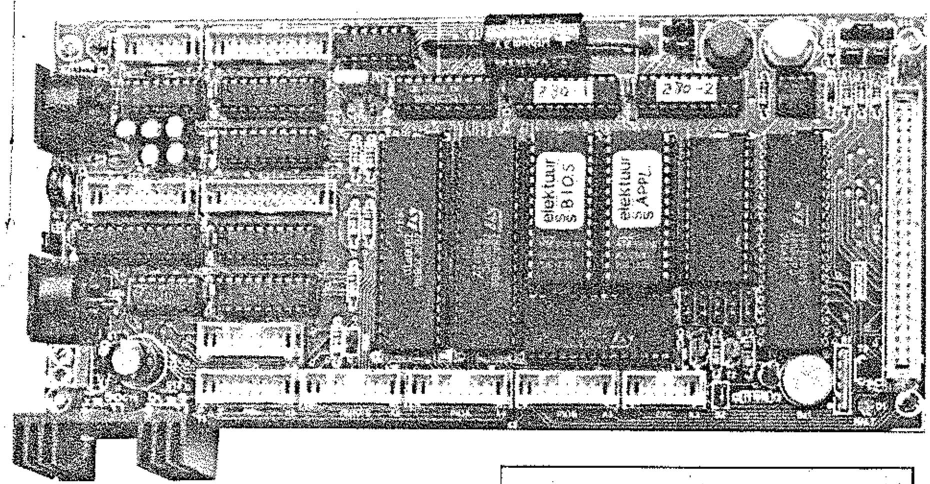
MULTI-PURPOSE Z80 CARD

PART 2: CONSTRUCTION AND TEST



Following last month's description of the system structure and the circuit diagram, this second and last instalment looks at building and testing the card.

Design by A. Rietjens

SOFTWARE SUPPORT

The multi-purpose Z80 is supported by the following software:

- **ESS 6111: a set of two GALs for address decoding and memory decoding;**
- **ESS 6121: one programmed 27128 EPROM containing the BIOS;**
- **ESS 1711: one 5¼-inch 360-KByte MSDOS diskette containing the following files:**
  - description of BIOS calls with examples (if necessary depending on the routine's level of complexity);
  - example of how the BIOS file can be incorporated in your own source code file;
  - description of the system variables;
  - EPROM listing of the BIOS in hexadecimal and binary format
  - assembly programming examples of (1) a 'hook' and (2) an EPROM definition for your own application;
  - description of how to put the contents of two EPROMs into a single 27256, so that 64 Kbyte RAM may be used;
  - Pascal source code listing of serial port control routines;
  - description of the serial command set.

Prices and ordering details relevant to these software items may be found on the Readers Services page elsewhere in this issue.

Test routines in BIOS

The card can be tested with the aid of a number of routines contained in the BIOS. These test routines are called automatically when only the BIOS is present. However, they may also be run when an application program is executed that starts up the card. All that is required to call the tests is to keep a key pressed while the system starts. The way in which the application is called offers the possibility to change the I/O routines (to a certain extent) for your own use. This is so because two routines contained in the application EPROM are called when the system starts: the first before, and the second, after, the test routines. For example, the first routine may set up a key code translation table for the IR receiver, which may be verified via the keyboard test routine. The second routine then contains the application proper.

Software support

The diskette available for this project (MSDOS 360 KByte 5¼-inch; order code 1711) contains examples that demonstrate the practical use of some of the software features discussed earlier. Among the examples are the things you have to put in an EPROM to enable it to be identified by the BIOS, and a software 'hook' that adds a routine to the 10-ms interrupt of Timer 3.

Also contained on the disk are the Turbo Pascal procedures used to produce the basic functions of the RS232 interface. After switching on the card, the baud rate and transmission format are automatically set to 2400 bit/s, 8 data bits, no parity, 1 stop bit.

The disk contains a file that enables owners of an EPROM programmer to burn their own BIOS EPROM. Those of you who do not have an EPROM programmer may obtain the BIOS EPROM through our Readers Services as item 6121. The BIOS file is also required when you wish to use 64 KBytes of RAM, since in that case the BIOS and the application are both contained in a single 27256 EPROM. How the two are combined is explained on the diskette.

The source code (assembler file) of the BIOS is not contained on the diskette; only a list with call addresses is provided, and instructions for use.

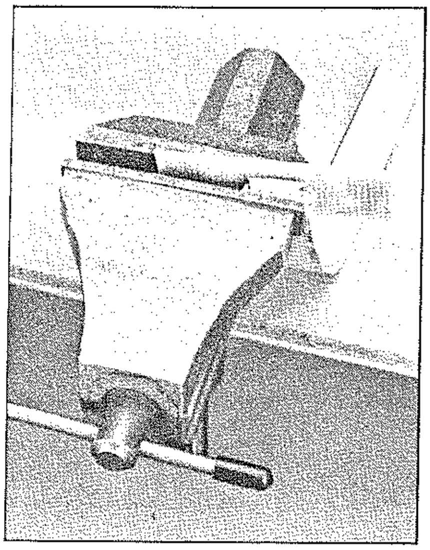


Fig. 7. There is nothing mysterious about fitting an IDC connector on to a flatcable. As shown here, a small vise does the trick. For IDC plugs, make sure that the pins are temporarily inserted into a few pieces of stripboard.

