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SETTING THE STANDARD

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IEEE P1000 STANDARD

PE HOBBY BUS STANDARD

THE MAGAZINE WITH PROJECTS FOR ALL HOME MICROS

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CONSTRUCTIONAL PROJECTS

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OUR MAY 1986 ISSUE WILL BE ON SALE FRIDAY, APRIL 4th, 1986 ***(see page 37)***

SETTING THE STANDARDS

BY RICHARD BARRON

Two micro-system back plane standards—the STEbus and the PE Hobby bus

THE electronics hobby has changed dramatically in recent years, largely due to the influence of LSI digital i.c.s and inexpensive personal computers. It was inevitable that cheap micros would give a new dimension to the hobby; providing new challenges as software engineering and computer applications projects became as much a part of amateur construction as radio receivers and power supplies.

However, whilst home micros have indeed given rise to the appearance of countless digital and analogue projects, interfaces and controllers, they have also created a number of problems, not least of these being compatibility. A multi-channel mains controller designed for a particular micro will, probably, not work with another computer.

This problem is not unique to the electronics hobbyist but is common to industrial and commercial designers. Printers, plotters, disc drives and monitors are often designed, exclusively, for one type of machine, and in many cases, cannot be used with different models. Sometimes, this is intentional as it can be good marketing strategy to sell a low cost but powerful computer which, on the face of it, seems an attractive package. Many people do not realise the pit-falls of exclusive add-ons until too late. They become a captive audience to a single range of accessories.

Similarly, in the manufacturing industry, robots, automated manufacturing systems, various control systems and a multitude of other devices are now available which may only be installed to certain and exacting specifications.

SOLUTIONS

Despite widespread awareness of the problems which confront the industry, solutions which provide compatibility have not, as yet, been widely accepted. And, in many cases, new standards have, themselves, created further problems or restrictions. For example, a group of mainly, large, Japanese companies including Hitachi, Mitsubushi and Toshiba, under the guidance of Microsoft (the software house), introduced the MSX standard. This standard was intended, primarily, to ensure software compatibility between machines manufactured by different companies, and secondly to standardise hardware facilities. To a large extent, the software solution was successful, despite a few minor problems. The same is true for the hardware approach; compatibility of peripherals was achieved. But, inherent restric-

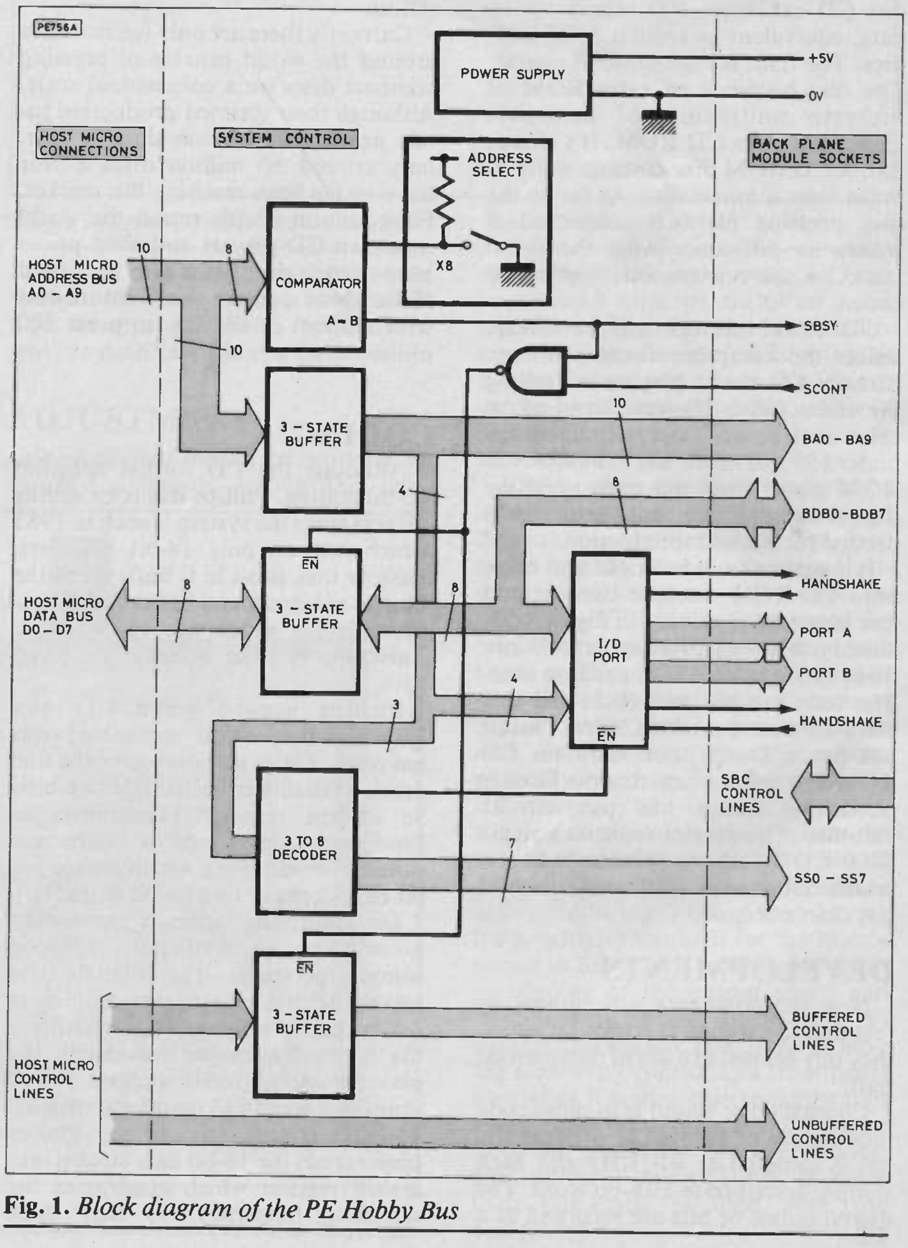


Fig. 1. *Block diagram of the PE Hobby Bus*

Table 1. *Compatible micros*

COMPUTER	PROCESSOR
ZX81	Z80
ZX SPECTRUM	Z80
BBC	6502
MSX	Z80
COMMODORE	6502
VIC-20	6502
AMSTRAD	Z80
RML	Z80
VARIOUS	6502
VARIOUS	Z80

tions in the design parameters meant that MSX machines are limited, and are unable to take advantage of more advanced technology and new developments.

Other examples of standardisation in the computer industry are those of communications protocols, such as the RS232 serial link and the parallel IEEE488. These two standards have, in fact, been widely accepted.

Many peripherals, particularly printers, are quoted as being IEEE488 compatible. Even so, it seems that there are still problems. Although the various signal standards are clearly defined, it has become apparent that manufacturers have not yet agreed on the type of connection leads, connectors or colour codes. The results are obvious.

Clearly, therefore, there are two important lessons to be learnt from these examples. Firstly, design standardisation should not impose unneccesary restrictions upon future developments. Secondly, standards should be clearly defined, allowing no room for ambiguity. With this criteria in mind, PE has decided to adopt two clear standards in an effort to provide readers with many advantages without sacrifice to flexibility or future development possibilities.

Our two standards will feature extensively in future projects and articles, and should prove interesting to all readers, whether hobbyists or professionals, actively engaged in the industry.

Designs for interfaces and peripherals will, for the first time, be compatible with almost any home micro. No longer will speech synthesisers designed for the Spectrum be useless to BBC owners. Even if you don't already own a computer, our inexpensive SBC projects will allow you full control over an enormous range of micro projects.

