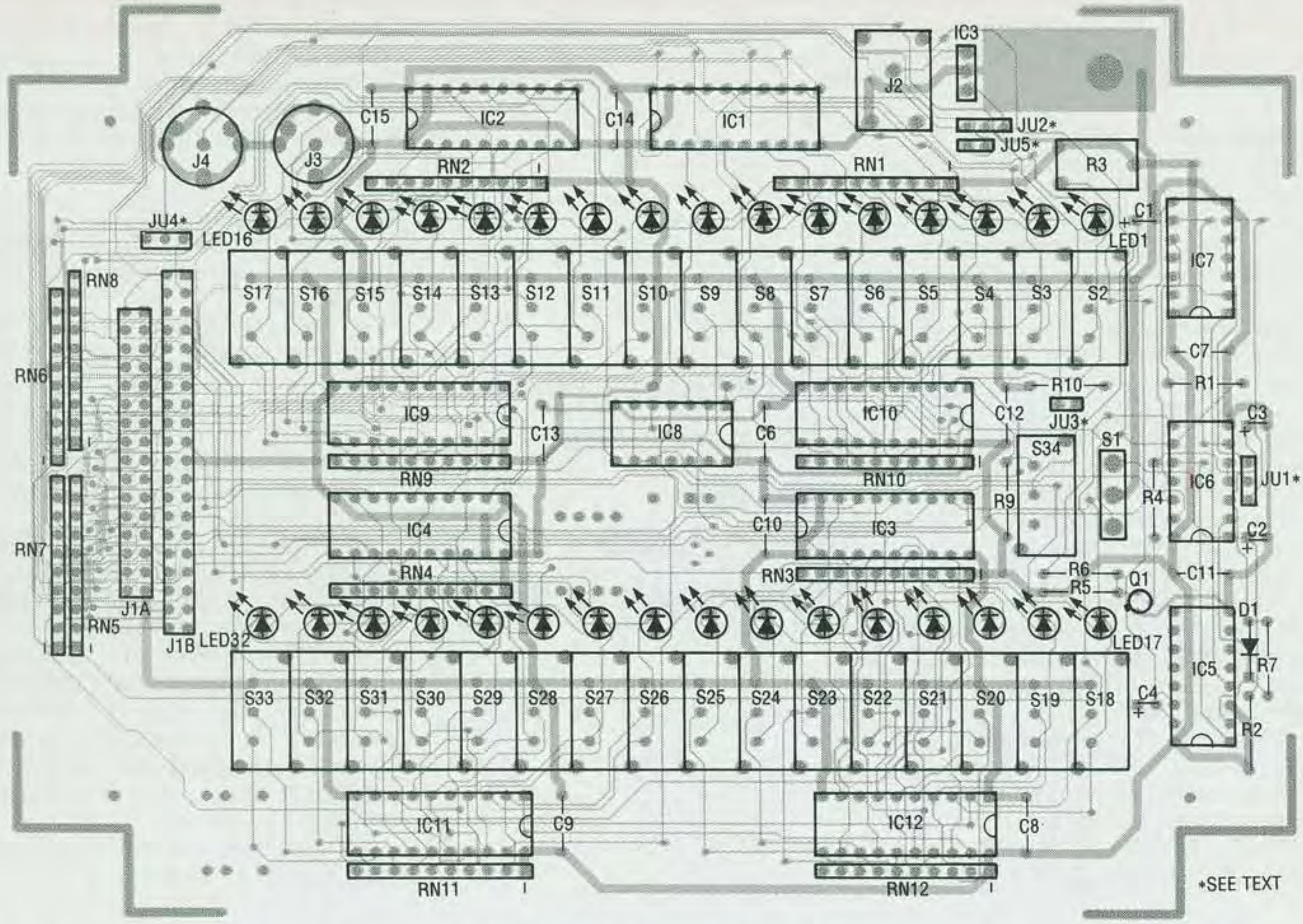


FIG. 5—MOUNT ALL COMPONENTS as shown here. Note that C4, J2, and all five jumper headers mount on the foil side of the board.