Connections to the outside world

Your own hardware experiments may be connected to the Z80 card via flatcables. Care should be taken to observe the polarity of the IDC headers on the cables, and the box

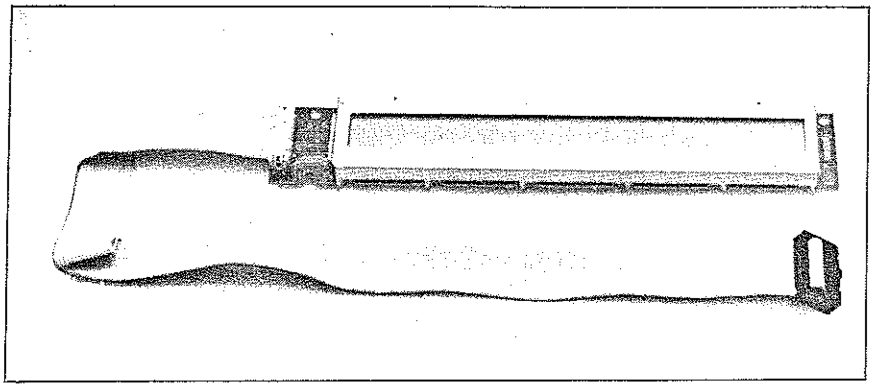


Fig. 8. The Hitachi LM092LN LCD is simple to connect via a 16-way flatcable with an IDC plug at one side, and an IDC socket at the other.

RS232 CONNECTIONS	
K11	D9-Connector (female)
1	1
2	6
3	2
4	7
5	3
6	8
7	4
8	9
9	5
10	

Fig. 10. Refer to this pinning overview in case you are forced to use a solder type 9-way sub-D connector for the RS232 link.

headers on the board. On both devices, pin 1 is usually marked by a small arrow. When making the flatcables, make sure that pins 1 of the IDC sockets you press on either end go to the same wire in the cable. To reduce cost, one side of the flatcable can be fitted with a connector for PCB mounting. In this way, you save on the cost of a boxheader. The PCB-mount IDC connector should, however, be fitted at one side of the cable only (preferably not at the side of the Z80 card). In this way, the Z80 card ia always available as a kind of motherboard to which application circuits can be connected as required. Use a small vise to clamp the IDC sockets on to the flatcable. To protect the pins of the PCB connectors, these are best inserted into two or three stacked pieces of veroboard (see Fig. 7).

The components list contains all connectors and flatcables necessary for the applications implemented on the Z80 card. The cables required are described below.

Liquid crystal display

The PCB connector for the LCD also provides the supply voltage for back-lighted displays. The LCD type given in the parts list is the easiest to use since it may be connected via a 'straight-through' 16-way cable. One end of a piece of 16-way flatcable is fitted with a normal IDC socket, and the other end with an IDC plug for PCB mounting (see Fig. 8). As already mentioned in last month's instalment, almost any LCD with one or two lines of up to 40 characters, with or without back-lighting, may be used. Although the pin functions of the LCDs seem to be standardised, the actual positions of the pins may differ. The back light must be an LED (there are also LCDs around that use a higher voltage for the back light). Depending on whether current drive or voltage drive is required, resistor R21 is calculated to pass the required current, or it is short-circuited. If the back light is powered via two separate connections instead of two wires in the flatcable, it is best to split wires 15 and 16 from the flatcable, and solder these directly (wire 15 = BL = anode; wire 16 = ground = cathode). The LCD connections are given in Fig. 9 for your reference. Whatever LCD type you use, make sure you have at least the connection diagram!

LCD CONNECTIONS		
	K10	Display
1	GND	VSS
2	+5V	VDD
3	CONTRAST	Vo
4	A1	RS
5	A0	R/W
6	DISP	E
7	D0	DB0
8	D1	DB1
9	D2	DB2
10	D3	DB3
11	D4	DB4
12	D5	DB5
13	D6	DB6
14	D7	DB7
15	BL	A(node)
16	GND	C(athode)

Fig. 9. Pinning of K10 (Z80 card) and the LCD. If necessary, the LCD back light may be powered separately via flatcable wires 15 and 16 (see text).

RS232 cable

Pay attention when making the RS232 flatcable. The pinning of the PCB connector does **not** correspond to that of a standard solder-type 9-way female sub-D connector. Here, we suggest the use of an IDC-style sub-D connector, i.e., one for flatcable mounting. The other end of the 9-way flatcable is fitted with a 10-way IDC socket of which pin 10 is not used. Those of you who wish to use a solder-type sub-D connector may find the connections listed in Fig. 10.

When the Z80 card is fitted in an enclosure, the 9-way sub-D connector will normally be fitted on the rear panel, so that a very short cable is required. A standard 9-to-9 male-to-female RS232 cable is then used to connect the Z80 system to a PC. If you can not obtain such a cable, you may have to make one yourself from a length of flatcable and two IDC connectors (see Fig. 11). Make sure that pin 1 of the female connector goes