PE HOBBY BUS

The PE standard interface for all home micros

Over the last few years, PE has published a large selection of computer projects including speech synthesisers, amplifiers, robot and printer interfaces, and digital and analogue ports. It's unfortunate that they, all, could not be used with a variety of host micros. Each project was dedicated to one particular machine, yet with a little thought could have been modified to suit most others.

By their very nature, computer ports and peripherals are very much alike, regardless of manufacturer or CPU employed. All home micros have an address bus, data bus and a number of control lines. Some have standard I/O ports. The differences between machines are usually minor obstacles to compatibility, such as I/O address space, bus connectors or program languages.

The PE Hobby Bus Standard is designed to allow for these minor differences and permit almost any machine to have full control over a wide range of peripherals and interface devices.

FLEXIBILITY

A block diagram of the PE Hobby Bus is shown in Fig. 1. A flexible I/O section provides buffering of address and data lines and input/output decoding. The spare I/O area for any host micro may be set up via only a few switches, giving enormous software and hardware flexibility. A short list of compatible micros is given in Table 1.

Also included, as standard, on the Hobby Bus, are 16 I/O lines plus four handshake lines which can be accessed from any position along the bus. These lines may be used in conjunction with a range of peripherals and can be controlled by any host micro.

In addition to the standard I/O lines, a further seven decoded Select lines are available, which together with the buffered control lines permit almost any type of device to be connected. A few of the planned devices which may be supported by the Hobby Bus are shown in Table 2.

Table 2. *Support projects*

PROJECTS	ISSUE
SPEECH SYNTH	TBD
ANALOGUE PORT	OCTOBER
BATTERY BACKED RAM	TBD
MINI PRINTER	TBD
ROBOT/SERVO CONTROLLER	TBD
SBC-1	JUNE
KEYBOARD/DISPLAY MODULE	JULY
EPROM PROGRAMMER	TBD
TBD = To Be Decided	

BACKPLANE

The PE Hobby Bus system is based around a 64-line backplane which allows up to seven uniquely addressed modules to be connected as well as a selection of other devices such as SBC's, PSU's or memory cards.

Modules are connected to the system via DIN 41612 standard, 64-way a-c, connectors. The module p.c.b.s are standard size Eurocards (100mm × 160mm) and module I/O connections are made via 15-way, D-type connectors. All components will be widely available and by using standard items, cost will be kept to a minimum. A schematic representation of the backplane and module sockets is shown in Fig. 2.

The on-board power supply, supplies 5V d.c. at around 750mA. This should be sufficient for most applications but should more current be required, this can be achieved via a plug-in module. Additional lines have been designated for other voltages for op-amp supplies, programming voltages and power fail requirements.

CONNECTOR PIN ALLOCATIONS

All of the designated signal lines are listed in Table 3. A brief description of some of their functions is given below.

BA0–BA9: These are the least significant 10 address lines. All connections

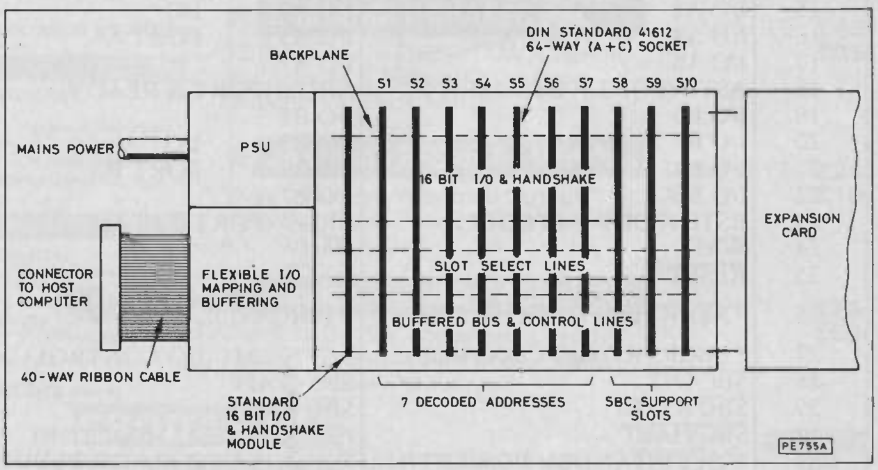
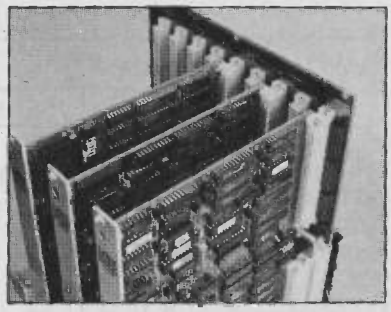


Fig. 2. *Block diagram of the backplane*



An industry standard backplane employing double Eurocard connectors

to these lines should be via three-state buffers.
DBB0–DBB7: These are the data transfer lines and are bi-directional via three-state buffers.
I/O A and I/O B: These are two 8-bit I/O ports and may be used to communicate with other modules or control peripheral devices. Strobe lines are also available.
SCONT: The System Control line is used to give bus control to any other modules, especially SBC's which may be used to control the Hobby Bus.
SBSY: This line indicates that the host micro has control of the bus.
SS0–SS7: These are the Slot Select lines used to select a particular module position (slot) on the bus. It should be noted that they are not available at all connector points. Seven connectors are designated as slots. Thus, Slot 1 would have SS1 available at pin 6, Slot 2 would have SS2 available at pin 6, and so on, up to Slot 7.

Next month we will publish Part 1 of the constructional series based on the PE Hobby Bus. This will include the complete circuit diagram and further details of system operation.

THE STEbus (IEEE 1000)
The 8-bit IEEE standard for all 8-bit processors

The STEbus is the only available 8-bit bus on a single Eurocard likely to gain full IEEE approval. It is now in the final stages of becoming the IEEE 1000 standard.

The IEEE 1000 bus was designed by engineers for engineers and was the result of a growing need for a compatible and flexible bus standard which could offer reliability and acceptance. As it now stands, the STEbus has become the one truly manufacturer independent standard, as a result of a team effort, from a number of engineers and consultants, from a variety of organisations. There are now manufacturers and distributors of STE products throughout the world, including the UK, Europe and the USA.

Table 3. *PE Hobby Bus System connection details*

PIN	A		B	
1	0V		0V	
2	12V		−12V	
3	BA4	BUFFERED	BA5	BUFFERED
4	BA6	ADDRESS	BA7	ADDRESS
5	BA8	LINES	BA9	LINES
6	SS1–SS7 (SLOT SELECT)		SCONT (SYSTEM CONTROL)	
7	SBSY (SYSTEM BUSY)		INT	
8	BDB0	BUFFERED	BDB	BUFFERED
9	BDB2	BI-DIRECTIONAL	BDB	BI-DIRECTIONAL
10	BDB4	DATA BUS	BDB	DATA BUS
11	BDB6		BDB	
12	BA0	BUFFERED	BA1	BUFFERED
13	BA2	ADDRESS LINES	BA3	ADDRESS LINES
14	I/O A0		I/O A1	
15	I/O A2	I/O	I/O A3	I/O
16	I/O A4	PORT A	I/O A5	PORT A
17	I/O A6		I/O A7	
18	ASTB (PORT A STROBE)		ARDY (PORT A READY)	
19	I/O B0		I/O B1	
20	I/O B2	I/O	I/O B3	I/O
21	I/O B4	PORT B	I/O B5	PORT B
22	I/O B6		I/O B7	
23	BSTB (PORT B STROBE)		BRDY (PORT B READY)	
24	WAIT		NMI	
25	RESET		HALT	
26	* RD/W (READ/WRITE LINE)		* 10RQ/Ø2 (I/O REQUEST CLOCK)	
27	* MREQ/RD (I/O CONTROL)		* SYNC/M1 (I/O CONTROL)	
28	SBC INT		SBC WAIT	
29	SBC RESET		SBC NMI	
30	SBC HALT		PSUMON (PSU MONITOR)	
31	V_{STBY} (STANDBY POWER)		V_{PGM} (PROGRAM SUPPLY)	
32	+5V		+5V	