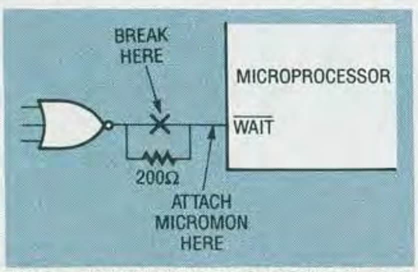


FIG. 6—CONNECT MICRO-MON to the target system directly, or insert a resistor in series with the WAIT line.

6) Verify that when S1 is in the "run" position, an oscilloscope probe attached to the WAIT connector (J4) measures a logic one (5 volts), and when in the "stop" position, a logic zero (less then 0.5 volts).

7) Hold S1 in the "step" position and verify the presence of high-going pulses at J4. The pulse has a narrow width (about 1 μs) and low repetition rate (2 Hz), so it may be hard to see. Use a scope in single-sweep mode or a logic probe with built-in pulse stretcher.

8) Verify that when you release S1, the J4 pulses halt.

9) Move S1 to the "step" position several times, and verify that the J4 signal pulses high when you do that.

If any of those tests fail, remove power and debug the circuit before continuing.

Final checkout

Now you're ready to connect the unit to a target system.

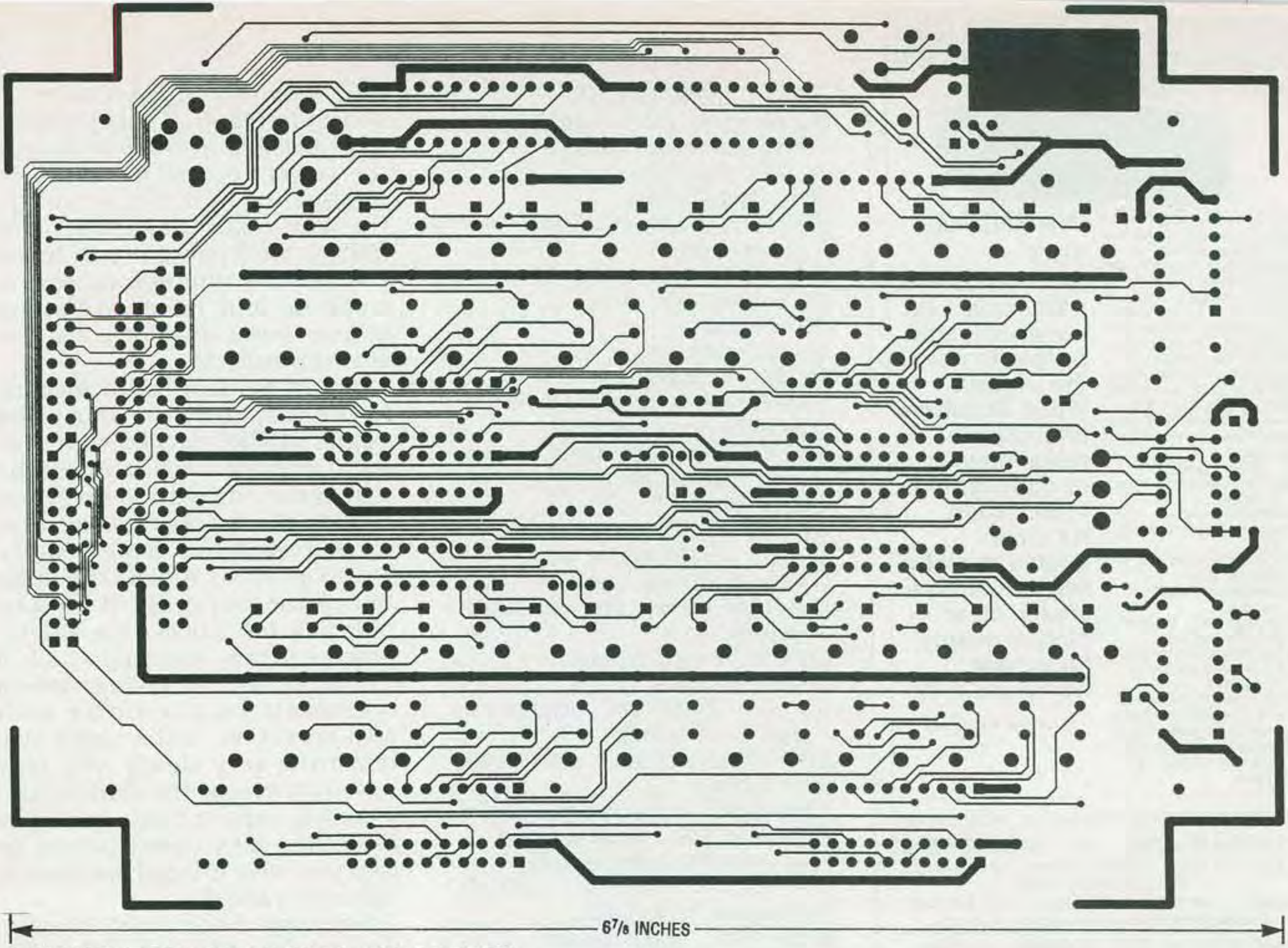
1) Attach a test cable to the MICRO-MON unit and connect the clip over the PROM in the target microprocessor system, at the same time ensuring correct pin-1 orientation.

