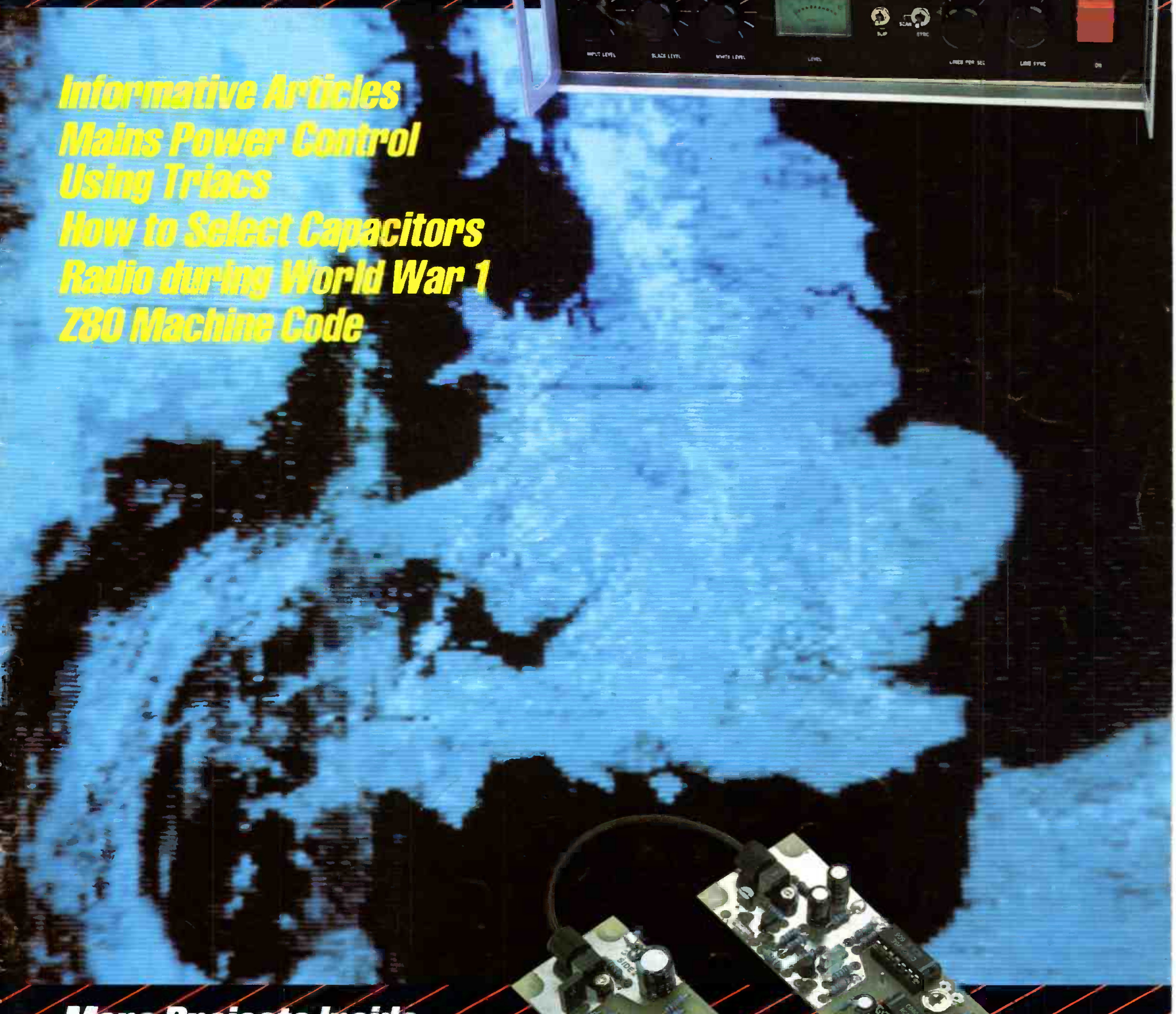
SEPTEMBER TO NOVEMBER 1986 PRICE 75p

Electronics
THE MAPLIN MAGAZINE

Decode and Display Data from Weather Satellites with our Decoder Project!



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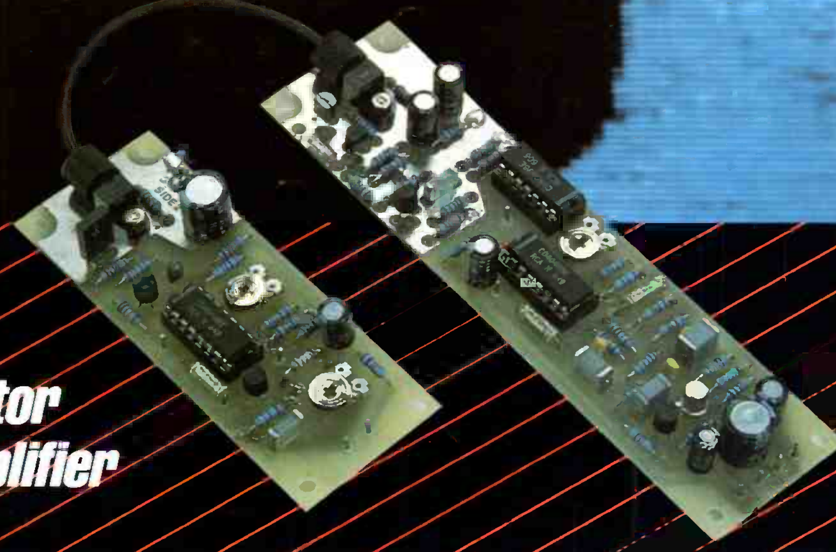

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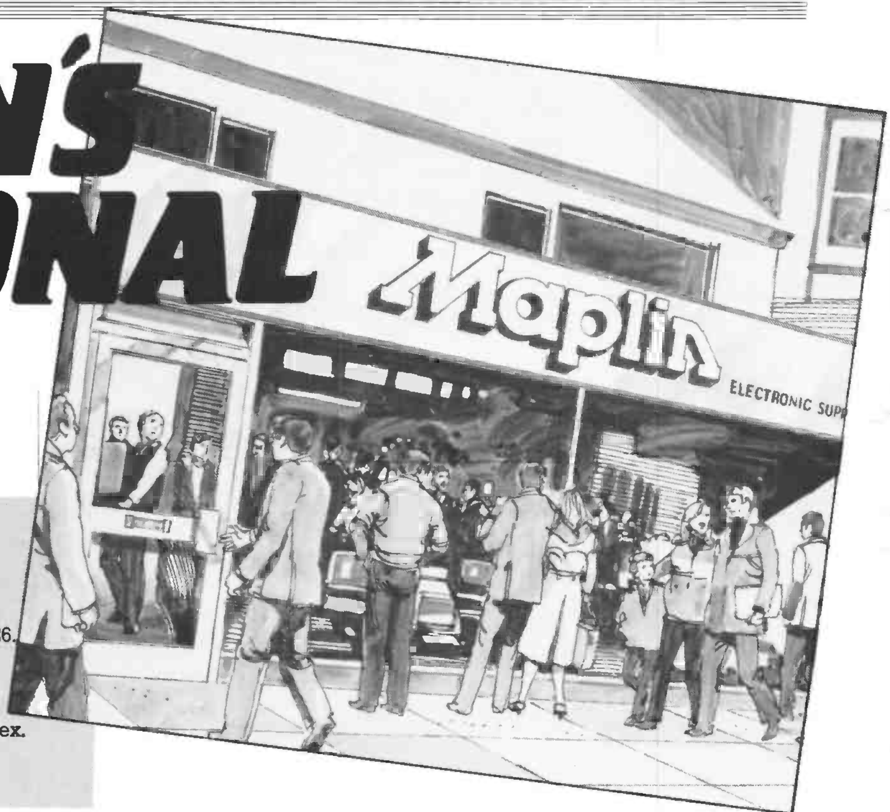

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September to November 1986
Volume 5 Number 20

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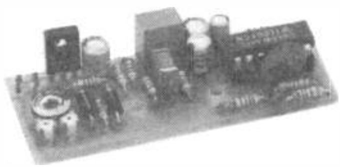
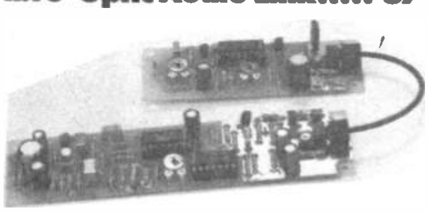
THE MAPLIN MAGAZINE

PROJECTS

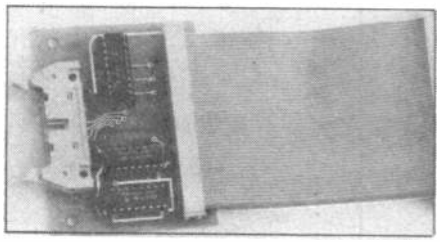
The second item of equipment for the Weather Satellite receiver system is the Decoder which enables the satellite picture to be displayed on a monitor by a home computer, from either a signal being directly received by the Receiver, or from a recording on cassette.



An infra red heat detector specialising in short range applications. It will serve as a detector guarding doorways and corridors, etc. Ideal as a heat or movement detector where coverage of room sized areas is not required.



Uses special on-board sending and receiving devices to transmit AC signals in the audio band along up to 20 metres of fibre-optic cable. Separate Transmitter and Receiver boards are used for coupling remote items of equipment. Although the project is aimed at educational and experimental applications, it may prove invaluable, for example, in electrically noisy environments.



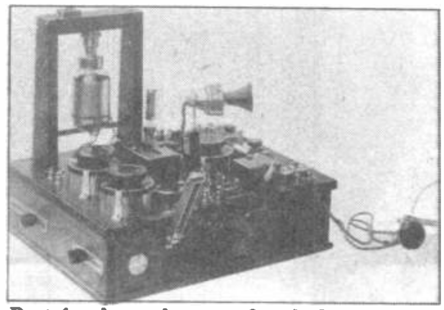
A simple 8-bit parallel input port for use with the CPC 464, and 664 and 6128 range of Amstrad computers. Can be used to interface to the Weather Satellite Decoder also in this issue.

For 200Ω to 600Ω impedance balanced or unbalanced microphones. The screened module also includes gain adjustment.

FEATURES

The newcomer to electronics cannot fail to have noticed the bewildering variety of different shapes, colours and specifications of all the range of capacitors available – even if they do happen to be of the same value. Why should the construction and composition of the different types, ostensibly so similar in value and voltage rating, be so diverse? Be prepared for some surprises . . .

The TRIAC has effectively revolutionised AC power control in recent times. However, powerful as these devices may be, they are not infallible. Before attempting to design such a control system some fundamentals have to be worked out first to ensure safe operation. This article presents a detailed insight into the internal workings of the modern TRIAC.



Part 4, where the new-fangled science of the invisible rays quickly came of age during the Great War. Those involved in other similarly fast growing technologies, aviation for example, took to it immediately, as did the Royal Navy for whom it was to become a valuable and indispensible tool. Traditionalists couldn't, or wouldn't, understand how it could be properly used.

Part 2 continues this series with some in-depth studies of how errors and tolerances are negated when taking measurements of real electrical properties. The principle of the measurement bridge circuit illustrates its wide range of applications.

Part 4 of this series describing the instructions for the ubiquitous Z80 CPU continues with conditional jumps, conditional calls and returns from subroutines, restarts, interrupts and the control group.

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Published by Maplin Electronic Supplies Ltd.
Typesetting by Essex Process and Engraving Co. Graphic House, Stock Road, Southend-on-Sea, Essex.
Printed by Mayhew McCrimmon Ltd., Star Lane, Great Wakering, Essex.
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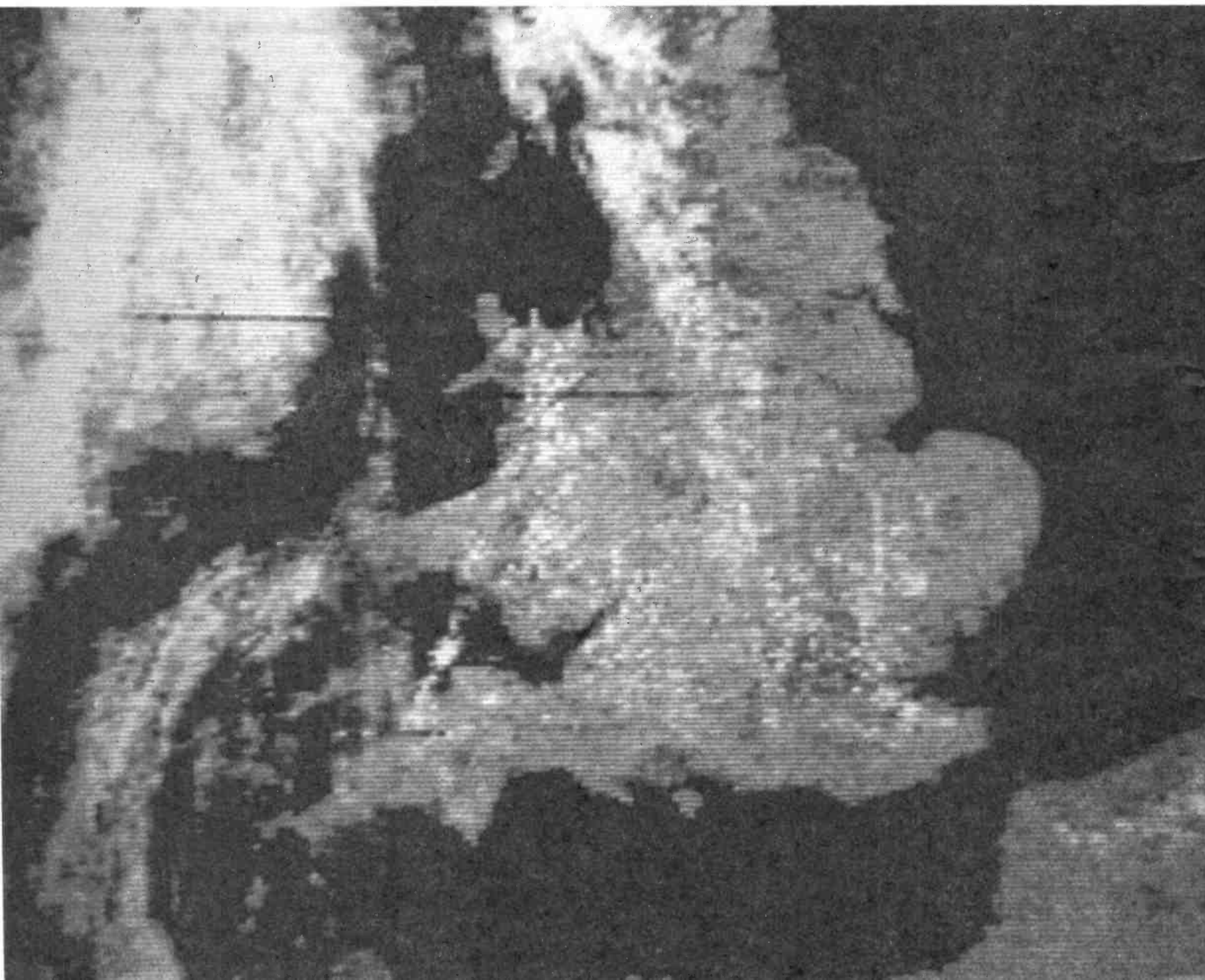


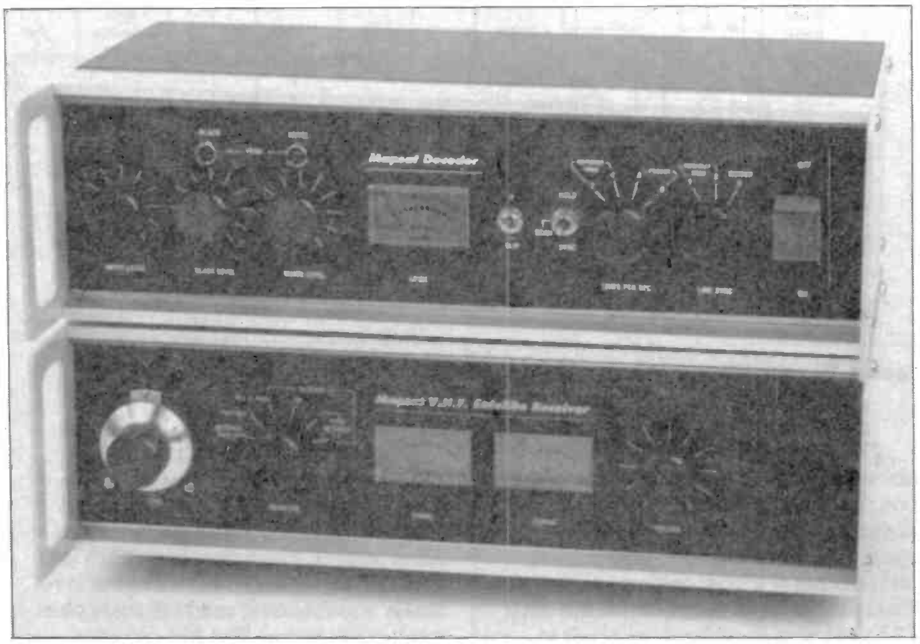
SATELLITE DECODER

by Robert Kirsch   Part 2

The Decoder

This article describes the Decoder needed to demodulate the APT (Automatic Picture Transmission) signals transmitted from most of the orbiting and geostationary weather satellites. These signals can be received using the Receiver described in Part 1 of this series.

The Decoder accepts audio signals either from tape or directly from the receiver and converts them into an 8-bit digital format with necessary synchronising pulses for connection to a suitable computer or frame store for display on a television or monitor. Controls are provided to enable the contrast of the picture to be adjusted and various types of synchronisation may be selected to suit different satellites. Power for the decoder comes from an internal power unit which will also supply the receiver.



Decoder with the Receiver

The APT Format

Pictures transmitted by most VHF American and Russian orbiting weather satellites, as well as WEFAX transmissions from the GOES series satellites (e.g. ESA METEOSAT 2), use the APT format. The radio frequency carrier is frequency modulated by a 2.4kHz subcarrier whose amplitude is modulated by the picture information and synchronising signals. Figure 1 shows the subcarrier envelope for a typical line of APT information.

Peak white, it will be noted, corresponds to maximum subcarrier level, and black to the minimum. Picture lines are transmitted either 2 or 4 times a second, each line having 600 cycles of subcarrier, thus the maximum horizontal definition is 600 pixels. The TIROS satellites send alternate lines of infra-red and visible information (when viewing the Earth in daylight) each line being preceded by synchronising pulses. Channel 1 (visible) sends 7 pulses at 1040 pulses per second and channel 2 (infra-red) sends 7 pulses at 832 pulses per second. Meteosat sends 7 pulses at 840 pulses per second at the start of every line, as well as a 300 pulses per second start and a 450 pulses per second stop signal for frame synchronisation.

The Russian Meteor satellites send approximately 2 lines per second with a synchronising tone of 300Hz for every line. The decoder described in this article produces line synchronising pulses by dividing the 2.4kHz subcarrier digitally, using a programmable divider to obtain the correct periods for various types of satellites. These pulses may be manually adjusted to correctly position the picture on the screen. (When using the optional sync tone decoder card this is achieved automatically.)

Circuit Description

Figure 2 shows a block diagram of the decoder, synchronising unit and power supply. Figure 3 shows the circuit diagram for the main circuit board. Live or recorded signals, selected by the receiver, enter via the 6-pin DIN socket and are first fed to a master level control. The signal at this point splits into three paths; the first goes to the A/D converter, the second to the Level Meter and AM detector circuit, and the third to the Phase Locked Loop carrier regeneration circuit.

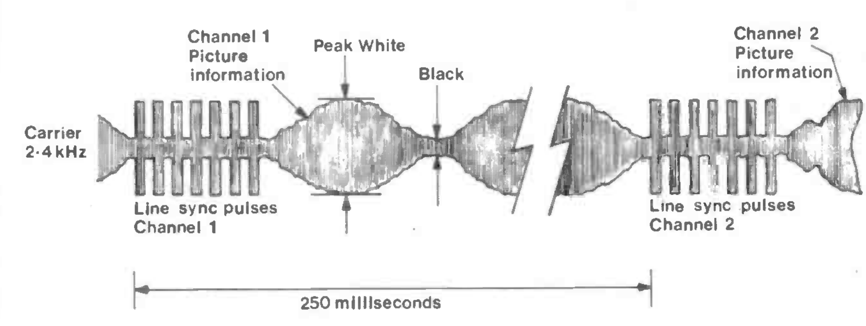


Figure 1. Typical APT information.

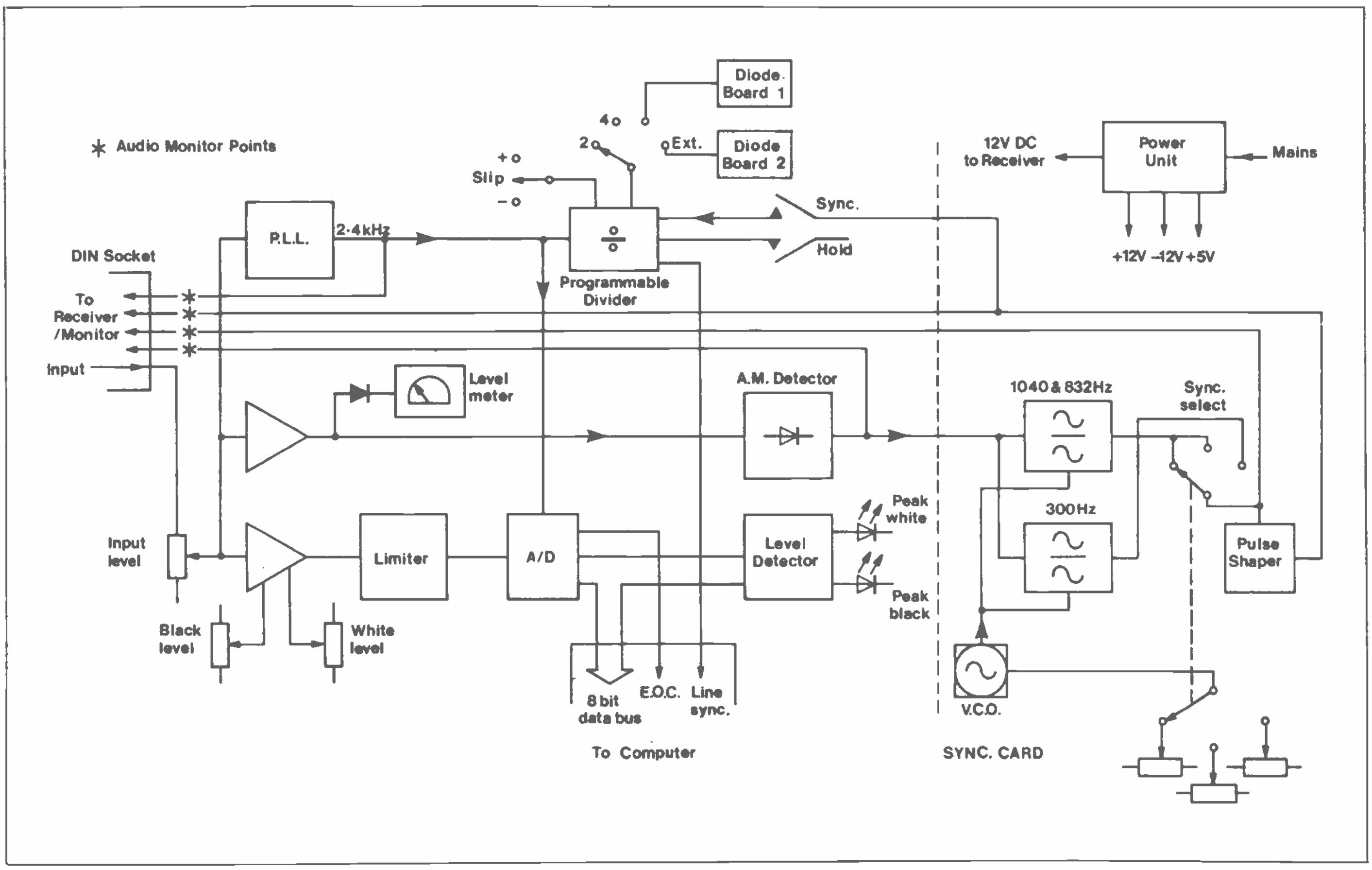


Figure 2. Decoder Block Schematic.

The conversion from the analogue subcarrier level to a digital code is accomplished by IC2, an 8-bit A/D converter. This device requires two inputs, one is the analogue information, and the other is a 'start conversion pulse'. The analogue input range of IC2 is from 0 to 2.5 volts to give codes from black to peak white. It is therefore important to adjust the level of the incoming signal in order to obtain correct contrast on the displayed picture. This function is provided by the op-amp IC1a. The gain of this device is adjusted by RV5 in the feedback circuit, this sets the white level. The output from IC1a is about ±2.5 volts but only the positive half cycle is fed to the A/D converter. RV4 sets the DC reference of the op-amp, and this offset is used to adjust the black level of the picture. Note, there is always a small amount of carrier at black level for synchronising purposes, so this circuit enables this level to produce true black on the display. The black and white level controls may also be used to enhance pictures particularly when only a few grey levels are available from the computer or frame store used.

The two light emitting diodes LED1 and LED2 are used to obtain the correct setting for the black and white level controls. The most significant bit from the output of the A/D converter is monitored and, when this bit goes high, TR2 turns on and causes LED2 to light, this indicates a level approaching peak white. All 8 bits are fed to the NOR gate IC5. When all 8-bits are low the output of this gate turns TR1 on, causing LED1 to light and indicate black level.

The second op-amp, IC1b, is fed with the incoming signal via the input level control. The output from IC1b is rectified by D3 and D4 to drive the level meter which should read full scale on a peak white signal. The AM detector formed by D1 and D2 is also fed from the output of IC1b and this audio signal is fed to the sync tone decoder card.

