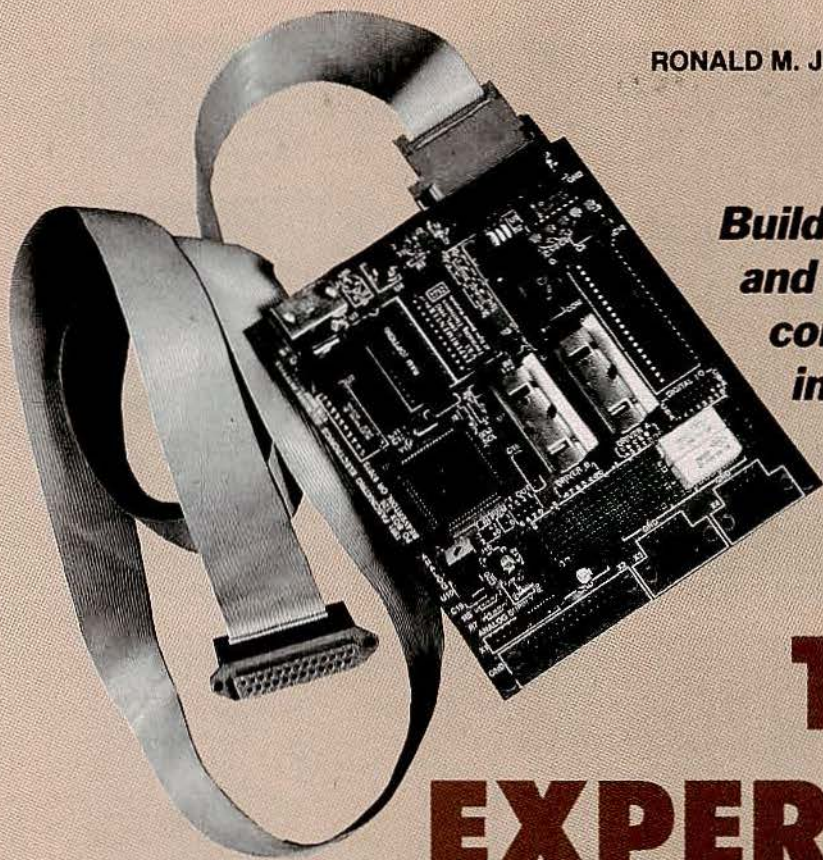RONALD M. JACKSON

Build the Experimenter, and put your personal computer to work doing interesting and useful real-time tasks.

THE
EXPERIMENTER

LAST MONTH WE WENT OVER THE OPerating theory of the Experimenter, and discussed the various commands that control it. Now it's time to build it.

Assembly

Experimenter is constructed on a double-sided PC board with fine conductive traces and through-hole plating. It is, admittedly, a difficult board for the hobbyist to make in his home workshop. Nevertheless, circuit foil patterns have been provided for those who choose to try it. Fortunately, a high-quality PC board, screened on both sides, is available from the source given in the Parts List. The component locations printed on the board make it easier to troubleshoot the board and add circuitry at a later date.

Figure 2 is the parts-placement diagram. Start component assembly work by installing power connector J2 first, and then inserting the power supply components. Figure 3 shows how to set the J1 jumpers to obtain the proper power-supply polarity. However, the voltage regulators are designed to withstand an accidental reversal in power-supply polarity.

Test the power supplies before installing any other components. A measurement of about 5 volts should be obtained at the logic-supply output. If you build the analog supply, adjust R6 so that the +5.12-volt test point measurement is as close to that voltage as possible. Jumper J10 makes the selection between the logic supply and the analog supply. Install J10 between positions 1 and 2 if you built the analog supply, or between positions 2 and 3 if you did not.

Install all of the jumpers before adding the remaining components. At this stage of the construction process you will have better access to the board than when all the larger components are in place. Set J4 through J7 for the specific EPROM that you intend to use (either the one that came with the kit of parts offered or one of your own choice). Figure 4 shows the jumper connections for the different kinds of EPROM's that can be used.