2) If the target microprocessor uses an open-collector or open-drain device in the wait circuit, simply clip the wait cable directly to the wait pin. Another method is to insert a 200-ohm resistor between the target's wait logic

TABLE 1—OPTION SELECT JUMPERS

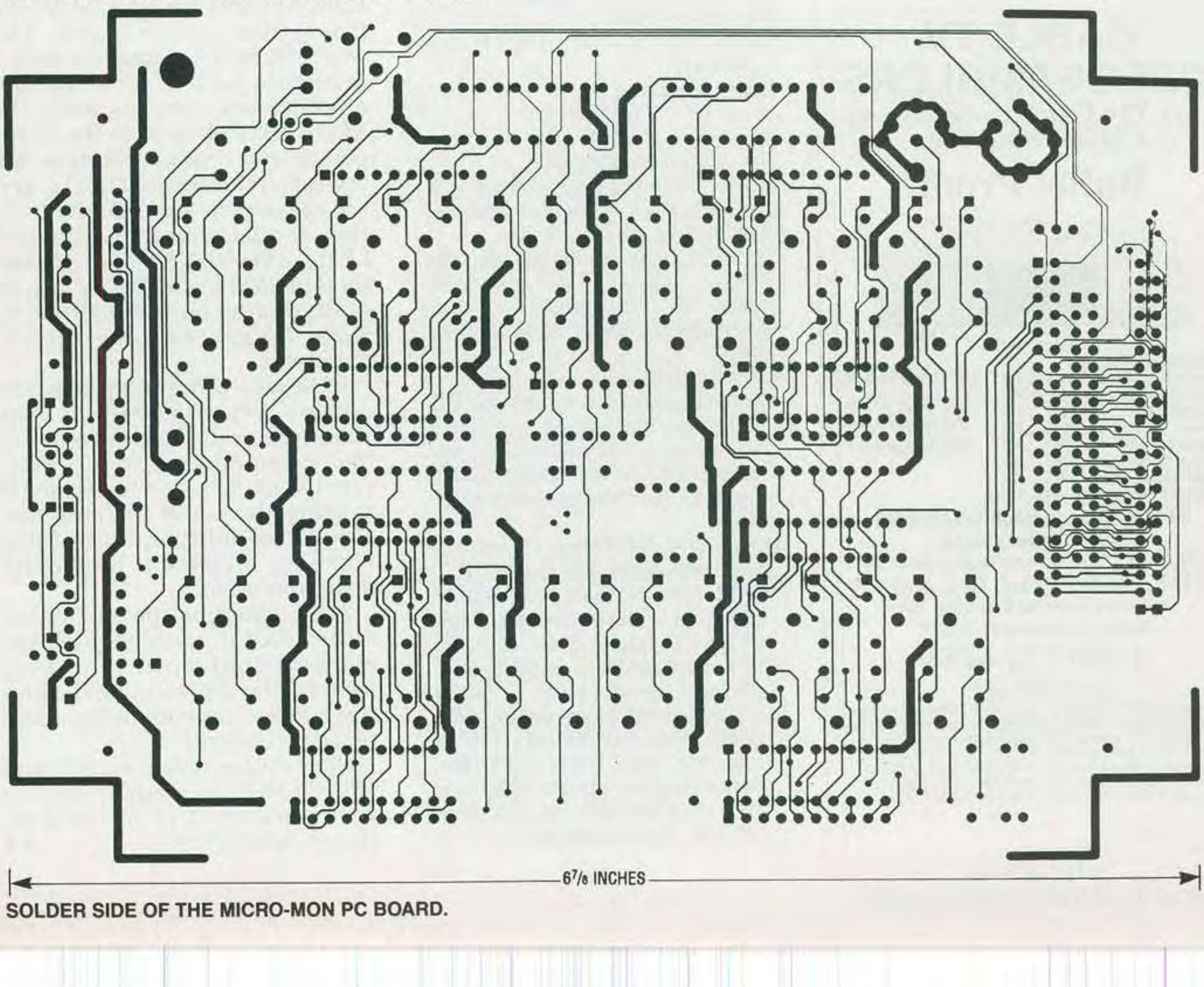
Jumper	Position	Description
1	1-2* 2-3	Wait low Wait high
2	1-2* 2-3	Enable internal power Enable power from test clip
3	On Off*	Enable Match Enable signal to test clip
4	1-2* 2-3	Enable Match Enable to 8-bit test clip Enable Match Enable to 16-bit test clip
5	On* Off	Enable power to test clip pin 30 Disable power to test clip pin 30