The phase locked loop, IC3, is fed with the incoming modulated signal and locks to the 2.4kHz subcarrier. The clean square wave output produced is used to generate the 'start conversion' pulse for the A/D converter and it is also fed to the programmable divider to produce line synchronising pulses.

The three counters IC6, 7 and 8 form the programmable divider whose division ratio is set by the data on pins 3, 4, 5 and 6 of each IC. The rotary switch S2 selects one of two preset ratios (1200 for 2 lines per second and 600 for 4 lines per second) and also two ratios that may be set by programming the optional diode cards, the circuit of which is shown in Figure 4. The SLIP control, S3, temporarily raises or lowers the division ratio to enable the picture to be moved in relation to the line sync pulse thus shifting the display left or right in relation to the television screen. The phase locked loop will produce an output even when no input is present, and therefore line sync pulses will also occur. For this reason the HOLD switch is provided to stop the

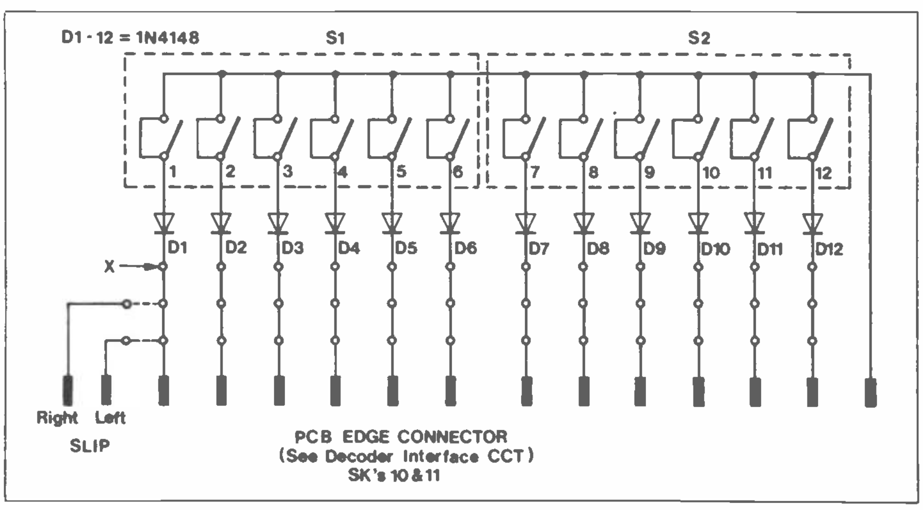


Figure 4. Diode Card Circuit.

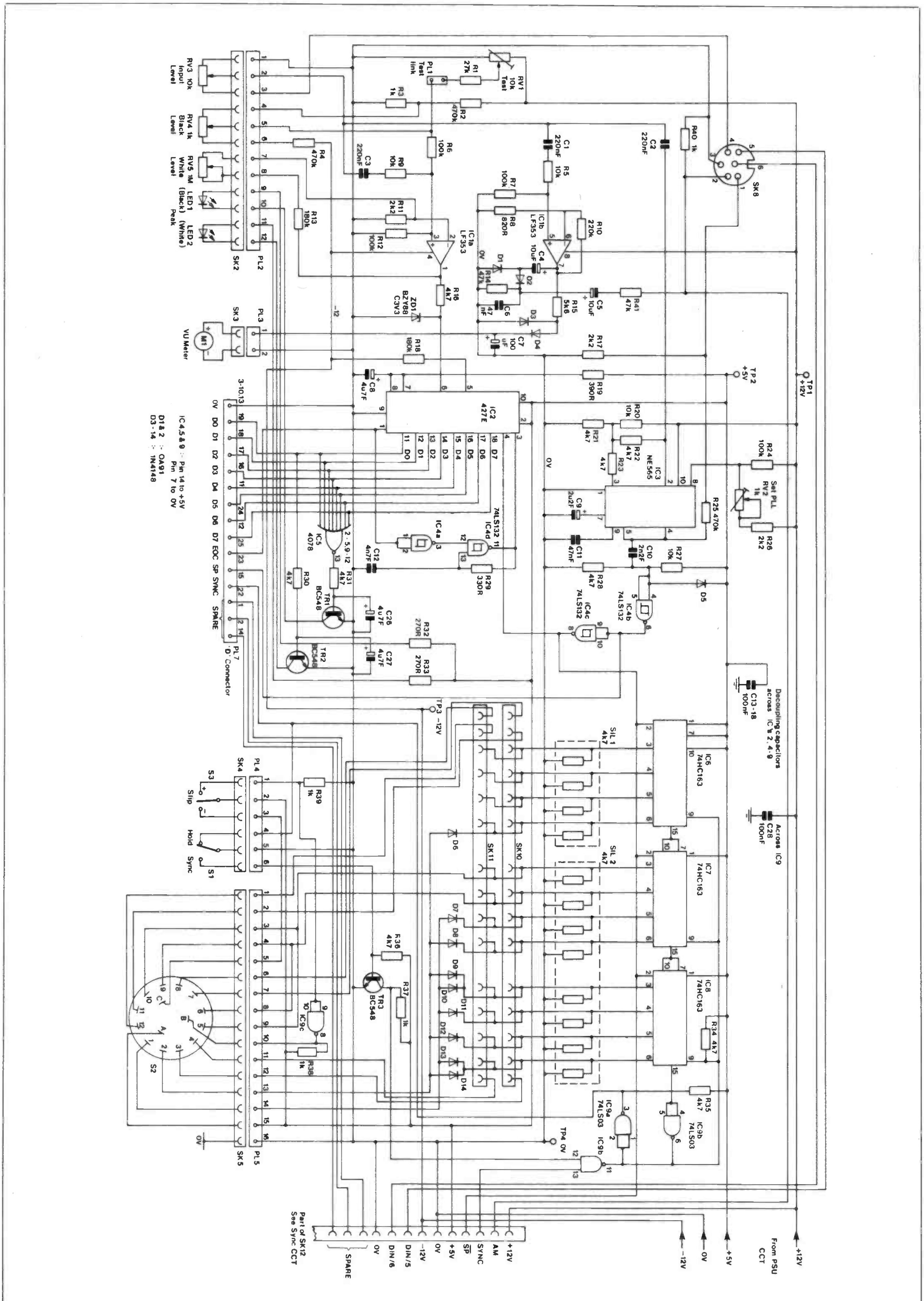


Figure 3. Decoder Circuit Diagram.

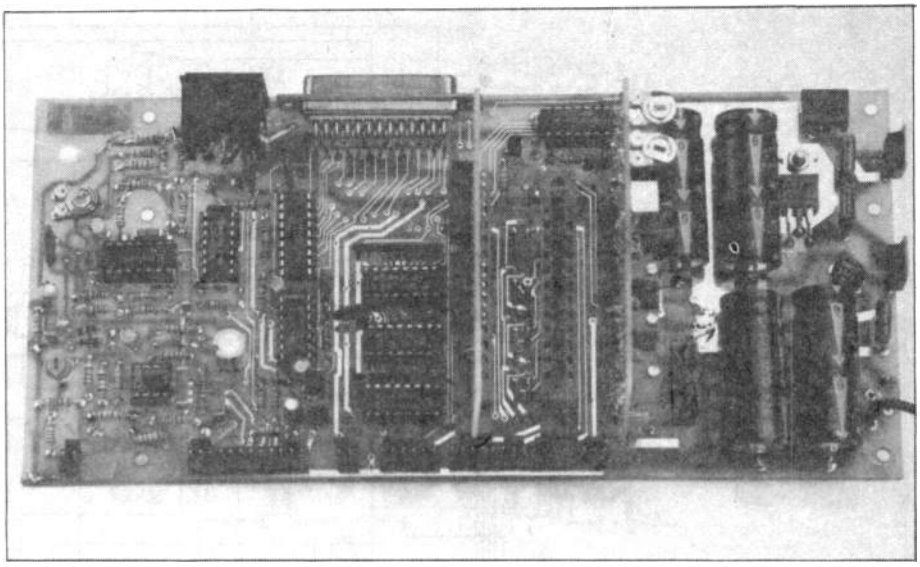
counter, thus preventing the current picture from being lost.

Four audio monitor points in the decoder are connected back to the receiver in order to help in setting up and testing. One of these is connected to the 2.4kHz output from the phase locked loop and another to the output of the AM detector. The remaining two monitor points coming from the optional sync tone card.

The preset RV1, along with the TEST LINK are provided to help in testing and setting up the A/D converter, computer hardware and software. This potentiometer provides an adjustable source of voltage to the input of IC1a which will simulate signal levels from black to peak white.

Sync Tone Card

This card is used to detect the line synchronising tone at the beginning of each picture line. Figure 5 shows its circuit, and it will be noted that a MF10 switched capacity filter (IC2) is used to select the tones. The frequency of this type of filter is determined by the frequency of the oscillator fed into pins 10 and 11 of the IC, in this case it is 100 times the required filter frequency. The two separate halves of IC2 have different bandwidths for optimum reception of different types of sync tones. The



Decoder Board

frequency of the voltage controlled oscillator, IC1, is controlled by the three multi-turn potentiometers RV3, 4 and 5 which are selected by S4 on the front panel.

The input level of IC2 is preset by RV1 and RV2, and the filtered output is buffered by TR1 and TR2. TR3 with D1, 2 and 3 form a threshold switching circuit whose output is used to reset the divider on the main board when the LINE SYNC switch is operated.

Construction

Referring to the Parts list and component overlay on the three circuit boards, Figure 6 shows the legend of the main decoder board, Figure 7 gives the tracks and overlay of the Sync tone card, as does Figure 8 for the Diode board; insert and solder all components in the following order: fixed resistors, capacitors, diodes and bridge rectifier, SIL resistors, IC holders, transistors and regulator IC's; veropins, preset resistors

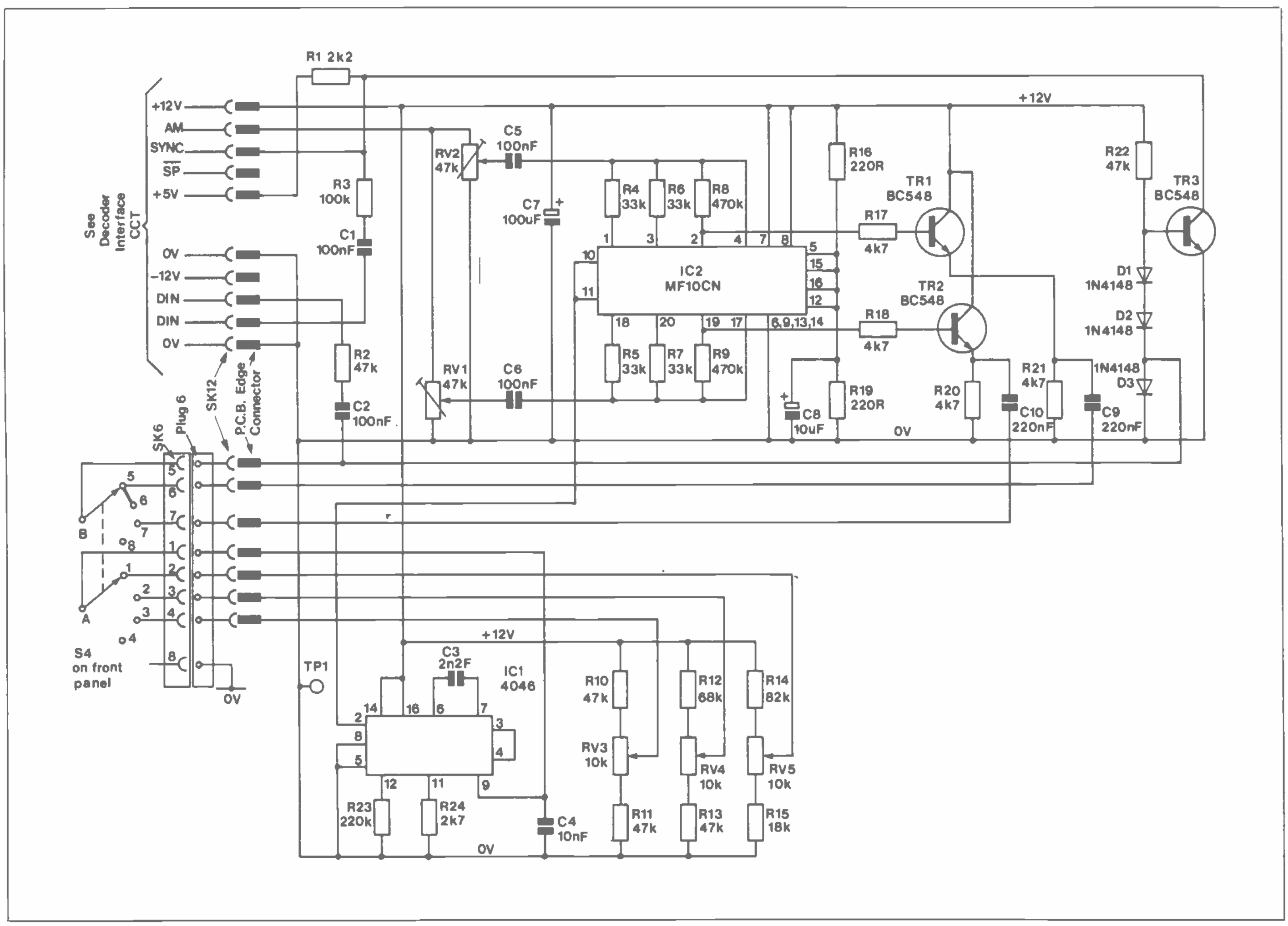


Figure 5. Sync Tone Circuit.

and finally plugs, sockets and edge connectors. **NOTE** - observe the correct polarity of transistors, regulators, diodes, LED's, meter, electrolytic capacitors and the bridge rectifier. The white dot marked at one end of the SIL resistor package should correspond to the white dot on the board overlay. The tags of the Minicon plugs should be to the rear of the circuit board. The white rings on the overlays indicate where the boards should be soldered on *both* sides; in addition TR1 on the sync card should be soldered on both sides also.

Insert the keys into the edge connectors, referring to the wiring diagram Figure 9. Carefully insert all integrated circuits into their correct holders ensuring that pin 1 marked on the board aligns with pin 1 of the IC. Carefully fit the clip-on heatsink to REG2.

Use the stick-on front panel as a template to mark out the front plate of the box, before drilling and cutting out, see Figure 11. Remove the protective backing from the front panel and carefully position it on the prepared front plate, pressing down evenly all over, making sure there are no air bubbles trapped underneath. Mount all controls and switches on the front panel. Referring to the wiring diagram Figure 9, connect all level controls, toggle and rotary switches, LED's and the meter to their appropriate Minicon housings via the ribbon cable provided, allowing approximately 5 inches of cable from each housing to the front panel. Note that the Minicon housings will have their lugs towards the rear of the circuit board when installed. (Refer to the Receiver article for details of how to make terminations to the Minicon connectors, Maplin Magazine Issue 18.)

Mount the toroidal transformer with the rubber washers provided on either side and place a solder tag under the fixing screw, the PSU circuit is shown in Figure 10. Insert the rubber grommet into the hole in the transformer bracket and pass the red, blue, grey, and yellow wires from the transformer through the grommet. Referring to Figure 11, mark and drill the base plate and mount the transformer bracket, placing the mains label in a visible position on this bracket. You can make your own bracket if you wish according to the dimensions shown in Figure 12. Drill and cut out the rear plate of the box and mount the fuseholder. (Check that when the case is finally assembled, the fuseholder tags will be clear of any obstructions.)

Pass the mains cable through the strain relief grommet and then through its hole in the rear plate and secure grommet in position, then refering to Figure 9, connect the brown wire via the fuseholder to the mains switch. The blue wire connects straight to the mains switch and the green/yellow wire to the earth tag under the transformer mounting screw. Terminate the two orange primary wires from the transformer at the

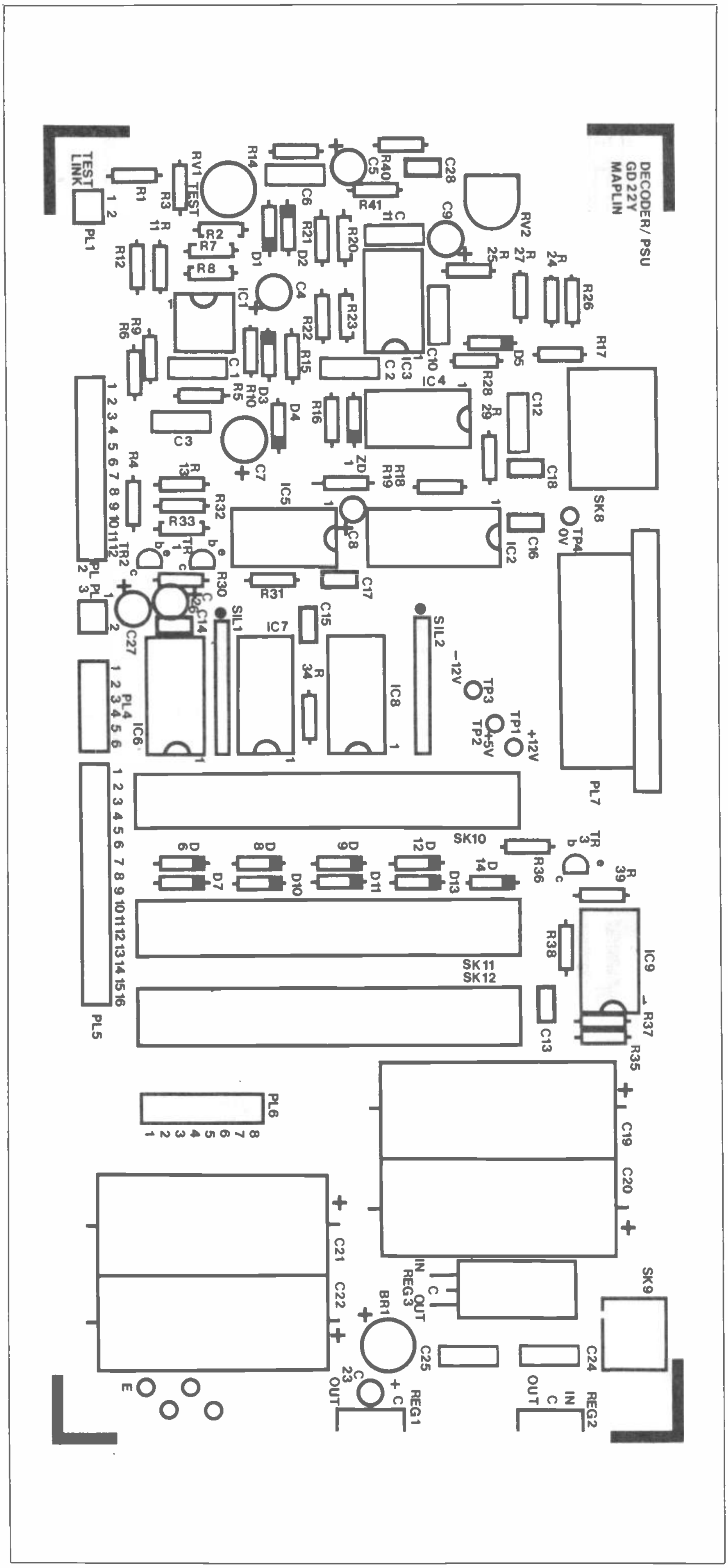


Figure 6. Decoder PCB Overlay.

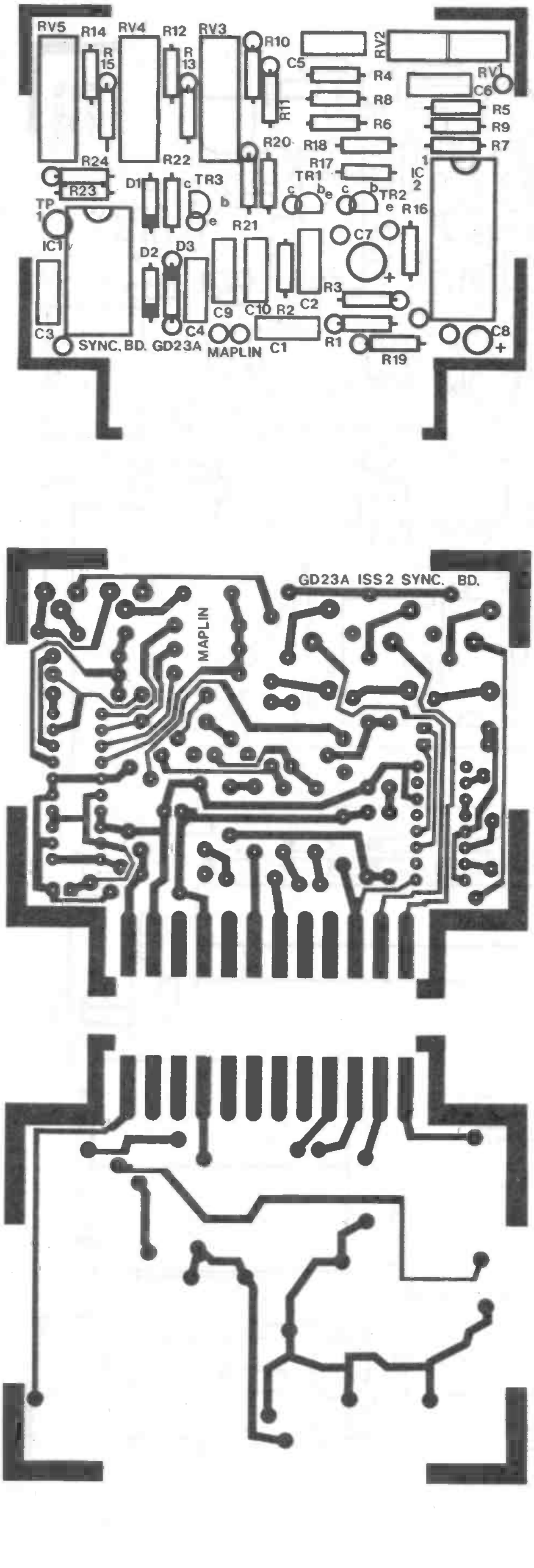


Figure 7. Sync Tone Tracks and Overlay.

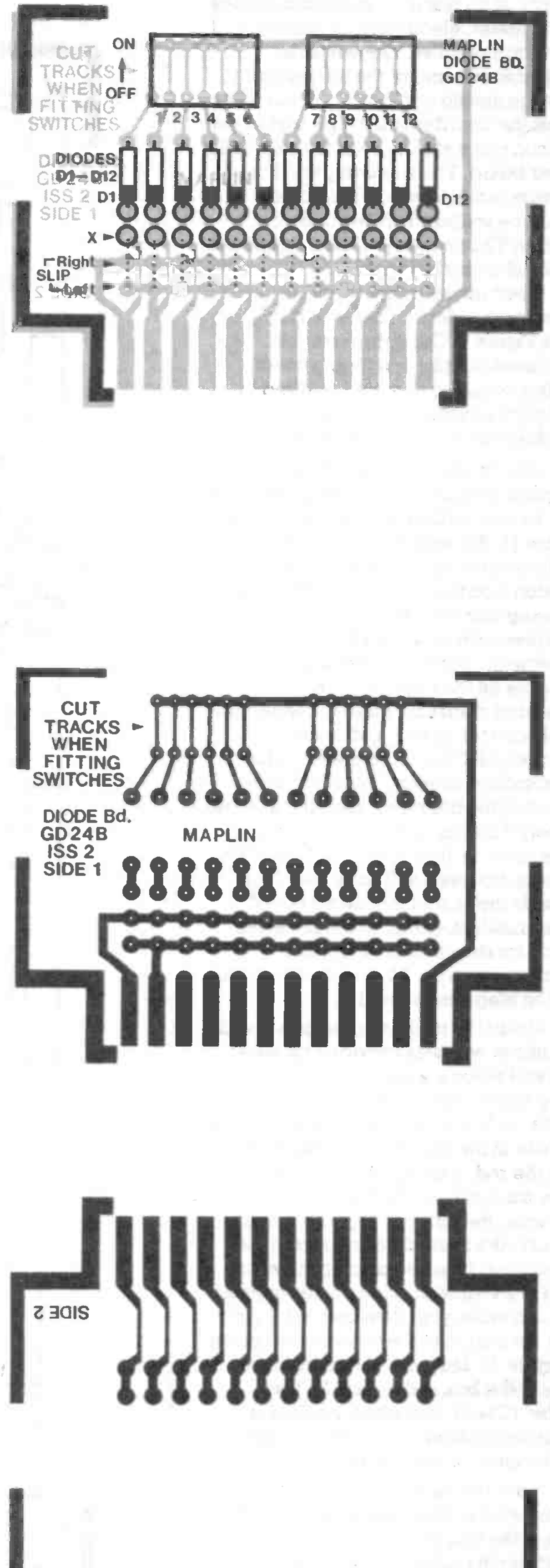


Figure 8. Diode Board Tracks and Overlay.

