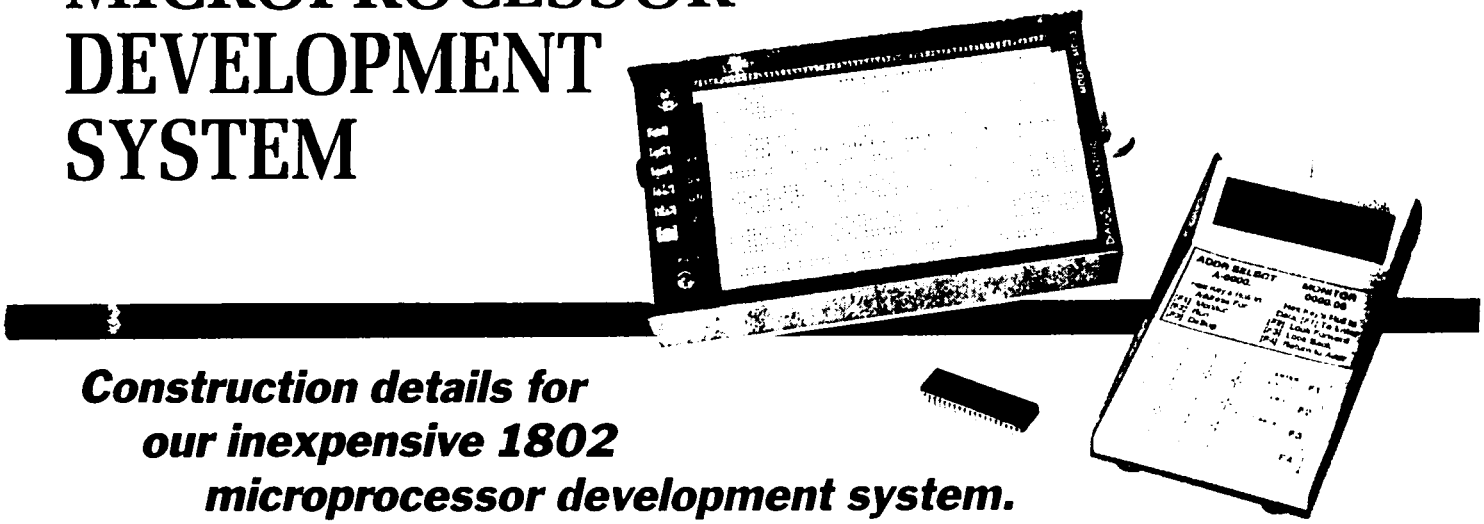
BUILD THIS MICROPROCESSOR DEVELOPMENT SYSTEM



Construction details for our inexpensive 1802 microprocessor development system.

LAST TIME WE DISCUSSED THE CIRcuitry for our 1802 development system and described how the software functions. This time we'll talk about construction and operation.

Construction

The complete unit uses three PC boards, corresponding to the sections of the circuit (main, keypad/display, EPROM). Foil patterns are provided if you want to make your own boards; boards and kits are also available commercially (see the parts list).

The main chassis measures 8" × 4.6" × 1.5". As shown in Fig. 7, S1 (reset) and S2 (EPROM power) mount on top of the chassis, as does a four-connector terminal block that brings several voltage sources out of the chassis for use by experimental circuits (developed on the breadboard). In addition, there is space for two 63-row solderless breadboards, and two 63-row power buses. Further, the rear edge of the case is slotted to allow the pins of P3 to protrude.

The power supply enters one side of the chassis through a grommet; the 6-wire telephone jack for the keypad/display unit fits in a slot on the other side.

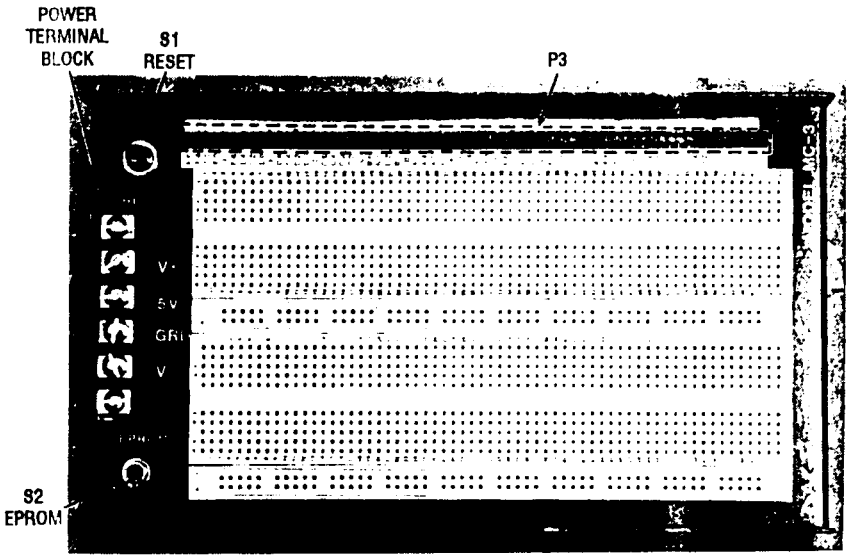


FIG. 7—MAIN CHASSIS ASSEMBLY. The terminal block on the left delivers power to breadboard circuits. Note that P3 consists of separate wire-wrap pins that protrude through a slot in the case.

Main board

Mount all parts on the main PC board, as shown in Fig. 8. Resistors R13–R24 must be ⅛-watt units in order to mount on 0.3" centers. All other resistors mount on 0.4" centers. Sockets should be used in all IC positions, and are required for IC20 (the EPROM burner slot) and IC22 (the EPROM that contains the operating system). You can buy a pre-programmed EPROM (see the ordering information in the parts list for details) or burn your own using the hex dump shown in Listing 1.

The operating system requires the first output port, IC2. The other output ports can be installed during assembly, or as the need arises. In addition, you can eliminate IC3–IC13 if you don't need parallel inputs. The author recommends that you install at least two output ports (IC2 and IC3) and two input ports (IC8 and IC9).

You must install the operating-system EPROM at IC22 (0000h), and 8K of RAM at IC19 (E000h). You needn't install components at IC20 and IC21 unless you need additional memory.

