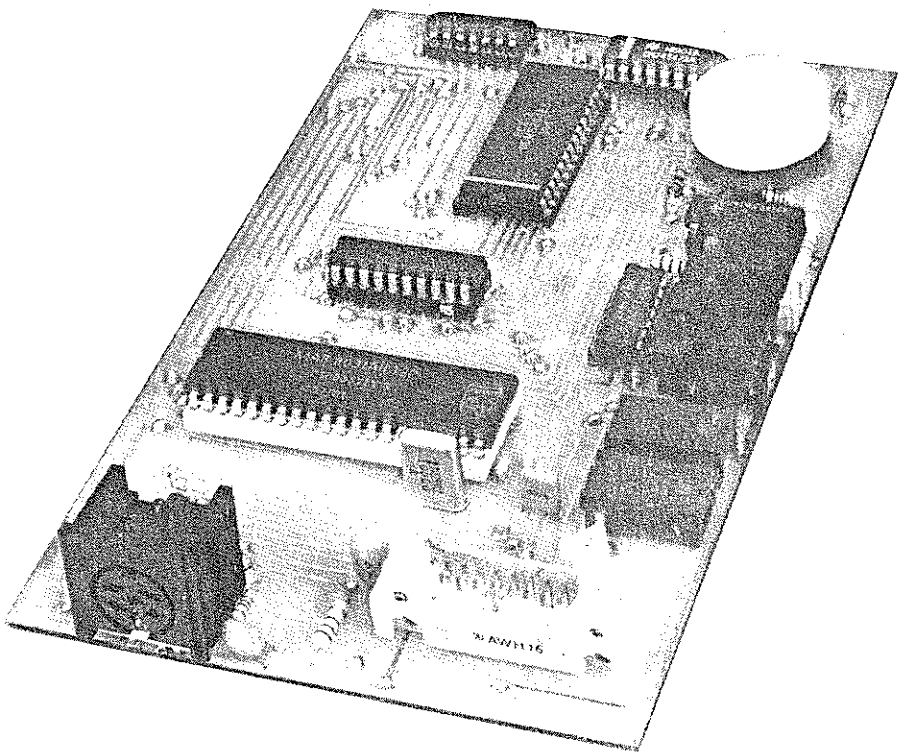
8031 SINGLE BOARD COMPUTER

Intel's 8031 embedded controller chip contains all the essential ingredients of a microcomputer — I/O ports, a UART, interrupt lines, 16-bit timers and counters, an 8-bit CPU, and 128 bytes of RAMstack. All that is additionally required to form a fully functional computer is an operating system, a means of getting machine code to the CPU, a few operating switches and a visual display. Such a computer is described here.



R. Grodzik

THIS project uses the Intel 8031 microcontroller to form a self-contained, machine code programmable computer board, measuring only 100 × 160 mm. The operating system, all 240 bytes of it (probably the world's smallest...), is contained in a pre-programmed PROM. The project is aimed in particular at experienced software and hardware designers who want to use the 8031 in stand-alone application circuits, such as automated control.

Circuit description

The block diagram of the single board computer, Fig. 1, shows the main elements of the computer: the 8031 MPU (master processing unit), 8 KBytes of RAM (random-access memory), a PROM (programmable read-only memory) and a data indication based on two LED displays. A handful of logic ICs complete the computer.

Port 1 (lines P1.0–P1.7) provides eight I/O lines, (latched input or output), whose logic status is continuously monitored by an intelligent hexadecimal display. Port 3 (lines P3.1–P3.4) provides four additional I/O lines, of which three have a dual function of external interrupt and counter input.

The computer is controlled by the operating system firmware resident in IC3, a PROM. The instructions in this PROM enable the 8031 to read the data from the serial input port, and send it to the RAM. In addition, the PROM provides the interrupt vectors for the system.

A major and useful feature of the board is the provision of battery back-up for the 6264 static RAM. As shown in the circuit diagram, Fig. 2, the RAM supply switching circuit consists of IC6, R6, R7, R8 and D3. With a 5-volt supply present on the board, the 3.6-V NiCd battery is permanently charged via D3, which is forward biased. Resistors R7 and R8 form a potential divider. The voltage drop across R8 drives transistor T2, whose collector voltage is brought low. Via the output of IC6B, a logic low is applied to pin 1 of IC6A.

