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# EVERYDAY WITH PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

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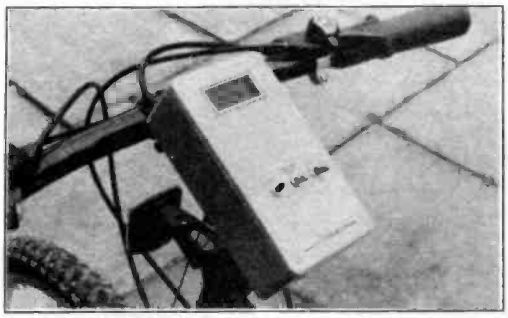
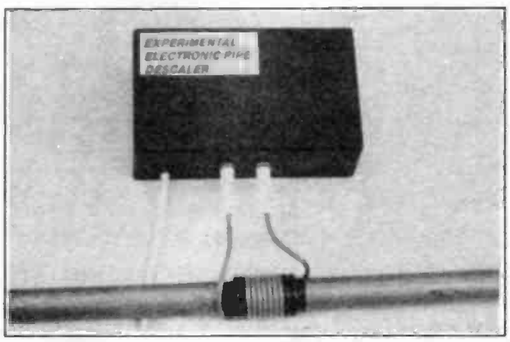
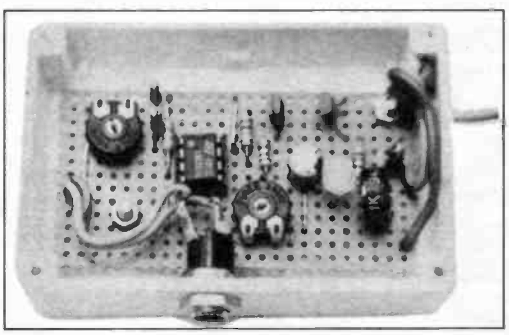
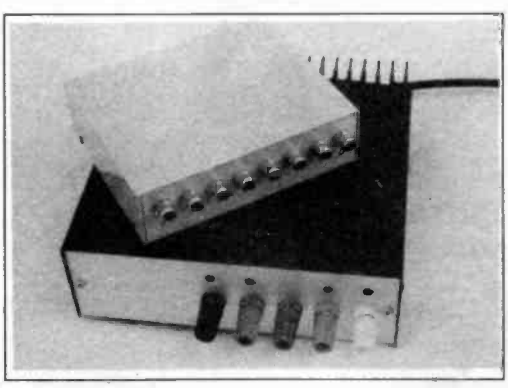









*Our September '93 issue will be published on Friday, 6 August 1993. See page 555 for details.*


## Projects

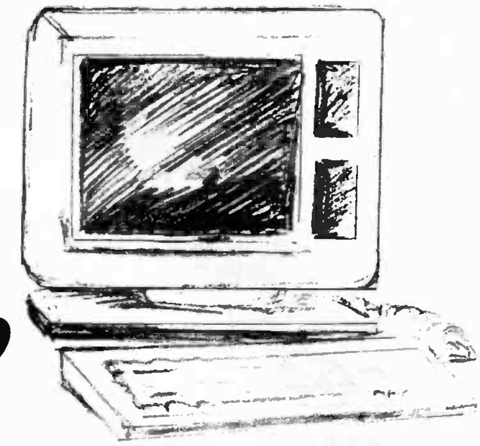


## Series



## Features

# AMSTRAD PCW 8-CHANNEL A/D CONVERTER



**JASON SHARPE**

- *Eight buffered analogue inputs*
- *Built in Sample/Hold Function*
- *Fast 2·5μS conversion time (0·4 MSPS)*

THE WORLD we live in is continuous, for example, seconds can be divided into tenths of seconds, hundredths of seconds, etc. to infinity. But the world of the digital computer is discrete, its shortest time period determined by the clock rate.

Our world is also analogue, for example, it can be very bright, bright, dim, dark etc. In the computer's world it would be either dark or not dark.

## A-to-D CONVERTER

The A/D converter enables a digital computer to take discrete samples of the continuous world. The Amstrad PCW 8-Channel ADC circuit is based on the popular AD7828 (IC2), an 8-channel ADC i.c., which contains an 8-channel analogue multiplexer, a sample and hold function, a half flash analogue-to-digital converter, and I/O control logic.

## QUICK AS A FLASH

The 7828 uses a half-flash technique to digitise the input signal. A 2-bit flash A/D converter is shown in Fig. 1. The analog input is compared simultaneously with $2^n - 1$ (where $n$ is the number of bits) equally spaced voltage reference voltages.

The comparitor outputs are fed into a $2^n$ bit priority encoder, which outputs the digital value. This is the fastest method of A/D conversion, using this method speeds of 300 million samples per second (MSPS) can be achieved.

The main problem with the Flash ADC is its price (e.g. an 8-bit, 20 MSPS flash ADC costs approx. £70, 150 MSPS costs approx. £125) this is because of the large number of comparators required ($2^{\text{No. Bits}} - 1$). Half-flash conversion is the second fastest conversion technique, it provides near flash speed with a much lower cost, thanks to a neat trick.