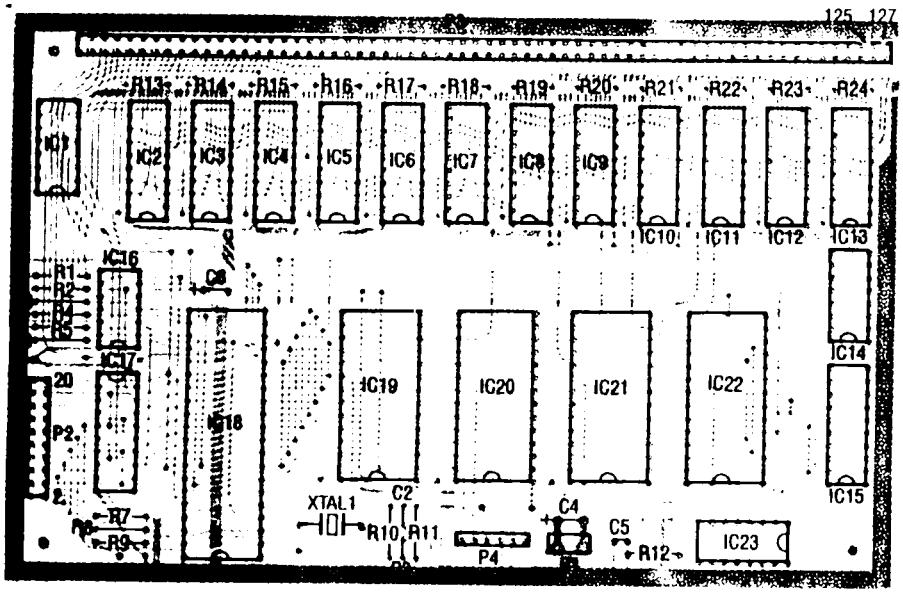


FIG. 8—MAIN PC BOARD. Note that R13–R24 must be ⅛-watt units to fit in the available space. Sockets are required for IC20 and IC22, and optional but recommended elsewhere.

The bus connector (P3) consists of 128 individual wire-wrap pins, each measuring 0.075". The best way to install them is to insert them through the board and into a female header to hold them perpendicular while soldering. Figure 9 details the function of each pin.

Connect one wire from ground to the reset switch, and another to the pad marked *reset* on the main board. Figure 10 shows the completed main board.

Keypad/display assembly

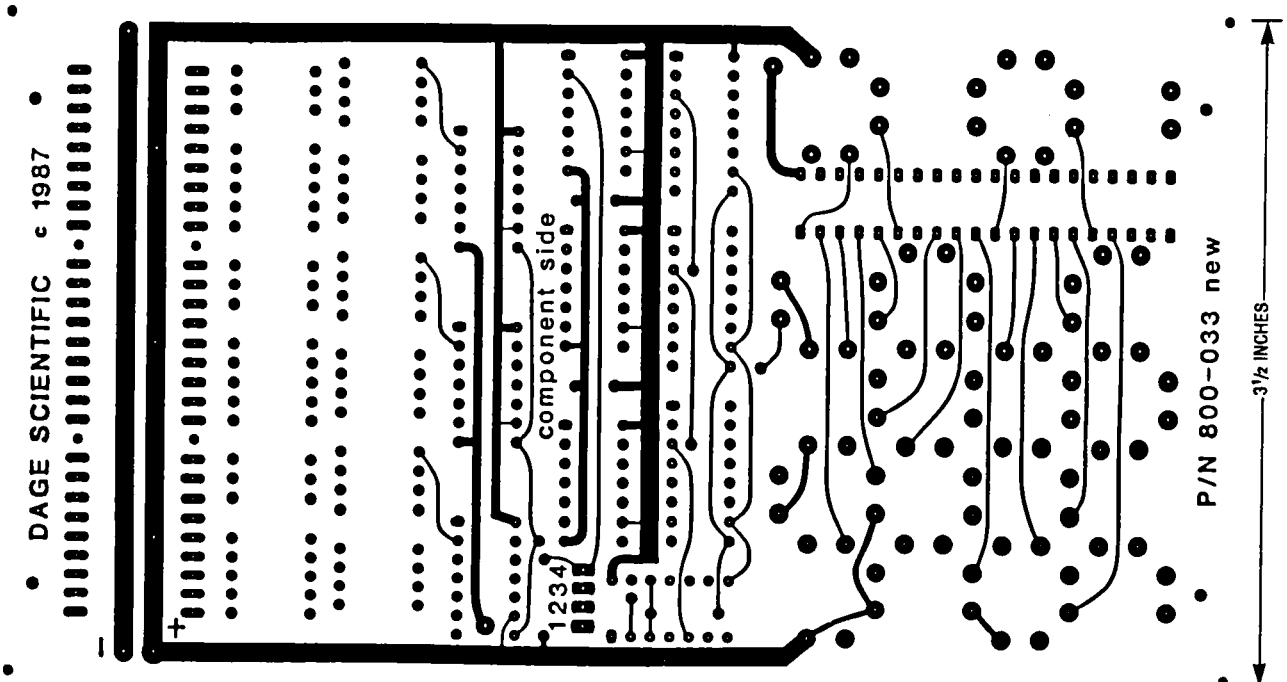
Assemble the keypad/display unit as shown in Fig. 11. Mount the IC's without sockets, as there is not enough clearance to use them. However, mount each display using half a socket under the rear row of pins only. Doing so angles the display about 20 degrees for better viewing. The pull-down resistors for the key switches must be ⅛-watt units to fit the 0.3-inch mounting centers.

The six-conductor telephone cord connects directly to the foil side of the board, as shown in Fig. 12; secure the cord with a nylon wire wrap. The other end of the cord has a modular plug that fits into J1 on the main board. The color codes in phone cords and connectors seem to vary, so we haven't provided specific details. It doesn't matter which color you use for which signal; just make sure that you're consistent at both ends of the cable. Figure 13 shows the completed keypad/display board.

EPROM board assembly

Assemble the EPROM board as shown in Fig. 14. Mount a six-pin female connector (J1) on the solder side of the board; it will mate with P4 on the main board, and serves to hold the EPROM board in place. The completed EPROM board is shown in Fig. 15. When mounted properly, the EPROM board rides about ½" above the EPROM that is being programmed (see Fig. 16). In front of this connector are two solder pads used to connect the EPROM programming voltage. Connect the ground side (gnd) only if the programming voltage doesn't have a common ground with the main board.