The Experimenter kit includes six rubber feet to hold the loaded PC board off the bench top. They mount in the formed holes along the sides of the circuit board. The feet can be difficult to install, so be patient. Push the tapered end of the foot through its mounting hole, and grasp the end with your fingers. With a blunt tool, push the base of the tapered piece through the hole while pulling on the tapered end. The foot will then pop into position.

Install the special heatsinks on driver IC's IC7 and IC8 before soldering them to the circuit board. The small hole in each heatsink must line up with the notch on the pin-1 end of the drivers. You won't be able to see the top of the driver when the heatsink is installed, so you must rely on the small hole for the correct orientation of the driver in the circuit board.

Solder the four center pins of the drivers to their heatsinks. A high-wattage, temperature-controlled soldering iron will make this task easier Exercise care and patience in making all solder joints. Be sure they are smooth and shiny. A cold solder joint (indicated by its dull sur-
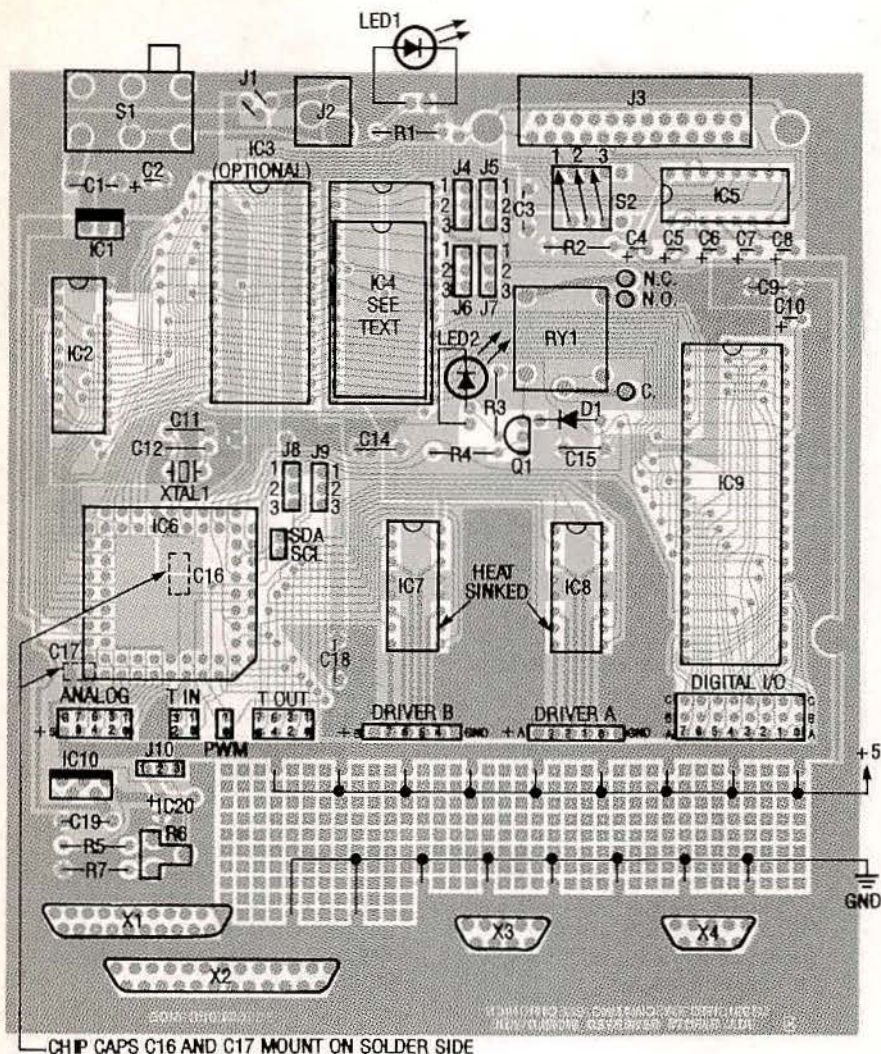
FIG. 2—PARTS-PLACEMENT DIAGRAM. Note that two chip capacitors, C16 and C17, mount on the solder side of the board.
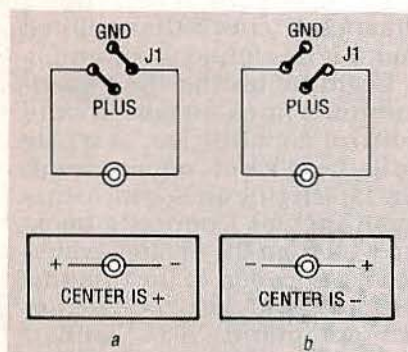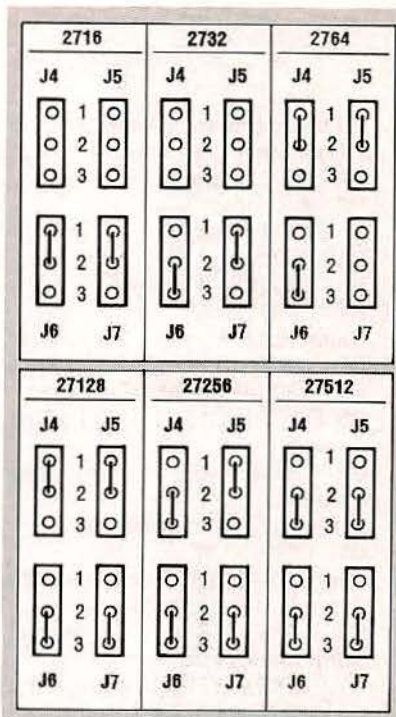
—CHIP CAPS C16 AND C17 MOUNT ON SOLDER SIDE