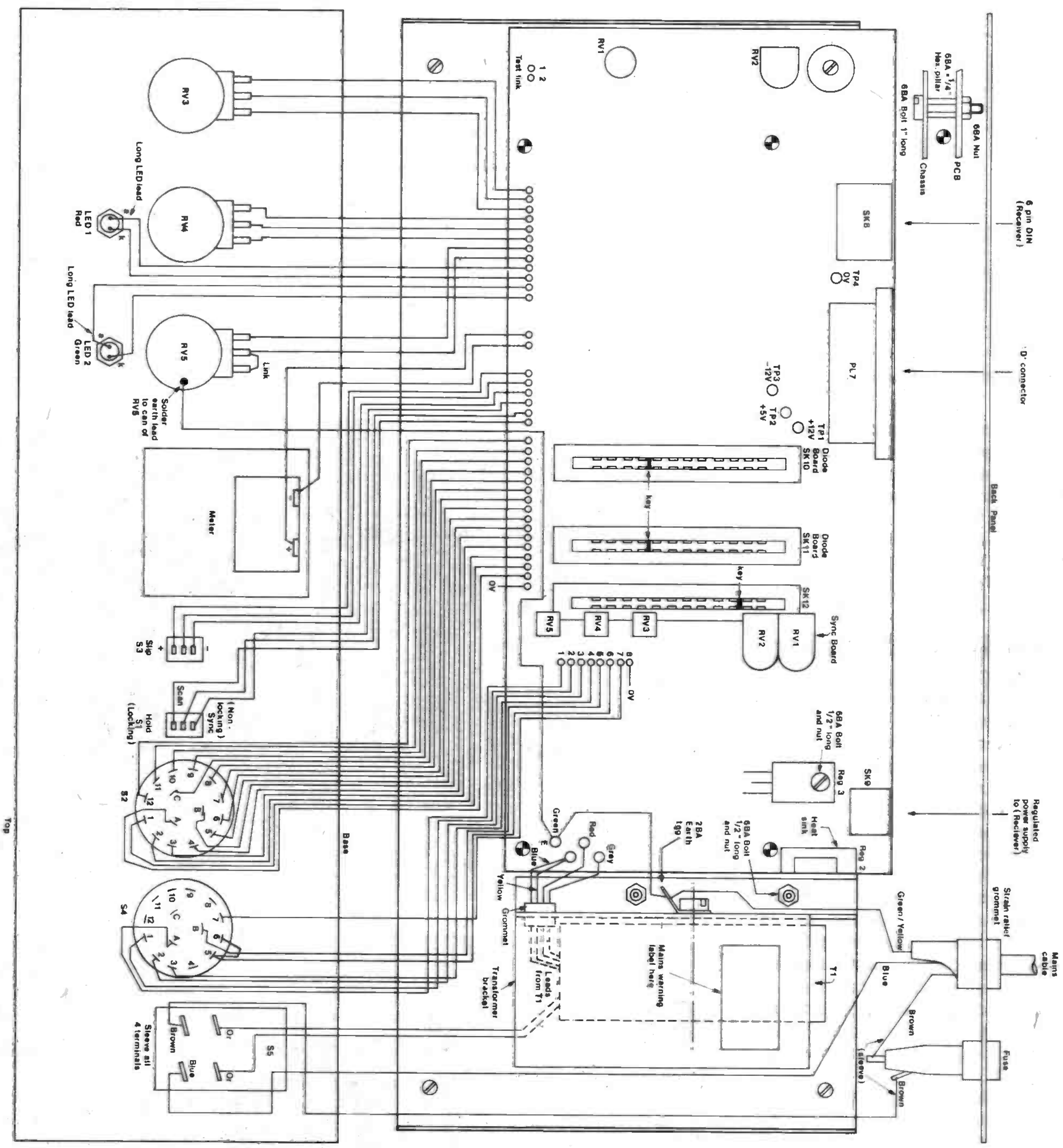


Figure 9. Wiring Diagram.

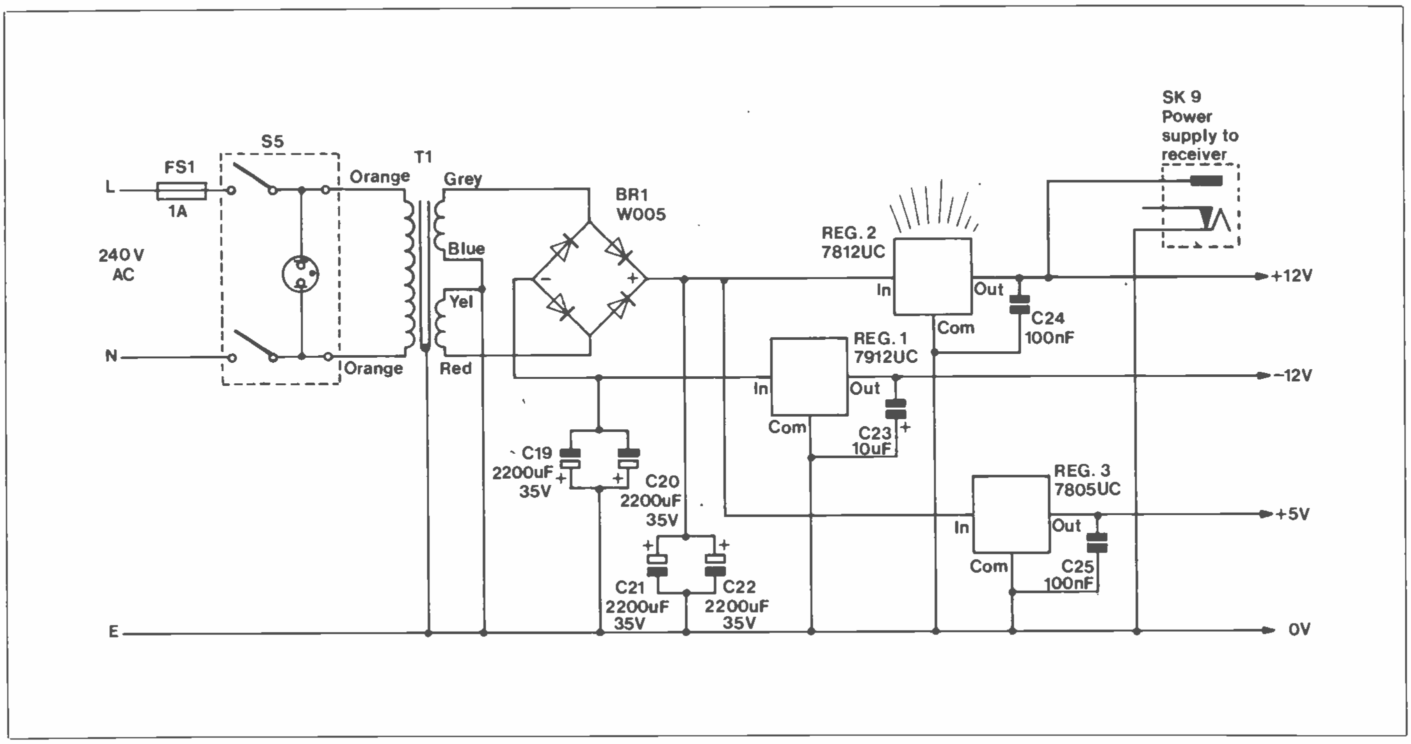


Figure 10. Power Supply Circuit.

mains switch. Insulate *all* exposed mains connections. Fix the main circuit board to the base plate, and solder the transformer secondary wires onto their respective pins.

The case may now finally be assembled and the front panel connectors plugged onto the circuit board. The decoder is now ready for testing.

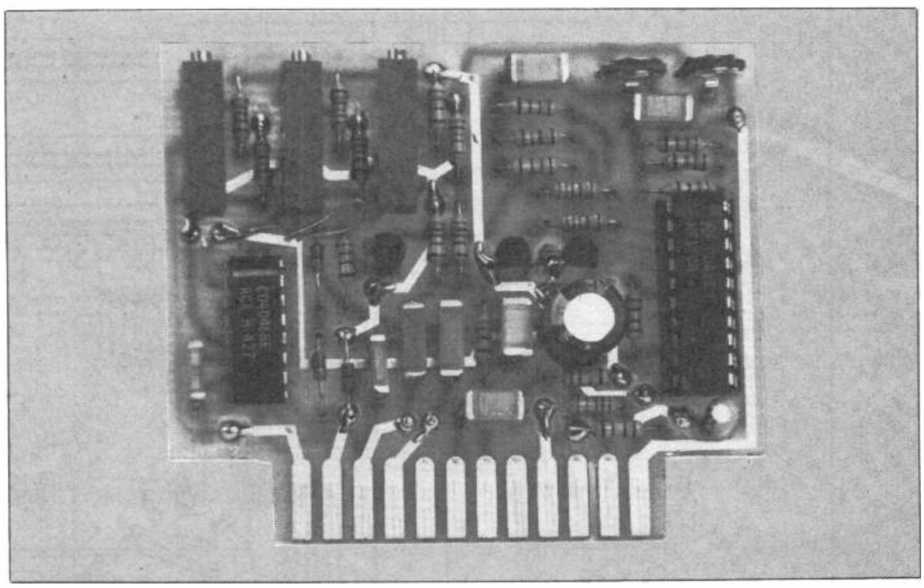
Setting-Up and Testing

WARNING - Take care when working on the decoder with the mains supply connected. **NOTE** - Do *not* connect the computer, framestore or receiver until the following tests have been carried out.

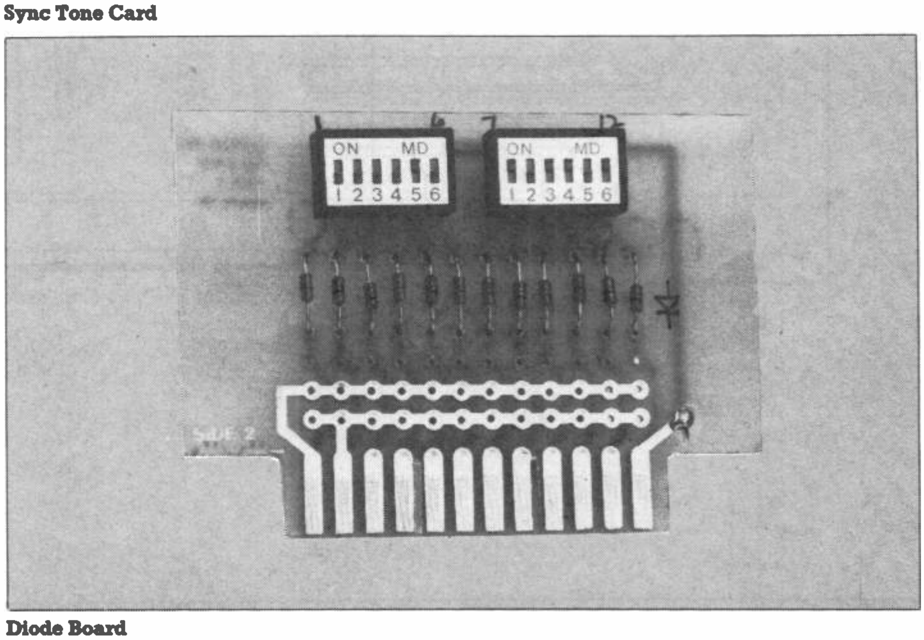
Set all three front panel level controls anticlockwise. Insert the 1 Amp fuse and connect the Decoder to the mains supply. Switch on. The mains indicator light in the power switch should glow and the red 'Peak Black' LED should be illuminated. Using a suitable multimeter check the power supply outputs at the test points provided to obtain the following readings (to within ±0.5 volts). All readings are relative to 0 volts (TP4) or chassis. TP1: +12 volts, TP2: +5 volts, TP3: −12 volts.

If these readings are correct, connect the Decoder to the parallel I/O port of the computer/framestore and run the appropriate software. (When using the Amstrad or BBC software provided in this article, set the horizontal resolution to 4.) Set the TEST preset (RV1) fully clockwise and the sync switch to SCAN. The lines per second switch should be set to 2. Join the two TEST LINK pins (PL1) together and note that the 'Black Peak' LED remains alight.

Slowly rotate the TEST preset anticlockwise whilst observing the monitor screen. The brightness of the scan lines moving up the screen should be seen to



Sync Tone Card



Diode Board

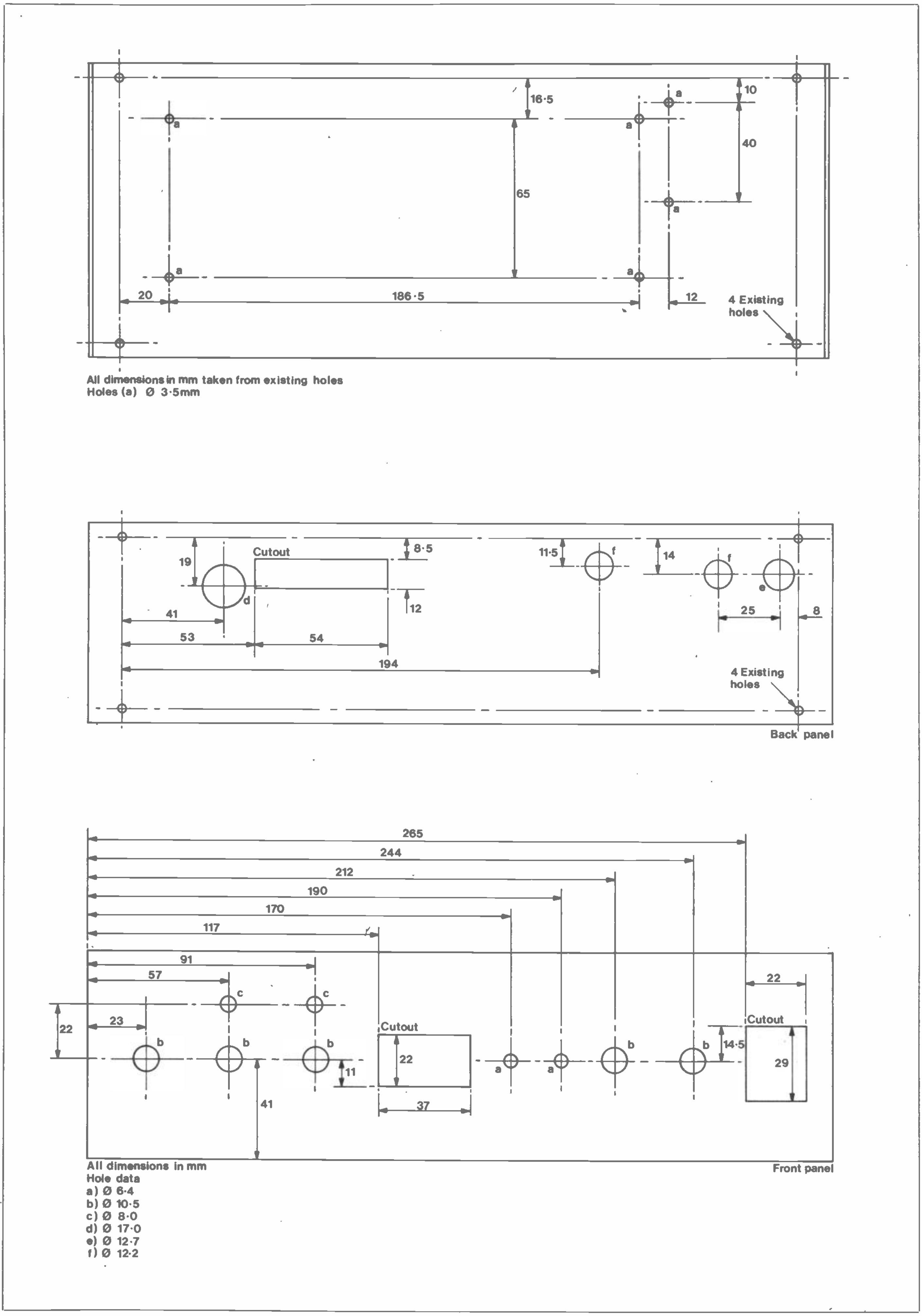
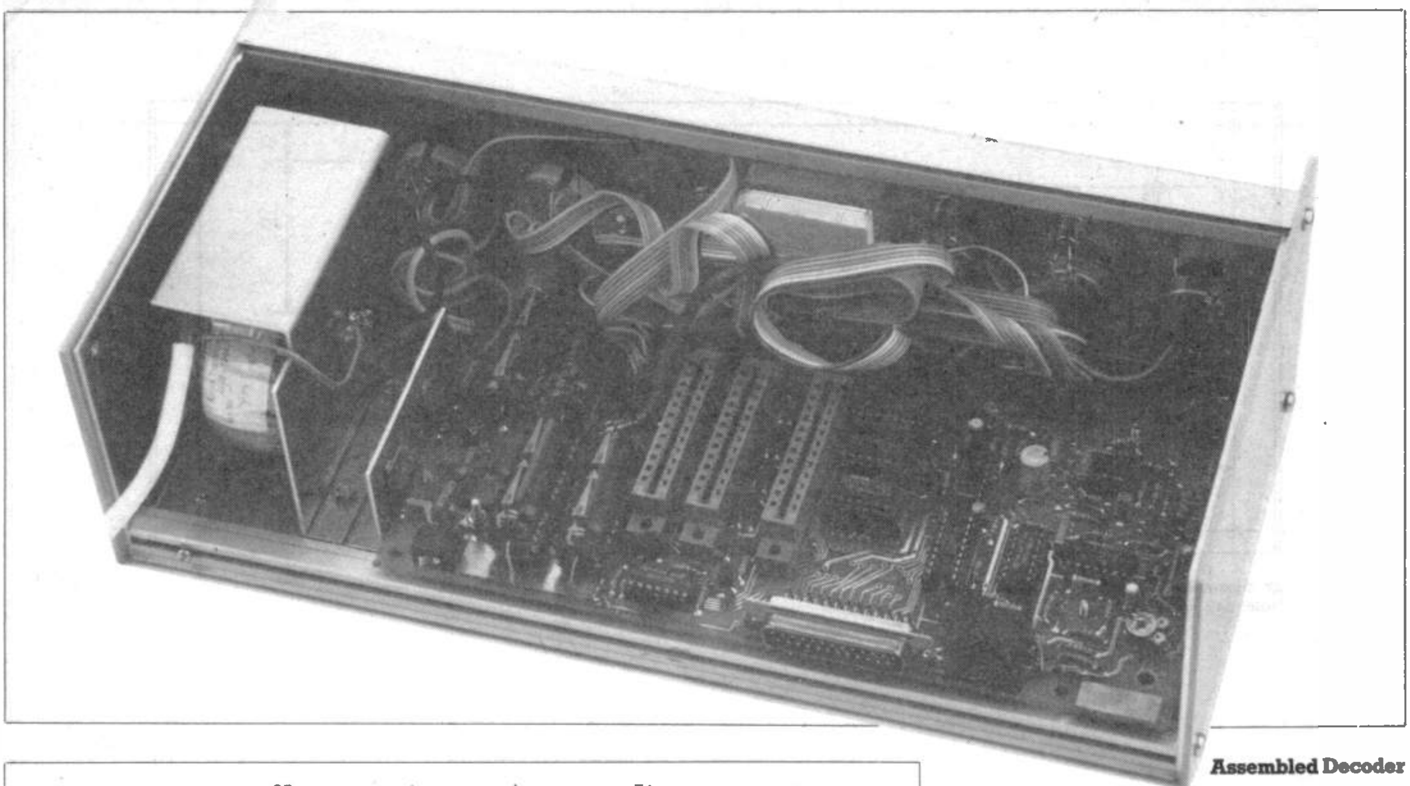


Figure 11. Case Cut-out Details.



Assembled Decoder

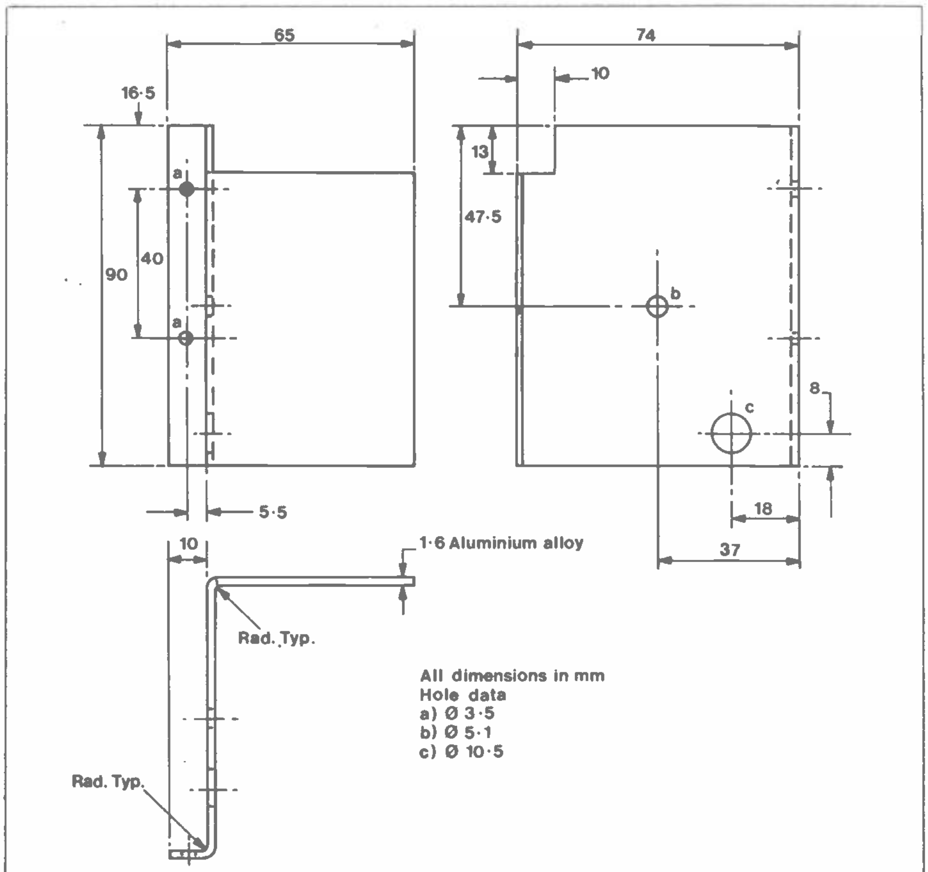


Figure 12. Transformer Bracket.

Sync Tone Switch Position	Frequency of Tone	Frequency at TP1 of Sync Tone Card
TIROS 1 (Channel A)	1040Hz	104 kHz
TIROS 2 (Channel B)	832Hz	83·2 kHz
METEOR	300Hz	30 kHz

Figure 13. Sync Card Frequency Settings.

progressively increase as the control is rotated. Repeat this test and note that the 'Black Peak' LED goes out before the first grey level appears on the screen and that the 'White Peak' LED comes on as the maximum white is approached. When the full number of grey levels appear on the screen move the scan switch to 'HOLD' (this should stop the picture being scanned) and check that the correct number of levels appear on the screen depending upon the type of display system in use. (The Amstrad and the framestore should produce 16 levels including black and white, and the BBC 8 levels including black and white). The 'TEST' link pins may now be disconnected.

The following tests should be carried out by using a good quality recording of the NOAA 6 or NOAA 9 satellites. Connect the Decoder to the Receiver via the 6-way audio DIN lead and the power lead. Connect the tape recorder to the Receiver, referring to the previous article (Issue 18). Play the recording of the satellite. Select TAPE OUT on the MONITOR switch of the Receiver and adjust the VOLUME to a comfortable level. Set the Decoder INPUT LEVEL control to minimum. Switch between TAPE OUT and PLL on the MONITOR switch, and adjust the preset RV2 on the Decoder board until the tone from the PLL is the same as that of the satellite's subcarrier.

To check this setting, the INPUT LEVEL may now be increased and the 'Black Level' LED should now flash or go out. Check that the LEVEL meter responds as the INPUT LEVEL control is increased.

The basic Decoder is now ready for use but if the sync tone card has been installed the following setting-up is required. The three multi-turn presets on the tone card are best adjusted using a frequency counter, with reference to Figure 13. Where no frequency counter is available, this adjustment may be carried out by using the audio monitor test points provided in the Receiver unit in the following manner.

When playing a recording of the NOAA satellites, the characteristic 'clip-clop' of the synchronising tones will be noted. The first two positions of the LINE SYNC switch ('TIROS') select one or other of these two tones, the third position is for the Russian Meteor satellites.

Play the recording as before and adjust the INPUT LEVEL to give about half scale on the LEVEL meter. Select the first position of the sync detector on the MONITOR switch. Switch the LINE SYNC switch to TIROS 1, and set the two presets RV1 and RV2 on the sync card to their mid-position, and adjust RV3 to obtain the loudest output for the *higher* tone.

Repeat this procedure with the LINE SYNC switch set to TIROS 2, and adjust RV4 to obtain the maximum output for the *lower* tone (RV5 may be adjusted in the same way when playing a recording of a Meteor satellite with the SYNC switch in the METEOR position).

Switch to the second sync detector position on the MONITOR switch and adjust RV2 on the sync card to obtain a short burst of noise that corresponds to every second sync tone of the recording. Check this setting in the other (TIROS) position of the SYNC switch. For the METEOR position of the SYNC switch, adjust RV1 to obtain the noise burst for every sync tone when playing a recording of the satellite.

Decoder in Use

The following information refers to the use of the decoder with the BBC B and Amstrad computers. (Information for using the Frame Store will be published later).

Program 1 is for the BBC model B, Program 2 is the machine code created by the GENA 3 assembly program from Amsoft. From Program 2 you can create your object file which can then be loaded by Program 3. When loaded and run, these will ask for the Horizontal Resolution to be entered; this value determines not only the definition of the displayed picture, but also the proportion of the total picture width displayed across the screen. The first time a recording is run, select full width (4), and then any interesting parts may be re-run with a lower setting to obtain greater detail. The SHIFT switch may be used to move the picture to the desired position at the beginning of the run, and if required, the full scan may be re-started by holding the space bar. (The sync when set is not lost until the tape is stopped or the signal fails.) Synchronisation to the start of a line is provided by the Sync Tone Card. The

Satellite	DIL Switch in ON Position												Slip Switch Connections	
	1	2	3	4	5	6	7	8	9	10	11	12	Left	Right
# 1	✓		✓	✓		✓						✓	9	8
# 2	✓		✓	✓					✓	✓	✓		8	6
# 3	✓		✓	✓		✓							9	8

Figure 14. Settings for Russian Satellites.

LINE SYNC switch selects the type of satellite and channel to be synchronised. With the recording running and the appropriate position of the LINE SYNC switch set, synchronisation is achieved by a short operation of the non-locking SYNC toggle switch.