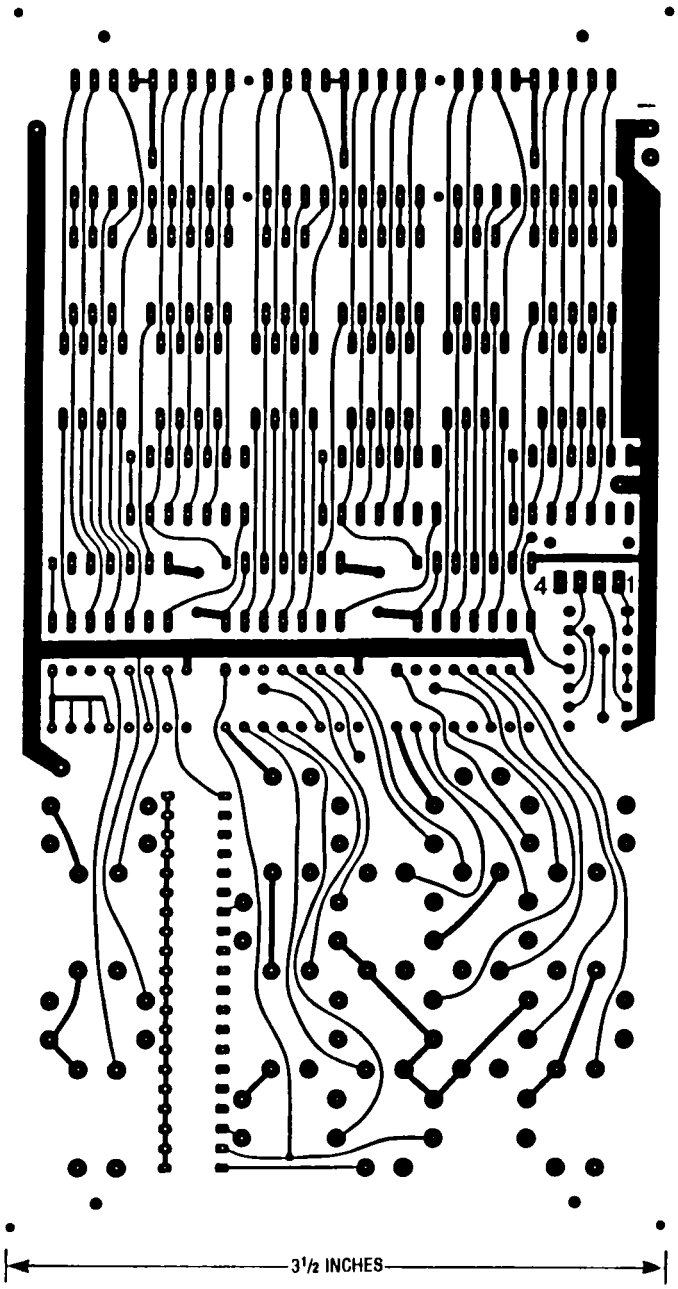
In case you want to install RAM in IC20, remove the EPROM circuit; otherwise every



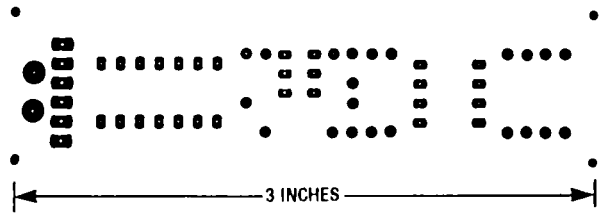
COMPONENT SIDE OF THE KEYPAD/DISPLAY BOARD.

LISTING 1—HEX DUMP OF OPERATING SYSTEM (0000—04FF)