Table 4. *STEbus connector pin designations*

PIN	A	B
1	0V	0V
2	+5V	+5V
3	D0	D1
4	D2	D3
5	D4	D5
6	D6	D7
7	A0	0V
8	A2	A1
9	A4	A3
10	A6	A5
11	A8	A7
12	A10	A9
13	A12	A11
14	A14	A13
15	A16	A15
16	A18	A17
17	CM0	A19
18	CM2	CM1
19	ADRSTB	0V
20	DATACK	DATSTB
21	SYSERR	0V
22	ATNRQ0	SYSRST
23	ATNRQ2	ATNRQ1
24	ATNRQ4	ATNRQ3
25	ATNRQ6	ATNRQ5
26	0V	ATNRQ7
27	BUSRQ0	BUSRQ1
28	BUSAK0	BUSAK1
29	SYSCLK	+VSTBY
30	−12V	+12V
31	+5V	+5V
32	0V	0V

Because of its popularity and acceptance in industry, PE has decided to adopt the IEEE 1000. There are already 100's of products available for the standard including SBC's, digital and analogue cards, power supplies, memory cards and disk controllers. As well as these, PE will be publishing a number of designs which will all be compatible.

BUS FEATURES

The STEbus works with any 8-bit microprocessor using both synchronous and asynchronous, non-multiplexed data transfer. It has a multi-user capability with eight attention request levels and an interrupt acknowledge cycle. Up to 1Mbyte of memory can be addressed with 8-bit data transfer at 5–6MHz bandwidth.

Power supply requirements are +5V, 0V and ±12V. All the signal and power lines are available on a 64-way backplane with 64-way a and c connectors conforming to DIN standard 41612. The module cards are based around a single Eurocard (100mm × 160mm) format and completed assemblies may be mounted in 19 inch rack systems. A complete list of STEbus Signals and pin designations is shown in Table 4. These will be described in greater detail in forthcoming projects.

STE-BUS POWER SUPPLY

BY FARIBA SANIEENEJAD

An STE compatible PSU with extra features including battery back-up and variable o/p

The STEbus power supply requirements are: +5V, ± 12V, 0V and Vstby. Current limits are not dictated in the standard, but are left to user requirements. Since the bus is designed to facilitate logic-based cards and modules, the 5V rail will cater for the greatest current demand.

The dual 12V supply will probably be used for analogue circuits and the stand-by rail for low current back up of static RAM. In addition to the specified power rails, in this design, to cater for EPROM programming, an additional variable voltage supply is available. The specifications of the p.s.u. are shown in Table 1.

Table 1. *P.s.u. specifications*

	I_{max}	V_{out}	Regulation
5V	2A	5V	10mV
+12V	200mA	+12V	0·4%
−12V	200mA	−12V	0·4%
V_{stby}	100mA	5V	0·2%
V_{pgm}	100mA	2V–24V	0·1%

DESIGN CONSIDERATIONS

Whilst many of the commercially available p.s.u.s for the STEbus may be of advanced technical design (often switch mode operation), the emphasis in this project lies in simplicity and reliability. Voltage regulation is achieved through the use of standard, readily available components.

As the unit is designed, primarily, to power microprocessor based circuits, a toroidal transformer was used, which offers low noise and EMI characteristics, and obvious size advantages. The cost of these devices is almost down to that of traditional transformers.

The PE P1000 Standard constructional series is based around a 19 inch Eurocard sub-rack system which is available from a number of suppliers. However, it is not absolutely necessary to use this system, as a simple back plane and separate p.s.u. will do the job, but at the expense of a professional finish. If the sub-rack system is adopted, then this project will fit, snugly, into a 20E Eurocard module, giving an extremely neat appearance. The sub-rack system and slide-in module is shown in Photo 1 (part assembled) and Photo 2 (assembled). In both, the back plane is not shown. More will be said about Eurocards and sub-racks in Part 2, next month.

CIRCUIT OPERATION

Fig. 1. shows the complete circuit diagram of the P1000 Standard Power Supply Unit. T1 is fed from the mains via a two pole, on/off switch which may be used to power down the system. The secondary winding of T1 is centre tapped to provide 18V RMS + 18V RMS via a semi delay 3A fuse. A semi delay type was used to allow for current surges on power up.

REC1, rectifies the low voltage a.c. to give approximately 36 × 1·41V (RMS conversion factor ≈1·41) peak to peak. This is equivalent to plus and minus 25·5V peak with respect to the centre tap, 0V. C1–C3 provides smoothing giving an unregulated d.c. supply with a small (hopefully) ripple content depending upon the current demand of the unit.

The ± 12V supplies are straight forward in their operation, relying simply on IC3 and IC5, 78 and 79 series regulators. Although these devices are capable of supplying up to about 1A, with suitable heat sinks, the ± 12V supply in this design, is only intended to supply around 200mA. Keeping to this limit, no heat sinks are required as the maximum power developed in them will be about 2·8W, which is well within their dissipation capabilities.

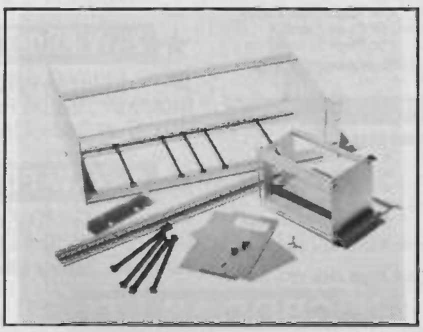


Photo 1. *19 inch rack assembly (part assembled)*

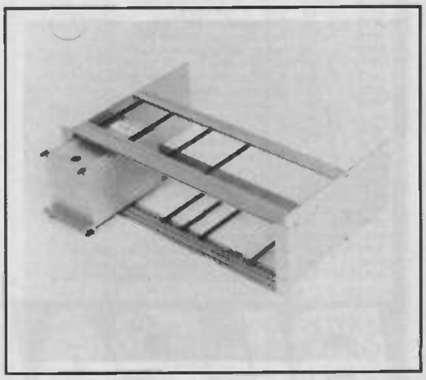


Photo 2. *19 inch rack assembly and module*

As said previously, most of the current taken from the supply will pass through the 5V regulator. To reduce the power requirement of this device, it is fed via a 3·3Ω, 17W resistor, R3. As more current flows through the regulator and thus the resistor, the potential across IC1 decreases thereby limiting the power developed.

Also to keep the temperature of the regulator down to an acceptable level, a 5°C/W heat sink is used. IC1 is internally protected but as an added precaution to protect both the p.s.u. and the load, a 2A fuse is included in the output.

PROGRAMMING AND STANDBY VOLTAGES

An adjustable 'programming' voltage (2–24V) is supplied via IC4, an LM317L variable voltage regulator which is capable of supplying up to 100mA. The output is adjusted by VR2 and is given by:

$$V_{out} = 1{\cdot}25\ (1 + VR2/R8)$$

The Vpgm voltage should be preset to the required level for a specific purpose, such as 21V for certain types of EPROM.