The INPUT LEVEL control should be set to give an average reading of about half scale on the LEVEL meter. (Note that if a known peak white signal is being received, the level should be adjusted to give a full scale reading on the meter.) Advance the 'White Level' control until the peak white LED just starts to flash, then adjust the 'Black Level' until the black LED is just flashing. This setting should give a fairly good picture, but some experimentation with the settings of these controls is required to achieve the best results.

The LINES PER SECOND switch should be set to 2 lines per second for NOAA pictures, as channel A and channel B are sent alternately. The 4 lines per second position is used for satellites such as Meteosat when part lines are displayed to improve the aspect ratio and increase the vertical resolution.

The two preset positions of this switch are used for satellites with other line rates, and are programmed by using the diode cards. The Diode Card may either be fitted with DIL switches, or with diodes in a pre-selected matrix. When the DIL switches are fitted, cut the shorting tracks under the switches, and fit all diodes. The correct setting for a satellite is found by switching the LINES PER SECOND switch to the A position, inserting a diode card, with DIL switches installed, in position (nearest to the sync card) and trying different settings of the switches until a synchronised picture is obtained. Figure 14 shows some settings for Russian satellites that have been found to synchronise correctly. When the setting has been determined, the code may be 'copied' onto a blank diode card by inserting diodes *only* in positions that correspond to the positions of those diodes that connect to the switches that are in the ON position on the original (DIL switch) Diode Card. The shorting tracks are left intact. The connections to the SLIP switch also appear on the Diode Card, and these are made by inserting wire links below the diodes. The method of setting these links is as follows:– Find the correct setting for the DIL switches as before, connect a short length of wire to the 'left' track and connect the other end to one of higher numbered pads marked X that does not have its associated switch in the ON (up) position. Run the tape and operate the SLIP switch to the LEFT position and note the effect on the picture. The correct setting is where the picture moves left at a controllable rate.

Once this connection point has been found, determine the position to the left of this connection where there is a switch in the ON position. Connect the RIGHT track to the 'X' connection of this position, and turn the switch OFF. Try running the recording again and check that when the SLIP switch is held in the RIGHT position, the picture moves to the right at a comfortable rate.

When the correct positions for the two connections have been found, permanent wire links may be fitted.

The picture scanning may be stopped at any time by using the HOLD switch. (This does not lose synchronisation if the incoming signal is uninterrupted.)

DECODER DIODE BOARD PARTS LIST

SEMICONDUCTORS

D1-12	1N4148	12	(QL80B)

MISCELLANEOUS

S1,2	DIL Switch SPST 6-Way	2	(FV44X)
	Diode PCB	1	(GD24B)

A complete kit of all parts is available for this project:
Order As LM09K (Decoder Diode Board Kit) Price £5.95
The following item in the above kit list is also available separately, but is not shown in the 1986 catalogue:
Decoder Diode PCB **Order As GD24B Price £3.25**

Program 1.

```
10 MODE 7
20 CLS:PRINT:PRINT
30 PRINT"INPUT HORIZONTAL RESOLUTION (1-4)";
40 INPUT HRES
50 MODE 2
60 VDU 23;8202;0;0;0
70 PRINT
80 DIM CODE% 500
90 ROWBSE=&70
100 ?ROWBSE=((HIMEM+20479) MOD 256)
110 ?(ROWBSE+1)=((HIMEM+20479) DIV 256)
120 DOTBSE=&72
130 ?DOTBSE=((HIMEM+20479)MOD 256)
140 ?(DOTBSE+1)=((HIMEM+20479)DIV 256)
150 SMPL=&74
160 TEMP=&75
170 RWBSSH=&76
180 FINSCN=&78
190 OVBRT=&7A
200 ?FINSCN=((HIMEM)MOD 256)
210 ?(FINSCN+1)=((HIMEM)DIV 256)
220 PORT=&FE60
230 FOR P=0TO2 STEP 2
240 P%=CODE%
250 [OPT P
260 LDA #&02
270 LDX #&00
280 JSR &FFF4
290 .INIT LDA #&00
300 LDX #&00
310 LDY #&00
320 SEI
330 CLD
340 STA &FE62
350 STA SMPL
360 STA TEMP
370 .WTSYNC
380 LDA PORT
390 AND #64
400 BEQ WTSYNC
410 .FINSYNC
420 LDA PORT
430 AND #64
440 BNE FINSYNC
450 .WASTE BIT PORT
460 BMI WASTE
470 .PING BIT PORT
480 BPL PING
490 INX
500 CPX#01
510 BNE WASTE
520 LDX #&00
530 .WTBUSY
540  BIT PORT
550 BMI WTBUSY
560 .WTSMPL
570 BIT PORT
580 BPL WTSMPL
590 INX
600 .RESH CPX #&02
610 BNE WTBUSY
620 LDA PORT
630 AND #&0F
640 LDX #&00
650 STX TEMP
660 LSR A
670 ROL TEMP
680 ROL TEMP
690 ROL A
700 ROL A
710 ROL A
720 ROL A
730 ROL A
740 ROL A
750 ROL OVBRT
760 ROL A
770 ROL TEMP
780 ROL TEMP
790 ROL A
800 ROL TEMP
810 LSR OVBRT
820 BCC TEST
830 LDA#21
840 STA TEMP
850 .TEST  LDA SMPL
860 LSR A
870 BCC ODD
880 ASL TEMP
890 LDA TEMP
900 ORA (DOTBSE,X)
910 STA (DOTBSE,X)
920 JMP NEWDOT
930 .ODD
940 LDA TEMP
950 STA (DOTBSE,X)
960 .NEWDOT
970 LSR SMPL
980 BCS UNE
990 INC SMPL
1000 JMP WTBUSY
1010 .UNE
1020 LDA DOTBSE
1030 SEC
1040 SBC #&08
1050 BCS TWO
1060 DEC DOTBSE+1
1070 .TWO
1080 STA DOTBSE
1090 LDA ROWBSE+1
1100 STA RWBSSH+1
1110 LDA ROWBSE
1120 STA RWBSSH
1130 SEC
1140 SBC #128
1150 BCS THREE
1160 DEC RWBSSH+1
1170 .THREE
1180 STA RWBSSH
1190 DEC RWBSSH+1
1200 DEC RWBSSH+1
1210 LDA DOTBSE+1
1220 CMP RWBSSH+1
1230 BNE WTBUSY
1240 LDA DOTBSE
1250 CMP RWBSSH
1260 BNE WTBUSY
1270 TYA
1280 PHA
1290 TXA
1300 PHA
1310 LDA #&81
1320 LDX #&00
1330 LDY #&00
1340 JSR &FFF4
1350 TYA
1360 BNE NEWLNE
1370 PLA:PLA:JMP EIGHT
1380 .NEWLNE PLA
1390 TAX
1400 PLA
1410 TAY
1420 LDA ROWBSE
1430 SEC
1440 SBC #&01
1450 INY
1460 BCS FOUR
1470 DEC ROWBSE+1
1480 .FOUR
1490 STA ROWBSE
1500 STA DOTBSE
1510 LDA ROWBSE+1
1520 STA DOTBSE+1
1530 CPY #&08
1540 BEQ SIX
1550 JMP WTSYNC
1560 .SIX
1570 LDA ROWBSE
1580 LDY #&00
1590 SEC
1600 SBC # 120
1610 BCS FIVE
1620 DEC ROWBSE+1
1630 DEC DOTBSE+1
1640 .FIVE
1650 STA ROWBSE
1660 STA DOTBSE
1670 DEC ROWBSE+1
1680 DEC ROWBSE+1
1690 DEC DOTBSE+1
1700 DEC DOTBSE+1
1710 STY SMPL
1720 LDA ROWBSE+1
1730 CMP FINSCN+1
1740 BEQ SEVEN
1750 BCC SEVEN
1760 JMP WTSYNC
1770 .SEVEN
1780 JMP EIGHT
1790 LDA ROWBSE
1800 CMP FINSCN
1810 BEQ EIGHT
1820 BCC EIGHT
1830 JMP WTSYNC
1840 .EIGHT
1850 CLI
1860 RTS
1870 ]
1880 NEXT P
1890 IF HRES>0 AND HRES<5 THEN ?(RESH+1)=HRES
1900 CALL CODE%
1910 GOTO 90
```

Program 2.

```
Hisoft GENA3.1 Assembler.

A028              10          ORG   41000
A028              20          ENT   $
F8F0              30 PORT:    EQU   #F8F0
9C40              40 TEMP:    EQU   40000
9C41              50 LUM:     EQU   40001
9C42              60 XREG:    EQU   40002
9C44              70 YREG:    EQU   40004
9C46              80 HXREG:   EQU   40006
9C48              90 BLKADD:  EQU   40008
A028  3E00       100          LD    A,#00
A02A  32479C     110          LD    (HXREG+1),A
A02D  CD0EBC     120          CALL  #BC0E
A030  219F00     130 RERUN:   LD    HL,159
A033  22429C     140          LD    (XREG),HL
A036  21C700     150          LD    HL,199
A039  22449C     160          LD    (YREG),HL
A03C  DD2142A1   170          LD    IX,BYTEAD+15
A040  3E0F       180          LD    A,#0F
A042  32409C     190          LD    (TEMP),A
A045  DD7E00     200 COLSET:  LD    A,(IX+0)
A048  47         210          LD    B,A
A049  4F         220          LD    C,A
A04A  3A409C     230          LD    A,(TEMP)
A04D  CD32BC     240          CALL  #BC32
A050  21409C     250          LD    HL,TEMP
A053  35         260          DEC   (HL)
A054  FA5CA0     270          JP    M,WTFRM
A057  DD2B       280          DEC   IX
A059  C345A0     290          JP    COLSET
A05C  CD19BD     300 WTFRM:   CALL  #BD19
A05F  CD19BD     310          CALL  #BD19
A062  F3         320 LOOP1:   DI
A063  01F0F8     330          LD    BC,#F8F0
A066  ED78       340 LINE:    IN    A,(C)
A068  CB77       350          BIT   6,A
A06A  28FA       360          JR    Z,LINE
A06C  ED78       370 ENLIN:   IN    A,(C)
A06E  CB77       380          BIT   6,A
A070  20FA       390          JR    NZ,ENLIN
A072  160A       400          LD    D,10
A074  15         410 DELAY:   DEC   D
A075  20FD       420          JR    NZ,DELAY
A077  F3         430 LOOP2:   DI
A078  1602       440          LD    D,2
A07A  01F0F8     450          LD    BC,#F8F0
A07D  ED78       460 SMPL:    IN    A,(C)
A07F  CB7F       470          BIT   7,A
A081  20FA       480          JR    NZ,SMPL
A083  ED78       490 ENSMP:   IN    A,(C)
A085  CB7F       500          BIT   7,A
A087  28FA       510          JR    Z,ENSMP
A089  15         520          DEC   D
A08A  20F1       530          JR    NZ,SMPL
A08C             540 GETLUM:
A08C  ED78       550          IN    A,(C)
A08E  E60F       560          AND   #0F
A090  32419C     570          LD    (LUM),A
A093  1F         580          RRA
A094  CB18       590          RR    B
A096  1F         600          RRA
A097  CB18       610          RR    B
A099  1F         620          RRA
A09A  CB19       630          RR    C
A09C  1F         640          RRA
A09D  CB18       650          RR    B
A09F  1600       660          LD    D,0
A0A1  CB00       670          RLC   B
A0A3  CB1A       680          RR    D
A0A5  CB1A       690          RR    D
A0A7  CB00       700          RLC   B
A0A9  CB1A       710          RR    D
A0AB  CB1A       720          RR    D
A0AD  CB01       730          RLC   C
A0AF  CB1A       740          RR    D
A0B1  CB1A       750          RR    D
A0B3  CB00       760          RLC   B
A0B5  CB1A       770          RR    D
A0B7  3A429C     780          LD    A,(XREG)
A0BA  1F         790          RRA
A0BB  3003       800          JR    NC,NOLFT
A0BD  B7         810          OR    A
A0BE  CB1A       820          RR    D
A0C0  32469C     830 NOLFT:   LD    (HXREG),A
A0C3  7A         840          LD    A,D
A0C4  32409C     850          LD    (TEMP),A
A0C7  210050     860          LD    HL,#5000
A0CA  3A449C     870          LD    A,(YREG)
A0CD  CB3F       880          SRL   A
A0CF  CB3F       890          SRL   A
A0D1  CB3F       900          SRL   A
A0D3  5F         910          LD    E,A
A0D4  1600       920          LD    D,0
A0D6  0608       930          LD    B,8
A0D8  29         940 MULT:    ADD   HL,HL
A0D9  3001       950          JR    NC,NOADD
A0DB  19         960          ADD   HL,DE
A0DC  10FA       970 NOADD:   DJNZ  MULT
A0DE  22489C     980          LD    (BLKADD),HL
A0E1  3A449C     990          LD    A,(YREG)
A0E4  CB27      1000          SLA   A
A0E6  CB27      1010          SLA   A
A0E8  CB27      1020          SLA   A
A0EA  E638      1030          AND   56
A0EC  67        1040          LD    H,A
A0ED  2E00      1050          LD    L,0
A0EF  ED4B489C  1060          LD    BC,(BLKADD)
A0F3  09        1070          ADD   HL,BC
A0F4  0100C0    1080          LD    BC,#C000
A0F7  09        1090          ADD   HL,BC
A0F8  ED4B469C  1100          LD    BC,(HXREG)
A0FC  09        1110          ADD   HL,BC
A0FD  3A409C    1120          LD    A,(TEMP)
A100  DD21429C  1130          LD    IX,XREG
A104  DDCB0046  1140          BIT   0,(IX+0)
A108  2001      1150          JR    NZ,PLOT
A10A  B6        1160          OR    (HL)
A10B  77        1170 PLOT:    LD    (HL),A
A10C  010100    1180          LD    BC,#0001
A10F  2A429C    1190          LD    HL,(XREG)
A112  B7        1200          OR    A
A113  ED42      1210          SBC   HL,BC
A115  3806      1220          JR    C,NEXY
A117  22429C    1230          LD    (XREG),HL
A11A  C377A0    1240          JP    LOOP2
A11D  219F00    1250 NEXY:    LD    HL,159
A120  22429C    1260          LD    (XREG),HL
A123  2A449C    1270          LD    HL,(YREG)
A126  B7        1280          OR    A
A127  ED42      1290          SBC   HL,BC
A129  3002      1300          JR    NC,NEWLIN
A12B  FB        1310          EI
A12C  C9        1320          RET
A12D  22449C    1330 NEWLIN:  LD    (YREG),HL
A130  C362A0    1340          JP    LOOP1
A133            1350 BYTEAD:
A133  00010204  1360          DEFB  0,1,2,4
A137  0506080A  1370          DEFB  5,6,8,10
A13B  0C0E1012  1380          DEFB  12,14,16,18
A13F  1416181A  1390          DEFB  20,22,24,26

BLKADD  9C48   BYTEAD A133   COLSET A045
DELAY   A074   ENLIN  A06C   ENSMP  A083
GETLUM  A08C   HXREG  9C46   LINE   A066
LOOP1   A062   LOOP2  A077   LUM    9C41
MULT    A0D8   NEWLIN A12D   NEXY   A11D
NOADD   A0DC   NOLFT  A0C0   PLOT   A10B
PORT    F8F0   RERUN  A030   SMPL   A07D
TEMP    9C40   WTFRM  A05C   XREG   9C42
YREG    9C44

Table used:    307   from    350
Executes: 41000
```

Program 3.

```
5 MEMORY 30000:MODE 2
10 LOAD"wefax1.obj"
20 INPUT"enter horizontal resolution 1-4";resh
30 IF resh>0 AND resh<5 THEN POKE &A079,
resh ELSE CLS:GOTO 20
40 CALL 41000
50 CALL &A030
60 GOTO 50
```

SATELLITE DECODER PARTS LIST

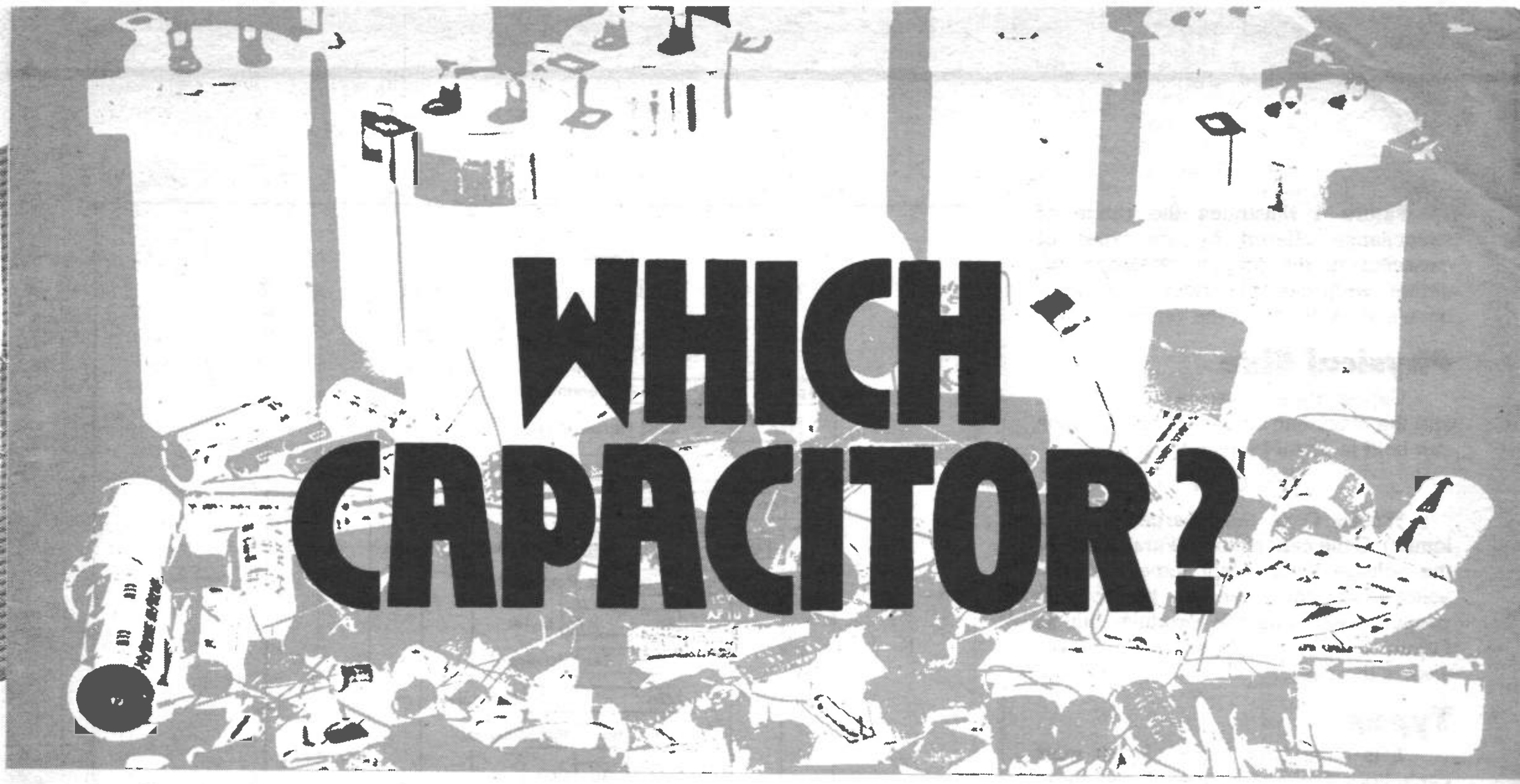
RESISTORS: All 0.6W 1% Metal Film			
R1	27k	1	(M27K)
R2,4,25	470k	3	(M470K)
R3,37,38,39,40	1k	5	(M1K)
R5,9,20,27	10k	4	(M10K)
R6,7,12,24	100k	4	(M100K)
R8	820Ω	1	(M820R)
R10	220k	1	(M220K)
R11,17,26	2k2	3	(M2K2)
R13	180k	1	(M180K)
R14,41	47k	2	(M47K)
R15	5k6	1	(M5K6)
R16,21,22,23,28, 30,31,34,35,36	4k7	10	(M4K7)
R18	180k	1	(M180K)
R19	390Ω	1	(M390R)
R29	330Ω	1	(M330R)
R32,33	270Ω	2	(M270R)
SIL 1,2	SIL 4k7	2	(RA29G)
RV1	10k Cermet	1	(WR42V)
RV2	1k Hor. S-Min Preset	1	(WR55K)
RV3	10k Pot Lin	1	(FW02C)
RV4	1k Pot Lin	1	(FW00A)
RV5	1M Pot Lin	1	(FW08J)
CAPACITORS			
C1-3	220nF Poly Layer	3	(WW45Y)
C4,5	10µF 16V Minelect	2	(YY34M)
C6,11	47nF Poly Layer	2	(WW37S)
C7	100µF 25V P.C. Electrolytic	1	(FF11M)
C8,26,27	4µ7F 35V Minelect	3	(YY33L)
C9	2µ2F 63V Minelect	1	(YY32K)
C10	2n2F Poly Layer	1	(WW24B)
C12	4n7F Poly Layer	1	(WW26D)
C13-18,28	100nF Minidisc	7	(YR75S)
C19-22	2200µF 35V Axial Electrolytic	4	(FB90X)
C23	10µF 16V Tantalum	1	(WW68Y)
C24,25	100nF Polyester	2	(BX76H)
SEMICONDUCTORS			
D1,2	OA91	2	(QH72P)
D3-14	1N4148	12	(QL80B)
ZD1	BZY88C3V3	1	(QH02C)
LED 1	Red LED Chrome large	1	(YY60Q)
LED 2	Green LED Chrome large	1	(QY47B)
TR1-3	BC548	3	(QB73Q)
BR1	W005	1	(QL37S)
REG1	µA7912UC	1	(WQ93B)
REG2	µA7812UC	1	(QL32K)
REG3	µA7805UC	1	(QL31J)
IC1	LF353	1	(WQ31J)
IC2	ZN427E	1	(UF40T)
IC3	NE565	1	(WQ56L)
IC4	74LS132	1	(YF51F)
IC5	4078	1	(QX28F)
IC6-8	74HC163	3	(UB42V)
IC9	74LS03	1	(YF03D)
MISCELLANEOUS			
M1	Signal Meter	1	(LB80B)
T1	Transformer Toroidal 30VA 15V	1	(YK11M)
S1	Switch Sub. Min. Toggle SPDT (C)	1	(FH02C)
S2,4	Switch Rotary 3-pole 4-way	2	(FF78S)
S3	Switch Sub-Min Toggle SPDT (D)	1	(FH03D)
S5	Switch Dual Rocker Neon	1	(YR70M)
FS1	Fuse 1A A/S	1	(WR19V)
PL1,3	Minicon latch Plg 2-Way	2	(RK65V)
PL2	Minicon latch Plg 12-Way	1	(YW14Q)
PL4	Minicon latch Plg 6-Way	1	(YW12N)
PL5,6	Minicon latch Plg 8-Way	3	(YW13P)
PL7	R.A. 'D' Range 25-Way PCB Plg	1	(FG68Y)
SK1,3	Minicon latch Housing 2-Way	2	(HB59P)
SK2	Mincon latch Housing 12-Way	1	(YW24B)
SK4	Minicon latch Housing 6-Way	1	(BH65V)
SK5,6	Minicon latch Housing 8-Way	3	(YW23A)
	Minicon Terminal	46	(YW25C)
SK8	6-Pin PCB DIN Socket	1	(FA90X)
SK9	Power Socket D.C. 2.5mm	1	(FK06G)
SK10-12	2x12-Way P.C. Edgeconn	3	(BK74R)
	Polarising Key 0.156in	3	(FD08J)
	Bolt 6BA x 1in	1 Pkt	(BF07H)
	6BA x ¼in Threaded Spacer	1 Pkt	(FD10L)
	Nut 6BA	1 Pkt	(BF18U)
	Tag 2BA	1 Pkt	(BF27E)
	Bolt 6BA x ½in	1 Pkt	(BF06G)
	Mains Warning Label	1	(WH48C)
	Cable Min Mains White	1 mtr	(XR02C)
	Ribbon Cable 20-Way	1 mtr	(XR07H)
	Grommet Small	1	(FW59P)
	S.R. Grommet 6W-1	1	(LR49D)
	Sleeving Heatshrink CP95	1 mtr	(YR17T)
	Clip-on TO220 Heatsink	1	(FG52G)
	Decoder PCB	1	(GD22Y)
	Veropin 2141	1 Pkt	(FL21X)
	DIL Socket 8-pin	1	(BL17T)
	DIL Socket 14-pin	4	(BL18U)
	DIL Socket 16-pin	3	(BL19V)
	DIL Socket 18-pin	1	(HQ76H)
	Safuseholder 20	1	(RX96E)
	Knob K10B	5	(RK90X)
	Transformer Mounting Bracket	1	(FD09K)
	Constructor's Guide	1	(XH79L)
OPTIONAL			
	Instrument Case NM2H	1	(YM51F)
	Decoder Front Panel	1	(FD05F)
	Araldite	1	(FL44X)
	DIN Plug 6-pin	2	(HH29G)
	Standard Power Plug 2.5	2	(HH62S)
	Cable Single Core Screened Grey	1 mtr	(XR13P)
	Multi-Core 6-Way	1 mtr	(XR26D)
	Decoder Interface Cable	1	(FD17T)

A complete kit of all parts, excluding optional items, is available for this project:
Order As LM07H (MAPSAT Decoder Kit) Price £79.95
The following items included in the above kit list are also available separately, but are not shown in the 1986 catalogue:
Sub-Min Toggle SPDT **Order As FH02C Price £1.20**
6-Pin PCB DIN Socket **Order As FA90X Price 50p**
0.156in Edgeconn Polarising Key **Order As FD08J Price 12p**
¼in x 6BA Threaded Spacer **Order As FD10L Price 88p**
Decoder PCB **Order As GD22Y Price £12.95**
MAPSAT Decoder Front Panel **Order As FD05F Price £3.95**
Transformer Mounting Bracket **Order As FD09K Price £1.20**
Instrument Case NM2H **Order As YM51F Price £14.95**
Decoder Interface Cable **Order As FD17T Price £6.85**
Constructor's Guide **Order As XH79L Price 25p** *NV*

DECODER SYNC TONE BOARD PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	2k2	1	(M2K2)
R2,10,11,13,22	47k	5	(M47K)
R3	100k	1	(M100K)
R4-7	33k	4	(M33K)
R8,9	470k	2	(M470K)
R12	68k	1	(M68K)
R14	82k	1	(M82K)
R15	18k	1	(M18K)
R16,19	220Ω	2	(M220R)
R17,18,20,21	4k7	4	(M4K7)
R23	220k	1	(M220K)
R24	2k7	1	(M2K7)
RV1,2	47k Vert S. Preset	2	(WR70Q)
RV3-5	10k 23-Turn Cermet	3	(WR49D)
CAPACITORS			
C1,2,5,6	100nF Poly Layer	4	(WW41U)
C3	2n2F Poly Layer	1	(WW24B)
C4	10nF Poly Layer	1	(WW29G)
C7	100µF 16V Minelect	1	(RA55K)
C8	10µF 16V Minelect	1	(YY34M)
C9,10	220nF Poly Layer	2	(WW45Y)
SEMICONDUCTORS			
D1-3	1N4148	3	(QL80B)
TR1-3	BC548	3	(QB73Q)
IC1	4046BE	1	(QW32K)
IC2	MF10CN	1	(QY35Q)
MISCELLANEOUS			
	Veropin 2145	1 Pkt	(FL24B)
	Sync 1 PCB	1	(GD23A)
	Track pin	1 Pkt	(FL82D)
	DIL Socket 20-Pin	1	(HQ77J)

A complete kit of all parts is available for this project:
Order As LM08J (Decoder Sync Tone Kit) Price £12.95
The following item in the above kit list is also available separately, but is not shown in the 1986 catalogue:
Sync 1 PCB **Order As GD23A Price £3.95**



WHICH CAPACITOR?