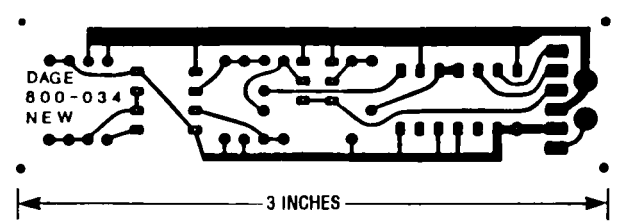
```
0000  71 00 F8 00 B3 F8 09 A3 D3 F8 FE B2 F8 FF A2 E2
0010  F8 00 B4 F8 60 A4 F8 00 B5 F8 70 A5 F8 00 B8 F8
0020  91 A8 34 3A E3 62 00 62 01 E2 D8 69 FB FF 3A 3D
0030  D8 D8 69 FA F0 C2 02 24 30 52 C0 04 A1 F8 00 52
0040  62 22 F8 06 A7 F8 00 52 7B 61 D8 22 27 87 3A 45
0050  30 22 FF FF FF FF FF FF FF FF FF FF C0 E0 00 D3
0060  E2 96 73 86 73 93 B6 83 A6 46 B3 46 A3 30 5F D3
0070  96 B3 86 A3 E2 12 72 A6 F0 B6 30 6F FF FF FF FF
0080  21 7D 13 19 4D 89 81 3D 01 0D 05 C1 A3 51 83 87
0090  D3 7B 7A 7B 7A 7B 7A 7B 7A 7B 7A 7B 7A 7B 7A 7B
00A0  7A 30 90 99 B6 89 A6 D5 FF D4 00 CE 46 B8 46 A8
00B0  46 B9 46 A9 46 A7 46 32 C3 E9 08 28 73 27 87 3A
00C0  BA 30 CA 48 59 19 27 87 3A C3 D4 00 EE D5 87 73
00D0  97 52 60 60 60 02 A7 22 02 B7 22 22 22 89 73 99
00E0  73 8A 73 9A 73 88 73 98 73 87 73 97 73 D5 60 42
00F0  B7 42 A7 42 B8 42 A8 42 BA 42 AA 42 B9 42 A9 60

0100  60 60 87 73 97 73 22 42 B7 02 A7 D5 87 73 97 73
0110  88 73 98 73 F8 00 B8 F8 91 A8 F8 02 B7 A7 27 97
0120  3A IE F8 00 52 62 22 F8 01 52 62 22 D8 69 FB FF
0130  3A 22 D8 69 FB FF 3A 22 D8 69 FB FF FA 0F 3A 22
0140  F8 10 B7 27 97 3A 43 F8 00 AA F8 00 52 62 22 F8
0150  01 52 62 22 D8 69 FB FF 3A 78 F8 08 AA D8 69 FB
0160  FF 3A 78 D8 69 FB FF FA 0F 32 47 F9 80 AA 60 72
0170  B8 72 A8 72 B7 F0 A7 D5 F6 33 6E 1A 30 78 FF FF
0180  88 73 98 52 F8 FF B8 F8 F0 A8 F8 05 58 18 F8 DF
0190  58 18 99 F6 F6 F6 F6 BA D4 02 09 9A 58 18 99 BA
01A0  D4 02 09 9A 58 18 89 F6 F6 F6 F6 BA D4 02 09 9A
01B0  58 18 89 BA D4 02 09 9A FF 01 58 18 09 F6 F6 F6
01C0  F6 BA D4 02 09 9A 58 18 09 BA D4 02 09 9A 58 09
01D0  BA 72 B8 F0 A8 D5 87 73 88 73 98 73 89 73 99 73
01E0  E6 72 B9 72 A9 E2 F8 00 B8 F8 91 A8 F8 00 52 62
01F0  22 F8 06 A7 E9 7B 61 D8 27 87 3A F5 E2 60 72 B9

0200  72 A9 72 B8 72 A8 F0 A7 D5 88 73 98 52 F8 00 B8
0210  F8 80 A8 9A FA 0F 32 1D FF 01 18 30 16 08 BA 72
0220  B8 F0 A8 D5 F8 00 B9 A9 D4 01 80 D4 01 D6 FF F0
0230  D4 01 0C 8A 52 FE 33 4A F8 04 A7 89 FE A9 99 7E
0240  B9 27 87 3A 3B 89 F1 A9 30 28 8A F6 33 5C F6 33
0250  56 F6 33 A0 30 24 D4 00 A3 D4 01 80 09 73 D4 01
0260  D6 FF F2 D4 01 0C 60 8A FE 33 88 F8 FF B8 F8 F7
0270  A8 02 FE FE FE FE 52 8A F1 52 08 28 58 18 02 22
0280  BA D4 02 09 9A 58 30 5E 8A F6 33 94 F6 33 9A F6
0290  33 9C 30 24 02 59 09 F3 3A 59 19 38 29 30 59 FF
02A0  F8 02 B1 F8 C8 A1 F8 FF B8 F8 FA A8 E8 49 73 49
02B0  73 09 73 E9 F8 D1 73 F8 79 73 F8 22 73 30 24 FF
02C0  42 70 22 78 22 52 30 D8 52 F8 FF B0 F8 F9 A0 F0
02D0  73 40 73 40 73 40 73 60 E2 92 B0 82 A0 22 F8 00
02E0  7E 73 F6 C5 F8 01 73 10 10 80 73 90 73 20 83 73
02F0  93 73 84 73 94 73 85 73 95 73 86 73 96 73 78 73

0300  97 73 88 73 98 73 89 73 99 73 8A 73 9A 73 8B 73
0310  9B 73 8C 73 9C 73 8D 73 9D 73 8E 73 9E 73 8F 73
0320  9F 73 F8 03 B3 F8 29 A3 D3 80 AF 90 BF 0F FA 0F
0330  AA B7 30 3B D4 01 0C 8A FE 33 59 90 BF 80 AF 8A
0340  B7 32 49 2F 2F 2A 8A 30 41 0F A9 2F 0F B9 1F D4
0350  01 80 D4 01 D6 FF F2 30 34 8A F6 33 98 F6 33 98
0360  F6 33 66 C0 00 09 D4 01 0C 8A FE 33 89 F8 04 A7
0370  89 FE A9 99 7E B9 27 87 3A 70 8A 52 89 F1 A9 D4
0380  01 80 D4 01 D6 FF F2 30 66 8A F6 3B 93 89 5F 2F
0390  99 5F 1F 97 AA 30 3B FF F8 03 B1 F8 9F A1 D1 F8
03A0  IF A7 20 27 87 3A A2 40 BF 40 AF 40 BE 40 AE 40
03B0  BD 40 AD 40 BC 40 AC 40 BB 40 AB 40 BA 40 AA 40
03C0  B9 40 A9 40 B8 40 A8 40 B7 40 A7 40 B6 40 A6 40
03D0  B5 40 A5 40 B4 40 A4 40 B3 40 A3 40 B2 40 A2 40
03E0  7A CE C4 7B 40 F6 22 22 C0 02 C0 FF FF FF 46 BB
03F0  46 AB 16 E6 F5 A7 26 9B 75 16 16 B7 17 F8 00 BD

0400  AD AC EB 97 3A 09 87 32 13 8C F4 AC C7 1D C4 27
0410  1B 30 03 8C A9 8D B9 D4 01 80 F8 FF BE F8 F0 AE
0420  9D F6 F6 F6 F6 BA D4 02 09 9A 5E 1E 9D BA D4 02
0430  09 9A 5E D4 01 D6 FF F0 D5 46 BB 46 AB 16 E6 F5
0440  A9 26 9B 75 B9 19 16 16 46 BC 46 AC 99 3A 52 89
0450  32 6A 0B 5C D4 01 80 D4 01 D6 FF F0 EC 0B F3 3A
0460  66 1B 1C 29 30 4C 9C B9 8C A9 D4 01 80 D4 01 D6
0470  FF F0 D5 46 B7 46 A7 27 17 27 87 C4 C4 3A 77 97
0480  27 17 27 C4 C4 3A 77 D5 D4 04 39 04 88 04 A0 FF
0490  00 D4 01 0C C0 02 24 FF D4 03 EE 00 00 00 00 30
04A0  09 7B F8 40 B7 57 F8 80 B7 07 7A F8 C0 B7 57 34
04B0  A1 F8 FE B2 A2 12 E2 69 22 6A 22 6B 22 6C 22 6D
04C0  22 6E 22 7B 7A 6F 67 66 65 64 63 62 61 22 3D B7
04D0  F8 00 B8 F8 91 A8 E3 7B 62 01 62 00 61 55 D8 E2
04E0  3E D6 F8 00 B8 F8 91 A8 E3 62 00 62 01 E2 D8 69
04F0  22 F8 00 52 62 7B 61 22 D8 3F E8 FF FF FF FF FF
```