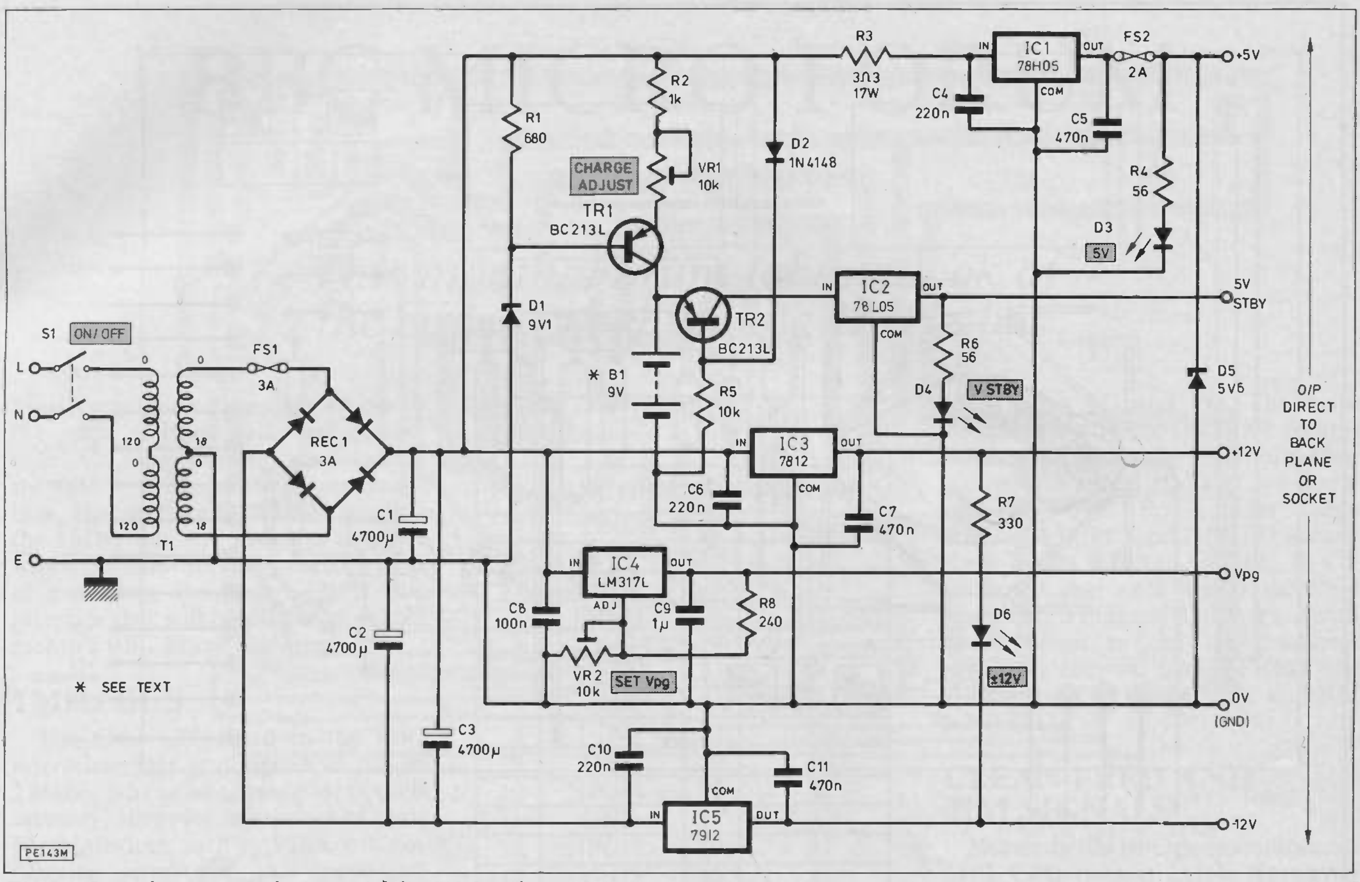


Fig. 1. *Complete circuit diagram of the PE STEbus p.s.u.*

COMPONENTS . . .

RESISTORS

R1	680
R2	100
R3	3Ω3 17W
R4,R6	56 (2 off)
R5	10k
R7	330
R8	240

All ¼W unless stated otherwise

POTENTIOMETERS

VR1	1k min trimmer
VR2	10k min trimmer

CAPACITORS

C1,C2	4700μ 25V elect. (2 off)
C3	4700μ 63V elect.
C4,C6,C10	220n Polyester (3 off)
C5,C7, C11	470n Polyester (3 off)
C8	100n Polyester
C9	1μ Polyester

SEMICONDUCTORS

D1	9V1 Zener 500mW
D2	1N4148
D3,D4,D6	Low current l.e.d. (3 off)
D5	5V6 Zener 5W
REC 1	3A Bridge rectifier (in-line)
TR1,TR2	BC213 (2 off)
IC1	78H05 Voltage regulator
IC2	78L05 Voltage regulator
IC3	7812 Voltage regulator
IC4	LM317L Voltage regulator
IC5	7912 Voltage regulator

MISCELLANEOUS

T1, transformer 18V + 18V secondary 2·78A toroidal; S1, 2-pole mains on/off switch; FS1, 3A 20mm fuse and p.c.b. mounting fuse clips; FS2, 2A 20mm fuse and clips; B1, 9V Ni-Cad PP3 batery and holder; capacitor horizontal mounting clip; TO3 heat sink, 5 deg C/W; P.c.b., PE 864-02 available from the PE P.c.b. Service; high voltage warning label; wire, cable, solder, etc.

EUROCARD MODULE DETAILS

Eurocard module 3U, 20E with fittings
Eurocard module screening kit 3U, 20E
24-way module plug and connector mounting plate

EUROCARD SUB-RACK

Sub-rack 19 inch 3U with fittings
160mm module guides
24-way module socket

It is likely that, at some time, the p.s.u. will be required to supply volatile memory devices whose contents are important. Under these circumstances, it is wise to arrange a back-up supply should the mains fail. In this design, a 5V standby supply is available from a Ni-Cad battery and a low power regulator, IC2.

When power is supplied to the board via T1, the base-emitter junction of TR2 is in reverse bias due to the current through D2 and R5. Under these conditions, B1 cannot supply current to IC2. Should the supply be switched off or inadvertently disconnected, C1 will discharge. When the voltage across C1 falls to approx. 8V, TR2 will conduct and IC2 will provide stand-by current.

CHARGING

A Ni-Cad battery was chosen for back-up as it can be automatically charged when power is supplied to the p.s.u., i.e., in normal use. The maximum constant charge rate for B1 is quoted as 1·1mA. This can be preset via VR1 and checked using a multimeter.