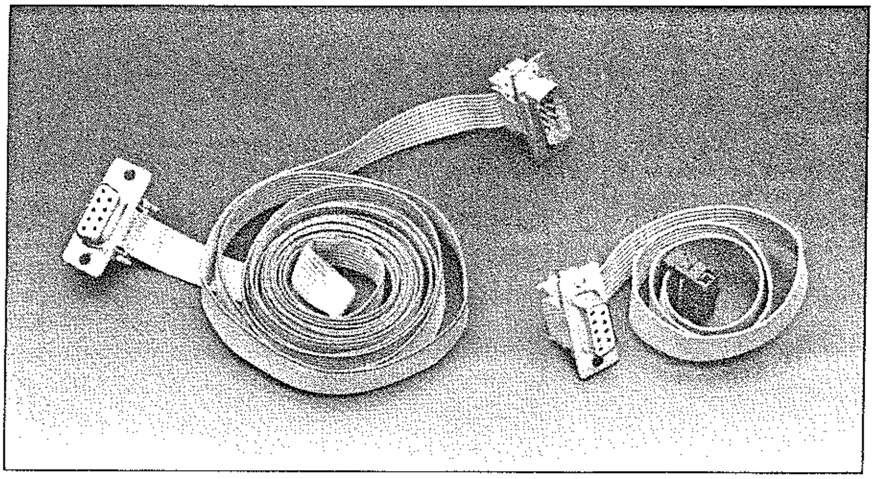


Fig. 11. A standard 9-to-9 male-to-female RS232 cable is not difficult to make from a length of flatcable and two IDC connectors.

to pin 1 of the male connector.

Infra-red remote control

The RC-5 infra-red remote control receiver is connected to the Z80 card via a length of 14-way flatcable. One end of the cable is fitted with an IDC socket, the other with an IDC PCB connector (see Figs. 12 and 13). The IR receiver module may be fitted on a front panel, together with the LCD. It is then best mounted on a small aluminium plate, which is secured to the rear side of the LCD. This requires the connections to the LED and the photodiode to be extended with wires to enable these components to be fitted on the front panel (see Fig. 13).

Printer connection

There are two printer connections: a standard one, PRN, and another, PRN', for specific applications. Figures 14 and 15 illustrate how the PRN connector is wired to a 25-way female D connector, to which a standard Centronics printer cable may be connected.

Battery backup

The memory backup battery may be either a dry cell, a rechargeable battery, or a lithium battery. Depending on the battery type used, one or two jumpers have to be fitted (Fig. 16).

Make sure that the jumpers are correctly fitted, because dry cells and lithium batteries must never be charged. When a lithium cell is used, this must be shunted by a 3.3-MΩ resistor to compensate the leakage currents that would otherwise cause the battery to be charged. Although we could not measure the charge current even at a resolution of 0.1 µA, it could be shown that the lithium battery on our prototype board was being charged, hence the use of the shunt resistor to prevent problems. The 3.3-MΩ resistor is best fitted at the solder side of the PCB.

The minimum and maximum battery voltages are 2 V and 4 V respectively. When the system is switched off, the current consumption of the RAM ICs is between 2 µA and 4 µA.

Construction and test

The PCB designed for this project is remarkably compact, and fits in a Retex Type RE.4 enclosure. Although the track layouts of both sides of the PCB are given in Fig. 17, along with the component mounting plan, it is not recommended to make this PCB yourself, mainly because of the high track density and the large number of through contacts.

Before you start populating the board, file away a small piece of PCB material near connector K2. This allows the supply wires to be bent away more easily later.

The ICs are best fitted last. It is recommended to use boxheaders in the connector positions on the board. A boxheader is a pin header with a plastic enclosure around it. It has a polarizing hole that prevents an IDC socket being inserted the wrong way around. If you have never seen a box header before, look at the photographs in this and last month's instalment. If the LCD mentioned in the parts list is used, fit a wire jumper in position R21.

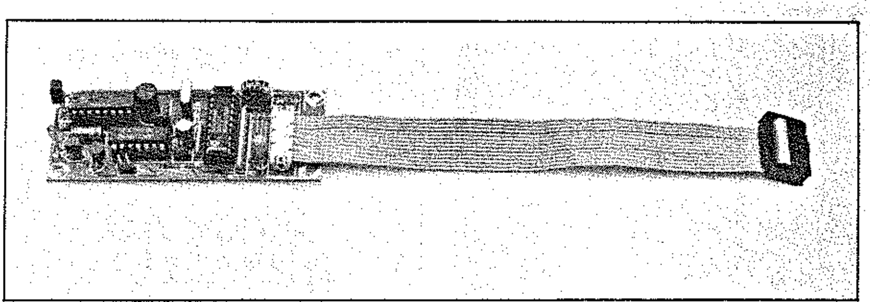


Fig. 12. The IR receiver is hooked to the Z80 card via a length of 14-way flatcable fitted with an IDC socket at one end, and an IDC plug (for PCB mounting) at the other.

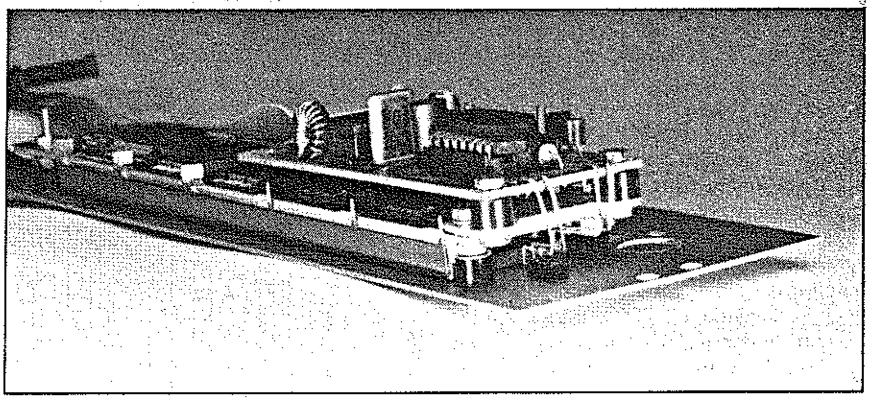


Fig. 13. Suggested mounting of the infra-red receiver on a small piece of aluminium secured to the rear of the LCD unit. The LED and photodiode connections need to be extended in this case to enable the opto components to be fitted on the front panel.