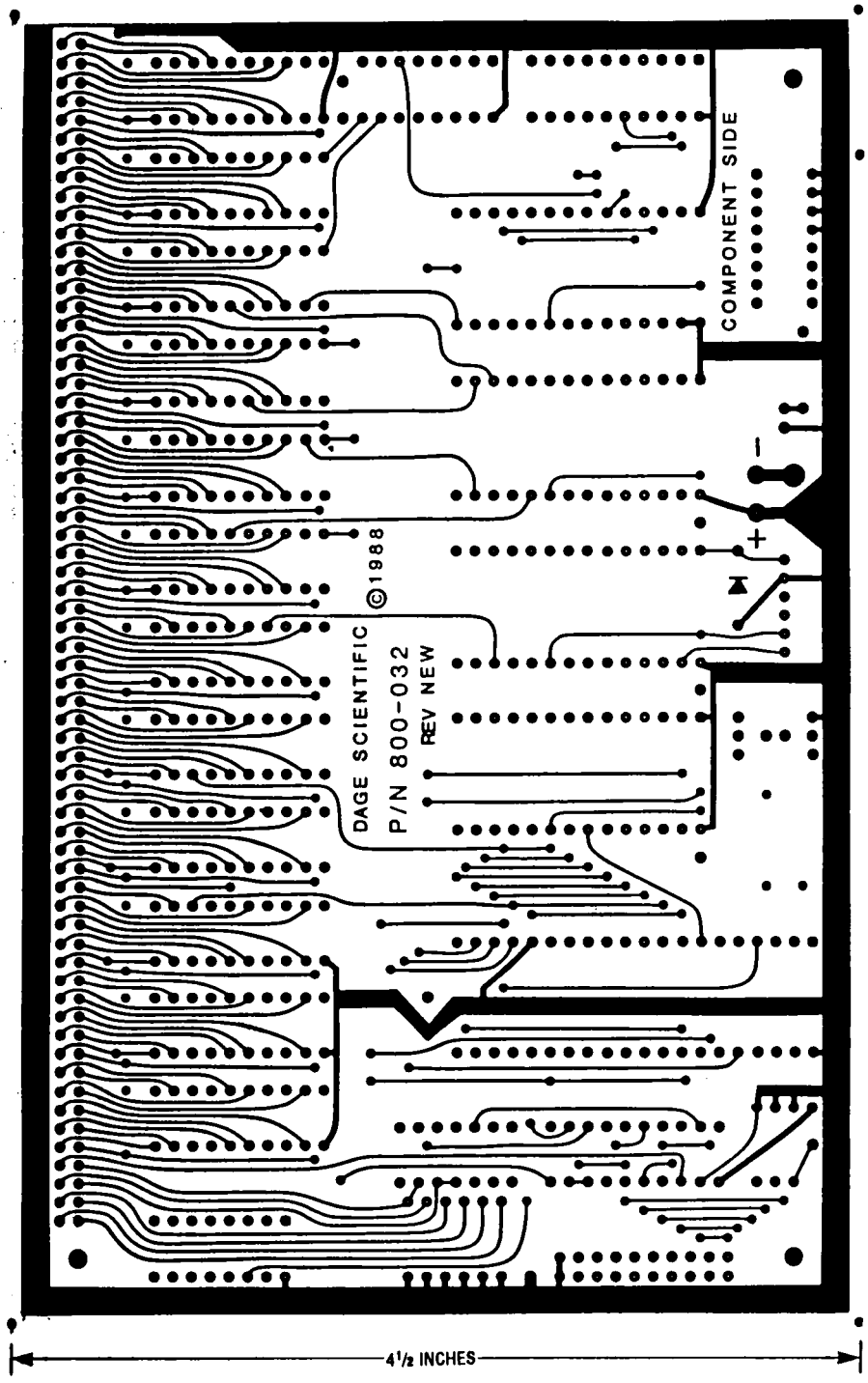
SOLDER SIDE OF THE KEYPAD/DISPLAY BOARD.



COMPONENT SIDE OF THE EPROM BOARD.



SOLDER SIDE OF THE EPROM BOARD.



COMPONENT SIDE OF THE MAIN PC BOARD.

access to that location will incur a 50-ms delay.

After assembling each board, check all work, and correct any mistakes. Then apply power, and hold down the 0 key. If all is well, all segments and decimal points of the display should light up. If they do not, remove power and check all connections again.

Electronic construction is complete; now you can mount the boards in their proper chassis locations.

Operation

Boot up normally; the display should read "A-0000." The "A" indicates Address Select mode; the zeros indicate the current address.

Actually, the monitor program has four modes: Address Select, Memory Monitor, Run, and Debug.

PARTS LIST—MAIN BOARD

All resistors are ¼-watt, 5%, unless otherwise noted
R1, R3–R8, R11, R12—1000 ohms
R2—150,000 ohms
R9—30,000 ohms
R10—22 megohms
R13–R24—51,000 ohms, ⅛ watt
Capacitors
C1—1 µF, 35 volts, tantalum
C2, C3—20 pF, ceramic
C4—10 µF, 25 volts, tantalum
C5, C6—0.1 µF, mini ceramic
Semiconductors
IC1—74HC238 3-to-8 line decoder
IC2–IC13—74HC373 octal D latch
IC14—74HC138 3-to-8 line decoder
IC15—74HC373 octal D latch
IC16—74HC86 quad 2-input XOR gate
IC17—74HC299 8-bit shift register
IC18—1802 microprocessor
IC19—6264 static RAM
IC20—see text
IC21—see text
IC22—2764 EPROM (with operating system)
IC23—4556 dual 1-of-4 decoder
Other components
XTAL1—2.010 MHz crystal
P1–P4—wire-wrap pins, 0.025" square × 0.75"
J1—6-conductor telephone jack

PARTS LIST—KEYPAD/DISPLAY BOARD

All resistors are ¼-watt, 5%, unless otherwise noted
R1–R20—51,000 ohms, ⅛-watt
R21–R68—330 ohms
R69—100,000 ohms
Semiconductors
IC1–IC6—74HC164 8-bit shift register
IC7—74HC00 quad 2-input NAND gate
IC8–IC10—4021 8-bit shift register
Other components
DS1–DS3—dual 7-segment LED display, 0.5", common anode
S1–S20—SPST, normally open, push-button, PC mount

When the display shows "A-," the monitor is in the Address Select mode. Any time the operating system is in control, pressing F4 returns you to Address Select mode.