The block diagram for an eight-bit half-flash convertor is shown in Fig. 2. The input signal is fed into an n/2 bit flash converter, which digitises the most significant part of the voltage, this data is then fed into an n/2 bit DAC.

The DAC output is subtracted from the input voltage and the resulting voltage is digitised by another n/2 bit flash converter, which provides the least significant part of the output. Using this method speeds of up to 20MSPS can be achieved. An eight-bit flash converter would need 255 comparators, but with this method only 30 comparators are required.

## CIRCUIT DESCRIPTION

The circuit diagram for the 8-channel A/D Converter is shown in Fig. 3. The circuit for the buffer i.c.s, IC3 to IC10, is repeated for each stage.

Address decoding is performed by IC1 (74HC688), a high speed CMOS 8-bit comparator. When each P-input is in the same state as the corresponding Q-input, pin 19

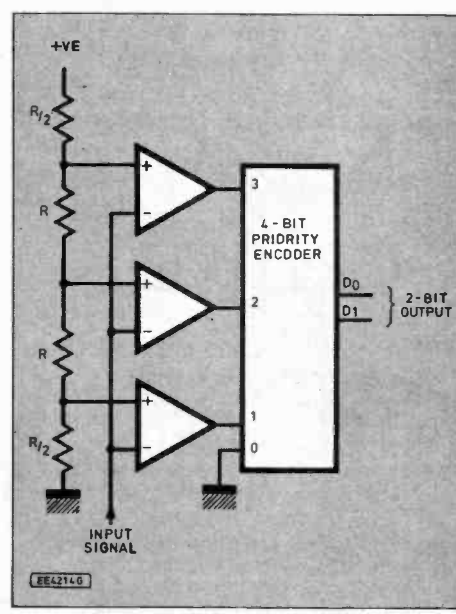



*Fig. 1. Two-bit flash converter.*

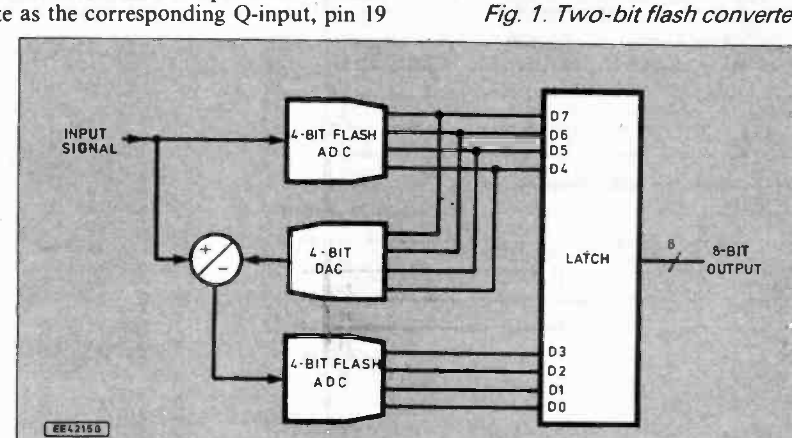



*Fig. 2. Block diagram for 8-bit half flash ADC.*

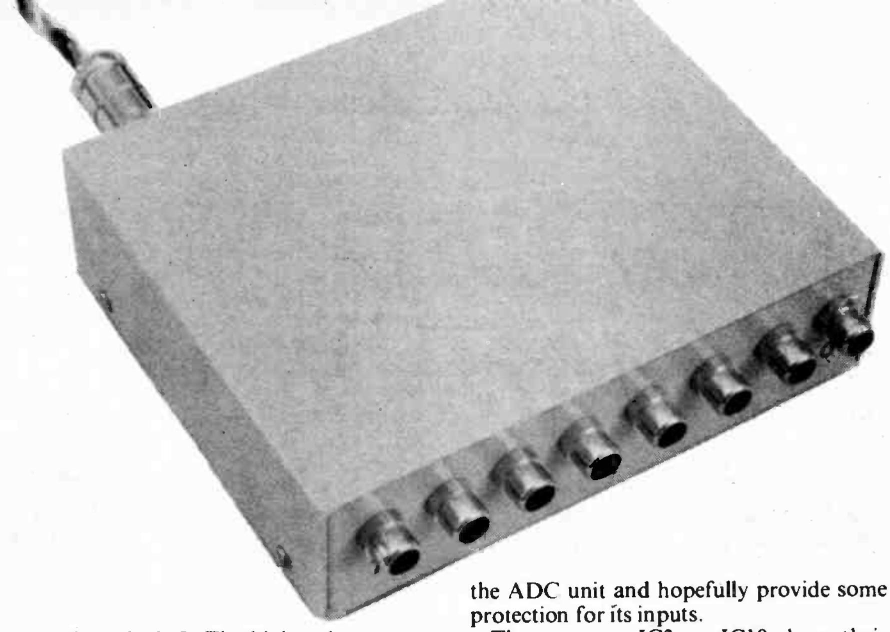
($\overline{P=Q}$) goes low enabling IC2. When NOT IOReQuest goes low and the low byte of the address bus (A0→A7) contain an address in the range 176 to 183 (Inclusive) the ADC i.c. is enabled.