FIG. 4—EPROM JUMPER SETTINGS. Six different types of EPROM's can be used, ranging in size from 2 Kbytes to 64 Kbytes. Some EPROM types do not use all four jumpers. Also note that types 2716 and 2732 are 24-pin devices, and must be installed in the lower part of the socket, leaving the top connections open.

FIG. 3—POWER SUPPLY JUMPERS. Be careful that the jumpers do not touch!

face appearance) might not be strong enough to hold the heatsinks securely in place.

When installing circuit board components, start by installing the smallest components first. Note that two ceramic chip capacitors, C16 and C17, are mounted on the solder side of the PC board.

Use sockets to install microcontroller IC6, EPROM IC4, the RS-232C interface chip (IC5), and the parallel interface chip (IC9). Note that the microcontroller socket has one flattened corner that must be oriented as shown in Fig. 2. The microcontroller also has a notched corner that must be positioned to match the notch on the socket.

If you install drivers IC7 and IC8 with sockets, they will be easier to replace if they fail due to overcurrent. However, their maximum power-handling capability will be limited to about 700 milliamps for each output. If you want to obtain 1 ampere from each output, you must solder the driver chips directly to

the circuit board for optimum heat transfer. The completed circuit board is shown in Fig. 5.

Test procedures

Connect the Experimenter to your computer with a standard serial interface cable (the same type that is used to connect to an external modem). Then run a communications program on your computer. Use ECHO-EXP.BAS or any communications program of your choice.

If you use a program other than the one given in this article, set it to use the correct serial port and the baud rate you wish to run, 8 data bits, no parity, and 1 stop bit. Before powering up the Experimenter, set baud-rate switch S2 for the baud rate you selected (see Table 8). If you use ECHO-EXP.BAS, the Experimenter must be set for 9600 baud. Flip all of the switches on S2 at least once to assure that solid electrical contacts are being made.