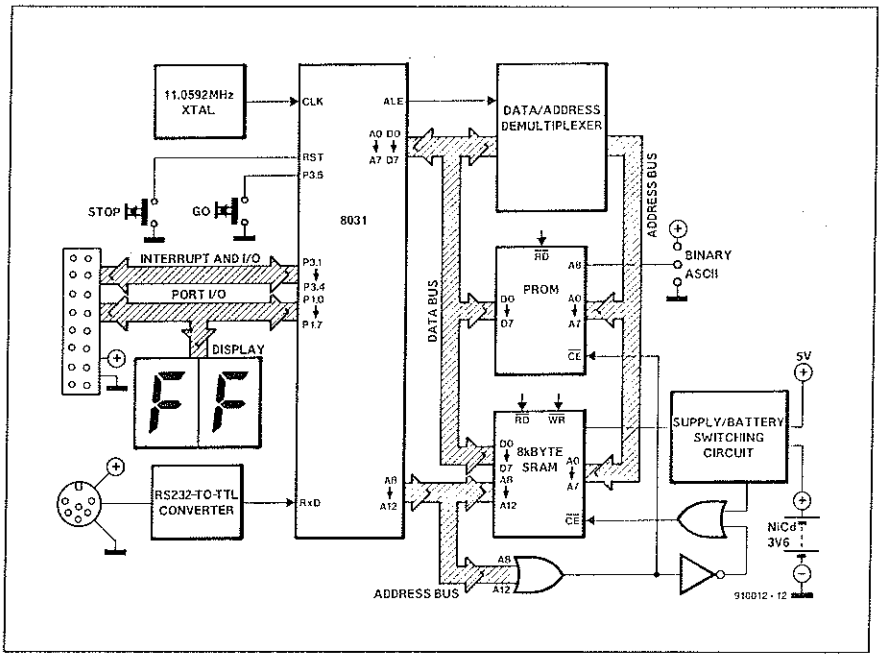


Fig. 1. Block diagram of the single-board computer.