As the ADC unit runs from a separate supply, the PCW's 5V line is also fed into IC1 to make sure the unit is disabled when the PCW is turned off. The PCWs pull up resistors R4 to R7 are used to bring the TTL level outputs upto CMOS levels ($\overline{IORQ}$ and A7 are tied high inside the PCW).

The AD7828, IC2, is set to mode 1. In this mode a conversion is started by reading from a port in the range 176 to 183 (B0 to B7 Hex), the channel on which the conversion is performed is determined by the address on lines A0, A1, A2.

Reading from port 176 starts a conversion on Channel 0, through to port 183 which starts a conversion on Channel 7. To get the results of the conversion just read from one of the eight ports, this will also start a conversion on the selected channel.

It was mentioned above that the 7828 has a track/hold function, this is basically achieved by charging 31 internal 1pF capacitors. These capacitors, plus about 14pF of stray capacitance must be charged to the input voltage through the resistance of the input multiplexer (approx. 5kΩ) in

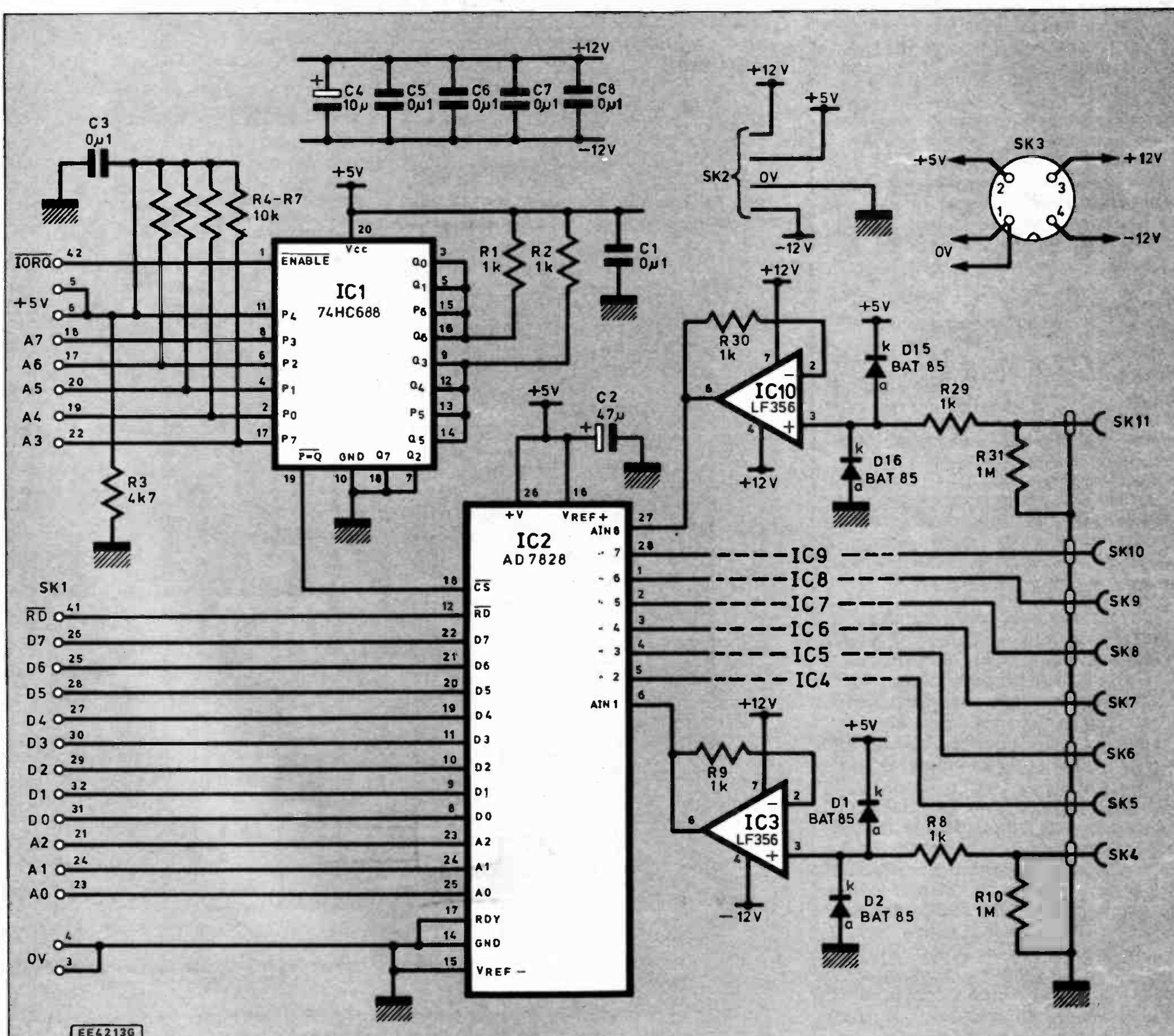


approximately 1µS. The higher the source resistance the longer it takes for the input capacitance to charge.