First, connect the Z80 card to a suitable power supply, and check that the current consumption is normal, i.e., a few milli-amps (the ICs are not fitted as yet). Next, perform the step-by-step test procedure given below. Each time you switch on the card, keep an eye on the current consumption, which is a good indicator when something is amiss. The typical current consumption of the Z80 card with all IC fitted will be around 100 mA; about 150 mA with the PC-XT keyboard connected, and about 300 mA with the keyboard and the back-lighted LCD connected.

Do not forget to switch off the power supply in between the steps. If the circuit does not behave as described, check for errors around the component(s) last fitted.

1. Fit IC18, and use an oscilloscope to check that the oscillator works (pin 6).

2. Fit the following ICs and jumpers: IC4 (Z80B-CPU); IC8 and IC9 (Z80 decoder 1 and Z80 decoder 2; GALs; order code 6111), IC19 (bankswitching); JP1 to JP5 at the ROM-select side. Set the memory configuration to '0' by fitting the 'con-0' jumper in position '0', and the 'con-1' jumper in position '0' also.

3. Fit IC1 (EPROM ESS 6121, a type 27128), and the LCD. Before re-applying power, temporarily connect the cathode of D5 to ground, and set P1 to mid-travel.

PRINTER CONNECTIONS

K9	D25-Connector (female)
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	18 - 25

Fig. 14. Printer cable connections.

When power is applied, the Z80 runs a RAM test. Since there is no RAM as yet, he result is negative, and the processor is switched to the 'halt' status, which is retained because no interrupts have been initialized as yet. Thus, if the card works correctly so far, the 'halt' LED must light.

The LCD is not yet initializd, but will indicate an empty line and a black line when

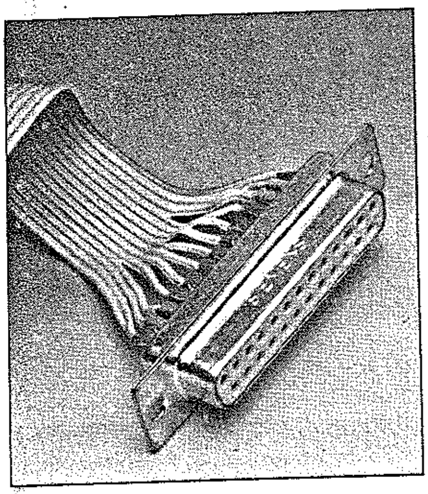


Fig. 15. Centronics printer cable details.

correctly connected. If nothing shows on the LCD, try to adjust the contrast by turning preset P1. If this does not work, review the LCD connections. If you are using a backlighted LCD, concentrate on the LED current. Measure the current consumption via the jumper marked 'LCD' — typical values are of the order of 120 mA to 150 mA. When current drive is used, the value of R21 must be determined by experiment. Fit jumper 'LCD' if you wish to have the back light on permanently.

4. FIt IC3 (a 43256 32-KByte RAM), IC7 (Z80B-PIO), IC5 (Z80B-CTC), jumper BZ, IC10 (MAX690), a jumper on pins 4 and 5 of K14; IR receiver and/or keyboard. After applying power, the 'halt' LED will not light permanently any more, which indicates that the upper addresses (08000H to 0FFFFH) in the RAM are 'good' (by the way, the RAM test is non-destructive, i.e., any data that was present before running the test remains intact and at the original location).

When this part of the RAM test is successfully completed, a copyright message is output to LCD, informing you that 32 KBytes of memory have been found. Also, a beep sounds to indicate that the I/O has been initialised. Next, a second RAM test is run to check for the presence of RAM in parallel with the EPROM (10000H to 17FFFH). After this test, a memory overview is shown. If no additional memory is found, the 'halt' LED lights briefly. If additional memory is found, a second beep sounds. The parallel RAM

BATTERY JUMPER CONNECTIONS

Pin number (K14)	1 2 3 4 5
no battery	4 – 5
normal battery	3 – 4
Lithium battery	2 – 3
NiCd battery	1 – 2 3 – 4

Fig. 16. Battery options and jumper settings.