Choosing the best type of capacitor for a circuit is not always easy. Manufacturers' data sheets are packed with helpful information like "Insulation resistance >5000 MΩ", and "Power factor <0.013 at 10kHz", but unless you know what it all means – and why it matters – you might just as well pick the cheapest component with an adequate voltage rating and hope for the best.

If you need a 0.1μF capacitor, for example, the Maplin catalogue gives you twelve to choose from, see Table 1. They range from a tantalum electrolytic the size of a dried pea, right up to a polystyrene component as big as a cigar butt. Why are there so many different types? The answer, of course, is that each has been carefully optimised for one of the many different roles capacitors have to fill – coupling in audio circuits, interference suppression, tuning RF oscillators, decoupling digital logic circuits, and so on.

Value

Capacitors are generally sold as preferred values in the range from 1pF to about 10,000μF. The lower limit is set by the inevitable stray capacitance around the component when it is used, and at the upper end of the range the components can store so much energy for such long periods that they are virtually batteries. Indeed, a 1 Farad capacitor is made especially to act as a short-term emergency power supply for computer memory boards.

The range of preferred values in each decade are often just 1, 1.5, 2.2, 3.3, 4.7, and (sometimes) 6.8, with a tolerance of typically 10%. This rather limited range is not always as restricting as it seems; after all, it doesn't really matter if the value of a decoupling capacitor is slightly higher than it need be. Capacitors intended for use in circuits where precision is important – like filters and oscillators, for example – are available in a much wider range of values and with tighter tolerances.

by J.K. Hearfield

Type	Price	Material	Working Voltage	Tol. %	Power factor %	Insulation Resistance Ω	Tempco % per °C
Minidisc	10p	Ceramic	16	+80 −20	<7	$>10^{10}$	−1
Polystyrene	54p	Polystyrene	63	±5	<0.05 @1MHz	$>10^{11}$	−0.016 ±0.008
Tant	15p	Tantalum	35	±20	<10	$>3.10^{7}$ (see text)	+0.1
Monocap	54p	Multilayer ceramic	50	±10	2.5	$>10^{11}$	−1
Disc	6p	Ceramic	40	+80 −20	<5	$>5.10^{9}$	−1
Minelect	10p	Electrolytic	63	±20	<9	$>2.10^{7}$ (see text)	+0.2
Monores	40p	Multilayer Ceramic	100	±10	<2.5	$>10^{10}$	−1
Mylar	6p	Polyester	100	±10	<0.01 @1kHz	$>10^{10}$	+0.02
Poly Layer	15p	PETP	250V DC 100V AC	±5	<0.8 @1kHz	$>7.5.10^{10}$	+0.02
Polyester	9p	PETP	250	±10	<0.013 @1kHz	$>3.10^{10}$	+0.033
IS Cap	35p	PETP	250V AC	±20	≤0.013 @10kHz	$>15.10^{9}$	+0.03
HV Cap	80p	Polypropylene	1000V DC 500V AC	±10	<0.015 @1kHz	$>10^{11}$	−0.02

Table 1. 0.1μF capacitors summary.

Family	Capacitance Range	Power Factor %	Tempco %/°C	Working Voltage Range
Ceramic	1pF – 1μF	5	−1	50 – 1000
Plastic	10pF – 1μF	0.01	+0.02	100 – 400
Electrolytic	100nF – 100,000μF	10	+0.2	10 – 450

(All figures are approximate.)

Table 2. The three main families of capacitor.

Figure 1 illustrates the range of capacitance offered by the types of capacitor in the Maplin catalogue, together with current prices for components at each end of the range.

Physical Size

Capacitors are used to store charge, and the maximum amount of charge each can hold is given by its CV product:

$$Q = C \times V$$

Where Q is the charge (in coulombs), C the capacitance (Farads) and V the voltage. One might expect a capacitor's physical size to be roughly proportional to its CV product, but as Figure 2 shows, this is by no means always the case.

Types

It is clear from Figure 2 that most capacitors belong to one of just three families: ceramic, plastic, or electrolytic. The important characteristics of each family are illustrated in Table 2.

Table 2 shows that, although the ceramic and electrolytic families between them cover the whole range from 1pF to 10,000μF, capacitors with plastic dielectrics are a much better choice when the application requires high stability or low loss.

Identification

Like resistors, some capacitors carry gaily coloured stripes to indicate their nominal values; the colour code is the same as for resistors. But it is much more common for capacitor manufacturers to print the component's value on its case along with its rated working voltage and the manufacturer's name. The value may be expressed as a three-digit code – for example, "154" would *not* mean 154pF, but 15,0000pF ('15' plus '4' zeros): that is, 150nF.

Voltage

Manufacturers specify the maximum voltage that may be applied across their capacitors without damaging them, and it is essential to observe this limitation. But in the same way as a resistor is more reliable if it is not allowed to get too hot, a capacitor (especially an electrolytic) tends to last longer if the voltage across it is kept well below its rated voltage. It's also important to ensure that the voltage across any electrolytic (and tantalum) type is of the correct polarity. As a rule of thumb, it is prudent to choose a capacitor with a working voltage about 20% greater than the voltage it will actually see in practice.

Temperature

Capacitance varies with temperature, although usually not very much. Its temperature dependence is known as its 'Tempco' (short for 'Temperature Coefficient,' though it sounds more like the name of a secretarial staff agency!).

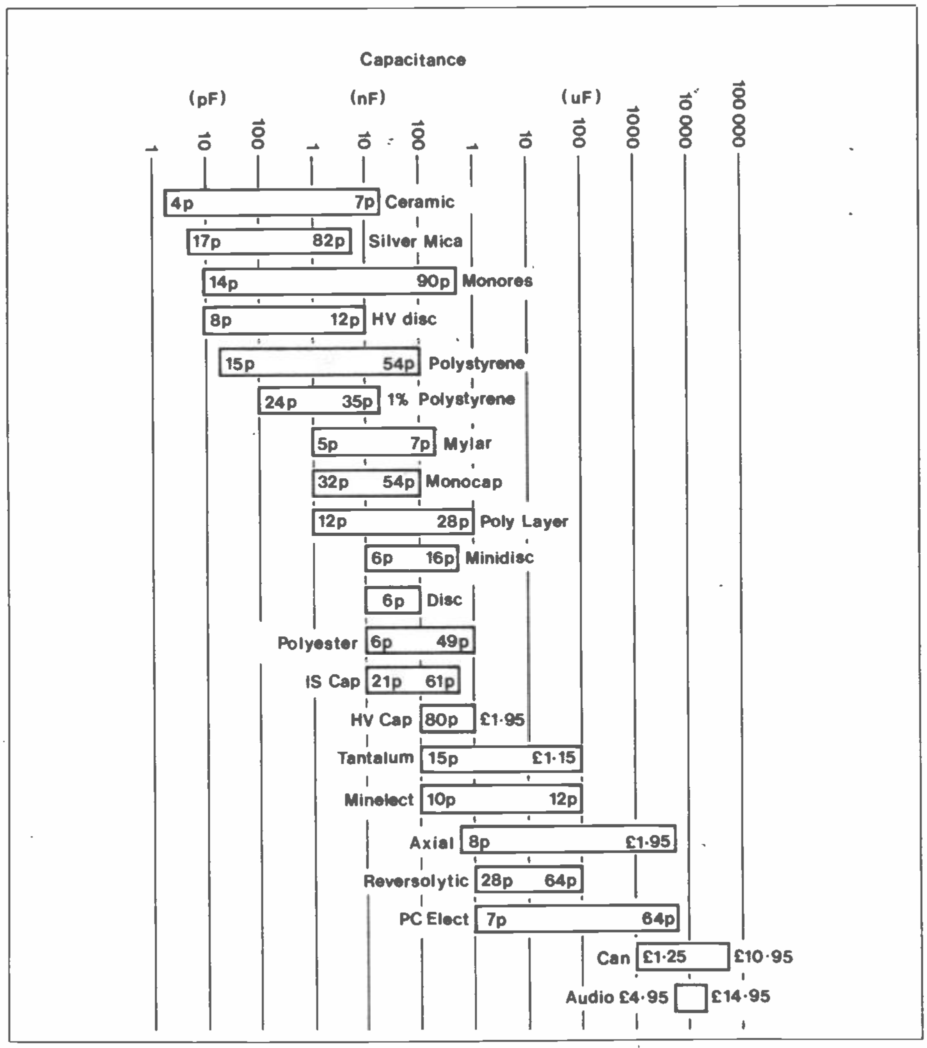


Figure 1. Capacitance range offered by different types.

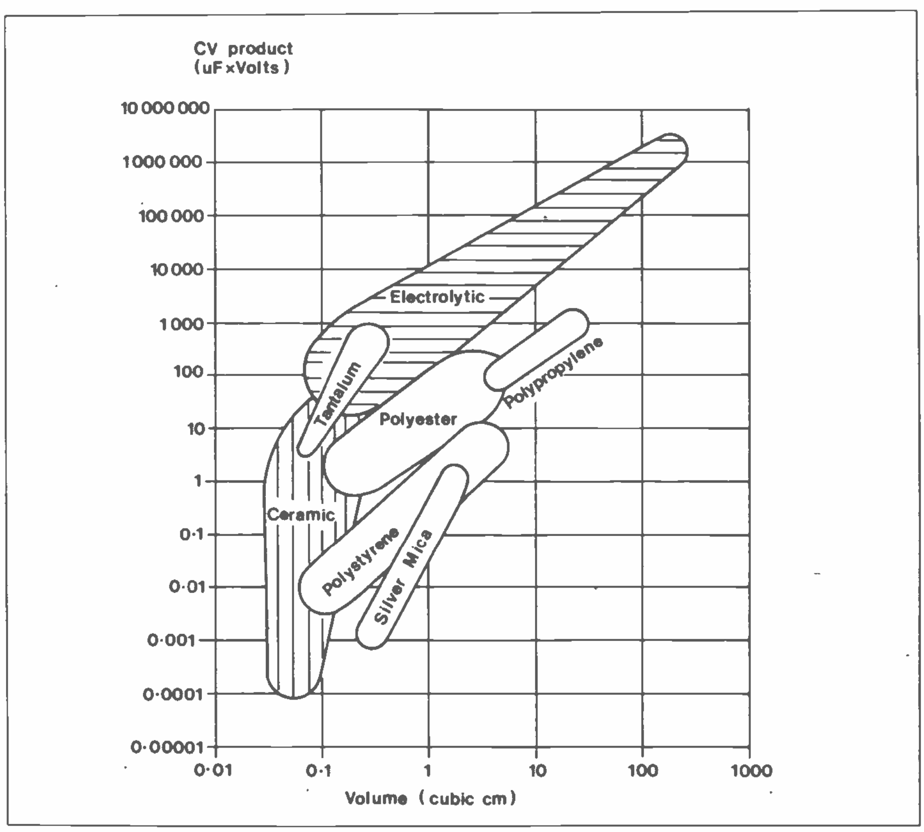


Figure 2. CV product and volume of capacitor range.

Tempco is measured in parts per million per degree C (ppm/°C) or as the percentage variation from its value at room temperature. Table 1 shows that plastic film capacitors are the most stable – their value changes by less than 1% between 0 and 50 degrees C. Over the same temperature range, electrolytics might vary by 5% or so, but ceramic-based capacitors could be as much as 25% less in value at 0° and at 50° than they are at room temperature!

Imperfections

The impedance of a perfect capacitor is always inversely proportional to frequency; its insulation resistance is infinitely large, and it never absorbs energy from the ripple current flowing through it. Unfortunately, perfect capacitors exist only in textbooks, and *real* capacitors suffer from all these defects to a greater or lesser extent. The capacitor's equivalent circuit, see Figure 3, shows how the imperfections can be modelled as series and shunt resistances, and series inductance.

Insulation Resistance

Some applications demand a capacitor having a very high effective parallel resistance – timing circuits, or sample-and-hold circuits, for instance. But as Table 1 illustrates, all except electrolytic types have an insulation resistance measured in thousands of Megohms.

Electrolytic and tantalum types have a small but continuous leakage current flowing through them. This current increases with temperature (reaching about twice its room temperature value at 50°C), and also with applied voltage.

Self-Resonance

The inductance of a length of straight wire is about 15nH per cm. Simple theory says that if each lead of a perfect 0.1μF capacitor is 5mm long, the resulting tuned circuit will resonate at a frequency of 4MHz. At frequencies below resonance, impedance falls as frequency rises and the combination behaves like a capacitor. But at frequencies above resonance the impedance *rises* with frequency: the capacitor behaves like an inductor! At the other end of the scale, if the component in question is a real 100μF capacitor instead, then self-resonance occurs at just a few tens of kHz.

The moral is to use the smallest component with the lowest practical value, and to keep the leads (not forgetting the wiring and/or the PCB track) as short as possible if the self-resonant frequency must be high.

Power factor and tan d

Manufacturers don't usually quote the size of the Effective Series Resistance (ESR) for their capacitors directly. Instead, they define the component's power factor, where:

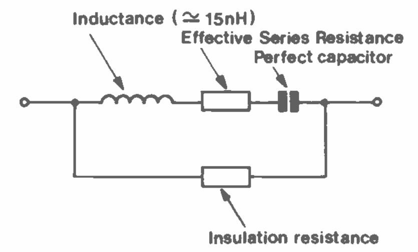


Figure 3. Capacitor equivalent circuit.

$$\text{Power factor} = \frac{\text{Effective Series Resistance}}{\text{Total impedance}}$$

Or more commonly, its dissipation factor:

Dissipation factor = tan d

$$\tan d = \frac{\text{Effective Series Resistance}}{\text{Capacitive Reactance}}$$

The two terms are almost identical provided ESR is small. Both are obviously frequency-dependent; they are often specified at a frequency of 1kHz or 10kHz.

It is straightforward to extract a value for ESR from the power factor. The 0.1μF Poly Layer capacitor, for example, has a power factor quoted as 0.008 at 1kHz. At this frequency the capacitive reactance is 1590Ω, so:

ESR = 0.008 x 1590 = 13 ohms.

Any current flowing through the capacitor flows also, by definition, through the ESR. Suppose the capacitor is carrying a ripple current of 50mA at 1kHz. The power dissipated in the ESR – and, hence, in the component – is then:

P = 0.05 x 0.05 x 13 = 33mW

Electrolytic & Tantalum

Though they pack a lot of capacitance into a very small space, electrolytics are *not* precision components. They are generally sold with a tolerance of ±20%, or even +50%/−10%. They are polarised, and therefore are intended to work in situations where a constant DC bias appears across them (though some can withstand a small continuous reverse bias); the bias voltage causes a leakage current of typically 1μA or so to flow continuously through them. Electrolytics are made in values from 0.1μF upwards, although the high-frequency performance of the larger ones is often poor. A high frequency, for an electrolytic, can be as low as only a few kHz.

Ceramic

The properties of a ceramic capacitor depend very much on the type of dielectric that it employs. So-called "low-K" types are available at 5% tolerance from a few pF to a few nF. They have excellent temperature stability and a low dissipation factor.

"High-K" types by contrast may show a startling decrease in capacitance from the value quoted at room temperature. They are available in values from a few nF to 1μF, and are used mainly in decoupling applications where their loose tolerance (10% or 20%) and poor dissipation factor are less important than their compactness, low inductance and low cost.

Polyester and Polycarbonate

Metallised film and foil capacitors are manufactured in values from 100pF to a few μF, usually at 10% tolerance. Their chief attraction is their low dissipation factor, particularly at low frequencies, but their performance may be good enough for some filter applications despite their relatively high Tempco (typically 300 ppm). They are often much cheaper than ceramic types, albeit physically larger.

Polystyrene

Their high stability and tight tolerance make polystyrene capacitors the obvious choice for precision work. They are available in 1% and 5% tolerances, from a few tens of pF up to 100nF. They have a moderate Tempco (typically −150ppm) and a low dissipation factor, even at high frequencies. At small values they can be much more expensive than equivalent ceramic types, but from about 1nF upwards they have no real competition.

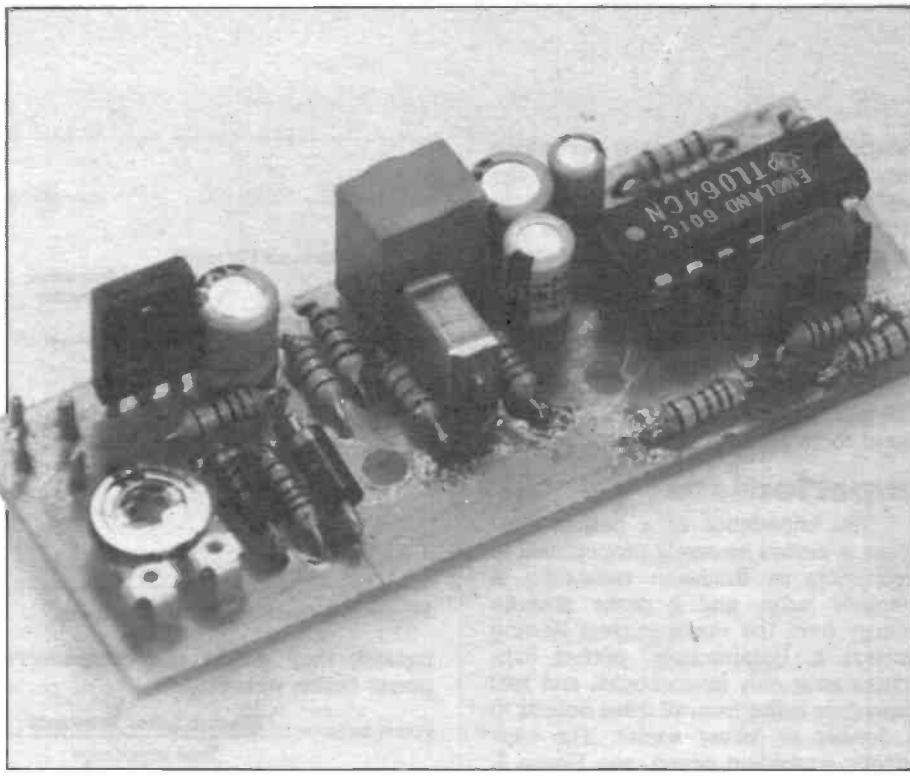
Silver Mica

Silver mica capacitors also have good stability and tight tolerance but their high price makes them difficult to justify for most applications. Like low-K ceramic types, they are available in values from a few pF to a few nF. The two types are physically much of a size, especially at low values, but silver mica capacitors can cost more than twice as much.

Summary

Each of the capacitor types described in this article is ideal for some particular task – and woefully inadequate for others. Picking the most suitable type involves deciding which properties matter most for the application you have in mind. Must the component fit into a very small space? Must its value be stable over a wide range of temperatures? Must it have very low loss? Armed with the answers to these questions, you can use the catalogue to identify just the component you need. Of course, it may not yet exist.....

INFRA-RED PROXIMITY DETECTOR



★ ***Low Cost, Short Range, Heat/Movement Detector.***
★ ***Ideal for Doorways, Stairs and Proximity Systems.***
★ ***Low Power Consumption for Long Battery Life.***

by Dave Goodman

Commercially available body heat, movement detection systems, although very sophisticated in their operation, can be rather expensive for use in limited applications where short range coverage is required. This I/R proximity detector has been designed as a simple low cost system for detecting heat changes, movement of a warm body, etc., such as those emitted from the human body. The unit responds to a definite change or disturbance in ambient – or background – heat levels and could be placed across a doorway or stairs to indicate movement in those areas.

Pyroelectrics

The F001P sensor uses a ceramic, ferroelectric element made from Lead Zirconate Titanate (PZT), which has the property of producing an electrical change at its surface when the temperature changes, due to a change in polarization intensity. If a moving object enters the field of view of this sensor, changes in infra red energy levels occur due to a difference in temperature between this object and the background. Infra red energy is converted into heat by the surface electrode of the element, thus causing a change in temperature within the element itself, and a small electric charge is created as a result (see Figure 1).

This small charge appears across the gate resistance Rg in Figure 2, and is impedance buffered by the FET source follower, where a change in voltage appears across source resistance Rs. A small DC bias voltage (IDRs) is produced by the quiescent current (ID) flowing through the FET while no signal is present, as Figure 3, and output signals from the source terminal overlap this level with a +Ve voltage swing.

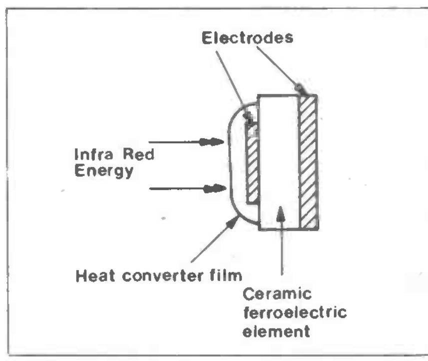


Figure 1. Pyroelectric Element.

In use, the voltage swing is very small, its amplitude being determined by the amount of incident energy available, which becomes smaller with increasing distance.

Done with Mirrors!

A negligible amount of energy is emitted from the human body which limits the effective working range of the module down to four feet or so. This range could be extended by increasing the sensitivity of the amplifier and developing velocity related filter circuits which would determine a given range of movement speeds and size of body.

An even more effective method is employed on commercial systems, in the form of collecting lenses and optical

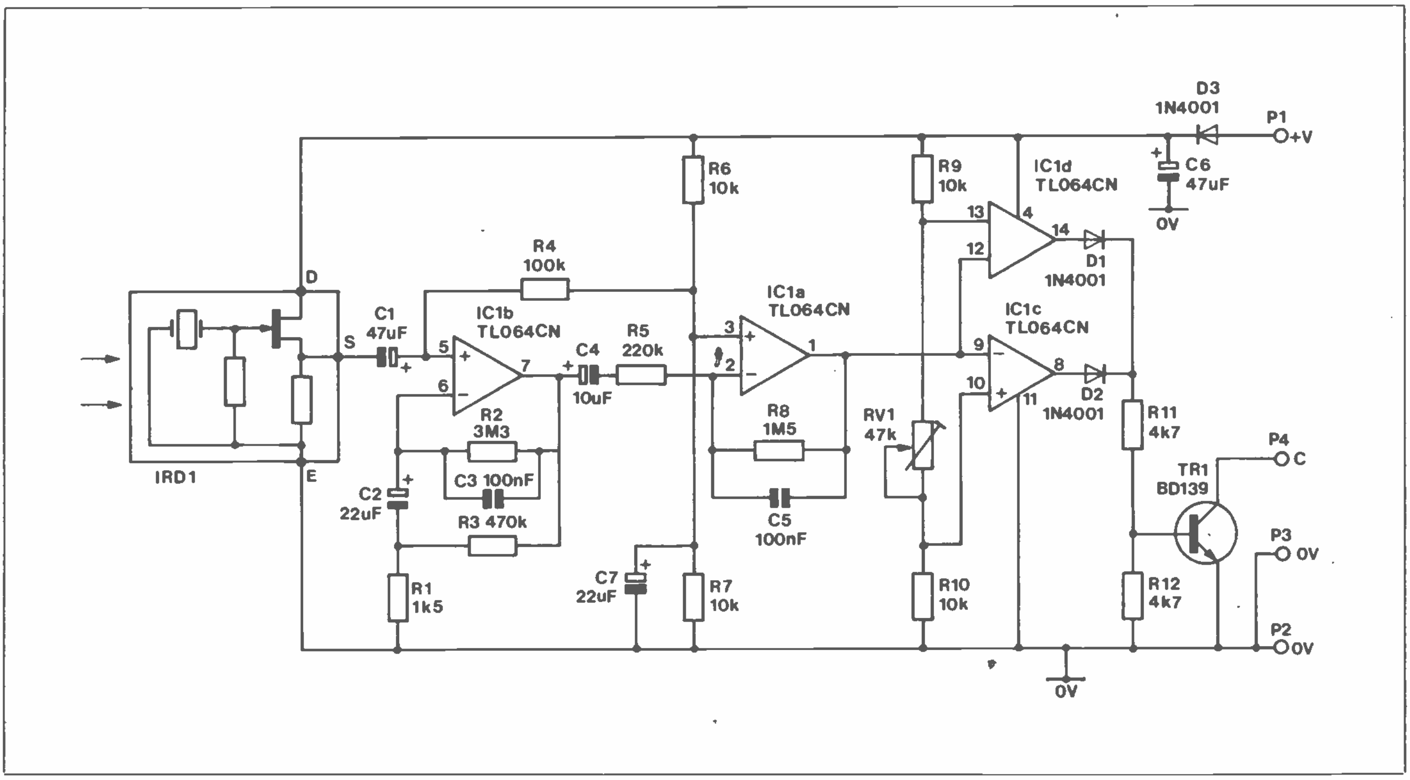


Figure 2. Sensor Circuit.

amplifying concave mirrors. Problems associated with energy collecting systems are: movements in the air, sunlight 'modulated' through curtains and even small animals generating fluctuations in the infra red energy background. To help overcome these sorts of problems, a multi-faceted, concave mirror is often used, which has the effect of expanding (or narrowing) the field of view into bands.