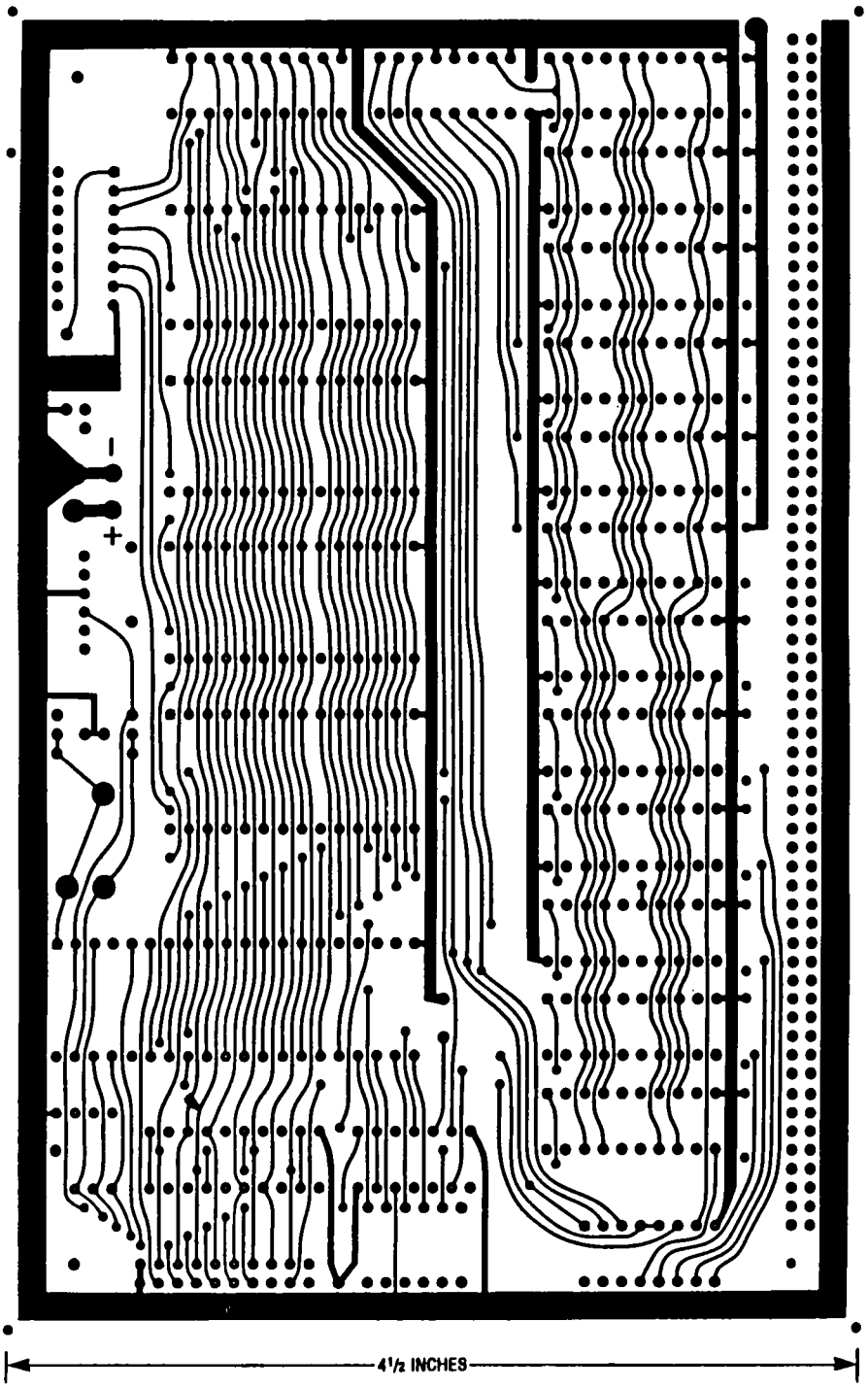
To enter a new address, just press the corresponding keys. The digits you enter scroll from right to left; if you make a mistake, simply enter new digits until you see correct address displayed.

After entering the desired address, you have three choices, with corresponding keys:

PARTS LIST—EPROM BOARD

All resistors are ¼-watt, 5%, unless otherwise noted
R1, R4—22 megohms
R2—47,000 ohms
R3—100,000 ohms
Capacitors
C1—0.001 µF, Mylar
C2—100 pF, ceramic
C3—0.001 µF, Mylar
C4—0.02 µF, 5%, Mylar
C5—0.1 µF, ceramic
Semiconductors
IC1—74HC02 quad 2-input NOR gate
IC2—555 timer
D1—1N4148 diode
Q1, Q2—2N4124 NPN transistor
Miscellaneous: Chassis & hardware, power supply, telephone cord & connectors, terminal block, toggle switch, push button switch, solderless breadboarding connectors, PC boards.
Note: The following items are available from Dage Scientific, 6124 Baldwin St., Valley Springs, CA 95252 (209) 772-2076:
- **Kit including everything but power supply (Model MC-2)—$195**
- **Surplus power supply (+12, +5, −5)—$11**
- **Operating system in EPROM—$10**
- **Set of 3 PC boards and manual—$35**

Please add $5 shipping & handling per order. California residents add applicable sales tax.



SOLDER SIDE OF THE MAIN PC BOARD.

Monitor (F1), Run (F2), and Debug (F3).

Monitor mode allows you to examine and modify memory contents on a byte-by-byte basis. Run mode lets the CPU execute the program at the current address. Debug mode inserts a breakpoint at the current address.

To enter Monitor mode, type the desired address and press F1. That address and its contents will appear. For example, 0000.FF indicates a hexadecimal value of FF at address 0000h.

In this mode, the function keys take on new meanings. F1 stores the currently displayed value into the currently displayed address and moves on to the next address. F2 displays the next address. F3 displays the previous address.

To change the currently displayed value, use the hex keys to roll new digits into positions 5 and 6. If you make a mistake, simply enter new digits until the correct value appears. Memory contents will not be altered until you press F1. When you do press F1, the currently displayed value will be stored at the displayed address, and the next address will be displayed. If the value can not be stored into memory, the address counter will not increment. (It's possible to program values one byte at a time into an EPROM using that procedure, but there's a better way, as discussed below.) And remember: Press F4 at any time to return to Address Select mode.