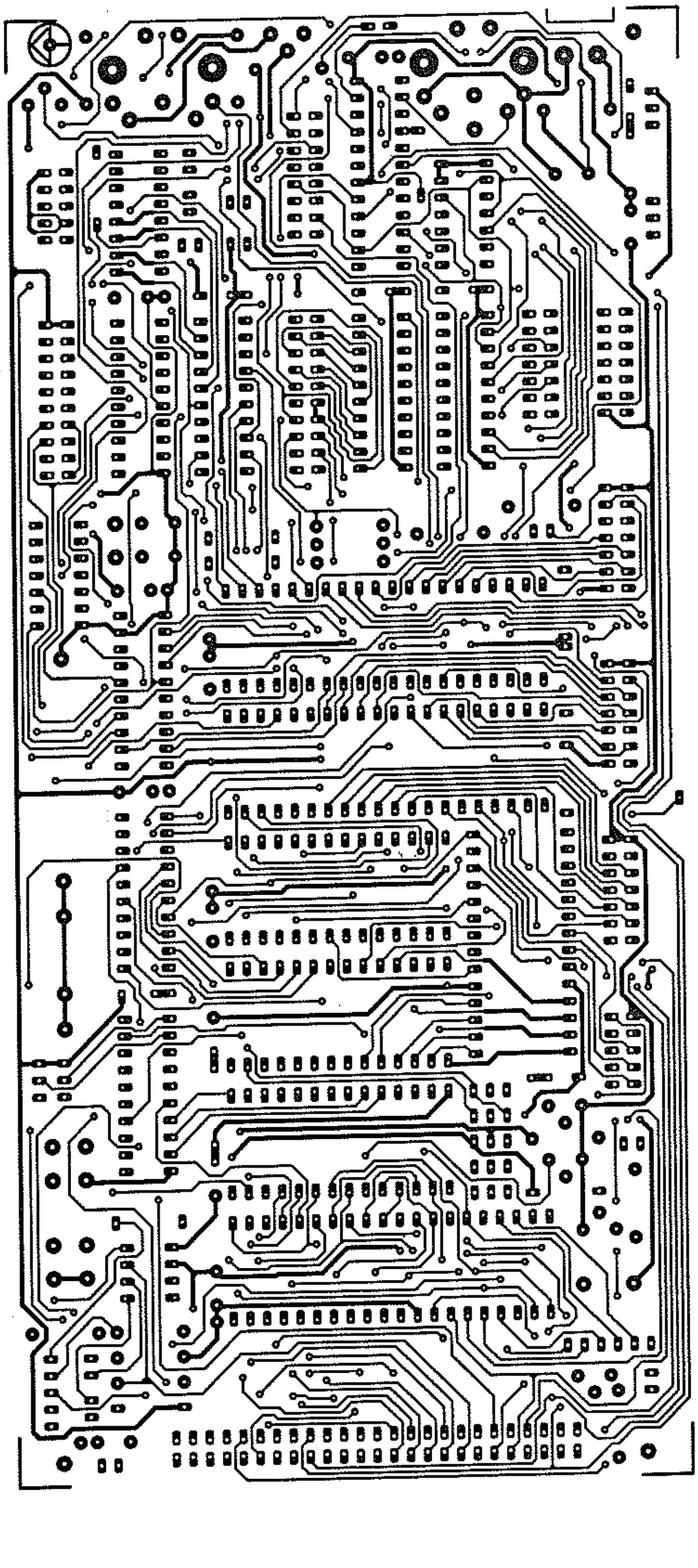


Fig. 17a. Component side track layout (mirror image).