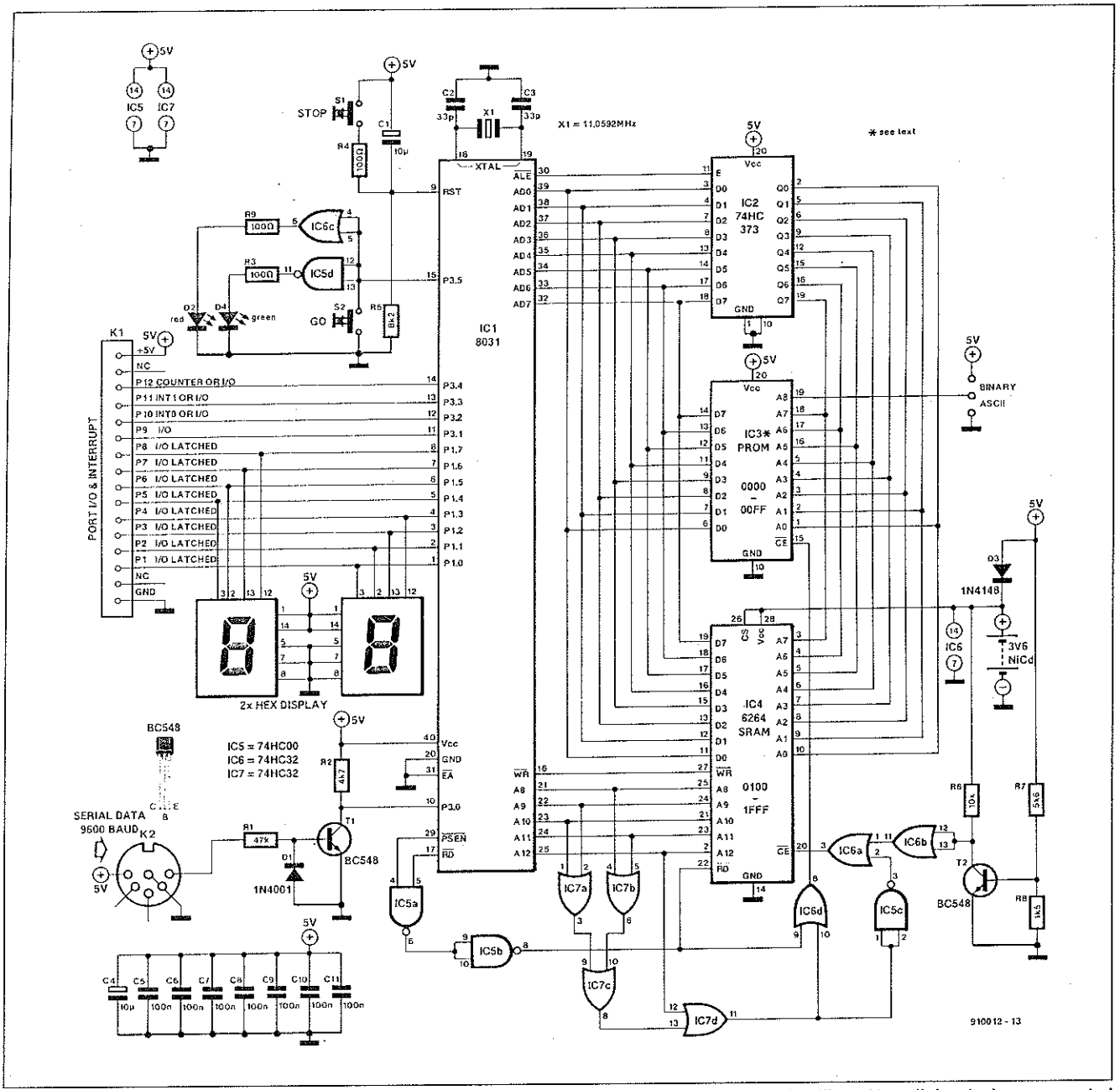


Fig. 2. Circuit diagram of the 8031-based computer. Data downloaded from the PC is shown on two 'intelligent' hex diplay devices connected to port 1 of the 8031.

Pin 2 of IC_{6A} remains high when the PROM is addressed. Above address $00FF_h$, one or more of the inputs of IC_7, configured as a five-input OR-gate, go high, which in turn is inverted by IC_{5C}. Next, a 'low' is applied to pin 2 of IC_{6A}; pin 3 of IC_{6A} goes low and thus enables RAM IC_4, while at the same IC_3 is disabled.

When power is removed from the board, diode D_3 becomes reversed biased, preventing any current from the battery reaching the base of T_2. Consequently, this transistor remains off, with its collector at battery voltage. The output of buffer IC_{6B} (pin 11), is therefore high. This propagates through IC_{6A} to pin 20 of IC_4, thus disabling the RAM. Simultaneously, keep-alive voltage is supplied to pins 26 and 28 of IC_4 to retain the memory contents.

Programming the computer

These days, most people have access to a personal computer (PC), and with the addition of one of many communications software utilities available, or, indeed, an 8031 assembler, it is relatively simple to produce machine code and download it via the PC's serial port to the input of the UART contained in the 8031. The code then resides in the on-board 8 KByte-large battery-backed RAM, which ensures that the downloaded program will remain intact in the event of loss of power. This method of programming a computer is particularly attractive because it dispenses with the time-consuming practice of programming and erasing EPROMs whilst debugging the software. Here, it is a simple matter to re-edit the code on the host PC, and then download the final version to the computer board at 9600 baud. Even for the full eight kilobytes, the transfer only takes a few seconds.

The author has deliberately avoided the use of Intel-hex or Motorola-s protocols. Object code can be downloaded in binary or ASCII format. The binary code is accommodated as byte-wide RS232 transmissions: 8 data bits, 1 stop bit, no parity, 9600 bits per second. Alternatively, each byte can be downloaded as two ASCII words: i.e., $2F_h = 32_{ASCII}$ followed by 46_{ASCII}. Line feeds, return codes and spaces must not be used in this format because the board's operating system will identify them as invalid codes, and the display will start blinking rapidly.

The board control switches could not be simpler: one 'go' and one 'stop' push-button.

Pressing the 'stop' button initialises the computer; the display will indicate '00' when the system is up and running. The board is now ready to receive data at its serial port. The display will twinkle as the data is accepted, and the last code received will be displayed. The received data (if ASCII) is converted by the operating system to machine code (bytes) and placed from start address 0100_h onwards in the external memory. It will be clear that binary code does not require translation, and may be fed direct to the RAM. The content of the PROM on the computer board, a 74S472, is given as a hex-dump in Fig. 4.