To make sure the capacitance is charged in time, unity gain buffers IC3 to IC10, with low output impedances, were added to the inputs of IC2. The use of these buffers also increases the input impedance of the ADC unit and hopefully provide some protection for its inputs.

The op.amps IC3 to IC10 draw their power from a ± 12V supply to allow a full output voltage swing of 0V to 5V. The output of the op-amps are capable of going within a few volts of the supply, so if say 7V was placed on an input the output would swing to 7V destroying the input of IC2!

*Fig. 3. Circuit diagram for the Amstrad PCW 8-Channel A/D Converter*



To provide some protection, diodes D1 to D16 were added to prevent the input of the buffers from going outside the 0V to 5V range. Schottky diodes are used as these have a low forward voltage drop and fast "reaction time." *These diodes only provide limited protection, and care should still be taken to keep the input voltage in the 0V to 5V range.*.

The op-amps chosen for the buffers have low input offset voltages, so they require no trimming.

## CONSTRUCTION

The 8-channel A/D Convertor is constructed on a double-sided printed circuit board (p.c.b.). The board component layout, top and underside full size copper foil master patterns are shown in Fig. 4. This board is available from the *EPE PCB Service*, code EPE838.

Track pins are used to connect tracks from one side of the p.c.b. to the other. These should be inserted into the holes (without components) marked ● on the component overlay. Push them in from the top of the p.c.b. and solder them, then turn the board over and solder them to the other side of the board – see Fig. 5a. After you have finished this check the tracks are actually connected with a multimeter.

Insert and solder the remaining components in height order, flattest up to tallest. The leads marked ⦿ on the component overlay should be soldered to the *top* layer as well as the *bottom* – see Fig. 5b. Be careful not to over heat the diodes, also when bending the leads make sure you do not damage the glass cases.

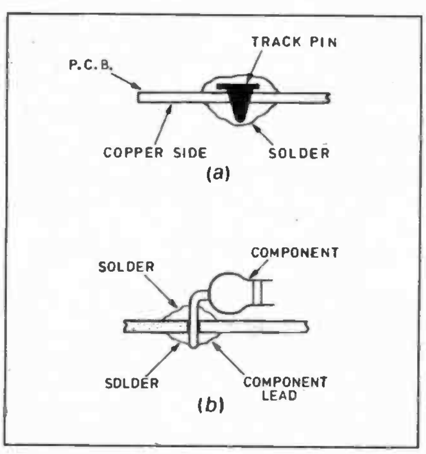
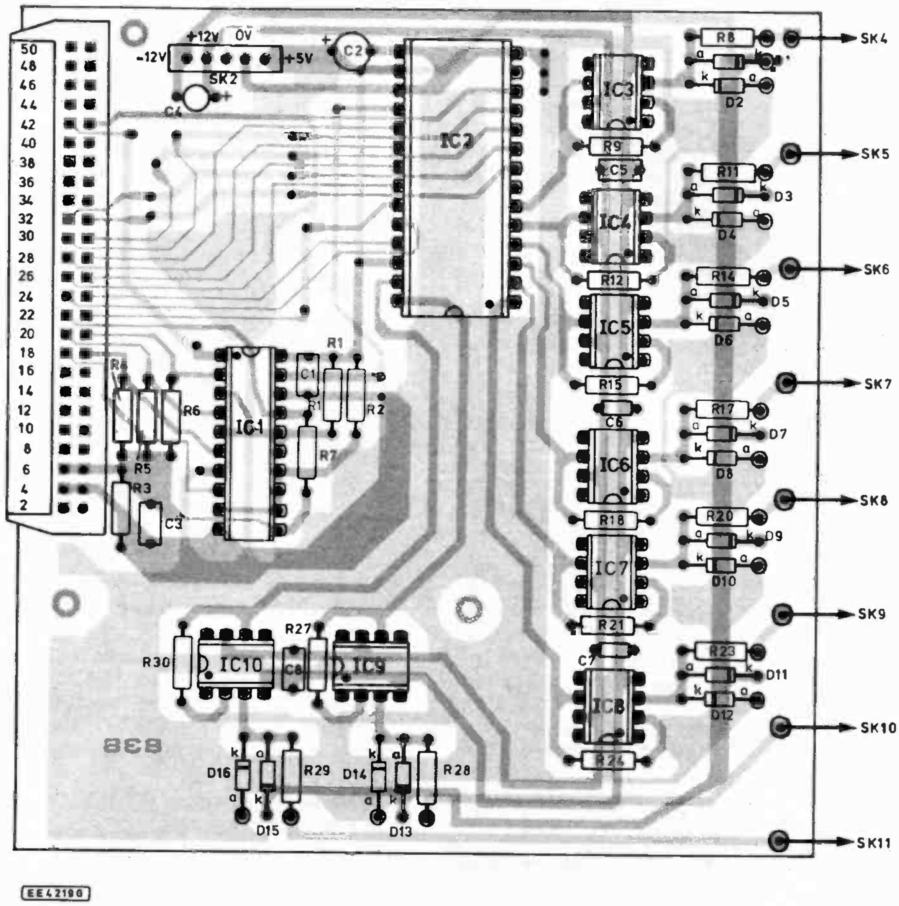