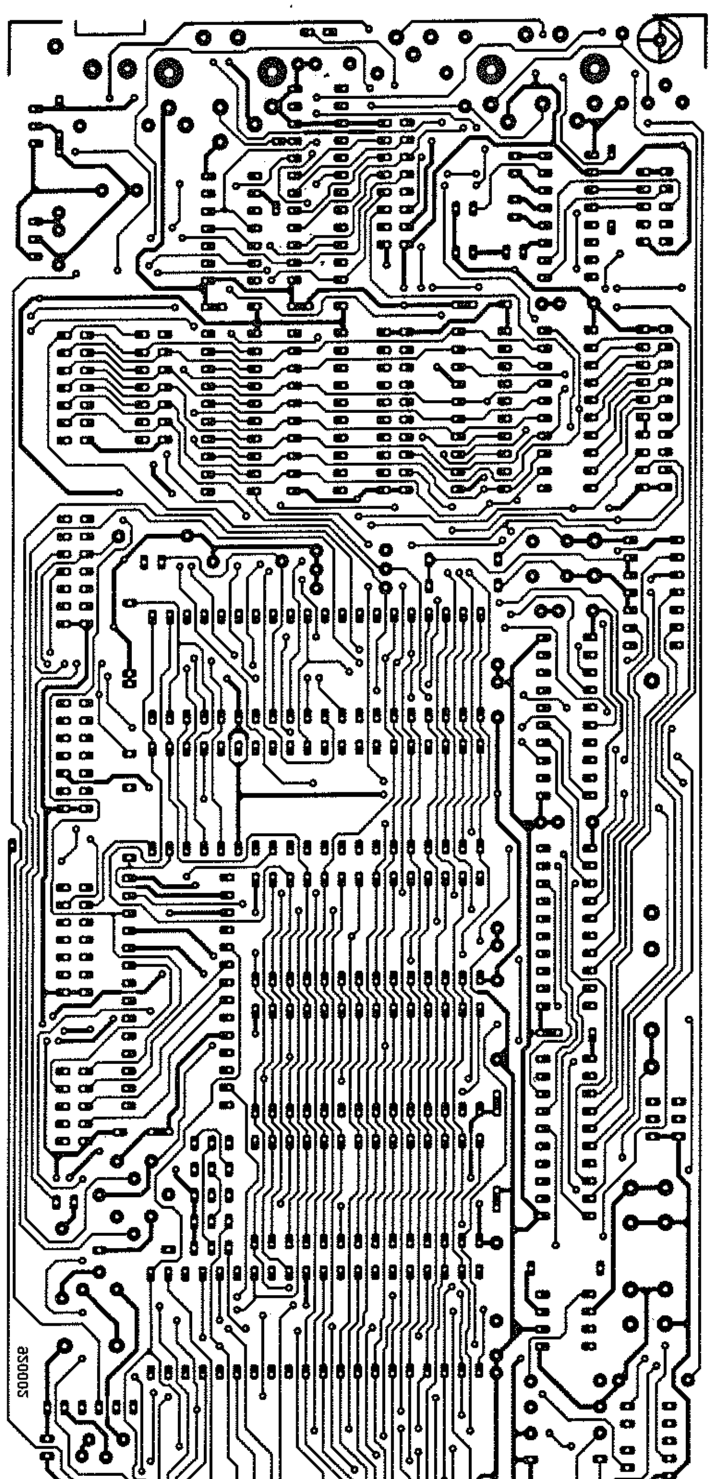


Fig. 17b. Solder side track layout (mirror image).

configuration is allowed in memory configurations 1, 2 and 3 only. Since we have set configuration '0' for the moment, no parallel RAM will be found, so that the RAM test will indicate 32 KByte, and only one beep sounds.

At this point, the Z80 card is in a wait cycle, which is left when a key is pressed on the keyboard. Next, the screen is cleared, and the system is in the display and keyboard test procedure.

The system tests the LC display as follows. Characters typed on the keyboard are displayed in the top line of the LCD. Next, the character is read back from the LCD, and copied to the same position in line 2. When a line is full, it is cleared for a short period, which results in the display flashing on and off while all positions show the last typed character. In this way, the system tests the read and write functions of the display.

When the ESC key is pressed, or the channel '1' key on the IR transmitter, the system switches to the next test routine. The system now responds to keyboard entries by beeping when a key is pressed, and displaying the character on the LCD. This test allows you to check that the keys work and produce the right codes.

5. Fit IC_{12} (COM81C17), and IC_{13} (MAX232). Before applying power, remove the wire between the cathode of D_5 and ground, and set P_1 to mid-travel. The RS232 interface is tested by connecting it to itself: connect RxD to TxD, and CTS to RTS. This is readily done by fitting two jumpers on the 10-way box header: link pin 3 to 5, and pin 4 to pin 6.

After powering up, readjust P_1. Skip the first two tests by pressing the ESC key three times. In this way, you enter the RS232 test routine, which is basically the same as the LCD test. Typed characters are sent and received ('echoed') via the RS232 interface. If the jumpers are not fitted, you will only hear beeps, and no characters will appear on the LCD.

6. Fit IC11 (AD7569), and connect a 100-kΩ potentiometer and a multimeter to K_1, as shown in Fig. 18.

After powering up, step through the test routines by pressing the ESC key until the A-D/D-A test routine is reached. The voltage reading on the multimeter must change proportionally as you turn the potentiometer. The voltage range is 0 V to 2.5 V when no jumper is fitted on pins 1 and 3. If the jumper is fitted, the range is 0 V to 1.25 V (in which case half of the travel of the potentiometer 'does nothing').

7. Fit IC_{16} (74HCT574) and IC_{17} (74HCT541). Press the ESC key as many times as necessary to arrive at the printer test routine. The message 'Test printer Y/N' appears. If you type 'Y', the Z80 card transmits three lines of text to the printer. An error message is produced when the printer is not connected. If everything is all right so far, the system prints the text shown in Fig. 19. When the system has finished printing the text, you are