VR1, D1, R2 and TR1 form a constant current source. As current passes through R2 and VR1, the voltage present at the emitter of TR1 will fall. When this falls to around 10V, TR1 will be in reverse bias and the

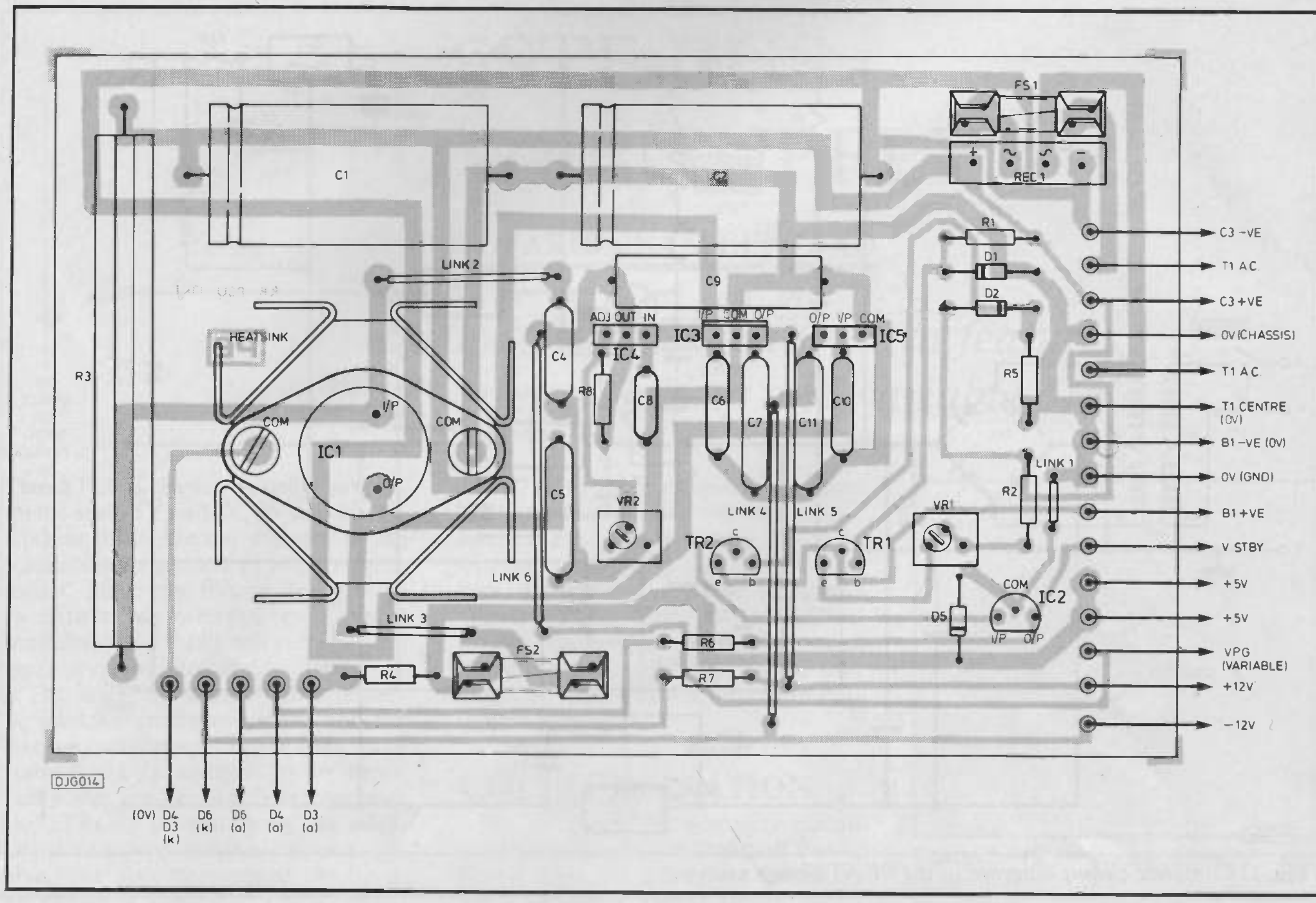


Fig. 2. *P.c.b. design and component overlay*

current through R2 and VR1 will fall. In this way, the current will find a natural level, dependent on the setting of VR1. If battery back-up is not required, simply disconnect B1.

D3, D4 and D6 are low current l.e.d.s which act as supervisory indicators. Under normal conditions, D3 and D6 should be illuminated and under mains failure, D4 should light. If either of the 12V rails fail, D6 will be unlit but D3 should remain illuminated.

CONSTRUCTION

The p.c.b. design and component layout is shown in Fig. 2. Construction and assembly should be fairly simple, but good workmanship is essential if errors and faults are to be avoided. Before mounting any of the components, drill the required holes for IC1. Smaller components such as resistors (not R3) should be mounted first, followed by the transistors, regulators (not IC1) and pre-sets.

The smaller capacitors (non-electrolytic) should be mounted next, followed by C1 to C3 and R3. Lastly, IC1 should be mounted. This component should be carefully positioned (with heat sink compound) together with the heat sink over its mounting holes, making sure that the input and output connections do not touch the heat sink.

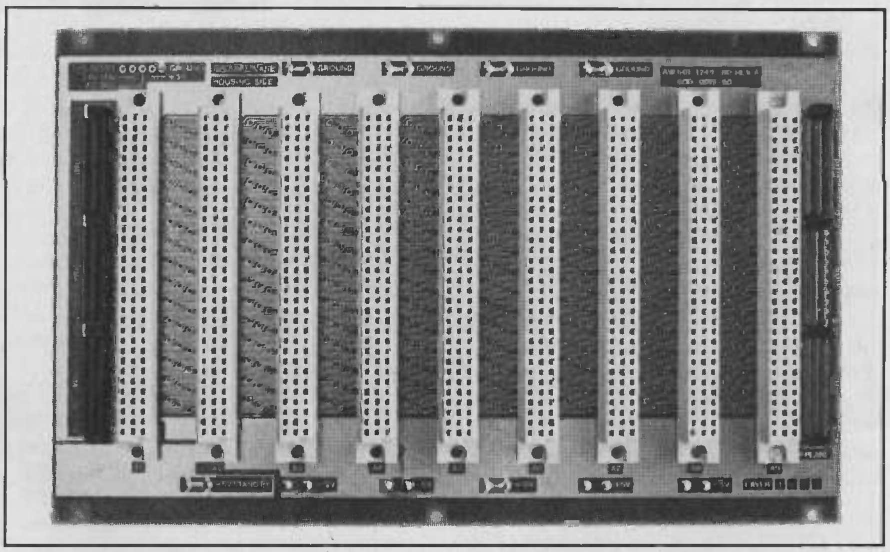


Photo 3. *A typical STEbus backplane*

The i.c. should then be bolted down and soldered in place. Note, that in this design, the case of IC1 is used as a ground connection for D3 and D4 cathodes, so it is essential that metal nuts and bolts are used, making good contact with the p.c.b. tracks.

HOUSING

If the p.s.u. is not being used as part of the PE IEEE P1000 system, or not being module mounted, then the board together with C3, B1, T1 and S1 may be fitted into any suitable case. However, if a Eurocard module is to be used, as it probably is, then mounting details are critical.

NEXT MONTH, this series continues with details of the rack system, STEbus back plane and final constructional details of the p.s.u.

TEMPERATURE-ANALOGUE INTERFACE

BY R. A. PENFOLD

Two-channel temperature interface plus dual analogue ports for the Amstrad and the Spectrum

THIS interface was designed to give the Amstrad CPC464 computer four analogue inputs, two of which are intended for use with semiconductor temperature sensors to give a measuring range of 0 to 51 degrees Centigrade with 0·2 degree resolution. However, the unit can be used as a straightforward four channel analogue to digital converter if desired.

Although the unit was not designed with the Spectrum computer in mind, it has been tried with this computer and worked perfectly well. The only modification required for use with the Spectrum is the use of a different edge connector.

The two analogue inputs have a full scale sensitivity of 1·2V and can be used together to provide a single differential input. If the inputs for the two temperature sensors are used as ordinary analogue inputs they have a full scale value which is adjustable from about 350mV to 1·2V. The sensitivity of each channel is individually adjustable. All four channels offer an accuracy of plus and minus 1 l.s.b.