PARTS LIST

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

R1, R3—220 ohms
R2—4.7 ohms
R4—1000 ohms
R5—750 ohms
R6—200 ohms, trimmer
R7—2700 ohms

Capacitors

C1, C19—0.47 µF, 50 volts, Mylar
C2—330 µF, 6 volts, electrolytic
C3, C9, C13–C15, C18—0.1 µF, ceramic
C4–C8—4.7 µF, 35 volts, electrolytic
C10—1 µF, 50 volts, electrolytic
C11, C12—33 pF, ceramic
C16, C17—0.1 µF, 50 volts, surface-mount chip capacitor
C20—330 µF, 6 volts, electrolytic

Semiconductors

IC1—LM2940CT-5.0 voltage regulator, National Semiconductor or equivalent
IC2—74LS373 octal latch, Texas Instruments or equivalent
IC3—5164 8K byte static RAM or equivalent (optional, see text)
IC4—27xxx family EPROM, or equivalent (see text and Fig. 4)
IC5—DS14C232CN RS-232 driver
IC6—S80C552-1A68 CMOS microcontroller, Intel or equivalent

IC7, IC8—SN754410NE high-current driver IC, Texas Instruments or equivalent
IC9—82C55A parallel interface, Toshiba or equivalent
IC10—LM2931CT voltage regulator, National Semiconductor or equivalent (optional, see text)
LED1, LED2—Red light-emitting diode, T1 package
D1—1N4001 silicon diode
Q1—2N3906 PNP transistor

Other components

RY1—SPDT relay, 5-volt coil (Omron G5LE-114P-PS)
S1—DPDT switch
S2—3-position DIP switch
XTAL1—7.3728 MHz crystal
J1, J4–J10—wire jumper
J2—5.5/2.0mm coaxial power jack
J3—PC-mount female DB-25 connector