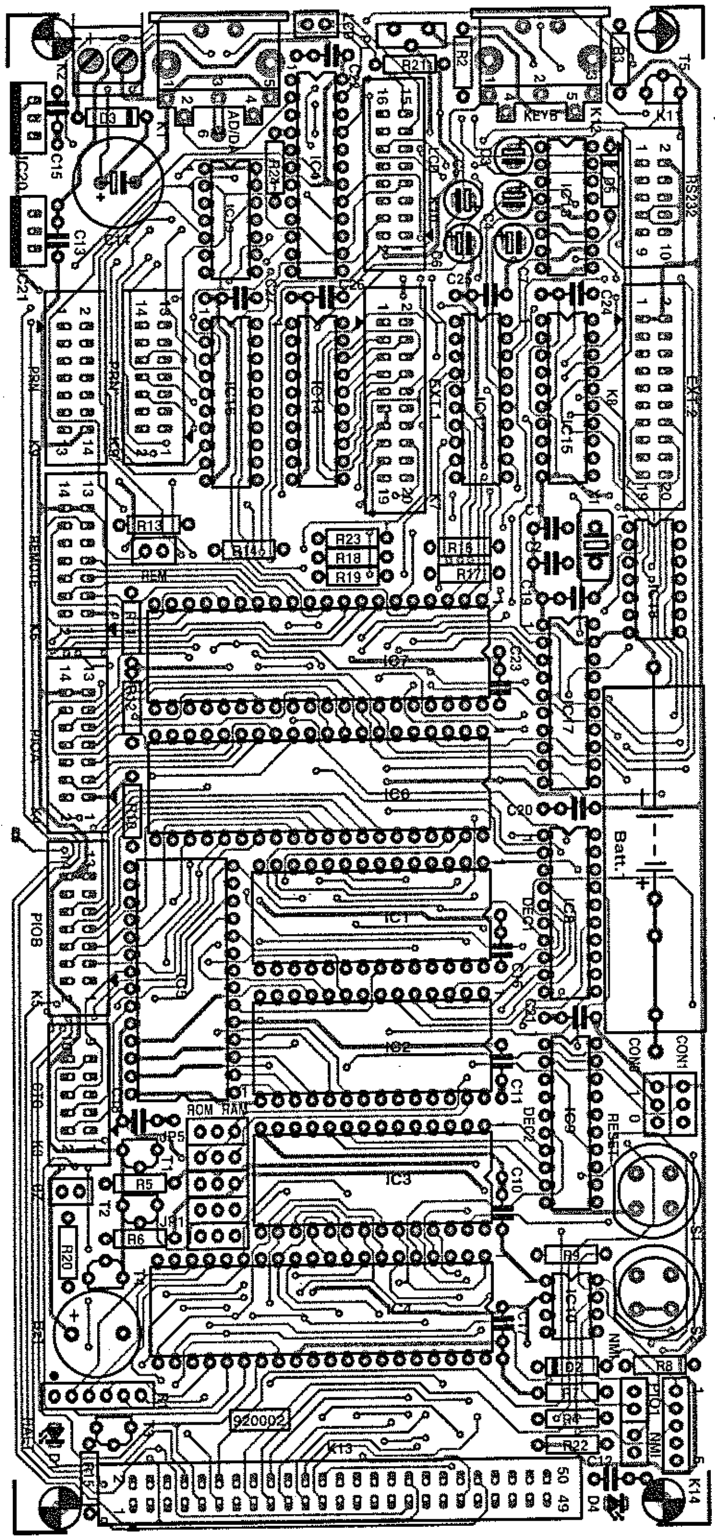


Fig. 17c. Component mounting plan.

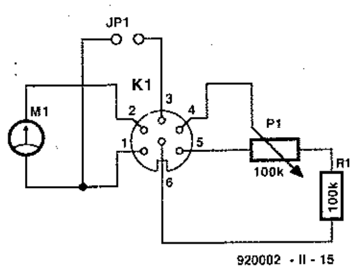


Fig. 18. ADC/DAC test circuit.

returned to the start of the test routine. This allows you to run the test repeatedly, which is useful when errors are to be eliminated.

8. Fit IC14 and IC15. Since the use of the external buses EXT1 and EXT is application-dependent, no provision is made to test them.

That concludes the test procedure. Depending on the application of the Z80 card, you may wish to fit it in an enclosure (as we did — see photographs), or build it into the enclosure of an existing application. In either case, flatcables are a good way to ensure a well-finished product (Fig. 20), that is, a neat looking unit without a wire mess inside. The flatcables may be left relatively long to enable them to be folded and tucked under the PCB. Note, however, that IC socket pins can cause problems by piercing the insulation of the flatcable wires when the PCB is pressed too hard on the flatcable. These problems may be avoided by cutting the protruding parts of the IC socket pins with pliers. Even better, do this before soldering the pins: fit the IC socket, and secure it by soldering two diagonally located corner pins only. Next, cut the other pins to the minimum length. Soldering will then not present problems in any case because the PCB is through-plated.

Practical use

Having constructed the Z80 card, you are ready to concentrate on applications. Unless you have a fully working application program in EPROM, you will need an EPROM simulator and a Z80 assembler to be able to develop software. Suitable assemblers are, for instance, the X80 and X280 from 2500 A.D. Software Inc., 109 Brookdale Ave, Box 480, Buena Vista, CO 81211, U.S.A.

If you expect to exchange EPROMs frequently, it is worthwhile to invest in a ZIF socket. Do not solder this straight on to the board, but use two or three stacked, normal, sockets in between. This has the advantage of being able to unplug the ZIF socket later, and use it in another circuit (removing an IC socket from a double-sided board is fairly difficult).

The description of the BIOS on the disk supplied for this project is sufficiently detailed to use the file, or parts of it, in your own source code. In many cases, the infor-

COMPONENTS LIST

Resistors:

1	5-way 10kΩ SIL array	R1
12	10kΩ	R2;R3;R4;R10; R11;R12;R14; R18-R20;R23;R24
3	1kΩ	R5;R6;R9
1	12kΩ	R7
1	47kΩ	R8
1	100kΩ	R13
1	330Ω	R15
2	2kΩ2	R16;R17
1	4Ω7 0.5W	R21
1	470Ω	R22
1	10kΩ preset V	P1

Capacitors:

2	68pF	C1;C2
5	10µF 16V radial	C3-C7
17	100nF	C10-C13;C15-C27
1	220µF 16V radial	C14

Semiconductors:

2	LED red 3mm	D1;D4
1	BAT85	D2
1	1N4001	D3
1	5V6 0.4W zener diode	D5
3	BS170	T1;T2;T5
1	BC557B	T3
1	BC547B	T4
1	27128 EPROM (BIOS *) or 27256	IC1
1	27128 EPROM or 43256 RAM (depends on application)	IC2
1	43256 RAM	IC3
1	Z80B-CPU	IC4
1	Z80B-CTC	IC5
2	Z80B-PIO	IC6;IC7
1	16V8 GAL (Z80 decoder-1) **	IC8
1	16V8 GAL (Z80 decoder-2) **	IC9
1	MAX690	IC10
1	AD7569	IC11
1	COM81C17	IC12
1	MAX232	IC13
2	74HCT245	IC14;IC15
1	74HCT574	IC16
1	74HCT541	IC17
1	74HCT04	IC18
1	74HCT74	IC19
2	7805	IC20;IC21

* this EPROM is available ready-programmed: order code ESS6121.
** these GALs are available as a ready-programmed set: order code ESS6111.