As an infra red emitting source crosses the field of view, radiated energy bounces off these facets in a sequence. The sensor responds with a series of related output pulses, and detection electronics can determine the size, velocity and direction of the source while it is moving. Quite a sophisticated achievement, and such a system is available in our catalogue, being more suitable for security and alarm uses than this particular system.

However, many applications exist where a simpler system is called for, especially for the home constructor!

Circuit Description

The circuit, shown in Figure 4, consists of two amplifying stages, with low pass filtering and a comparator threshold stage. Output voltage swings from the IRD are amplified by IC1b, which is configured as a non-inverting amplifier. The IRD receives energy from many sources, and a mixed waveform would be produced at IC1b output, therefore C3 integrates continuous low level signals and acts as a low pass filter.

The somewhat unusual arrangement of resistors R1 and R4 allow C2 to charge slowly during initial power up. C2 is necessary for isolating IC1b −Ve input from the 0V supply rail. With single supply op-amps, it is common to gen-

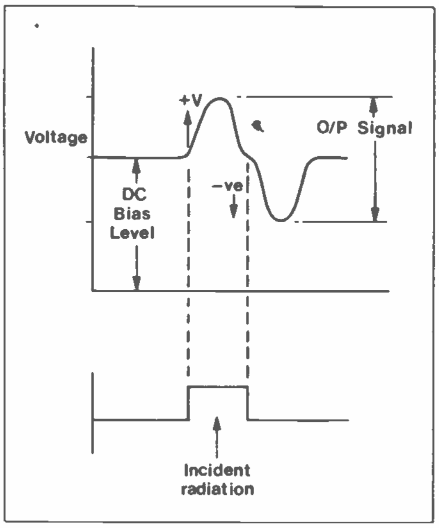


Figure 3. Source Output Voltage Swing.

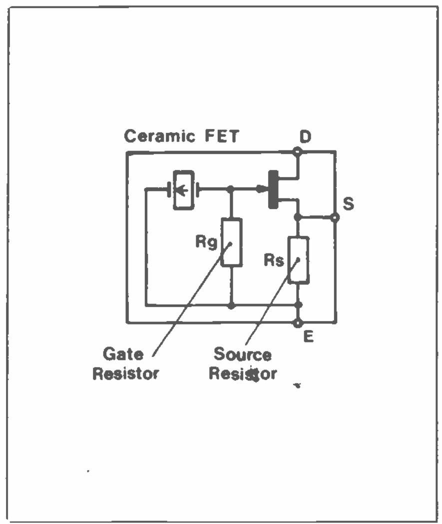


Figure 4. Proximity detector Circuit.

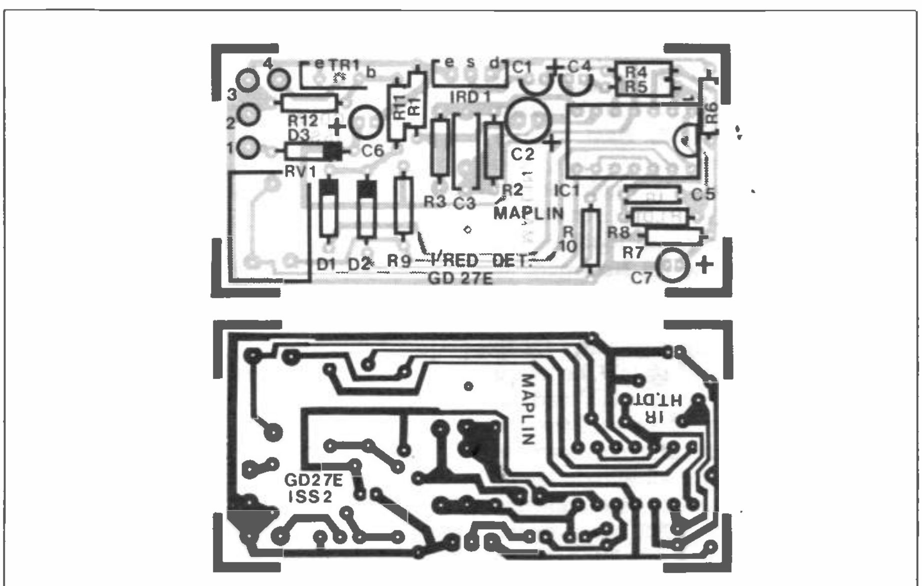


Figure 5. PCB Artwork.

erate a half supply DC voltage reference to bias the differential inputs, thus allowing output voltage swings about this level. The effect of integration on the continuous input signals produces a very low frequency output signal, which is applied to C2.

The charge across C2 varies with the magnitude of the output signal (from pin 7), and limits heavy transients from saturating this stage.

IC1a is a standard inverting amplifier, again voltage referenced to half supply by R6 and R7. C7 decouples the reference voltage to prevent comparator supply spikes from being introduced into the stage. IC1d and IC1c serve as a simple comparator. The threshold voltage reference, determining when the comparators will trigger, is set by RV1 in the potential divider chain R9 and R10.

Positive voltage swings from IC1a trigger the IC1d comparator causing D1 to conduct, while negative swings trigger IC1c causing D2 to conduct. From Figure 3 it can be seen that the output voltage swing from the IRD is, firstly, in a positive direction and then secondly in a negative direction. The ultimate effect from the comparator output at R11 is therefore not one but two pulses turning on transistor TR1.

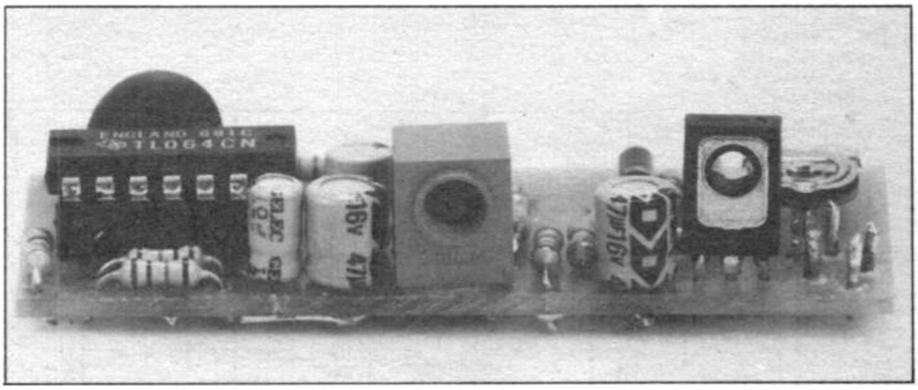
Either one of diodes D1 or D2 could be removed for single pulse output and which particular one to remove must be decided under full operational conditions. TR1 is an open collector switch, and will sink external loads (sourced from their own external +V supply) to the 0V common rail when conducting.

Construction

For information on building details and components, refer to Figure 5 for the board layout and to the 'Constructor's Guide' supplied with this kit (if you do not intend to purchase the complete kit then see the Parts List for the order code of the Constructor's Guide, price 25p). Identify and insert resistors R1 to R12. Solder these components and remove excess wire before continuing.

Mount diodes D1 to D3, and insert veropins at Pin 1 to Pin 4 in the holes marked with white circles. Next, insert a 14-pin IC socket in position IC1, and bend a few legs over the track pads to hold it in position. The PCB is quite small with tracks running close together, so care must be taken whilst soldering, as short circuits between tracks can easily occur.

Identify and insert capacitors C1 to C7. Polylayer type C3 should be fitted carefully to prevent breaking the lead out wires from each end of the package. Fit preset RV1, and solder all components in position. Again, cut off all excess leads, then fit TR1 and the sensor IRD1 shown in Figure 6. One side of TR1 has a metal, heat transfer mounting plate fitted. Insert TR1 with this plate facing outward towards the edge of the pcb. The sensor IRD1, shown in Figure 7, could be



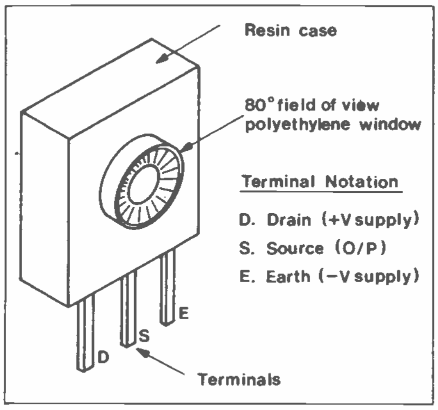


Figure 6. Sensor pin-outs.

mounted vertically from the pcb, or horizontally off the pcb as detailed. Mount the sensor as close as possible – in both cases – to the pcb in order to reduce noise induced into this area.

Either mounting position will have to take into account the boxing (case) requirements, and this is left to the fitting as required by the constructor. Solder any remaining components, cut off all excess wires and clean up the track area to facilitate inspection.

Testing

Supply requirements for the module are 9V DC @ 2mA. Current consumption is low, which allows long periods of use from small battery packs such as the PP3. Connect the battery +Ve to Pin 1, and −Ve to Pin 2; diode D3 prevents damage to components in the event of accidentally reversed battery polarities.

Check the supply current with an milliammeter, which will be around 2.5mA for a minute or so, dropping to 1 – 1.5mA after this period. Current consumption increases by approximately 1mA while the comparator stages are operating.

The output transistor TR1 does not *source* current, but being open collector will sink current from an external supply load. Figure 8 suggests various methods of switching external loads, and diagram (a) could be used for testing purposes. Connect the LED cathode (k) to collector Pin 4, and wire the battery to one end of a 1kΩ resistor connected to the LED anode (a).

If using the same battery for both module supply and LED supply, then the second battery −Ve connection is not

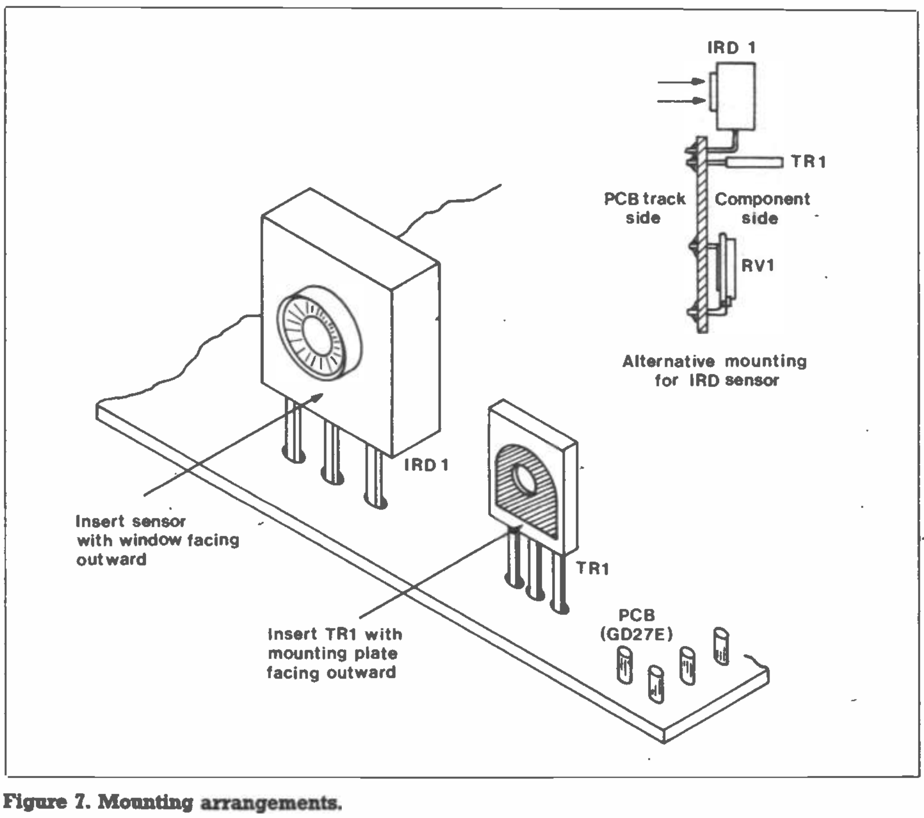


Figure 7. Mounting arrangements.

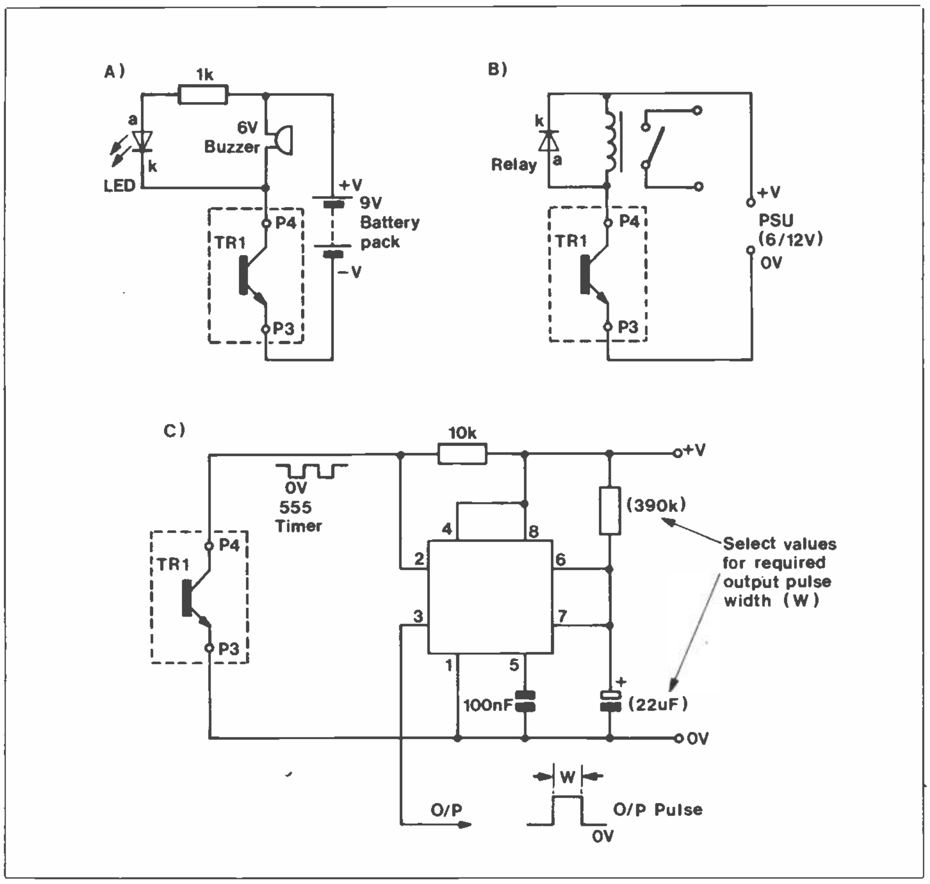


Figure 8. External Circuit Connections.

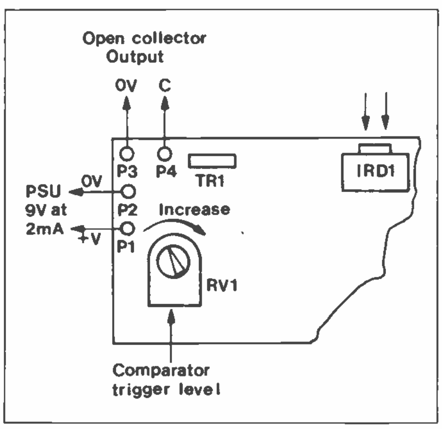


Figure 9. External PCB Connections.

required. Turn the comparator threshold control, RV1, to half travel (Figure 9), and after the initial 'warming up' period, move your hand across the sensor window. Do not poke the window with fingers as grease deposited will reduce sensitivity and may prevent operation completely! Figure 10 shows the spectral response expected in the window. The LED will light for a few seconds. If the LED is permanently aglow, turn the trigger level down by moving RV1 wiper anti-clockwise.

Using the Module

TR1 is not capable of switching heavy loads and should be used on external systems up to 12V DC, and current levels below 100mA. Relays could be used for controlling larger voltage/current devices (Figure 8b), or a timer could be employed to generate long operating periods once triggered (Figure 8c). On the prototype, a 6V @ 35mA buzzer was used, on a separate supply, to good effect. Any battery supplying the electronics should not be used for supplying the external devices as well, if more than a simple LED arrangement is to be used. Battery connections to Pin 1 and 2 should be kept short – a PP3 clip lead is ideal for this – and mount both module and battery together in the same housing with a suitable ON/OFF switch.

Sensing range is 4 to 5 feet, depending upon the sensor's field of view and variations in the light/heat background levels. A whole room, for instance, could not adequately be covered by this system, but doorways, narrow hallways and corridors are suitable areas. Another use for the module could be in a shower cubicle, using a timer circuit for controlling the water pump. Obviously, low voltage switching systems are important in this application.

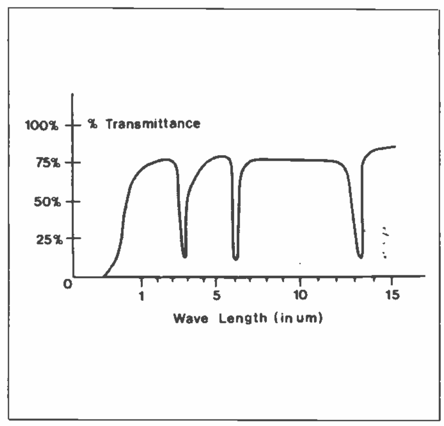


Figure 10. Window Spectral response.

INFRA RED PROXIMITY DETECTOR PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	1k5	1	(M1K5)
R2	3M3	1	(M3M3)
R3	470k	1	(M470K)
R4	100k	1	(M100K)
R5	220k	1	(M220K)
R6,7,9,10	10k	4	(M10K)
R8	1M5	1	(M1M5)
R11,12	4k7	2	(M4K7)
RV1	47k Hor. Sub-min Preset	1	(WR60Q)

CAPACITORS

C1,6	47µF 16V Minelect	2	(YY37S)
C2,7	22µF 16V Minelect	2	(YY36P)
C3	100nF Polyester	1	(WW41U)
C4	10µF 16V Minelect	1	(YY34M)
C5	100nF Minidisc	1	(YR75S)

SEMICONDUCTORS

D1-3	1N4001	3	(QL73Q)
TR1	BD139	1	(QF07H)
IC1	TL064CN	1	(RA66W)
IRD1	F001P	1	(FD13P)

MISCELLANEOUS

	I/R Detector PCB	1	(GD27E)
	Veropins 2145	1 Pkt	(FL24B)
	DIL Socket 14-Pin	1	(BL18U)
	Constructor's Guide	1	(XH79L)

A complete kit of all parts is available for this project:
Order As LM13P (I/R Detector Kit) Price £10.95
The following items in the above kit list are also available separately, but are not shown in the 1986 catalogue:
I/R Detector PCB **Order As GD27E Price £1.95**
I/R Detector F001P **Order As FD13P Price £5.95**
Constructor's Guide **Order As XH79L 25p** ***NV***

MAINS POWER CONTROL WITH TRIACS

by J.M. Woodgate B.Sc.(Eng.), C. Eng., M.I.E.E., M.A.E.S., M.Inst. S.C.E.

There are many useful devices, from greenhouse heating controls, through motor speed controllers to disco lights, that need some way of controlling mains power by means of low-level signals, either analogue or digital. Relays can be used for simple on/off control, and recent developments have made switching current ratings of the order of 20A available in small relays of reasonable cost. For many applications, however, solid-state control devices are preferable, on the grounds of physical size or cost, or because proportional control is required.

Thyristors are used for DC, and high-power AC/rectifier applications, while for other AC applications the triac, being a bi-directional device, is better. It can control powers up to at least 10kW (single-phase), and substantially higher powers in multi-phase systems.

High power bipolar and MOS transistors are also available, at reasonably competitive prices, for power-control applications, and are useful with high-frequency supplies, or where controlled turn-off is required: in these cases gate-turn-off (GTO) thyristors are also used for powers up to about 100kW.

In this article, however, we shall concentrate on a qualitative explanation of the working of the triac, and a look at design methods in some typical, basic applications.

Construction of the Triac

The triac is a four-layer semiconductor, but, being bi-directional, its structure is at first sight somewhat complex. We can build up an explanation of the structure and operation by first considering the thyristor.

The thyristor can be modelled by an interconnected complementary pair of bipolar transistors, as shown in Figure 1. From equation A.1 of Appendix 1, the current in response to a positive voltage on the p-n-p emitter (anode) relative to the n-p-n emitter (cathode) is critically dependent on the product of the DC current gains, and becomes unlimited when the product is equal to 1. This occurs at quite low values of the collector currents, in the region where the current gains are proportional to the collector currents. A small current injected at either base can therefore trigger the device into conduction. The n-p-n base, or 'gate', shown in Figure 1, is known as a *cathode gate*. A low power, four-layer device, BRY39 (page 294 of the 1986 Maplin Catalogue), is available which gives access to both anode *and* cathode gates. The device is very versatile, offering many small signal switching applications, but these are outside the scope of this article.

For full-wave AC power control, two of these model devices would be required, connected in inverse parallel. Luckily, it is possible to integrate the two devices on a single die, and an example of such a triac structure is shown diagrammatically in Figure 2. This is a centre-gate structure; other structures are manufactured, and the geometry has significant effects on the device characteristics.

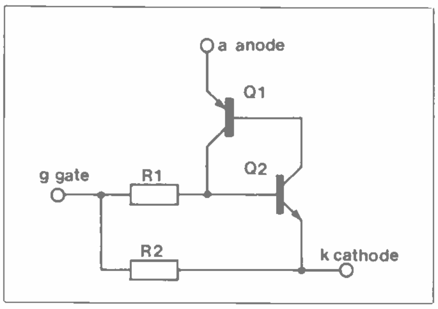


Figure 1. 2 transistor equivalent of a Thyristor

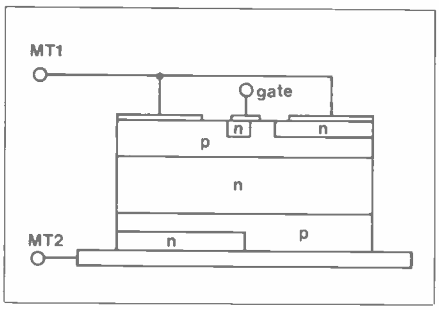


Figure 2. Centre-gate Triac structure

Electrical Characteristics of Triacs

If the anode to cathode voltage applied to the model device of Figure 1 is increased sufficiently, the increased leakage currents will themselves raise the current gains to the critical values, and the device is then said to have 'broken down'. This is not a normal mode of operation however, and conduction is usually started by applying to the gate terminal a positive voltage (in the case of the model device) relative to the cathode.

The characteristics of the semiconductor materials used in a triac are different from those of a bipolar transistor (for example, the same region has to work both as a collector *and* as a base),

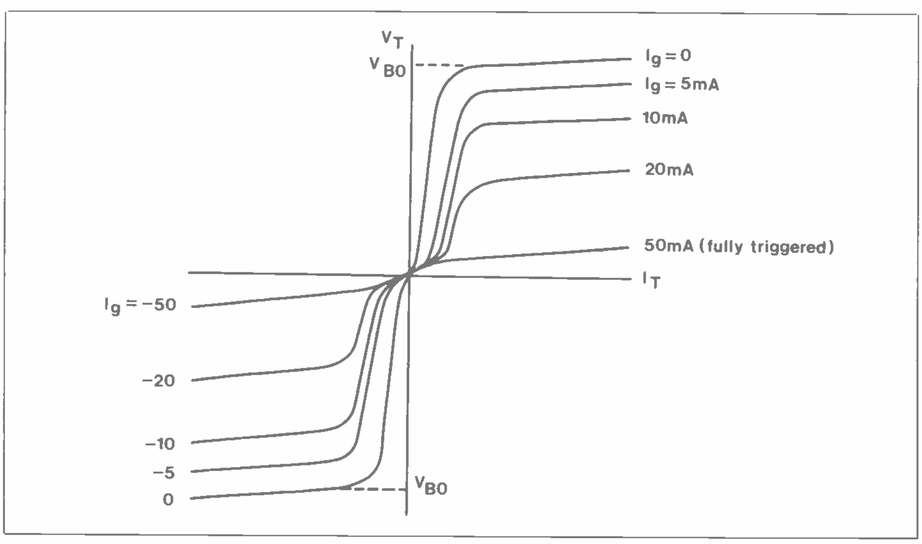


Figure 3. Triac main voltage/main current characteristics with gate current as parameter

and the gate input characteristics are rather different from those of a 'conventional' base-emitter junction.

Part of this difference can be represented by the resistors R1 and R2 in Figure 1. These differences in characteristics raise the gate voltage at, say, 10mA gate current from the 600mV of a typical silicon transistor junction to about 900mV. The presence of R1 means that conduction in the main circuit cannot be stopped by connecting the gate to cathode or MT1; thus the gate current can be applied in the form of a short pulse. Conduction is normally stopped by allowing or forcing the main circuit current to fall below the minimum value necessary to hold the current gains at or above their critical values. This current is known as the *holding current* I_H, and, in AC applications, the current normally falls below this value as a matter of course once every half-cycle.