Miscellaneous: PC board, six plug bumpers (rubber feet), 6–15 volt DC power supply with 5.5mm/2.1mm coaxial plug, TO-220 heatsink for IC1, two 16-pin DIP heatsinks for IC7 and IC8, 28-pin DIP socket for IC4, 16-pin DIP socket for IC5, 68-pin PLCC socket for IC6, 40-pin DIP socket for IC9, wire, solder.
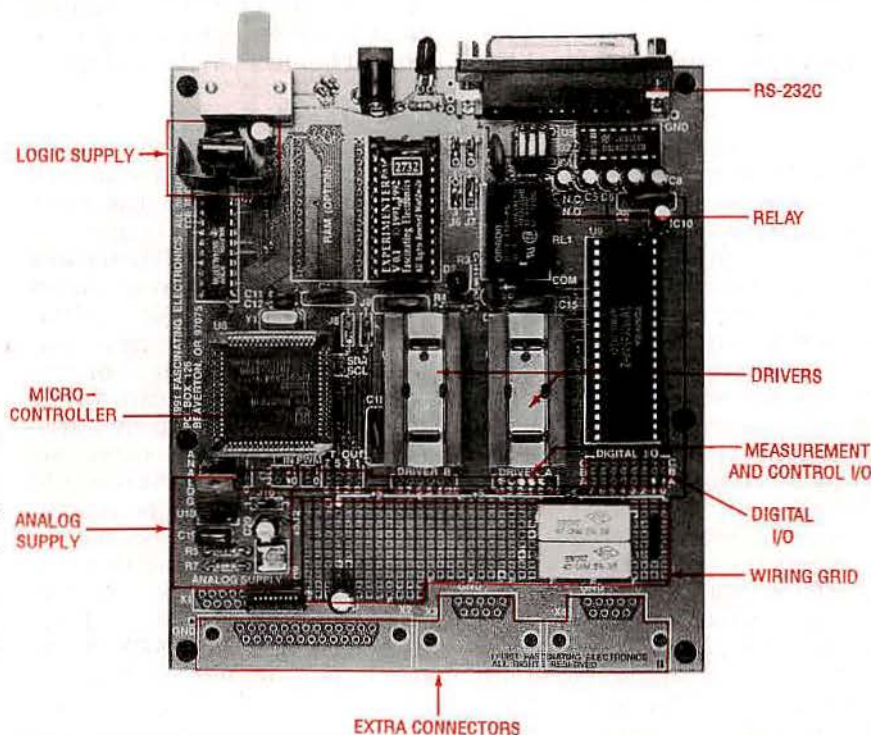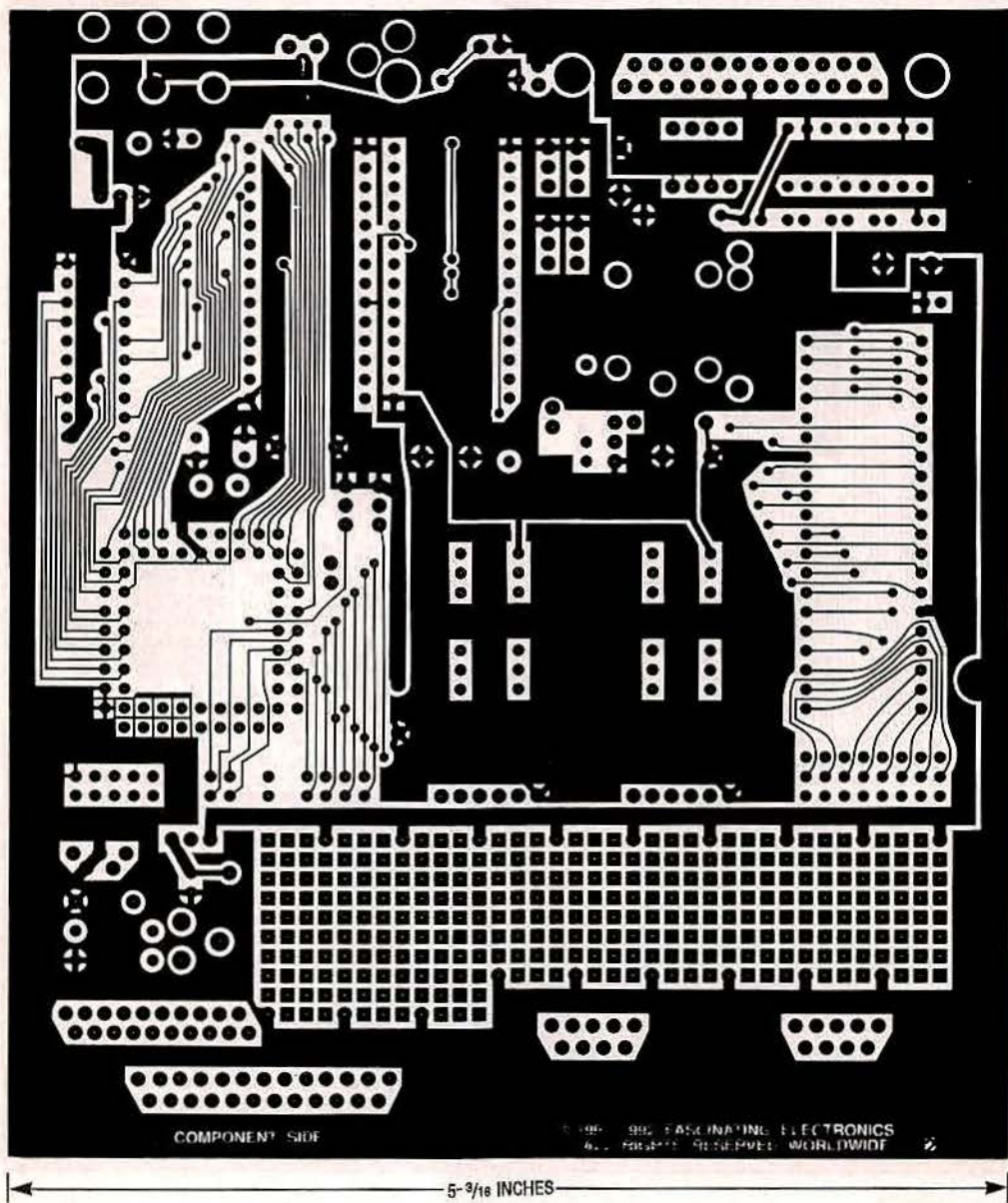
FIG. 5—CLOSEUP OF THE EXPERIMENTER. The Experimenter is a powerful measurement and control board that links your computer to the physical world with a variety of functions.

After turning on Experimenter's power, it should transmit a message listing its software version. It also runs a diagnostic check that will tell you if it has found an error.