Memory map and interrupt vectors

The 8 KBbytes of external RAM occupy address range 0100_h to $1FFF_h$ (see Fig. 3). The first page, addresses 0000_h to $00FF_h$, is occupied by the PROM. Therefore the maximum addressable range of the RAM is 7936 bytes ($1F00_h$).

The three interrupt vectors (from external interrupts INT0, INT1 and timer 0) point to addresses at the top of the user RAM:

INT0 interrupt vector	$1FFD_h$
TIMER 0 interrupt vector	$1FFA_h$
INT1 interrupt vector	$1FF7_h$

At these locations, a jump to the address of the interrupt service routine is usually placed, e.g.:

```
1FFD:   02 02 00        LJMP 0200
```

to jump to address 0200_h and service the interrupt request from there. The TIMER 1 interrupt is reserved for use by the operating system and therefore not available for general programming.

As shown by the memory map of the system, Fig. 3, page 0 of the RAM (addresses 0000_h-$00FF_h$) is reserved for use by the operating system. To execute the program, simply press the 'go' button. Execution of the program will commence at address 0100_h. Connect on an ADC or DAC to the port lines, and there you have it: computer control of the outside world. Data acquisition, monitoring, counting, timing — the list is endless; it all depends on you.

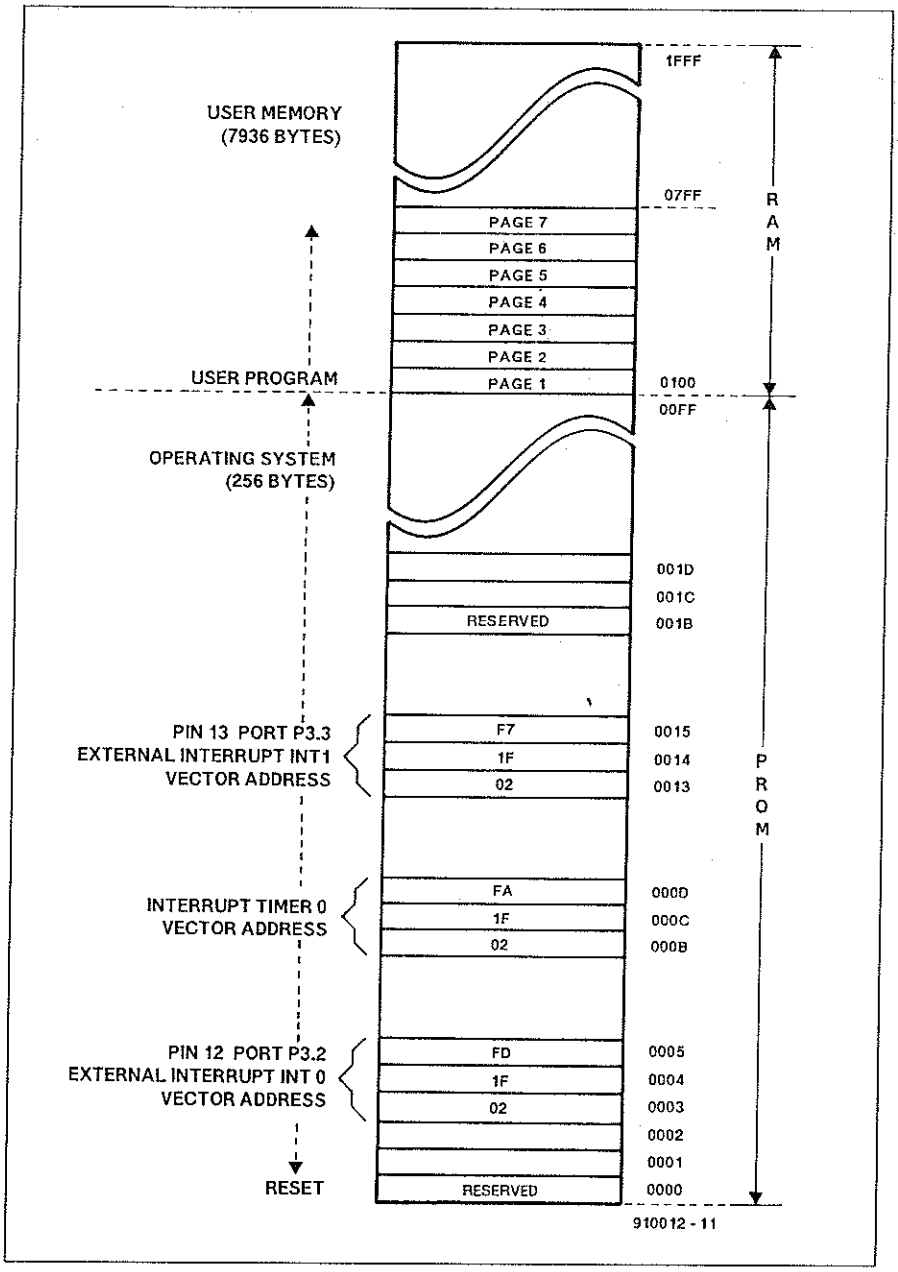


Fig. 3. Address map of the system. The first 256 bytes in the address space are reserved for the firmware PROM that contains the operating system and a number of interrupt vectors. The user memory has a size of slightly less than eight kilobytes.

Construction

Construction of the 8031 computer is fairly simple, as relatively few parts are involved. A double sided PCB is used with special purpose 0.8-mm pins for pinning through. These pins are much better than odd bits of thin wire which tend to break or fall through. The CMOS displays are static sensitive and fairly expensive, so use the standard static precautions when handling these devices. It is recommended to fit the displays and all ICs in sockets, which make for easier fault-finding. The NiCd battery is secured to the PCB with a few drops of two-component glue.