*Fig. 5 (a) Connecting one side of p.c.b. to the other with "track pins". (b) soldering component to both sides of board.*

Power is connected to the board using a "Minicon" connector. Strip about 5mm of insulation from the end of the wire, and tin it. The wire can then be crimped to the metal connector, this can be carried out using a pair of thin nose pliers. Then push the assembly into the plastic housing until the locking pin clicks into place, as shown in Fig. 6.

The one megohm (R10 to R31) between the inputs and "ground" are soldered between the input phono sockets SK4 to SK11 and their solder tags. One end of the lead is used to connect the p.c.b. input to the phono socket. One of the solder tags should also be connected to the 0V input.

Case construction is shown in Fig. 7. Make the hole for the 50-way connector quite high so that some "grommet strip" can be used to cover the sharp edges and prevent damage to the ribbon cable.




● = *Track solder pin.* ⦿ = *Solder to top and bottom tracks.*

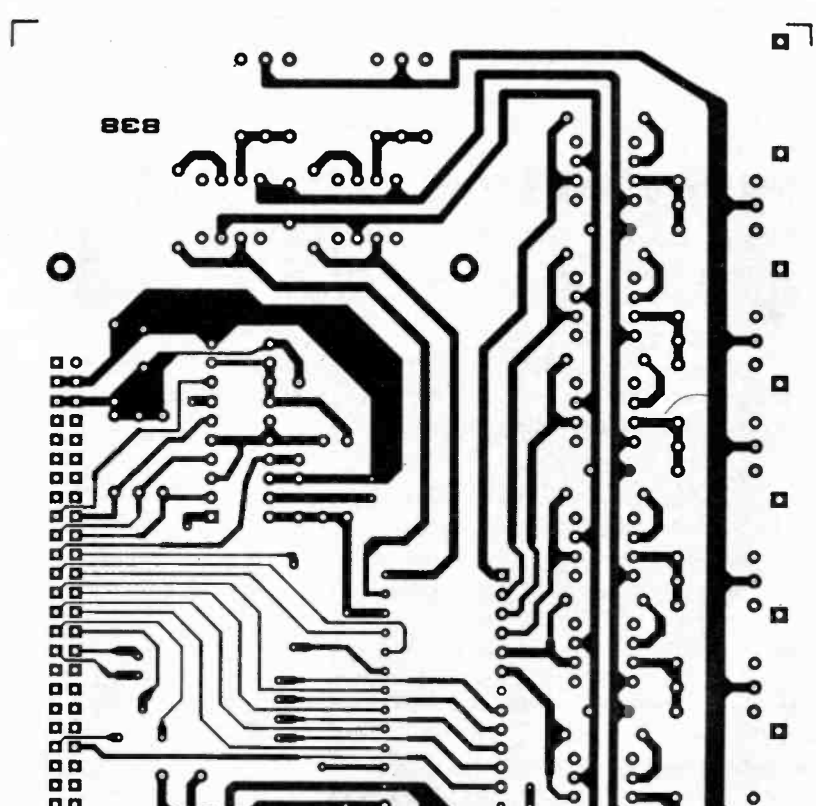
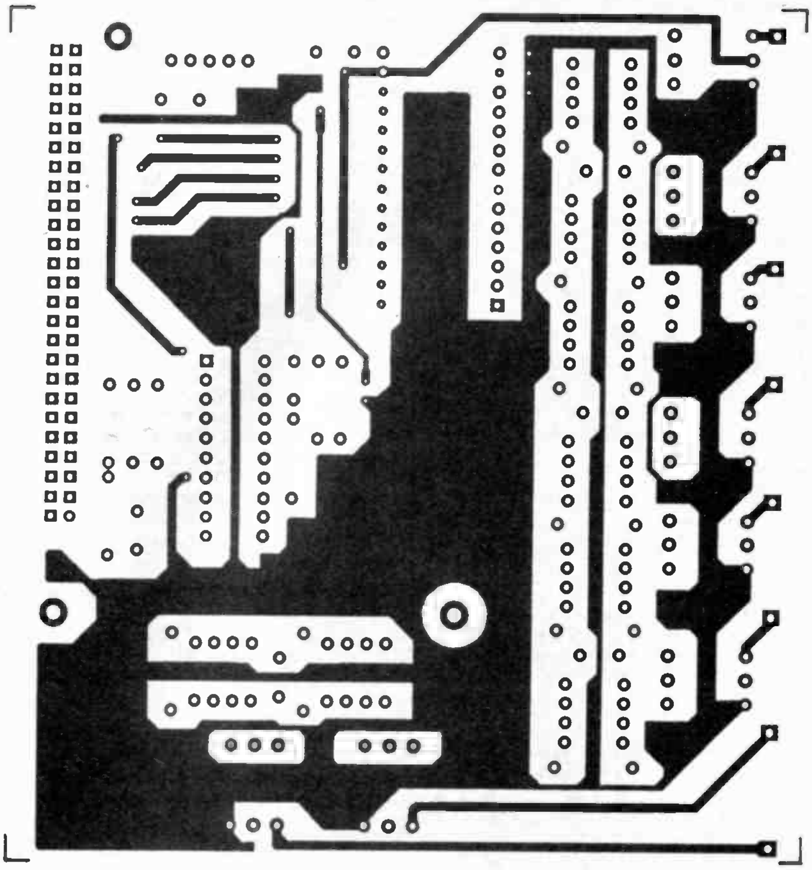