Begin by testing the Experimenter's measurement and control capabilities, starting with the block of connections at the far left (the analog measurement inputs). Connect a hookup wire from the analog ground (AG) connection to the Channel 0 input. Send the Experimenter the command "A 0," and it should respond with a "0". Now jumper from the Analog +5 connection (A+5) to channel 0. This time when the A 0 command is given, Experimenter should respond with "5115," its full-scale reading. Repeat this procedure for channels 1 to 7.

Now check the time-measurement capabilities and the pulse-width modulators. Connect a hookup wire from PWM 0 to

COMPONENT SIDE

|←——————————————— 5-³/₁₆ INCHES ———————————————→|

COMPONENT SIDE of the Experimenter board.

$T_{IN}0$. Give the command "E 0 204 144." That sets PWM 0 to an 80% duty cycle pulse at a rate of about 100 Hz. The command "C 0 7" will read the period, and respond "10030," meaning 10,030 microseconds. The command C 0 5 will read the positive pulse width, a value of 8020 microseconds. The command C 0 6 will read the negative pulse width, a value of 2010 microseconds. You can repeat this procedure for PWM 1, and the other timer inputs (T_{IN} 1–3).

The timed outputs (T_{OUT} 0–7) can also be tested with the time-measurement functions. Connect a wire from $T_{OUT}0$ to $T_{IN}0$. The command "I 0 1 10 1" will

produce a train of pulses on $T_{OUT}0$ that remain high for about 10 milliseconds and low for 1 millisecond. The command C 0 5 will measure the positive pulse width, and respond with 9990 microseconds. The command C 0 6 will measure the negative pulse width, 1000 microseconds. Repeat this procedure for the other timed outputs.

To test the driver outputs (DRIVER A 0–3 and DRIVER B 4–7), connect a power source to the + A and + B inputs. For this test, wire those supply inputs to the +5-volt logic supply. Caution: Do not try to run any large motors from this supply! Not

much current is available, and motors introduce electrical noise into their power sources. The noise could interfere with your Experimenter's proper operation. The connections to the + 5-volt logic supply are marked among the top row of holes in the user-available wiring grid.

Now test the driver outputs the same way you tested the timer outputs. Recall that the only difference between the timer outputs and the driver outputs is that the driver outputs are buffered. Connect a wire from DRIVER A 0 to $T_{IN}0$. Give the commands E 0 255 and E 1 255 to assure that the PWM's are fully enabling the drivers.