Miscellaneous:

1	6-way PCB-mount DIN socket (240°)	K1
1	2-way PCB terminal block; pitch 5mm	K2
2	10-way boxheader	K3;K11
5	14-way boxheader	K4;K5;K6; K9;K9'
2	20-way boxheader	K7;K8
1	16-way boxheader	K10
1	5-way PCB mount DIN socket (180°)	K12
1	50-way boxheader	K13
1	5-way SIL pin header	K14
2	PCB-mount push-button	S1;S2
1	3-V lithium battery with connectiing wires, e.g., Varta CR 1/2 AA 950 mAh (no. 6127), or Varta CR 1/4 AA 360 mAh (no. 6147)	Batt1
1	Quartz crystal 5.0688 MHz	X1
1	Active buzzer 5V	Bz1
1	50-pin strip for jumpers	
15	Jumper	
1	Heat-sink for IC20 and IC21, e.g. SK59/37.5 SA	
1	LCD 2×40 characters with back light (e.g. Hitachi LM092LN)	
1	Enclosure, e.g., Retex RE.4	
1	10-way IDC socket (RS232)	
2	9-way female sub-D flatcable connector (RS232)	
1	9-way male sub-D flatcable connector (RS232)	
1	16-way IDC plug (LCD)	
1	16-way IDC socket (LCD)	
1	25-way sub-D socket for panel mounting (PRN)	
2	14-way IDC socket (PRN and Remote)	
1	14-way IDC plug (Remote)	
1	Printed circuit board	920002
1	Diskette	ESS 1711

Approx. 2.5m (8 ft.) flatcable with 30 wires min.

Options:

1	RC-5 infra-red receiver (Ref. 2; 910137)	
1	Infra-red transmitter Policom IRC301	
1	PC-XT keyboard	
1	mains adapter 9-15V @1A	

```
>>>>>>>>>>>>>>> ELEKTOR PRINT TEST <<<<<<<<<<<<<<<<
ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz
1234567890!@#$%^&*()_+-=[]{};':",./<>?\'~
```

Fig. 19. Printer test text.

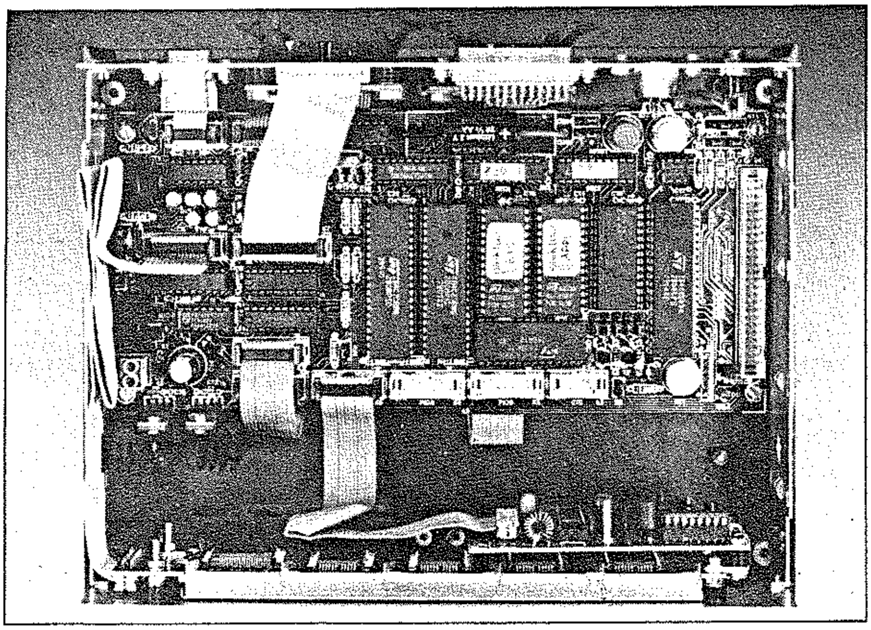


Fig. 20. Folded flatcables give a neat impression and add considerably to a 'professional look'.

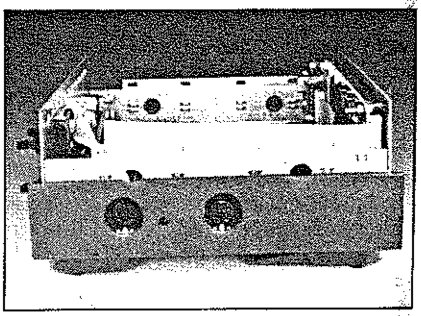


Fig. 21. Holes in the side panel give ready access to sockets K1 and K12, and preset P1

mation contained on the disk, together with the variables and the associated addresses set up by the BIOS, will prove extremely useful to write a program quickly and efficiently.

Talking of future applications, the present Z80 card will form the 'brains' of an advanced photographic slide control system to be described in a forthcoming issue of *Elektor Electronics*. The system, called DiAV (for Digital Audio/Visual), is capable of controlling up to 16 slide projectors. Note that the GALs and the EPROM required for the DiAV controller are **not** the same as the ones used here, and order codes will be published in due course. The DiAV requires a 32-KByte RAM (43256) to be fitted on the Z80 card. ■