After storing a program in memory, you can execute it using the Run command. Starting from Address Select mode, enter the desired starting address and press F2. The monitor program then transfers control to your program. If your program hangs, press the

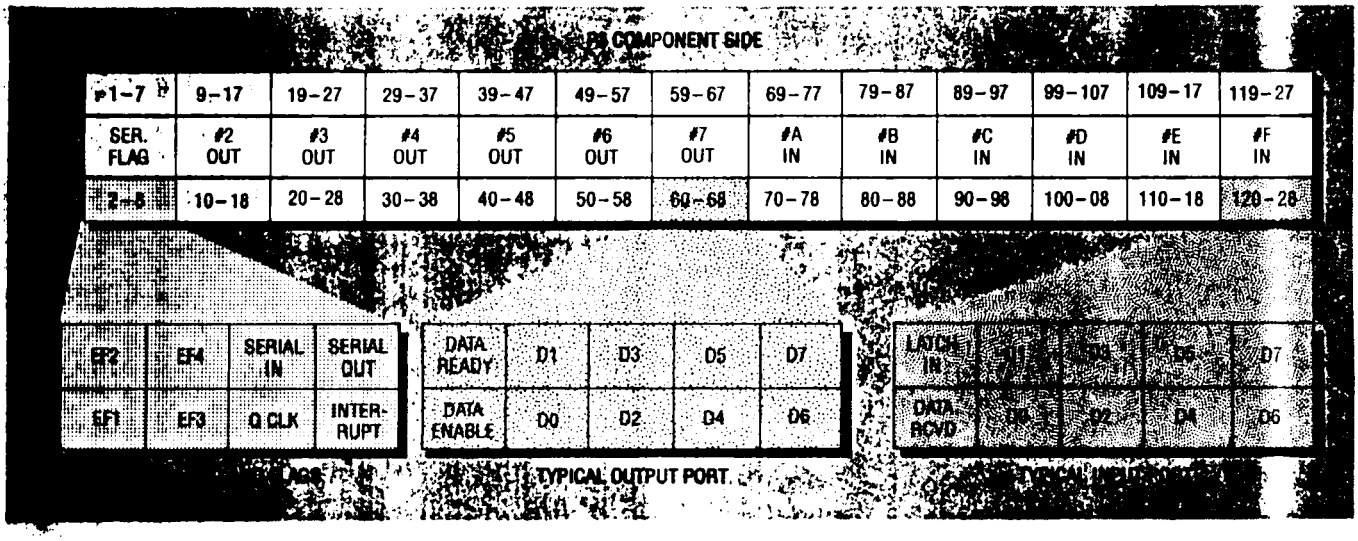


FIG. 9—PLUG P3 CONNECTIONS. The 128 pins of P3 consist of one group of 8 pins (for serial I/O, EF flags, Q clock, and interrupt) and 12 groups of 10 pins each. Those 12 groups break down into six input ports and six output ports, each with pinouts as shown.

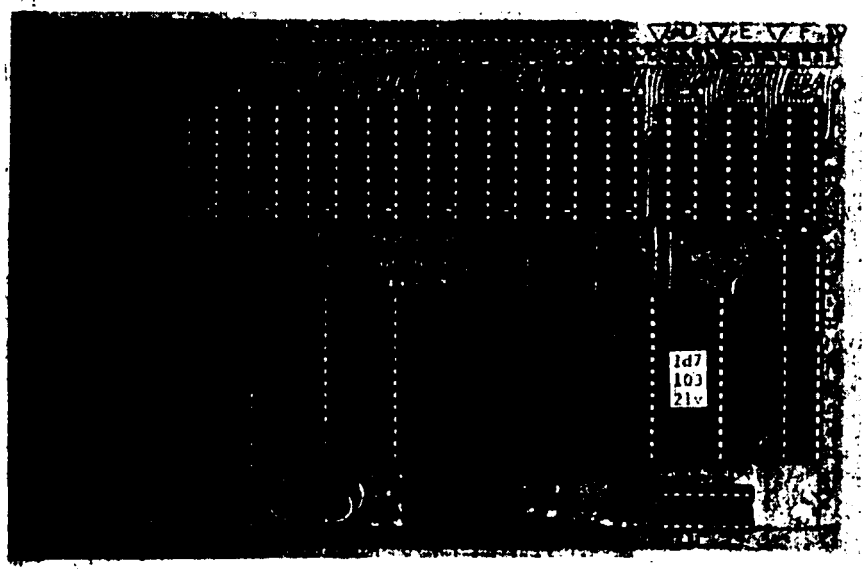


FIG. 10—THE COMPLETED MAIN BOARD. Sockets should be used in all IC positions, and are required for IC20 (the EPROM burner slot) and IC22 (the EPROM that contains the operating system).

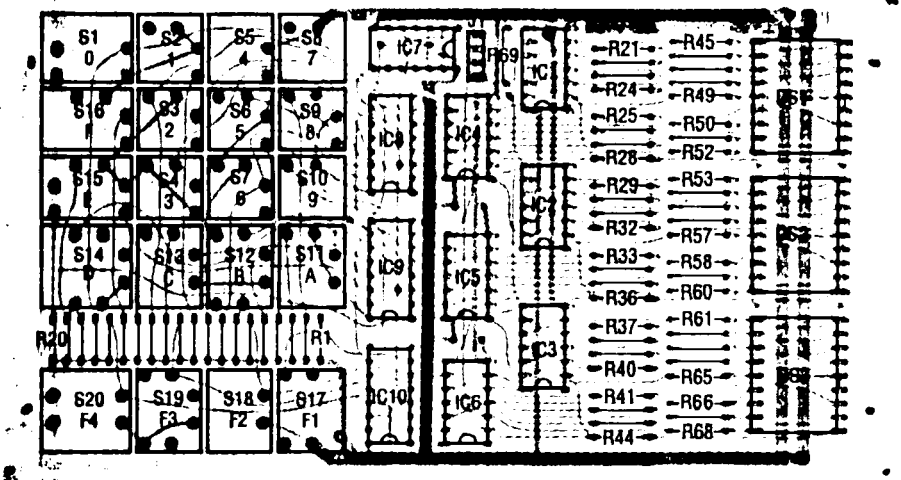


FIG. 11—KEYPAD/DISPLAY PC BOARD. Mount all parts as shown here. If you use our case, don't use IC sockets except under the rear row of display pins.

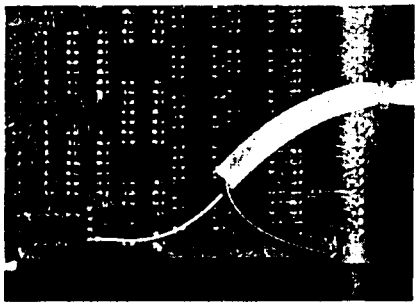


FIG. 12—PHONE CABLE connections. Solder the wires directly to the foil side of the board.

reset switch to regain monitor control.