SYSTEM OPERATION

A circuit of this type could be quite complex, but in this case things are kept remarkably simple by using a modern four-channel analogue to digital converter chip (the ADC0844CCN) and an equally modern temperature sensor chip (the LM35DZ). Fig. 1 shows the block diagram for the interface, and several of these blocks represent the internal circuit of the ADC0844CCN.

At the heart of the unit is the single successive approximation converter of the ADC0844CCN. The way in which this type of converter functions has been described in previous articles in this magazine, and we will not consider this aspect of the unit in detail here. While not providing ultra-fast conversions, the successive approximation technique is reasonably fast and can be achieved by a relatively low cost device. In the case of the ADC0844CCN the conversion time is no more than 40μs, and at 25 degrees Centigrade is typically 30μs. This enables up to about 25000 conversions per second to be achieved, which is more than adequate for the vast majority of applications. The reason for the exact conversion time being temperature dependent is that the ADC0844CCN has a built in clock oscillator which includes on chip timing components. The lack of frequency stability that this inevitably produces is of little practical importance, and it helps to minimise the number of discrete components that are needed.

A four-channel analogue multiplexer ahead of the converter provides the unit with its four input channels. This is not as good as having four separate converters as each channel in use has to be read in turn. With all four channels in use this enables each channel to be read only about 6000 times or so per second, but even this reduced rate is far higher than is required for most applications.

The required channel is selected by writing data to the converter, but only the four least significant bits are utilized when doing this. The data is stored in a four-bit latch, and in addition to selecting the channel to be converted it also sets the operating mode of the device and initiates a conversion. There are three operating modes, and these are single ended, differential, and pseudo differential. The single ended mode is the normal one where each input responds to the input voltage relative to the earth rail. In the differential mode the converter becomes a two-channel type with one pair of input voltages applied to chan-

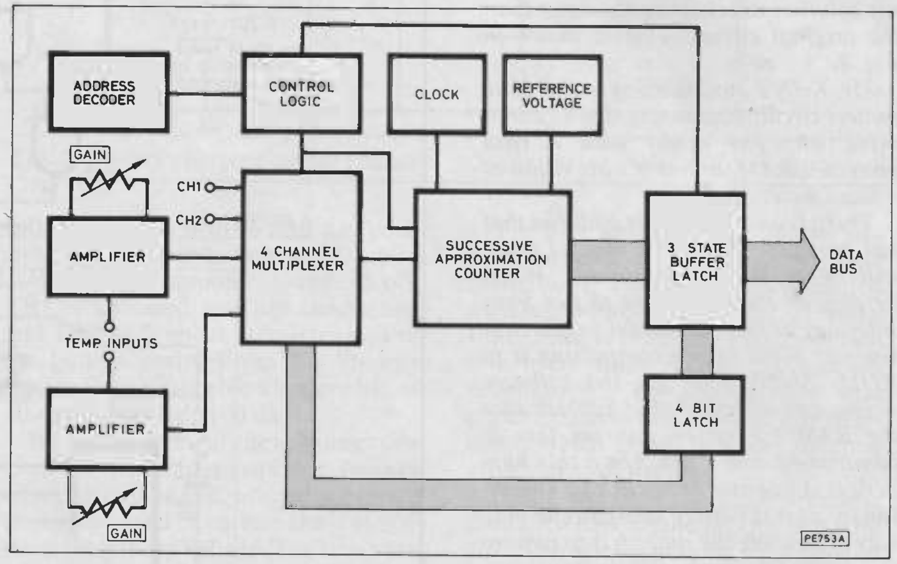


Fig. 1. *Block diagram*

Unlike many analogue to digital converter chips, the ADC0844CCN does not include an internal reference voltage source. The full scale value of the converter is equal to the reference voltage used, and this can be any voltage of 5V or less. In the interest of good linearity it is not advisable to use a reference potential of much less than about 1V though. In this circuit a highly stable 1·2V reference source is utilized.

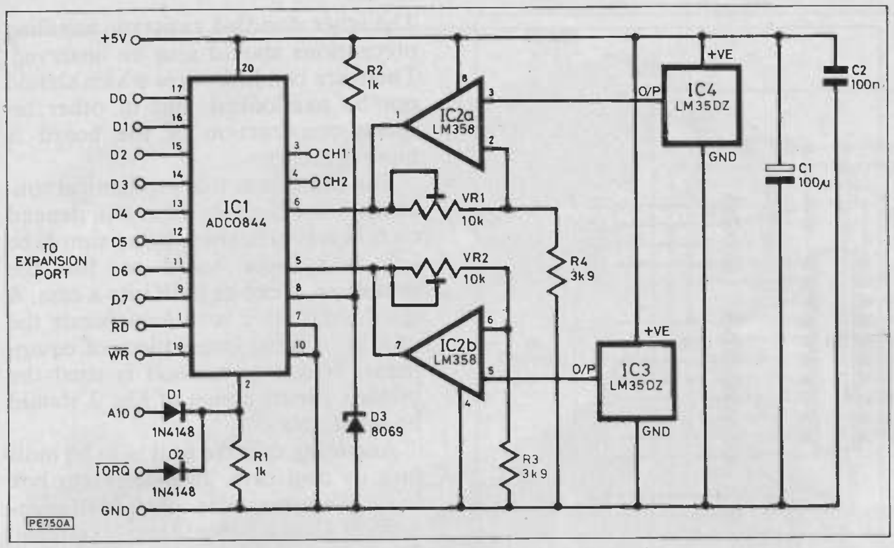


Fig. 2. *Complete circuit diagram*

nels 1 and 2, and the other two applied to channels 3 and 4. In the pseudo differential mode the unit is reduced to three channels (1, 2, and 3) with channel 4 being used as the inverting input for all three channels. This mode is not really applicable in this case due to the amplifiers added ahead of the channel 3 and channel 4 inputs.

When a conversion has been completed the result is stored in an eight-bit data latch which has three state outputs. The outputs of the latch can therefore be connected direct to the data bus of the computer. Although the converter has four channels it only occupies one address, and the channel read at that address is the one previously selected by a write operation. Even if the same channel is read each time, a write operation must precede the taking of each reading in order to initiate fresh conversions. Otherwise the same conversion would be read repeatedly.

The address decoder is extremely simple, and only decodes one address line plus one control line. This is made possible by the simple system of input/output mapping used in the CPC464 and Spectrum computers, plus the fact that the ADC0844CCN is specifically intended to interface with 8080/Z80 based systems, and has inputs for the $\overline{RD}$ (read) and $\overline{WR}$ (write) lines.

TEMPERATURE SENSOR

There are normally difficulties if a semiconductor temperature sensor is connected direct to the input of an analogue to digital converter without using some form of signal conditioning circuit. For example, the popular LM335Z provides an output of 10mV per degree Kelvin, or 2·73V plus 10mV per degree Centigrade in other words. A temperature range of (say) 0 to 50 degrees Centigrade therefore gives an output voltage range of 2·73V to 3·23V. Obviously the output of the sensor could be fed to an analogue input having a full scale value of 3·23V, but this would be a very inefficient way of doing things since input voltages from 0V to 2·73V would never occur, and most of the converter's input range would be wasted. This is not merely of academic importance, and in practice would result in the system having relatively poor resolution and accuracy.