*Fig 4. (top) Printed Circuit board component layout, (top right) full size component side copper foil pattern, (above) full size underside copper foil master pattern.*



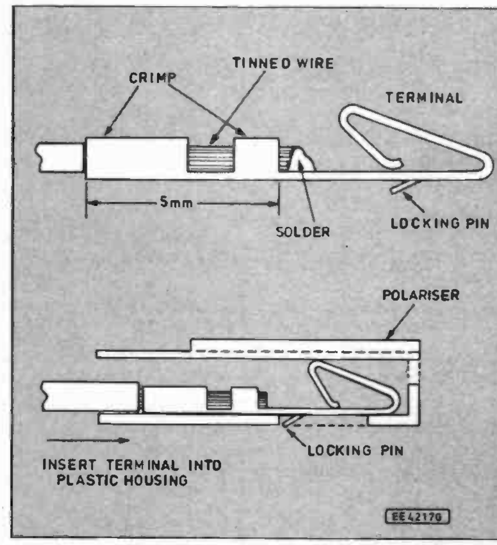


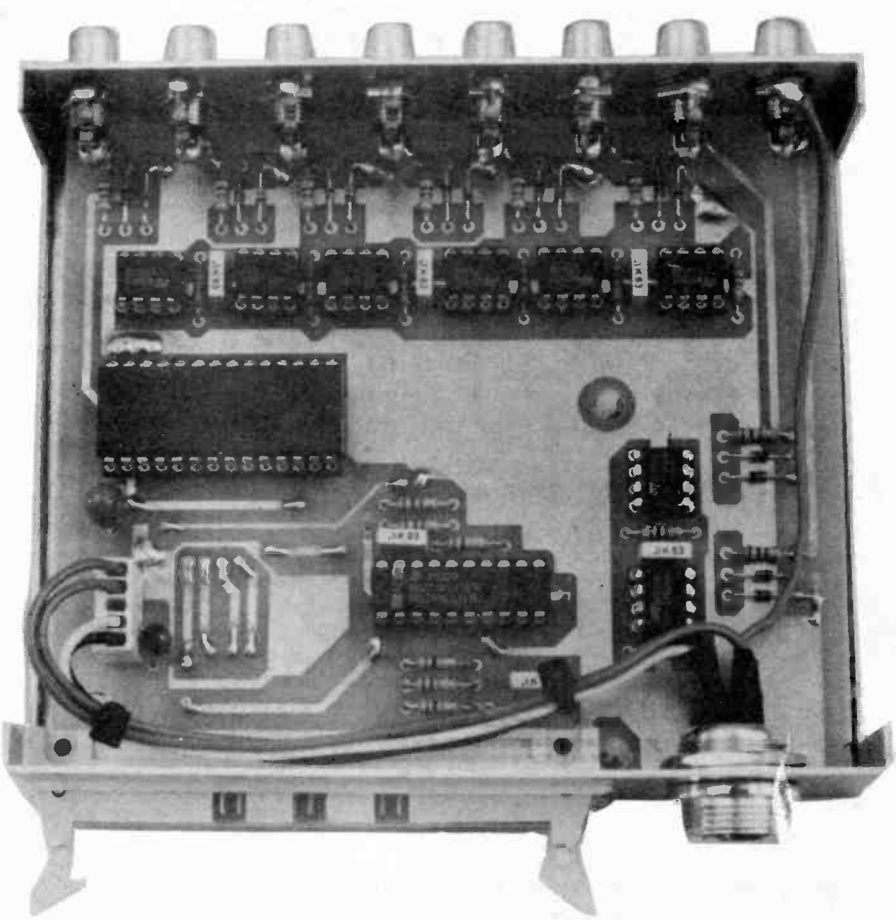

*Fig. 6. Assembly of the "Minicon" connector.*

The unit should be connected to the PCW using ribbon cable terminated at one end with a 50-way IDC connector, and at the other with a 50-way IDC edge connector (check when assembling the lead that pin one of the edge connector is connected to pin one of the IDC socket).

The cable should be kept as short as possible (less than 50cm). If longer, ringing and cross-talk may become a problem.