If the gate current is increased slowly from zero, with a resistive load in the main circuit (see Figure 3), the voltage across the main terminals falls, eventually to a low value, represented in the model by the saturation voltage of the p-n-p transistor plus the base-emitter voltage of the n-p-n transistor, or *vice versa* for an opposite supply polarity. This is the normal on-state of the device, and operation at *lower* values of gate current than is necessary to achieve it should normally be avoided, because the power dissipation in the device is considerably increased by this. Thus it is wise to ensure that, subject to the limits of peak and average gate dissipation, the worst-case gate current available from the trigger circuit comfortably exceeds the gate current required to trigger a least-sensitive device.

Capacitance within the device, between the main terminals and the gate, can cause the triac to trigger if the main-terminal voltage rise rate (dV/dt) is sufficiently fast. This, too, is normally an undesired effect, but can be avoided by correct design. Some types of triac are very resistant to this sort of false triggering, having maximum dV/dt values of several hundred volts per microsecond, but are limited in their triggering modes (see below). Where the load is inductive, and the triac is required to go from the conducting to the non-conducting state, the maximum permissible dV/dt is dependent on the current flowing in the main circuit and its rate of fall (−dI/dt), a high current or rate of fall reducing the permissible dV/dt, which is then known as 'commutation dV/dt'.

If we look at the main circuit voltage/current characteristics in Figure 4, we can see significant hysteresis: the main circuit current has to rise to I_L, the latching current, before the gate loses control, whereas the current can fall to I_H, the holding current, before conduction substantially ceases.

The off-state leakage current I_D is sufficient to disqualify the triac as a circuit isolator, and a mechanical isolator switch should always be provided for maintenance and/or service operations!

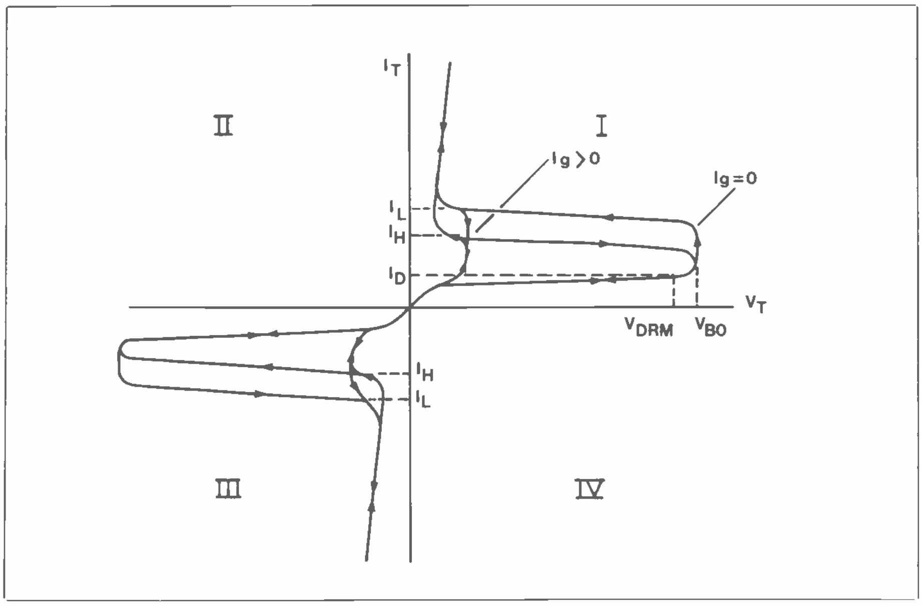


Figure 4. Dynamic main current/main voltage characteristics

The quadrants of the V/I graph are conventionally numbered I to IV. Operation in quadrant I is satisfactory with the gate either positive or negative with respect to MT1; and in quadrant III with a negative gate, but for a positive gate in quadrant III the gate sensitivity is, for most types of triac, much reduced, and this triggering mode may not be recommended by the device manufacturer. The latching current may also be different in the two quadrants, and decreases somewhat with increasing gate-current pulse width (see below). The *data sheet* values, rather than measured values, should be accepted for design work.

When the gate current is in pulse form, as is the case in many practical circuits, the rather large capacitance between the gate and MT1 effectively makes triggering dependent on the total charge at the gate, i.e. for a square pulse, the product of gate current and application time. The precise nature of this dependence is not linear however. Typical characteristics are shown in Figure 5. Very short pulses of less than 1μs duration should be avoided, because only part of the die area may be triggered. This will cause a hot-spot to form, and may destroy the device. The manufacturer may specify a pulse width, which should be regarded as a recommended minimum value. Once the device is properly triggered, complete conduction is established typically in about 1μs. There is, however, a delay time of several microseconds before conduction begins, as shown in the timing diagram of Figure 6.

A group of characteristics which is not usually mentioned in data sheets describes the effects of the anode voltage and the main circuit current on the gate voltage. The gate drive circuit has to have a high impedance for these to be observed. For example, the continuity of the load in the main circuit can be confirmed, while the triac is in the blocking state, by monitoring the gate voltage. This is particularly of value where the load is a projector lamp,

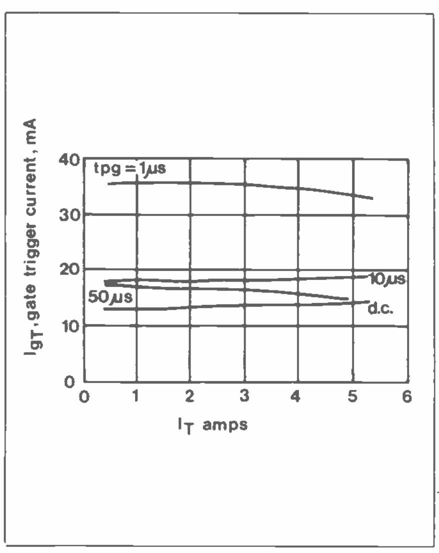


Figure 5. Peak gate trigger current as a function of trigger pulse duration

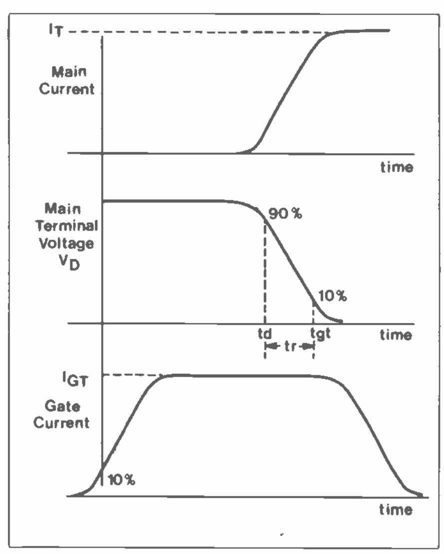


Figure 6. Timing diagram for the triggering process

whose failure might spoil an audio-visual presentation, and the use of this technique is advocated in a draft international standard [1].

The gate voltage in this condition is due to the capacitance between the gate and MT2. This is usually large enough to be practically useful only for triacs of 10A rating or greater, smaller triacs requiring an unreasonably high impedance at the gate. The effects of main circuit current on the gate characteristics depend on the triac geometry. When the gate voltage is of the same polarity as the MT2 voltage, the existence of main-circuit current simply reduces the gate current produced by a given voltage, see Figure 7a.

A transient appears at the onset of main circuit current, due to the gate to MT2 capacitance. If the gate polarity is opposite to that of MT2, (I− and III+ modes), there is spectacular disturbance of the gate voltage caused by transients in the main terminal voltage waveform, see Figures 7b and 7c. This characteristic can be traced by applying an alternating voltage through a resistive load to the main circuit, and an out-of-phase current to the gate. Figure 7b shows the Ig/Vg characteristic of a TIC226D, which has a high dV/dt rating but is not characterised in the III+ mode. Figure 7c shows the behaviour of another type, which is characterised for all modes, but has a lower dV/dt rating. Figure 7d shows that the gate voltage of the TIC226D is affected by the MT2 voltage, even if the external trigger gate current is insufficient to trigger the device. The occurrence of fast pulses of reverse polarity gate voltage due to capacitive effects, and of negative resistance regions in the gate characteristics, can give rise to considerable r.f. interference. This suggests that operation in the reverse-polarity modes (I− and III+) should be avoided, where possible, for all triacs, even if they are characterised for this service.

Thermal Characteristics

There are limits to both the peak power and the average power that can be dissipated at the gate, and care is necessary to design the gate drive such that fast and reliable triggering is achieved without exceeding these limits. This should always be verified by taking measurements.

The main power loss in the device is due, naturally enough, to the main-circuit voltage drop during conduction, and the manufacturer normally provides data on this, for both half-wave and full-wave operation, as well as for various triggering points along the waveform. When the power loss has been determined, an electrical analogue circuit, see Figure 8, can be used to calculate the heat-sink requirements (see Appendix 2).

The performance of the chosen heat-sink design, in its final environment or housing, should always be measured,

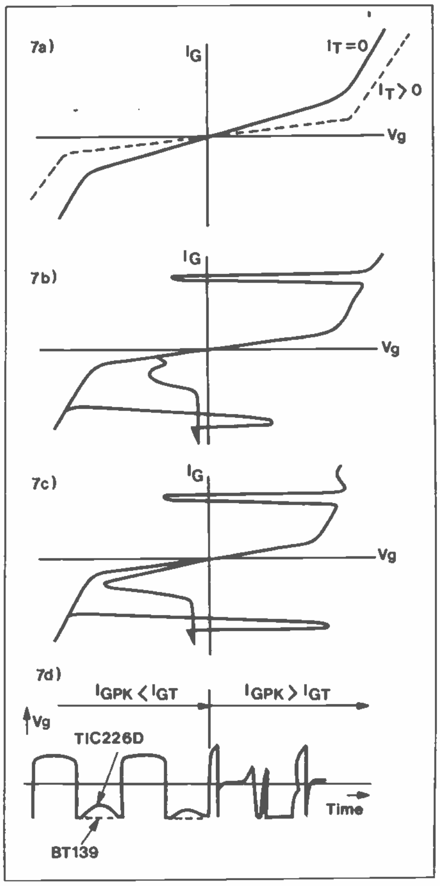


Figure 7 (a). Gate dynamic characteristics with gate and main currents in phase.
(b). Gate dynamic characteristics of TIC226D with gate and main currents in phase opposition.
(c). Gate dynamic characteristics of BT139 with gate and main currents in phase opposition.
(d). Gate voltage waveforms in untriggered and triggered conditions.

allowing for worst-case conditions of load current, ventilation and ambient temperature.

Gate Drive Techniques

For a simple switching circuit, it is possible to supply gate triggering current from a resistor connected between

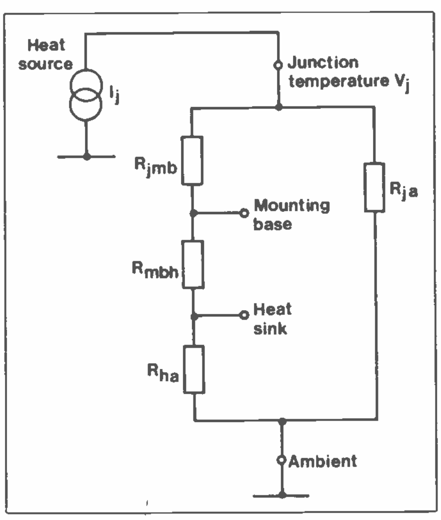


Figure 8. Electrical analogue of thermal circuit

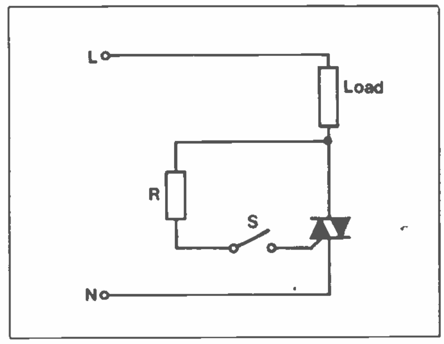


Figure 9. Simple Triac switch

gate and MT2, as shown in Figure 9. The device is switched on by closing the (low-power) switch. As the load current falls through zero each half-cycle, control is regained by the gate, so the load current will cease at the end of the half-cycle during which the switch is opened. This circuit has the advantage of simplicity and is widely recommended in American textbooks.

But with a British 240V mains supply, it may be difficult to ensure reliable triggering of least-sensitive devices without exceeding the permitted peak gate dissipation. It is preferable to apply gate current in pulse form, and one common way of doing this is to use a device known as a diac, or Silicon Bilateral Switch (SBS).

This is the solid-state equivalent of a neon-tube, that is to say as far as its electrical behaviour is concerned, and has a V/I characteristic as shown in Figure 10, with prominent negative resistance regions. Its action can be likened to a bi-directional zener diode. Connected as a relaxation oscillator, shown in Figure 11, a series of current pulses are produced in the resistor R2,

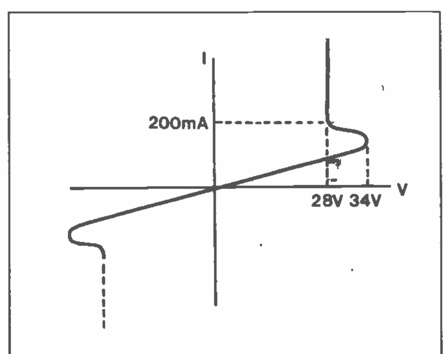


Figure 10. Typical Diac characteristic

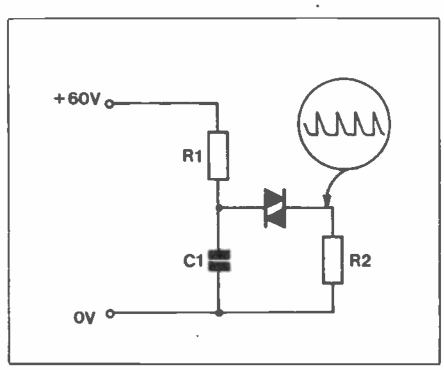


Figure 11. Diac relaxation oscillator

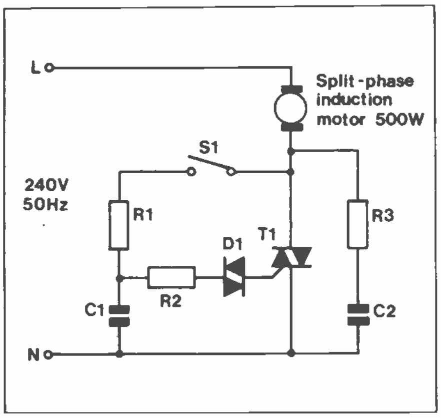


Figure 12. Practical Triac switch for a motor-driven appliance (for component values see Appendix 3).

representing the triac gate. For measurement of the gate-current pulse-width, an actual triac should be connected in place of R2, because the impedance at the gate is very non-linear and cannot be satisfactorily represented by a fixed resistor.

Figure 12 shows the resulting triac switch circuit. Normally the triac fires on the first gate pulse, but if it does not, trigger pulses continue to be applied until firing occurs. This is particularly significant with inductive loads, since the current may not rise above I_L, the latching current, until some milliseconds after the triac has first been fired. Operation of this circuit with highly inductive loads may in any case be unsatisfactory for other reasons. With partially inductive loads, the snubber network R3, C2, is necessary. C2 reduces the rise rate of the MT2 voltage (dV/dt) at current cut-off, while R3 controls the current dumped from C2 into the triac as it begins to conduct.

With resistive loads, it is necessary to add interference suppression components. The interference r.f. is generated by the rapid collapse of the voltage across the triac as it fires. The detailed design of this circuit is dealt with in Appendix 3.

A unijunction transistor may also be employed as a trigger-pulse generator, but this will require a DC supply. Note that to avoid operation (or non-operation!) in the III+ mode, any single-polarity gate drive should consist of *negative-going* pulses.

In the triac switch circuit, it is necessary for the triac to fire as early in each half-cycle as possible, so as to minimise the loss of load power. Conversely, by *varying* the delay between the start of the half-cycle and the time at which the triac fires, the load power can be controlled. This can be done by varying the phase relationship of the gate voltage to the main terminal voltage, and this method is therefore called 'phase control'. Simple household lamp-dimmers use this technique, which has the considerable disadvantage of generating a great deal of r.f. interference, due to the sudden fall in the voltage across the triac as it fires. Suppression components L1, C4 are essential, and a typical circuit is shown in Figure 13.

This is one of those circuits whose operation is more complex than appears at first sight. If the components R2, R3 and C2 were omitted, the dimmer control R1 would suffer from considerable hysteresis. The lamp comes on suddenly, and quite brightly, as the control is advanced (reducing the resistance). When the control is turned the other way, the lamp becomes much dimmer, until it finally goes out at a control position noticeably different from that at which it came on. This effect is due to the loss of charge from C1 into the triac gate when the diac breakover voltage is only just exceeded.

Suppose that the resistor R1 is set to a value such that the diac breakover voltage of, say, 34V is just not exceeded. The capacitor C1 charges to +34V on one half-cycle, then discharges to zero and charges to −34V on the next half-cycle, giving a change of capacitor voltage of 68V. If the resistor R1 is then slightly reduced, so that the diac conducts, this quickly reduces the voltage across the capacitor to, say, 28V. Thus, on the following half-cycle, the change in capacitor voltage is only 62V, so that the breakover voltage is reached at an earlier 'epoch' (i.e. time during the half-cycle), and, when the steady-state is reached, breakover is occurring considerably before the end of the half-cycle, and the lamp is quite bright.

Increasing R1 then smoothly reduces the conduction angle (firing time approaches the start of the half cycle), and, hence, the brightness of the lamp is reduced. This effect can be overcome with the additional components R2, R3 and C2. Gate current is drawn from C2, which is recharged via R2 from the much larger C1, with hardly any effect on the voltage across C1 and consequently on the firing epoch. R3 serves to limit the discharge current from C2, which is desirable on reliability grounds anyway, and reduces the recharging demand made of C1. With these additional components, 'backlash' is practically eliminated. This circuit also works well as a speed-controller for series-wound commutator motors, such as are found in power tools. Speeds can be reduced by around 10 times without an unacceptable loss of torque. A snubber network, R4 and C3, is included to avoid false triggering due to excessive dV/dt from the inductive load and the commutator noise spikes, is necessary. However, the circuit is *not* ideal for phase-control of loads having significant inductance, because if the firing epoch is not precisely the same for both polarities of supply voltage, then the load current will contain a DC component due to the unbalance, and this may cause undesirable effects due to the saturation of the magnetic circuits of the load.

When resistive loads of greater than about 1kW dissipation have to be switched or controlled, the r.f. interference generated by the circuits described above becomes a serious problem. For such applications as stage and disco-lighting, there are few alternative techniques, and relatively costly filters are used to eliminate the interference. But for heaters with a large thermal inertia, burst-firing with synchronous switching can be used.

Synchronous Switching

Synchronous switching is a technique for minimising the amplitude of the voltage transient across the triac as it fires, and it works best when the latching current of the triac is very much less than the full load current. Gate drive is applied in pulse form, the leading edge of the pulse occurring at, or preferably before, the zero-crossing of the supply voltage, so that the triac remains conducting as the load current falls below the holding current and goes through zero. The pulse must, of course, last long enough to maintain the device in the 'on' condition for the load current to rise in the next half-cycle, to a value exceeding the latching current.

There is then no voltage transient, and consequently no r.f. interference. The technique can also be applied to phase control, where detection of the zero-crossing of the supply voltage is used as a reference for timing the trigger pulses more accurately, and more controllably, than can be achieved with RC phase-shift networks.

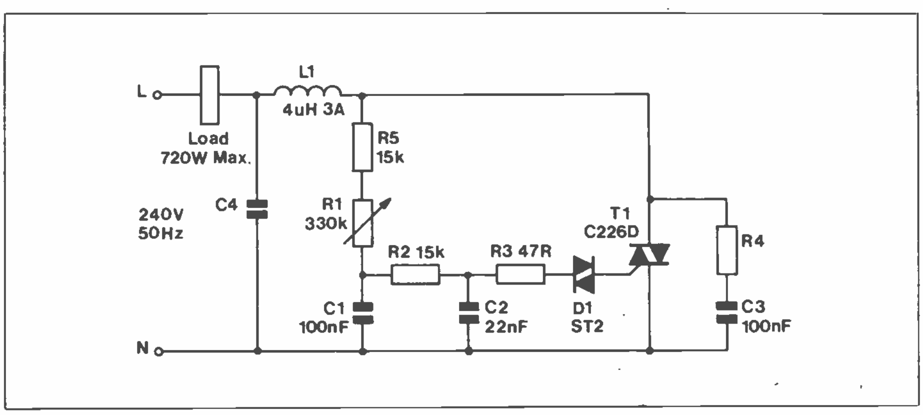


Figure 13. Lamp-dimmer or speed-controller for an AC series commutator motor

Synchronous switching circuits can be designed using discrete transistors[2], but integrated circuits are now available which offer improved performance, and usually a number of additional features. An example is the TDA 1024. This is an advanced phase-control device especially suitable for very low-differential temperature control or speed-control of series commutator motors. It can be powered either directly from the mains supply via a suitable voltage dropper, rectifier and stabiliser circuit, or from a local DC supply, and will control the conduction angle of the associated triac in accordance with a DC voltage, which may be obtained from a tacho-generator or a temperature sensor, for feedback control, or from a potentiometer, for open-loop control.

Synchronous switching also provides a solution to the problem, mentioned above, of firing-point asymmetry causing DC saturation in phase-controlled inductive loads. In this case, it is particularly important to use a synchronous switching circuit, or zero-crossing detector, which does not itself suffer from asymmetry. Most of the current integrated circuits satisfy this requirement.

Burst Firing

Burst firing, with synchronous switching, is a technique for controlling load power without generating r.f.i. Instead of varying, as in phase control, the fraction of each half-cycle for which load current is allowed to flow, the current is allowed to flow for an exact number of half-cycles, followed by an interval, also an exact number of half-cycles in duration, when no current is permitted.

Isolated Driving Circuits

It is *essential* for safety reasons that low-level drive signals derived from microprocessors, remote sensors etc., should not be applied directly to the triac, if it is, as usual, connected directly to the mains supply. All low-level circuits *must* be isolated from the mains. If they are earthed, the isolated coupling (opto-isolator, pulse transformer etc.) must withstand 2000V for 60 seconds, but if not, then *circuit* isolation to withstand 3000V for the same period is necessary. It should be noted that many opto-couplers and low-cost pulse trans-formers will *not* meet these requirements!

Of the two devices mentioned, the opto-coupler is perhaps simpler to incorporate in a design, and there is little difference in cost. Furthermore, for AC applications, an optically-triggered triac is much easier to use than a coupler with a bipolar output device. Such a device is the Triac Isolator (Maplin Stock Code: QQ10L), and this can directly replace the switch S1 in Figure 12 and in similar circuits. The input of this device can be driven directly from TTL logic, and easily interfaced with CMOS. There is also a version, Order Code RA56L, which includes a zero-crossing detector.

References

1. *IEC Publication 574-3A:* Audio-visual, video and television equipment and systems. *Part 3A:* Connectors for automatic slide-projectors with built-in triacs, for audiovisual applications. International Electrotechnical Commission, Geneva. (To be published.)

2. D.R. Armstrong, 'Zero-crossing detector circuits', *Mullard Technical Communications No.132* Page 63-68. October 1976.

Appendix 1

In the model circuit, (Figure 1):

$$I_m = I_{c1} + I_{c2}$$
$$I_{c1} = I_{ceo1} + I_{b1}h_{FE1}$$
$$= I_{cbo1}(1 + h_{FE1}) + I_{c2}h_{FE1}$$

Similarly:

$$I_{c2} = I_{cbo2}(1 + h_{FE2}) + I_{c1}h_{FE2}$$
$$I_{c2} = I_{cbo2}(1 + h_{FE2}) + \{I_{cbo1}(1 + h_{FE1}) + I_{c2}h_{FE1}\}\, h_{FE2}$$
$$I_{c2}(1 - h_{FE1}h_{FE2}) = I_{cbo2}(1 + h_{FE2}) + I_{cbo1}(1 + h_{FE1})\, h_{FE2}$$

Similarly:

$$I_{c1}(1 - h_{FE1}h_{FE2}) = I_{cbo1}(1 + h_{FE1}) + I_{cbo2}(1 + h_{FE2})\, h_{FE1}$$

So, $I_{c1} + I_{c2}$

$$= \frac{I_{cbo2}(1 + h_{FE2})(1 + h_{FE1}) + I_{cbo1}(1 + h_{FE1})(1 + h_{FE2})}{1 - h_{FE1}h_{FE2}}$$
$$= \frac{(1 + h_{FE1})(1 + h_{FE2})(I_{cbo1} + I_{cbo2})}{1 - h_{FE1}h_{FE2}}$$

Appendix 2

1. From a graph similar to Figure A.2.1, which will be found in the triac data sheet, find the power, P_T, dissipated by the triac at the given value of load current, I_T, and conduction angle a.

2. From the data sheet, substitute values in the electrical equivalent circuit, Figure 8.

R_{j-a} = thermal resistance of triac junction to ambient.

R_{j-mb} = thermal resistance of triac junction to mounting-base.

R_{mb-h} = thermal resistance between the mounting-base and the heat-sink. Allow 1°C/W for a mica washer, 1.5°C/W for contact resistance without thermal jointing compound, 1°C/W for contact resistance with silicone grease, and 0.5°C/W for contact resistance with oxide-loaded thermal jointing compound. These values apply for TO-220, TO-3 and similar encapsulations.