*** = Default**



6⁷/₈ INCHES

COMPONENT SIDE OF THE MICRO-MON PC BOARD.



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SOLDER SIDE OF THE MICRO-MON PC BOARD.

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and the microprocessor, as shown in Fig. 6. If neither method is feasible, you must evaluate the target's circuit design to determine the best way to tap into the wait logic. Remember that MICRO-MON uses the WAIT line to control the microprocessor, so stepping and match functions will not work without a wait circuit connection.

3) Having made the connection to the WAIT line, you must now adjust MICRO-MON's wait timing. The objective is to adjust the WAIT pulse so that the target executes one operation each time the step switch is depressed. Potentiometer R3 adjusts the duration of the WAIT pulse. If the WAIT pulse is too short, the microprocessor may not step at all; if the WAIT pulse is too long, several operations may occur for each step operation. If the target system runs very slowly, you may have to increase the value of C4, which is mounted in a socket to facilitate easy substitution in case you have to experiment with different values.

One way of adjusting the WAIT pulse is to obtain or blast an EPROM containing all "NOP" (No Operation) instructions. The NOP PROM will cause the target microprocessor to cycle through all addresses. After installing the NOP PROM, place S1 in the "stop" position; a random address will appear in the address LED's, and the opcode for the NOP instruction should appear in the data LED's. Pressing S1 once should increment the address by 1, 2, or 4, depending on the instruction word length of your microprocessor.

If the WAIT pulse is too long, the address will increment by more than 1, 2, or 4; if the pulse is too short, the address won't increment at all. The best technique is to start short and increase the WAIT-pulse duration until it just starts to increment by one instruction word.

After adjusting the WAIT pulse, ensure that the auto-step feature works. Hold down the step switch; the LED's should show the address incrementing about twice per second.

Checkout is now complete and MICRO-MON is ready to use on your workbench or in the field. Happy debugging! **R-E**