Much better results could be obtained using a signal conditioning circuit to remove the 2·73V offset, and to spread out the 0 to 50 degree range over the full input voltage range of the converter. This type of manipulation is rendered unnecessary by the LM35DZ temperature sensors used in this design. These have a built-in circuit to eliminate the offset voltage, so that the output voltage is nominally 10mV per degree Centigrade. This gives a 0 to 510mV output voltage range over the 0 to 51 degrees Centigrade temperature span covered in this case. A simple d.c. amplifier at each of the two temperature sensor inputs boosts this to a 0 to 1·2V range which fully drives the converter. The converter provides readings of 0 to 255, which conveniently converts to readings in degrees Centigrade simply by dividing returned values by five. The gain of both amplifiers has been made variable so that they can be set up for optimum accuracy.

It must be pointed out that at very low temperatures of only about 1 degree Centigrade the LM35DZ may not give good accuracy, but it will give good results over a range of 2 to 51 degrees Centigrade. In its favour it has the advantage of not requiring a highly stable supply, or even a stabilised supply for that matter, and it will operate over a 4 to 30 volt supply range. With a current consumption of only 56µA there is little self heating.

CIRCUIT OPERATION

The full circuit diagram of the interface appears in Fig. 2. D3 and R2 form a shunt regulator which provides the 1·2V reference for converter chip IC1. D3 is not an ordinary Zener diode, but is a highly accurate and temperature compensated regulator chip. IC2 provides the two amplifiers which are conventional operational amplifier non-inverting mode types. The LM358 is one of the few operational amplifiers that is capable of providing output voltages right down to the earth rail, and this renders a negative supply rail unnecessary. IC3 and IC4 are the two LM35DZ temperature sensors.

The unit connects to the floppy disc port of the CPC464 computer, which is really a general purpose expansion port having the full buses etc. available. The system of input/output mapping used in the CPC464 is to have circuits activated by taking one the eight most significant address lines low. One or more of the eight least significant address lines can be decoded as well if an input/output circuit requires several addresses (which is obviously not the case here). Address line A10 is available for external add-ons, and this line is decoded with the $\overline{IORQ}$ (input/output request) line and used to generate the negative chip select pulse for IC1. D1, D2, and R1 form a simple 2-input OR gate. The interface is placed at address &F800 in the

COMPONENTS . . .

RESISTORS

R1,R2	1k (2 off)
R3,R4	3k9 (2 off)
All ¼W 5% carbon	

POTENTIOMETERS

VR1,VR2	10k 0·1W horizontal preset (2 off)

CAPACITORS

C1	100µ 10V radial elect
C2	100n ceramic

SEMICONDUCTORS

D1,D2	1N4148 (2 off)
D3	8069
IC1	ADC0844CCN
IC2	LM358
IC3,IC4	LM35DZ (2 off)

MISCELLANEOUS

Case about 133 by 70 by 38mm; printed circuit board, PE 101; computer connector; 20 pin d.i.l. i.c. holder; 8-pin d.i.l. i.c. holder; stereo jack socket (3 off); stereo jack plug (3 off); 14-way ribbon cable; connecting wire; solder, etc.

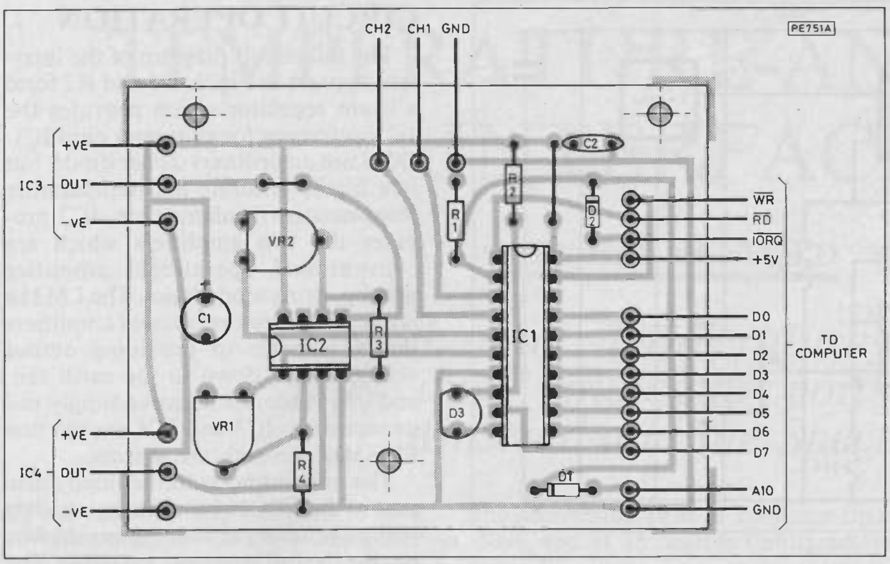


Fig. 3. *P.c.b. design and component layout*

input/output map. Of course, as there is only partial address decoding the circuit can be activated using a large block of addresses, but the one mentioned above is the base address and is a convenient one to use in practice.

In essence the system of input/output mapping adopted for the Spectrum is the same as that used in the CPC464. There is a slight difference in that one of the lower eight address lines is taken low to activate input/output circuits, and one or more of the upper eight address lines are used if additional addresses are required. For the Spectrum it is address line A5 that is gated with the IORQ line, and address 65503 that the circuit occupies. Again, due to the partial address decoding the circuit occupies a great many addresses, but in practice 65503 is probably the best one to use.

POWER SUPPLY

The circuit requires a single (+5V) supply. The current consumption is only a few milliamps, and both the CPC464 and the Spectrum can readily supply this.

CONSTRUCTION

Fig. 3 shows the printed circuit board design for this interface. An important point to note is that IC1 is a CMOS device and should accordingly be fitted in a (20 pin d.i.l.) i.c. holder. The other standard antistatic handling precautions should also be observed. There are two link wires which should not be overlooked, but in other respects construction of the board is quite ordinary.

The exact form that mechanical construction of the unit takes will depend on how it is to be used. It can simply be left as a loose board or, like the prototype, it can be built into a case. A third alternative is to incorporate the unit in to some larger piece of equipment. Whatever method is used the printed circuit design of Fig. 3 should be satisfactory.

Assuming that the unit is to be built into its own case, an aluminium box having approximate outside dimensions of 133 by 70 by 38mm is suitable. The temperature sensors would not normally be mounted on the printed circuit board, but would be remotely located and connected to the interface by way of three-way cable. In order to minimise problems with stray pick up of noise it is advisable to use twin overall screened cable, with the screen carrying the negative supply rail connection. On the prototype three stereo

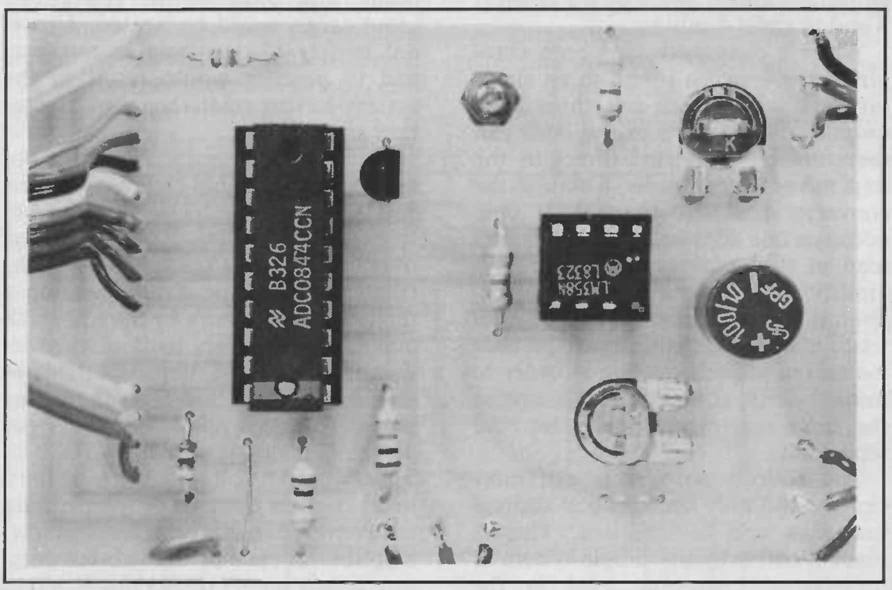


Photo 1. *P.c.b. and component mounting details*

jack sockets are mounted on the front panel, and connections from the sensors to the printed circuit board are made via two of these. The third one is used for the two ordinary analogue inputs.