For binary download operation, strap pin 19 of IC3 to +5 V (pin 20); for ASCII downloading, strap pin 19 of IC3 to 0 V (pin 10).

Once the discrete components, the crystal and IC sockets have all been soldered into place, check for solder bridges and 'dry joints'. Use an ohmmeter to check for continuity between all parts of the circuit. Next, apply power (5 V), and with the aid of a logic probe, ensure that the supply voltages and 0 V potentials are present at the appropriate pins of each IC socket. For example, check IC2 pin 20 (+5 V), and pin 1 and pin 10 (both 0 V).

Disconnect the power and insert IC1, the 8031, into its socket. This is where the author's fault-finding tool, an inexpensive transistor radio, comes in. Power up the board, tune into the medium-wave band and you should hear a hum of microprocessor activity. Placing your finger on the PROM socket to simulate software will modulate the output from the radio. If this does not happen, proceed no further, as there is probably an open or short on your circuit board. Investigate and rectify. Next, switch off and populate the board with the remaining ICs. Power up and check with a logic probe that pins 32 up to and including 39 of IC1 are strobing. If everything is all right, the display reads '00'. If not, recheck everything.

Connecting up

Data connections to the serial port are via a 6-way DIN socket and mating plug. Note that the board is also powered via this DIN

COMPONENTS LIST

Resistors:

1	47K	R1
1	4K7	R2
3	100Ω	R3;R4;R9
1	8kΩ2	R5
1	10kΩ	R6
1	5kΩ6	R7
1	1kΩ5	R8

Capacitors:

2	10µF 16V tantalum bead	C1;C4
2	33pF	C2;C3
7	100nF ceramic	C5 – C11

Semiconductors:

1	8031 or 80C31	IC1
1	74HC373	IC2
1	PROM 74S472 (see note)	IC3
1	6264	IC4
1	74HC00	IC5
2	74HC32	IC6;IC7
2	1N4148	D1;D3
2	BC548	T1;T2
2	LED (1 green, 1 red)	D2;D4

Miscellaneous:

2	keyboard rocker switch with indicator (RS 319-843)	S1;S2
1	11.0592 MHz quartz crystal	X1
1	16-way IDC box header	K1
1	PCB-mounting 6-way DIN socket	K2
1	3V6 NiCd battery	
	0.8-mm pcb pins	