## TESTING

Check all joints and connections and make sure there are no shorts caused by



## COMPONENTS

**Resistors**

| | |
|---|---|
| R1, R2, R8, R9, R11, R12, R14, R15, R17, R18, R20, R21, R23, R24, R26, R27, R29, R30 | 1k (18 off) |
| R3 | 47k |
| R4 to R7 | 10k (4 off) |
| R10, R13, R16, R19, R22, R25, R28, R31 | 1M (8 off) |

All 0·25W
5% carbon film

**See SHOP TALK Page**

**Capacitors**

| | |
|---|---|
| C1, C3, C5, C6, C7, C8 | 0µ1 polyester (6 off) |
| C2 | 47µ tantalum bead, 16V |
| C4 | 10µ tantalum bead, 35V |

**Semiconductors**

| | |
|---|---|
| D1 to D16 | BAT85 Schottky diode (16 off) |
| IC1 | 74HC688 CMOS 8-bit comparator |
| IC2 | AD7828 High speed 8-bit 8-channel analogue-to-digital converter |
| IC3 to IC10 | LF356N f.e.t.-input wideband op.amp (8 off) |

**Miscellaneous**

| | |
|---|---|
| SK4 to SK11 | Phono or BNC socket (8 off) |

Aluminium case, size approx. 125mm x 105mm x 35mm; double-sided printed circuit board available from *EPE PCB Service*, code 838; Minicon connector; 50-way IDC socket and R/A plug; 50-way IDC edge connector; 50-way ribbon cable; 4-pin locking chassis plug and line socket; 8-pin low-profile d.i.l. socket (8 off); 10-pin low-profile d.i.l. socket; 28-pin low-profile d.i.l. socket; interconnecting wire; plastic self-adhesive p.c.b. stand-off pillars (3 off); stick-on rubber feet (4 off); plastic edging; solder etc.

*Approx cost guidance only* **£56**

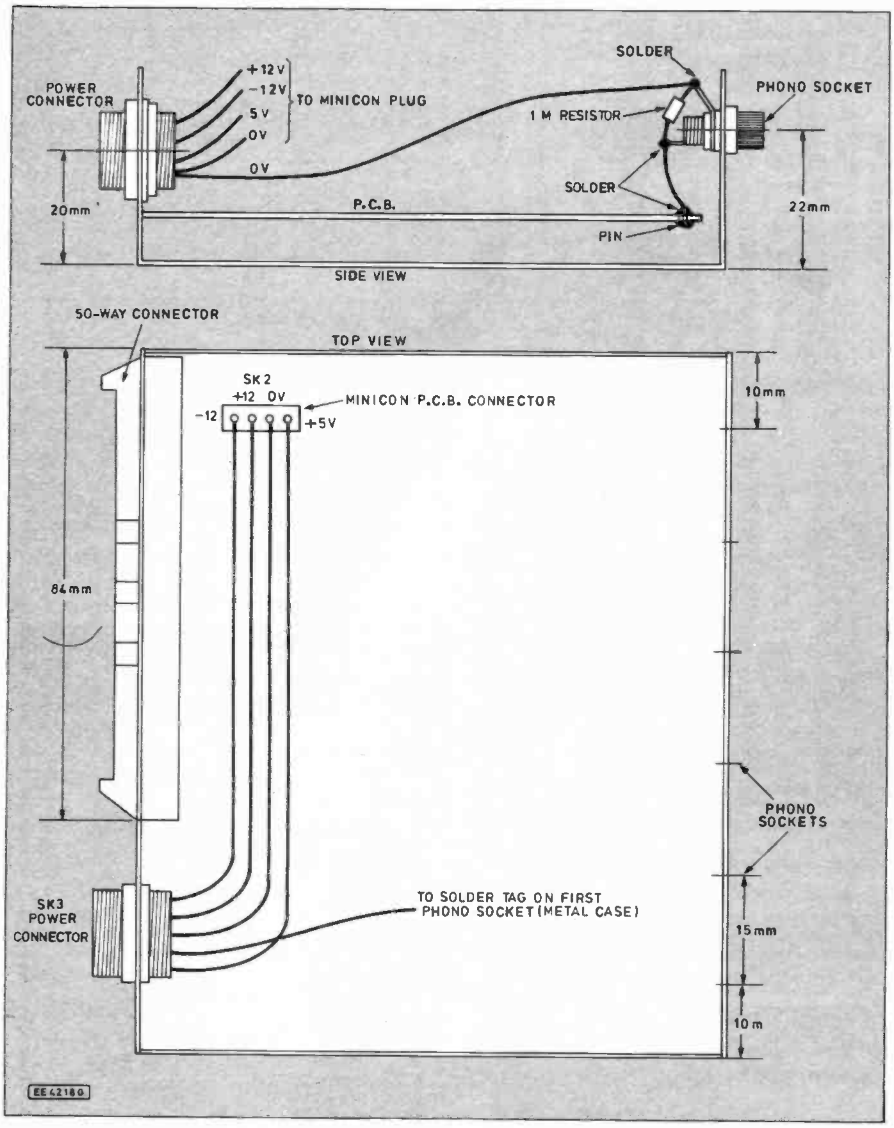



*Fig. 7. Interwiring, installation and case drilling details.*

excess solder. Before inserting the i.c.s or connecting to the PCW, connect the power supply and check the voltages at the Mincon connector are correct (with a circuit containing a £20 i.c. this is worth doing!).