SOLDER SIDE

5-³/₁₆ INCHES
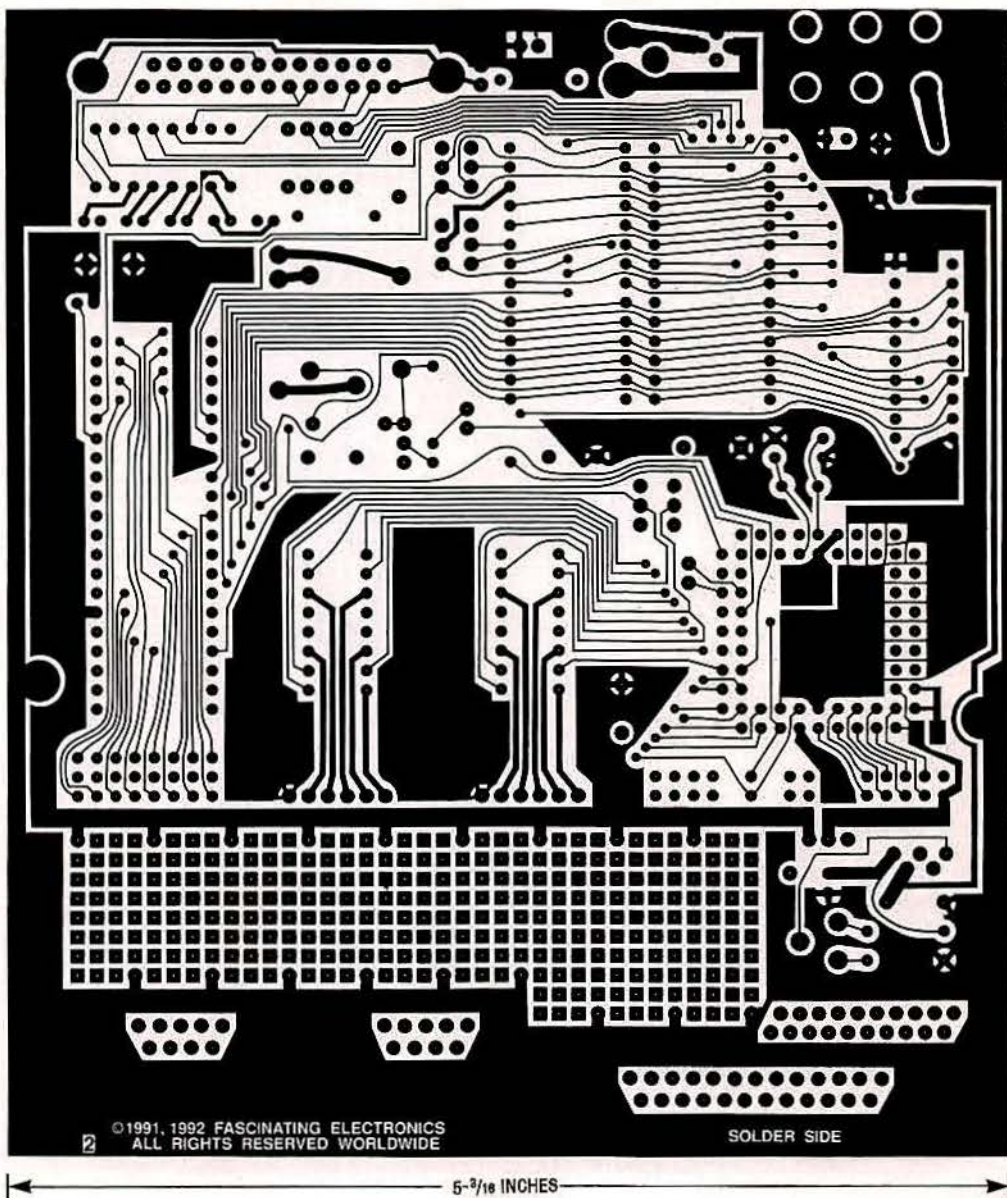
SOLDER SIDE of the Experimenter board.

Use the command I 0 1 10 1 to send a pulse train to DRIVER A 0. Use the command C 0 5 to measure the positive pulse duration. It should read about 9990 microseconds, as in the timed output tests. Repeat the test for the other driver outputs.

Finally, test the digital input/output with a logic probe, a digital multimeter, or with a wire jumper to an analog signal generator input. The command D 3 128 programs ports A, B, and C to be outputs. Because the microcontroller resets at power-on to all zeros, probing each output should show that each has a logic low state. The command D 0

255 sets all outputs on digital I/O port A high. Verify those outputs, and then test ports B and C with the commands D 1 255 and D 2 255.

Congratulations! You have now built and tested a versatile computer peripheral tool that vastly expands the capabilities of your computer. Next month we will describe a project based on Experimenter's digital output, time measurement, and stepper-motor control capabilities. That project will be the ultrasonic "radar" that actually makes very accurate distance measurements to nearby objects.   Ω
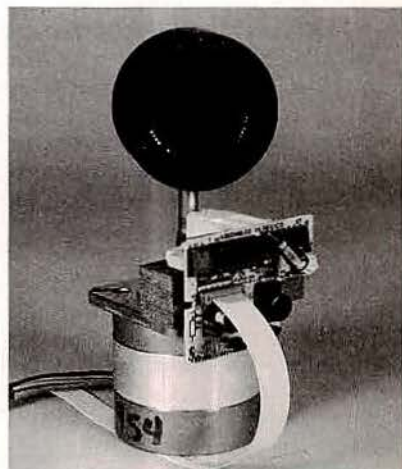
HERE'S THE RADAR PROJECT that we'll be working on next month.