Note:
The pre-programmed PROM and the PCB artwork for this project are available from: R. Grodzik • 53 Chelmsford Road • BRADFORD BD3 8QN • ENGLAND. The price of the PROM is £15.00 including P&P.

```
SPRINTplus listing of file A:8031.prm in device National Semi DM74S472

00000:  02 00 C0 02 1F FD FF FF   FF FF FF 02 1F FA FF FF   '................'
00010:  FF FF FF 02 1F F7 FF FF   FF FF FF 02 00 3A FF FF   '.............:..'
00020:  C2 F0 90 01 00 D2 B5 75   98 50 75 89 20 75 8D FD   '.......u.Pu. u..'
00030:  D2 8E D2 AF D2 AB 80 FE   80 FC 20 B5 09 75 09 00   '.......... ..u..'
00040:  75 08 D0 C2 8E 32 30 98   F1 C2 8E C2 98 E5 99 54   'u....20........T'
00050:  7F F5 90 12 00 68 10 F0   08 C4 F5 70 D2 F0 D2 8E   '....h.....p....'
00060:  32 25 70 F0 A3 D2 8E 32   F8 54 F0 B4 30 02 80 18   '2%p....2.T..0...'
00070:  B4 40 06 C3 E8 94 47 40   02 80 13 E8 B4 40 02 80   '.@....G@.....@..'
00080:  F8 C3 94 37 22 00 00 00   E8 C3 94 3A 40 02 80 0B   '...7"......:@...'
00090:  E8 94 2F 40 06 C3 E8 94   30 80 E9 74 00 F5 90 12   '../@....0..t....'
000A0:  00 AB 74 88 F5 90 12 00   AB 80 F0 7E 80 1E 7F FF   '..t........~....'
000B0:  1F BF 00 FC BE 00 F6 22   FF FF FF FF FF FF FF FF   '.......".......'
000C0:  74 00 F5 90 02 00 20 FF   FF FF FF FF FF FF FF FF   't..... .........'
000D0:  12 00 AB C2 B5 02 01 00   FF FF FF FF FF FF FF FF   '................'
000E0:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
000F0:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
00100:  02 00 6B 02 1F FD FF FF   FF FF FF 02 1F FA FF FF   '..k.............'
00110:  FF FF FF 02 1F F7 FF FF   FF FF FF 02 00 3A FF FF   '.............:..'
00120:  C2 F0 90 01 00 D2 B5 75   98 50 75 89 20 75 8D FD   '.......u.Pu. u..'
00130:  D2 8E D2 AF D2 AB 80 FE   80 FC 20 B5 09 75 09 00   '.......... ..u..'
00140:  75 08 63 C2 8E 32 30 98   F1 C2 8E C2 98 E5 99 F5   'u.c..20........'
00150:  90 F0 A3 D2 8E 32 7E 80   1E 7F FF 1F BF 00 FC BE   '.....2~.........'
00160:  00 F6 22 12 00 56 C2 B5   02 01 00 74 00 F5 90 02   '..".V.....t.....'
00170:  00 20 FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '. ..............'
00180:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
00190:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
001A0:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
001B0:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
001C0:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
001D0:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
001E0:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
001F0:  FF FF FF FF FF FF FF FF   FF FF FF FF FF FF FF FF   '................'
                                                    910012 - 14
```

Fig. 4. Hexdump of the firmware PROM, a type 74S472.

socket. At the host computer end, connect a single screened cable to the ground and TXD pins of the serial port. Also tie the RTS and CTS pins together.

All the port I/O, interrupt, and power lines of the 8031 computer are brought out to a 16-way IDC pin header (K1), for connection via ribbon cable to peripheral devices. As shown in the photograph of the prototype, the pin header is a box type connector with eject headers.

For further reading

Various publications are available from Intel, detailing the programming of the 8031:

(1) Intel 8-bit Embedded Controller Handbook (1989) (RS code 910-749);
(2) Intel Embedded Controller Applications Handbook (RS code 910-777);

These books, and data sheets on the 8031, are available from
Intel Literature Sales • P.O. Box 7641 • Mt. Prospect • IL 60056-7641 • USA.
or, in the UK, from
Intel Corporation (UK) Ltd. • Pipers Way • Swindon • Wilts SN3 1RJ. Telephone: (0793) 696000. ■

SLIDE POTENTIOMETERS IN THE VIDEO MIXER — AN UPDATE

We understand that the mounting of the slide potentiometers in the video mixer published last year has caused a small difficulty with some constructors.

There appear to be two types of slide potentiometer around, which, although they have the same track length, are mounted differently. In some cases, the type with two mounting lugs (Fig. 1) requires a few washers, or short PCB spacers, to be positioned at the right height above the PCB. The second type (Fig. 2) has two holes through the potentiometer body. To enable this type to be secured to the PCB, mount two small support plates and two spacers at the track side of the PCB, as shown in Fig. 2. The length of the spacers is determined by the required height of the slide potentiometer above the PCB surface. ■

"Video Mixer", *Elektor Electronics* January, February and March 1990.