If all is okay insert the i.c.s. The 7828 and 74HC688 are both CMOS and so should be handled carefully (wearing an anti-static wrist-strap is recommended).

Connect the unit to the PCW and the power supply. First switch on the external supply, then switch on the computer and "boot up" as normal. If the computer will not boot up or does anything abnormal turn off the PCW then the power supply, unplug the unit and check all joints, orientation of the i.c.s etc.

To test the inputs connect a 10 kilohm or 20 kilohm potentiometer (multi-turn are best as they give better resolution per turn) between the 0V and +5V outputs of the power supply and the wiper to Channel 0 of the ADC to form a variable voltage source. Enter the test program, Program 1, and then run it.

Enter 0 when the prompt "Which Channel" appears. A list of values will scroll up the screen, which should vary between 0 and 255 as the potentiometer is turned. If the values don't change check you are using the correct channel. The other 7 channels can also be tested in this way.

### Program 1: Test Program

```
10 Input "Which Channel (0 to 7):",
        channel
20 REM **Read last result, and start next
        conversion, then repeat**
30 PRINT INP(176+channel) :GOTO 30
```

## TAKE CARE

Phono connectors were used for the input sockets SK4 to SK11 as they are widely available and are quite low cost compared to most other screened connectors. Care should be taken when connecting things to the ADC using phono plugs as the centre conductor mates before the screen (this is not really a very good design). Unless the ADC and the source it is being connected to have a common ground this could cause damage to the ADC unit.

The best ways around these possible problems are:

a) To connect the phono socket first and then connect the source (with another type of connector).
b) Use a common earth for the units (only connect the screen to the ground at one end).
c) Make all the connections before the power is switched on.

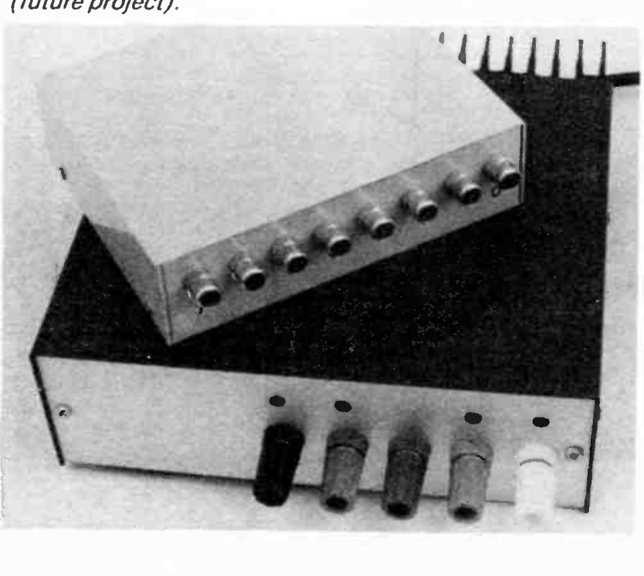
## PROGRAMMING

This unit is very simple to use. The main thing you must remember is that the value read from the port is the result of the *last* conversion.

The conversion program, Program 2, is an example of the above, it prints the values of Channels 7 and 0 repeatedly on the screen. First (line 20) the old value is cleared from the ADC and discarded, this also starts a conversion on Channel 7 (port 183).

The result of this conversion is printed at line 40, which also starts a conversion on channel 0 (port 176). The result of this conversion is pinted at line 60, which also starts a conversion on channel 7. The program then loops round to line 40.

*The completed unit sitting on the "Linear" Power Supply (future project).*



### Program 2

```
10 REM **Start conversion on channel 7 (discard value read from
        port)**
20 Discard% = INP(183)
30 REM **Start conversion on channel 0 and print result of last
        conversion**
40 PRINT "Value of Channel 7 < ";INP(176);
50 REM **Start conversion on channel 7 and print result of last
        conversion**
60 PRINT "> Value of Channel 0 < ";INP(183)">"
70 GOTO 40 :REM Repeat
```

There are many uses for this compact analogue-to-digital converter unit. In Part Two, next month, more programming details and some possible applications will be given when we set out and give information on "Using The ADC Unit". For example, how to use the ADC for monitoring/data logging – with simple sensors, its use for sampling signals at higher sampling rates and some elementary signal processing will be outlined.

Also, a future article will present a "Linear" Power Supply designed especially for the A/D Converter. However, the outputs of +12V at 1A; +5V at 1·5A; −12V and −5V at 0·5A make it ideal for many general purpose uses and an invaluable acquisition for the "test gear" collection. □