A 14-way ribbon cable up to about one metre long connects the printed circuit board to the floppy disc port of the CPC464 or the expansion port of the Spectrum. For the Amstrad computer a 2 by 25-way 0·1 inch pitch edge connector is required. As it is unlikely that a connector having a suitable polarising key will be available care must be taken to fit the connector the right way up, and it is advisable to clearly mark the top edge. The Spec-

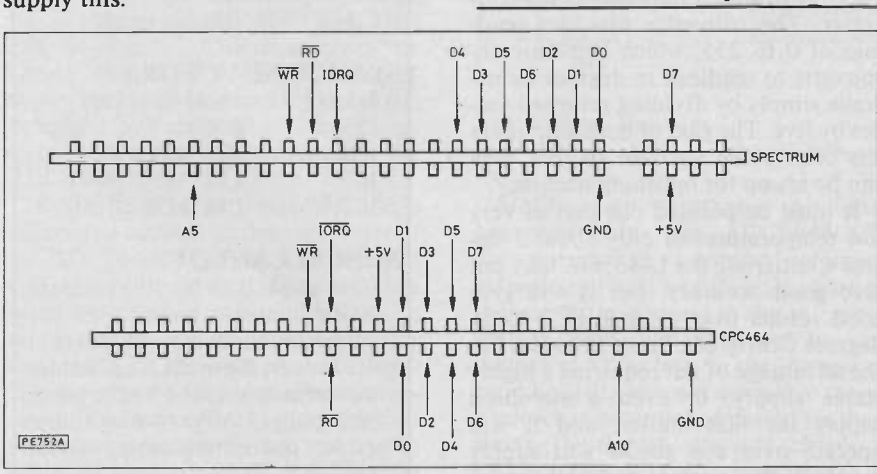


Fig. 4. *Computer connection details*

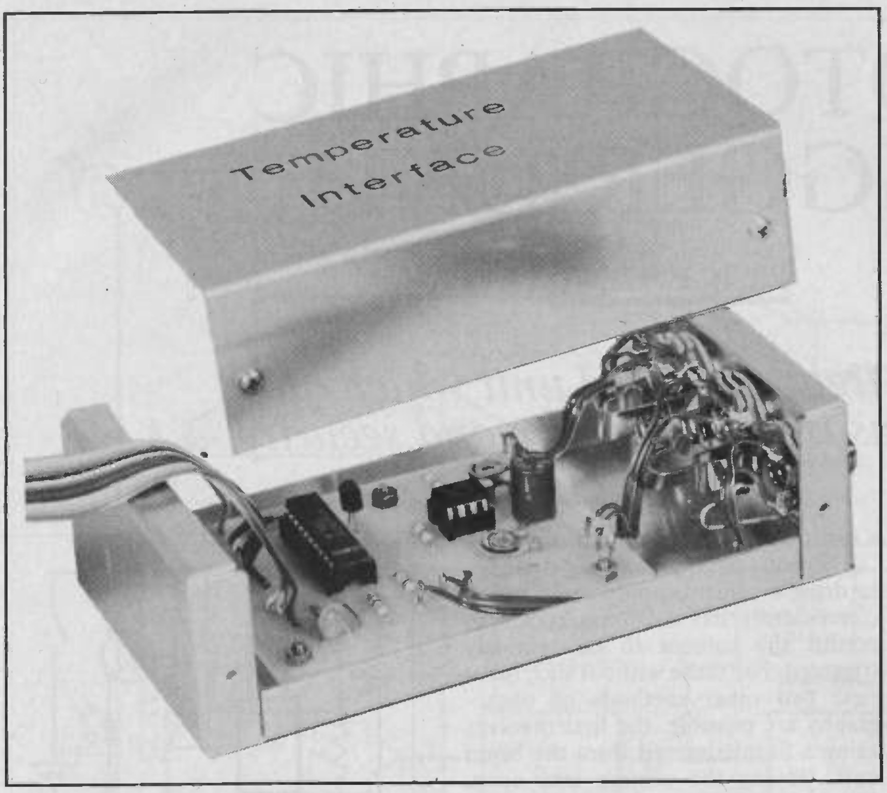


Photo 2. *Constructional details of the Temperature Interface*

Table 1. *Amstrad listing*

```
10 REM CPC464
20 MODE 0
30 LOCATE 8,5
40 PRINT "DEGREES C."
50 OUT &F800,6
60 LOCATE 5,10
70 PRINT (INP(&F800))/5
80 OUT &F800,7
90 LOCATE 15,10
100 PRINT (INP(&F800))/5
110 FOR D = 1 TO 1000:NEXT
120 LOCATE 5,10
130 PRINT "     "
140 LOCATE 15,10
150 PRINT "     "
160 GOTO 50

10 REM SPECTRUM
20 PRINT AT 8,10;"DEGREES C."
30 OUT 65503,6
40 PRINT AT 16,7;IN 65503/5
50 OUT 65503,7
60 PRINT AT 16,20;IN 65503/5
70 PAUSE 50
80 PRINT AT 16,7;"       "
90 PRINT AT 16,20;"       "
100 GO TO 30
```

trum's expansion port requires a 2 by 28-way 0·1 inch pitch edge connector, and types having a suitable polarising key are readily available. Fig. 4 gives connection details for both computers.

Take great care not to make any wiring errors, and thoroughly check all the wiring once it has been completed. With the specified case it is possible to take the ribbon cable out between the top and base sections, but if an alternative is used it might be necessary to cut an exit slot in the rear panel.

TESTING AND USE

Start with VR1 and VR2 set at about half maximum resistance. Connect the interface to the computer before switching on the computer. The two simple programs shown in Table 1 can be used to give a temperature readout in degrees Centigrade for both temperature channels.

From BASIC, the OUT instruction is used to write the appropriate number to the converter to start a conversion and select the required channel. The number is 6 to read IC4 and 7 to read IC3. The INP function (IN for the Spectrum) is used to read the converter, and as explained earlier, dividing the reading by five gives a reading in degrees Centigrade. The relative slowness of BASIC means that a conversion will always have been completed by the time the unit is read, but when using machine code a delay loop to provide a hold off of at least 40µs will be required.

In order to calibrate the unit both sensors should be taken to a known temperature, and one that represents about 50% to 100% of the full scale value. The two presets are then adjusted to give the correct reading. If the sensors are to be used in liquids they should be fitted in a small test tube or a similar container to protect them. Some silicon grease can be used to give a good thermal contact between each sensor and its container.

In the single ended mode analogue channels 1 and 2 are selected using values of 4 and 5 respectively. When these are used as a single differential input they are selected using values of 0 (channel 2 is the inverting input) or 1 (channel 1 is the inverting input). PE

Photo 3. *Front panel details*