In case your program doesn't work the first time, you can use Debug mode to track down problems. Use Address Select mode to select a likely address for troubleshooting and press F3. You'll return to Address Select mode. Now enter the desired starting address and press F2. Later, when the CPU hits the breakpoint address, it will start executing a special debug program that allows you to view the CPU's internal registers, and to verify that what you intended to happen is indeed happening.

You can set only one break point at a time; you cannot breakpoint addresses in ROM. When your program reaches the breakpoint, it will halt and display the current address. You are now in the Debug mode.

In Debug mode, the display appears the same as in Monitor mode. However, as you press the hex keys the display will show the internal register number (in positions 1–4) and the value in

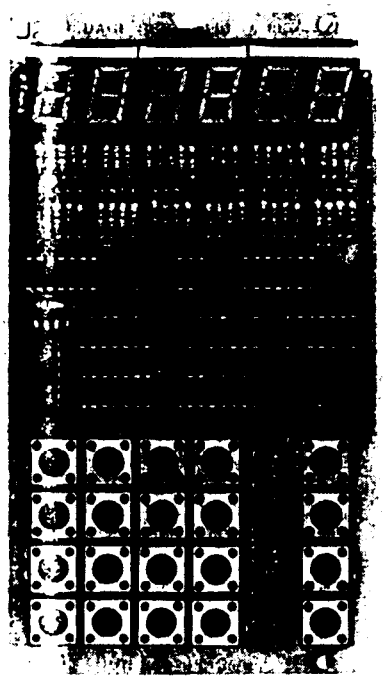


FIG. 13—COMPLETED KEYPAD/DISplay board. Mount each display using half a socket under the rear row of pins only, to provide better viewing.

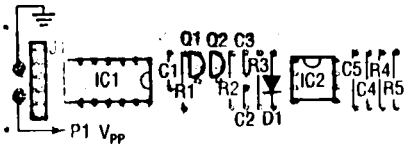


FIG. 14—EPROM PC BOARD. Mount all parts except J1 on the component side of the board; mount J1 on the foil side.

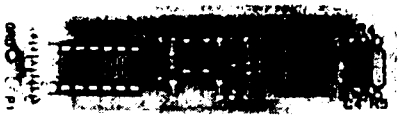


FIG. 15—THE COMPLETED EPROM board. A six-pin female connector (J1) on the solder side mates with P4 on the main board.

that register (in positions 5–6).

The debug program uses registers 0 and 1, which have been reserved for DMA and interrupt. Pressing hex key 0 displays the contents of the D register in positions 1 & 2, the X register in position 3, and the P register in position 4. Pressing hex key 1 displays Q in position 2 (set = 1, reset = 0) and DF in position 4.

While in debug mode, register contents can be altered by first selecting a register pair and then pressing function key F3. Change the value by rolling new digits in from right to left. When the correct value appears, press F1; otherwise press F3 to back out without changing the current register. Registers D, X, P, Q, and DF can also be modified by selecting hex keys 0 and 1 as described above. To exit debug mode and continue execution, press F2. Of course you can press F4 to return to Address Select mode.

The debug breakpoint alters program memory by replacing three bytes at the selected address. When the user program reaches the breakpoint address, the debug program takes over and restores the original three bytes to the proper locations. However, if the user program never reaches the breakpoint, those three bytes will never be restored. In that case you must restore them either by continuing execution at the breakpoint, or by reentering the bytes manually using Monitor mode. If you continue at the breakpoint, the debug program will restore the three bytes and immediately jump into Debug mode. As usual, you can modify registers, continue execution, or return to Address Select mode.

TABLE 1—MOVE UTILITY ADDRESSES	
Address	**Memory Contents**
FF03	Start address (hi)
FF04	Start address (lo)
FF05	End address (hi)
FF06	End address (lo)
FF07	Destination address (hi)
FF08	Destination address (lo)

EPROM programming

With the EPROM programming board connected to J4 and the proper programming voltage available, flip the EPROM switch to on, and you are ready to program the EPROM mounted at IC20. All that is required to program a location is to "write" to it. As mentioned earlier, you can do this byte at a time using the Monitor mode. However, due to the error-prone nature of that procedure, the author recommends a more automated procedure.

The preferred method is to enter your program in RAM and then transfer it to EPROM with the operating system's built-in "move" utility, which in fact will move a block of data anywhere in memory, not just to EPROM. Start the utility by running at 0488. Doing so transfers the move utility itself to RAM starting at FF00. Now enter the start, end, and destination addresses as shown in Table 1.

Double-check your values to ensure that they are correct, and then run at FF00. The display will show the remaining number of bytes to be transferred. It will be changing rapidly, but will at least give some idea about how things are progressing. In case data cannot be transferred correctly, the program will terminate and the display will show the address that didn't change.

That about wraps things up. Actually, now that the hardware's built, the real fun is just about to begin. R-E

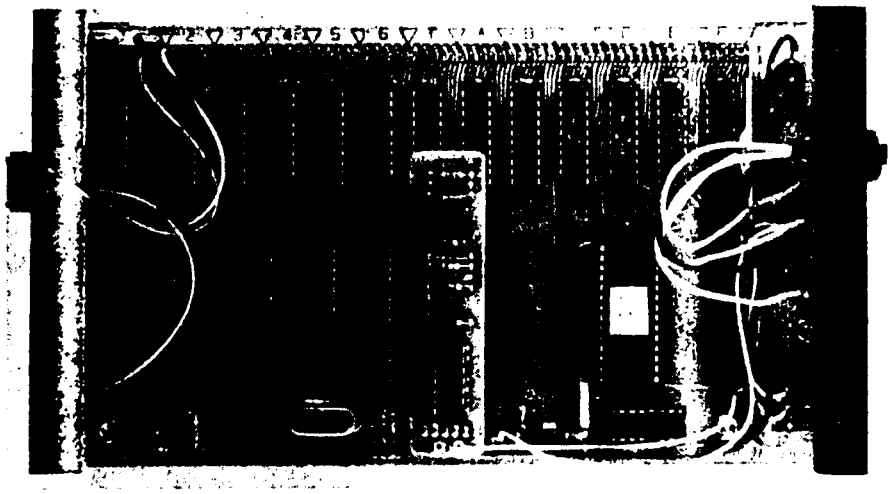


FIG. 16—THE EPROM BOARD mounts on the main board and rides about ½" above the EPROM that is being programmed.