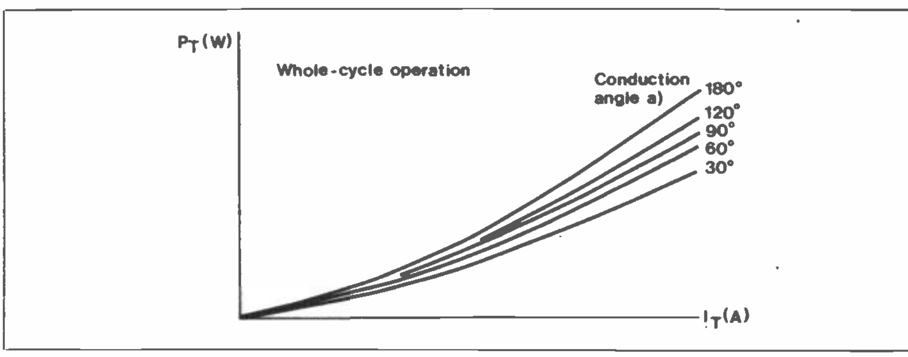


Figure A. 2. 1. Triac dissipation verses main current, with conduction angle as parameter.

We have to find R_{ha} = thermal resistance of the necessary heat-sink.

3. Substitute $I_j = P_T$, also $V_j = (T_{j\,max} - T_{amb})$, where $T_{j\,max}$ is the maximum permitted junction temperature of the triac, from the data sheet, and T_{amb} is the maximum value of ambient temperature (35°C for the normal household environment). Preferably, reduce the value of V_j by 10°C, for greater reliability.

4. From the equivalent circuit:

$$I_j = \frac{V_j}{R_{j-a}} + \frac{V_j}{R_{j-mb} + R_{mb-h} + R_{h-a}}$$

This is just Ohm's Law. For many devices and applications, R_{j-a} can be neglected (thereby adding a safety factor).

Then $R_{h-a} = (V_j/I_j) - R_{j-mb} - R_{mb-h} =$

$$\left\{ \frac{(T_{j\ max} - T_{amb})}{P_T} \right\} - R_{j-mb} - R_{mb-h}$$

Appendix 3

Referring to Figure 12, the triac, T1, is chosen to have a V_{BO} rating greater than the peak voltage of the supply. For 240V mains, a V_{BO} of 400V must be regarded as a minimum. The I_T rating obviously depends on the required load current. It is wise to choose a generously-rated device, because this does not usually increase the cost greatly, and often gives a lower thermal resistance as a bonus. For example, a TIC226D, rated at 400V/8A r.m.s., could be chosen for this circuit, and is quite inexpensive.

We next look at the snubber network, R3 and C2. In the absence of these components, the series inductive component L_L of the load impedance will cause a voltage spike to appear across the triac when it switches off. This spike may exceed the dV/dt rating of the triac and cause it to remain conducting! To avoid this, C2 is added to slow down the transient and reduce its amplitude, and R3 is included to ensure that the tuned circuit L_L/C2 is, at least, critically damped.

Unfortunately, the value of L_L is often not known, and it is not easily measured because, being dependent on an iron-cored component, it varies with the applied voltage and frequency. Under these conditions, it is usual to choose an initial value for C2, such as 100nF, and to examine the resultant voltage transient with an oscilloscope. Any necessary adjustment, to achieve a desired value of dV/dt, can then be easily made. If L_L is known, then:

$$C2 > 2V_s^2/\{L_L(dV/dt)^2_{\ max}\}$$

Similarly, the value of R3 depends on that of L_L:

$$R3 > 2\ L_L/C2$$

and, in practice, is adjusted so that the voltage transient is observed to be well damped.

C2 should be rated for 250V AC working, and a self-healing 'X-type' capacitor should be used.

R3 has to pass a current transient greater than 3A if power is applied to the circuit at a voltage maximum, and should be chosen accordingly. Some low-cost metal-film resistors are unsuitable.

D1, the diac, can be chosen from the few types (e.g. ST2 (QL08J)) available. The symmetry of the breakover voltage is important in minimising the DC component in the load current. It is worth noting that the prices of rather similar devices of this type vary considerably.

C1 is chosen to store enough charge to supply the gate current required for reliable triggering. Most samples of triac require typically one-tenth of the triggering current given in the data sheet, so an experimental approach is unwise here. C1 should *not* be made too large, as this will delay the triggering and cause loss of load power and increased r.f.i. A value of 47nF is satisfactory in this circuit. Again, a 250V AC rated component of 'X-type' is preferred.

R1 should have a resistance much lower than the impedance of C1, so that the triggering delay is minimised. But if R1 is made too low, a short-circuit in, or across, C1 may cause such a severe overload in R1 that it burns the printed-circuit board and adjacent components. A simple fault may thus destroy the circuit. Luckily, a value of 18kΩ will avoid this problem, without delaying the trigger point unacceptably.

R2 is required to adjust the trigger current pulse duration to exceed the minimum recommended value, which is 20μs for the TIC226D. A value of 47Ω is satisfactory.

The switch S1 can be any form of low-current switch, such as a light-touch push or a reed switch, but it must be insulated for use in direct connection with the mains supply.

We can determine the heat-sink requirements using the final result from Appendix 2. From the device data-sheet, $T_{j\ max}$ = 110°C, P_T = 2W at I_T = 2.08A, and R_{j-mb} = 1.8°C/W. Allowing for a mica washer, without thermal jointing compound, R_{mb-h} = 2.5°C/W, T_{amb} = 35°C and the derated $T_{j\ max}$ = 100°C.

Then R_{ha} =

$$\left\{ \frac{(T_{j\ max} - T_{amb})}{P_T} \right\} - R_{j-mb} - R_{mb-h}$$

$$= \left(\frac{65}{2} \right) - 4.3 \quad = 28.2°C/W$$

By comparison, R_{j-a} = 62.5°C/W, from the data-sheet. This is not negligible compared with the heat-sink requirement, and would allow the use of a heat-sink having a thermal resistance of 50°C/W rating. The final design should be checked by measurement.

CORRIGENDA

Vol. 1 No. 1
Combo Amplifier: In the power supply section of the Control Board circuit the junction of C59/C60 should connect to pin 9, junction of D8/D9. Also the arrow going to the PSU supply from the junction of R72/R76 should be designated +15V.

Vol.5 No. 19
Amstrad PSU: In Figure 8, the legend of pcb GD07H is incorrect. The circular shape designated REG1 should be BR1, and the rectangular shape designated BR1 should be REG1. In addition, in the text it is suggested that transformer YK10L could be used. Do not use YK10L as the maximum unregulated DC voltage must be less than +27V.
Mixer PSU: In the Parts List, a heatsink Penta (FG84J) is called for; this is changed to two heatsinks Plastic types (FL58N).

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For further details please see 'Prices' on catalogue page 15.

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All items whose prices have changed since the publication of the 1986 catalogue are shown in the list below. Those where the price has changed since the last Price Change Leaflet (dated 12th May 1986) are marked '•' after the price.

A complete Price List is also available free of charge – order as XF08J.

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‡	An additional £5.50 carriage charge must be added.
NV	Indicates that item is zero rated for VAT purposes.
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PA67X 100m 16/0.2 Wire Grn £4.00
FA30H 16/0.2 Wire 10M Gry 50p•
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FA31J 16/0.2 Wire 10M Orn 50p•
PA69A 100m 16/0.2 Wire Orn £4.00
FA32K 16/0.2 Wire 10M Pnk 50p•
PA70M 100m 16/0.2 Wire Pnk £4.00
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FA34M 16/0.2 Wire 10M Vio 50p•
PA72P 100m 16/0.2 Wire Vio £4.00
FA35Q 16/0.2 Wire 10M Wht 50p•
PA73Q 100m 16/0.2 Wire Wht £4.00
FA36P 16/0.2 Wire 10M Yel 50p•
PA74R 100m 16/0.2 Wire Yel £4.00-

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XR39N Zip Wire 9p•
XR60Q HD Loudspeaker Cable 40p•
XR72P HiFi Loudspkr Cable 58p•
XR89W 4-Wire Burgler Cable 15p•

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XR66W 4-Wire Phone Cable 12p
PA76H 100m 4-Wire Phone £8.65•
XR74R Flat IDC Cable 20way 32p•
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PA43W 30m Clr Cd IDC 40W £77.95•
XR85G Clr Cd IDC Cable 50W £1.20•
PA44X 30m Clr Cd IDC 50W £97.95•

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XR09K HD Mains Black 54p•
XR10L HD Mains White 54p•
XR11M HD Mains Orange 54p•
★BL72P Stretchflex 6A £4.95

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XR15R Min Screened 18p•

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XR21X Cable Twin 24p•
XR23A Cable Quad 45p•
PA18U 50m Cable Quad £16.95
XR29G Brown Low-loss Coax 20p•
XR87U White Low-loss Coax 20p•

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BH16S Systoflex 4mm White DIS•
BH17T Systoflex 4mm Yellow DIS•

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BH26D Safix 4 9p
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WX16S Mics 180pF 26p•
WX17T Mica 220pF 26p•
WX19V Mica 330pF 35p•
WX21X Mica 470pF 35p•
WX23A Mica 680pF 42p•
WX25C Mica 1000pF 42p•
WX31J Mica 4700pF 98p•

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★FB53H Axial 100uF 200V £1.56

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WL69A Trimmer 10pF 24p•
WL70M Trimmer 22pF 28p•
WL72P Trimmer 65pF 30p•

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HX60Q Crystal Socket 25u 38p•
HX61R Crystal Socket 6u 60p•

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XG10L 12V 3A Power Unit DIS•
YB00A Low-Pass RF Filter £4.80

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LB72P Intercom 2-Station £11.95

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AF10L AM/FM Radio DIS

COMPUTERS

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YJ34M MPF-1P Speech Synth £86.25

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XG64U TV Monitor V7001 £84.95•
XG65V TV Monitor CM14 £239.95•

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YX87U S/S D/D Disk 5.25 £1.75•
YJ00A 10 S/S D/D Disk 5.25 £15.95•
FT80B D/S D/D Disk 5.25 £1.95•
YJ70M 10 D/S D/D Disk 5.25 £18.95•
FT81C S/S Q/D Disk 5.25 £2.20•
YJ71N 10 S/S Q/D Disk 5.25 £19.95•
FT82D D/S Q/D Disk 5.25 £2.50•
YJ72P 10 D/S Q/D Disk 5.25 £22.95•
YJ73Q 10 S/S D/D Disk 3.5 £28.95•
YJ74R 10 D/S D/D Disk 3.5 £39.95•

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YK87U Flip n File Minibx15 £8.95
YK98E Flip n File Box 50 £16.95
UG04E Atari User Grp Mag 4 DIS•
UG05F Atari User Grp Mag 5 £1.00•
UG06G Atari User Grp Mag 6 £1.00•

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KB25C Galactic Trader Cass DIS
KF02C Hellfire Wrrior Cass DIS
KF03D Hellfire Wrrior Disk DIS
KF05F Dngr Drindisti Disk £2.95
BQ83E Crush Crumble Cass £4.95
BQ84F Crush Crumble Disk DIS•
KF07H Keys Of Acheron Disk DIS
KB34M Kng Arthr's Heir Dis DIS
★YG55K Kingdom £2.95
KF15R Morloc's Tower Disk DIS
BQ21X Rescue Rigel Cass DIS•
BQ24B Star Warrior Cass DIS
KB35Q The Nightmare Disk DIS•
BG65V Space Shuttle Mod 1 DIS
BG50E Angle Worms Cassette DIS
KF66W Anti-Sub Patrol Cass DIS
KF67X Anti-Sub Patrol Disk DIS
KF54J Attck Ep-Cyg-4 Cart DIS
KB75S Beja Buggies Disk DIS
BG36P Bug Attack Cassette DIS
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BQ69A Caverns Of Mars DIS

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KB80B Clwns & Ballons Disk DIS•
KF57M Fortune Hunter Cart DIS
BQ64U Ghost Hunter DIS
BG78K Guns Fort Defiance DIS
BG38R Haunted Hill Cass DIS
KB16S K-Razy Antics Cart DIS
BQ63T K-Razy Sht Out Cart DIS
BG49D Lunar Lander Disk DIS
KF01B Monster Maze Cart DIS
KF45Y Mountain King Cart DIS
KB14Q Nautilus Disk DIS
KF12N Plattermania Cart DIS
KB08J Preppie Disk DIS
KF55K Princess & Frog Cart DIS
KB48C Rear Guard Disk DIS
BQ36P Shoot Gallery Cass DIS
BG97F Shootout Galaxy Cass DIS
KF27E Sky Blazer Disk DIS
KB56K Space Games Cass DIS
KB54J Stratos Disk DIS
BG18U Threshold Disk DIS
BQ37S Thunder Island DIS
KB03D Wizard of Wor Disk DIS
KB99H Armour Assault Disk DIS
BG63T Battle Shiloh Cass DIS
BQ97F Battle Shiloh Disk DIS
KB41U Cytron Masters Cass DIS
BG82D Midway Campaign Disk DIS
BG84F NA Convoy Raider Dsk DIS
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BG66W Acquire Cassette DIS
YL33L Fast Gammon DIS•
KF79L Kids 3 (4 progs) Dis DIS

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BG91Y Stocks and Bonds Cas DIS
KF56L Typo Cart DIS•
KB09K Wordrace Disk DIS
KB10L Wordrace Access Disk DIS
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BG12N Bob's Business Disk DIS
BG08J Mini Word Procr Cass DIS
BG09K Mini Word Procr Disk £4.95
YG52G Statistics Cassette DIS
YG46A Conversation Spanish DIS
KF87U Music Major Disk DIS
KB23A My First Alphbt Disk DIS
YG69A Pilot Consumer DIS
BG64U The Next Step Disk DIS
KF88V Graphics Machne Disk DIS
KF90X Instedit Disk DIS
BQ54J Scrolling Disk DIS
KF71N Charctr Graphcs Disk DIS
KF73Q GTIA Grphcs 9-11 Dis DIS
KF75S Sound Effects Disk DIS
KF76H Memory Map Tutrl Cas DIS•
KF77J Memory Map Tutrl Dis DIS
KH59P Sam Tutorial Disk/At DIS•
KH66W Basic Prog Tools Dsk DIS
KH65V Fancy Fonts Disk /At DIS

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BC36P Cave Hunter DIS
BC34M Cosmic Invaders DIS
BC79L Galax Attax Cart DIS
BC35Q Ghost Attack DIS
BC33L Meteoroids DIS

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KL62S Word Proc Cas (32) DIS
KL66W Number Gulper Cas 32 DIS
KL75S Forth Cass (32) DIS•
BC61R Crsh Crmbl Chmp Disk DIS
BC57M Temple Of Apshai Dis DIS
BC58N Uppr Rchs Apshel Dis £2.95
KS03D M5 Tank Battalion DIS
KS04E M5 Step Up DIS
KH56L Pool Cass (SP) DIS
KK36P VIC Aggressor Cart DIS

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KK10L Crsh & Cmp + 16K Cass DIS
KK09K Sword Frgoal 16K Cas DIS
AC98E VIC Writer Disk DIS
BC12N Know Your Own IQ DIS
BC14Q Know Yr Personality DIS•
BC22Y MM Data 1 DIS
BC23A MM Data 2 DIS•
BC00A VIC Maths 2 DIS
KM52G VIC Pixel Power Cass DIS•
AC55K Programmers Aid DIS

CONNECTORS

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HF45Y 2mm Socket Blue 20p
HF34M 4mm Patch Cord DIS

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FJ85G Stereo 2.5mm Jack Pl DIS•
FT94C 2.5 Stereo Chas Skt DIS•
FT93B 2.5 Sterao Line Skt DIS•

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HH07H Co-ax Plug Aly 32p•
YW08J Co-ax Plug Plas 24p•
HH08J Co-ax Socket Pan 35p•
HH09K Co-ax Socket Flush 35p•
YW09K Co-ax Line Skt 40p•
HH11M Co-ax Conn 24p•

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HH16S FM Aerial Plug 20p•
HH17T BNC Plug £1.20•
FJ72P BNC R/A Plug £1.80•
HH18U BNC Socket £1.05•
QY22Y BNC Earth Tag 15p•
YW00A BNC Square Socket £1.05•
YW02C BNC Straight Adaptor £1.95•
YW03D BNC T Adaptor £3.25•
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FJ73Q UHF R/A Plug 95p•
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BW83E UHF Reducer Large 24p•
HL95D RA PL259 Plug £1.10•
BW84F UHF Socket Round 85p•
BW85G Socket SO239 72p•

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BW87U UHF Straight Adaptor 70p•
BW88V UHF T Adaptor £2.95•
RK00A UHF Female T Adaptor £2.95•
RK01B UHF Adaptor FFLA £1.95•
RK02C UHF Adaptor FMLA £2.25•
YW04E Adaptor 239 £1.95•
YW05F Adaptor 259 £1.95•
FJ79L N Type Chassis Skt £1.95•
FJ80B N Type Chass Skt Sq £1.45•
FJ81C N Type Inline Adapt £2.25•
FJ82D N Male to BNC Adapt £2.95•
FJ83E BNC Male to N Adapt £2.95•
FJ84F BNC Female to N Fem £2.95•

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FJ70M 8 Pin EIA Plug £2.75•
FJ71N 8 Pin EIA Skt £2.50•
FJ41U Scart Plug (21 way) £1.24•
FV89W SCART Socket 48p•
RK52G 10 Way Line Skt £2.90•

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RK53H	10 Way Line Plug	£3.70●
FM60E	Lkg Audio Plug 2-Way	64p●
FK22Y	Lkg Audio Skt 2-Way	66p●
FM61F	Lkg Audio Plug 3-Way	64p●
FK23A	Lkg Audio Skt 3-Way	66p●
FM62G	Lkg Audio Plug 4-Way	66p●
FK24B	Lkg Audio Skt 4-Way	69p●
FM63H	Lkg Audio Plug 5-Way	76p●
FK25C	Lkg Audio Skt 5-Way	80p●
FM64J	Lkg Audio Plug 6-Way	80p●
FK26D	Lkg Audio Skt 6-Way	85p●
FK27E	Lkg Audio Plug 7-Way	£1.20●
FK28F	Lkg Audio Skt 7-Way	£1.28●
FK29G	Lkg Audio Plug 8-Way	£1.30●
FK30H	Lkg Audio Skt 8-Way	£1.40●
FT91Y	Lkg Audio Plg 10-Way	£2.95●
FT92A	Lkg Audio Skt 10-Way	£1.95●

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BW89W	XLR Line Plug	£2.05●
BW90X	XLR Chassis Socket	£3.30●
BW91Y	XLR Line Socket	£2.40●
BW92A	XLR Chassis Plug	£1.78●

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YX90X	PC DIN Skt 2-pin	22p●

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RK60Q	D-Range 9 Way Plug	57p●
BK58N	D-Range 15-Way Plug	78p●
YQ48C	D-Range 25-Way Plug	£1.08●
FV71N	D-Range 37-Way Plug	£1.55●
FV74R	D-Range 50-Way Plug	£1.98●
RK61R	D-Range 9 Way Skt	86p●
BK59P	D-Range 15-Way Skt	£1.24●
YQ49D	D-Range 25W Socket	£1.60●
FV72P	D-Range 37-Way Skt	£2.25●
FV75S	D-Range 50-Way Skt	£2.90●
FG25C	RA D-Range 9-Way Skt	£1.35●
FG26D	RA D-Rnge 15-Way Skt	£2.00●
FG27E	RA D-Rnge 25-Way Skt	£3.50●
FG66W	RA D Range 9 Way Plg	£1.02●
FG67X	RA D Range 15 Wy Plg	£1.50●
FG68Y	RA D Range 25 Wy Plg	£2.40●

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★YR56N	Edge Conn Foot Open	24p

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★RK65V	Minicon Latch Pl 2w	18p
★BX98E	Minicon Latch Pl 3w	24p
★YW11M	Minicon Latch Pl 4w	28p
★FY93B	Minicon Latch Pl 5w	35p
★YW12N	Minicon Latch Pl 6w	38p
★YW13P	Minicon Latch Pl 8w	40p
★RK66W	Minicon Latch Pl 10w	48p
★YW14Q	Minicon Latch Pl 12w	60p
★BH61R	Minicon Latch Pl 17w	80p
★BK65G	Minicon Latch Pl 18w	86p
★FY92A	RA Lch Minicn Pl 2w	35p
★YW15R	RA Lch Minicn Pl 3w	38p
★FY91Y	RA Lch Minicn Pl 4w	42p
★RK67X	RA Lch Minicn Pl 5w	48p
★FB99H	RA Lch Minicn Pl 6w	58p
★YW16U	RA Lch Minicn Pl 8w	64p
★RK68Y	RA Lch Minicn Pl 10w	66p
★YW19V	RA Lch Minicn Pl 12w	78p
★FT67X	RA Lch Minicn Pl 17W	95p
★RK69F	RA Lch Minicn Pl 18w	98p
★HB50P	Mncn Ltch Hsg 2way	8p
★BX97F	Mncn Ltch Hsg 3-way	9p
★HB58N	Mncn Ltch Hsg 4way	10p
★BH66W	Mncn Ltch Hsng 5-way	12p
★BH65V	Mncn Ltch Hsng 6-way	15p
★YW23A	Mncn Ltch Hsng 8-way	18p
★FY94C	Mncn Ltch Hsng 10way	20p
★YW24B	Mncn Ltch Hsng 12way	24p
★RK68A	Mncn Ltch Hsng 17way	36p
★YW26D	Minicon Skt 3-way	20p
★YW27E	Minicon Skt 4-way	40p
★YW28F	Minicon Skt 6-way	48p
★YW29G	Minicon Skt 8-way	58p
★YW30H	Minicon Skt 12-way	78p

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FJ62S	Centronix Type Con R	£4.95
BK96E	34 Wy IDC Skt + Cble	£3.30

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RW61R	Cas Lead Paros	62p
RW66W	Cas Lead Telefunken	58p
FT37S	Fused Euro Ch Plg	£1.40

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BW98H	Euroconn Lead	£1.95

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HL30H	Mains Plug SA2019A	DIS
HL31J	Mains Socket SA2020	DIS
HL37S	Mains Socket P636	£1.68●

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★FV94C	Small Locking Plate	48p

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★FG30H	Printer Cable 1	£8.95
★FG31J	Printer Cable 2	£8.95

ELECTRICAL

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RW68Y	Dis Board 4-way	£8.95

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HL78K	Shaver Skt Isolated	£21.95
FQ10L	250W Rotary Dimmer	£8.95

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LB63T	Bayonet L/Hldr	60p●
FQ06F	Ceiling Rose	£1.10

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XY09J	Extn Lead 5A	£10.95
XY09K	Extn Lead 13A	DIS●

HARDWARE

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LR63T	Isotag M4	28p●
LR64U	Isotag M3	28p●

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LR03D	Terry Clip 1/2in.	18p●
LR73Q	Terry Clip 1.1/2in.	28p●

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XH39N	Transfer 1/8in Black	£1.50
XH40T	Transfer 1/8in Red	£1.50
XH41U	Transfer 1/8in White	£1.50
XH42V	Transfer 1/4in Black	£1.50
XH43W	Transfer 1/4in Red	DIS
XH44X	Transfer 1/4in White	£1.50
XH46Y	Panel Transfer Black	£1.50
XH46A	Panel Transfer Red	£1.50
XH47B	Panel Transfer White	£1.50

HEATHKIT

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HK61R	HW-5400 Syn HF Xcvr	£549.95

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HT27E	Heathkit SW-7800	£299.95
HT28F	Heathkit HDP-7800	£84.95

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HT30H	Heathkit HD-1986	£44.95

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HK25C	HD-1234 Antenna Sw	£22.95
HK53H	Heathkit SA-2060A	£289.95
HC51F	Heathkit HL-2200	DIS●

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HK23A	HD-1250 Dip Meter	£89.95

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HC91Y	Heathkit CO-1015	£279.95
HC95D	Heathkit CMA-1550-1	£15.95
HK31J	CI-1080 Exhst Anlysr	£129.95

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HK80B	NE-2112 Heat Sniffer	£19.95●

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HK92C	GD-49 Ultra Intruder	£79.95
HC95F	Heathkit GD-1183	£19.95

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HK11M	ETW-3100B Assembled	£184.95●

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HM05F	EE-1003 Anlg Dsn Crs	£89.95

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HM27E	EE-110 Laser Course	£99.95

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HM32K	ETS-4200 Laser Trnr	£279.95
HK14Q	ETW-3200B Assembled	£184.95●

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HK91Y	EWA-3400 Assembled	£279.95
HM15R	EC-2001 Cmptr Fndmnt	£99.95
MD28D	Heathkit EC-2002	£99.95

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MD31J	Heathkit EC-2003	£69.95

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HS80B	ETS-18 Hero Assembld	£2149.90
HM26D	ET-18-9 Hero 1 Basic	£49.95

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KA00A	Hero Jr Kit RTR-1-1	£299.95

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MD36P	Heathkit RTC-1-9	£29.95
HM20W	RTC-1-10 Jr Programr	£39.95
HM21X	RTC-1-11 Jr Mscl Chr	£34.95

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HM11M	EB-6140 C of E Text	£24.95 NV
HM12N	EB-6140-40 C E Wkbk	£10.95 NV
HM13P	EB6140-60 C E Instr	£9.95 NV
HM14Q	EB-6140-30 C E Parts	£29.95
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HM17T	EB-6101-40 DC Wkbk	£10.95 NV
HM18U	EB6101-50 DC Instr	£9.95 NV
HM19V	EB-6101-30 DC Parts	£24.95
HM22Y	EB-6102 AC Elec Text	£19.95 NV
HM23A	EB-6102-40 AC Wkbk	£10.95 NV
HM24B	EB6102-50 AC Instr	£9.95 NV
HD58N	Heathkit EEA-3102A	£19.95
HM25C	EB-6102-30 AC Parts	£19.95 NV
HM28F	EB-6103 Semicnd Text	£19.95 NV
HM29G	EB-6103-40 Semi Wkbk	£10.95 NV
HM30H	EB6103-50 Semi Instr	£9.95 NV
HD61R	Heathkit EEA-3103A	£19.95
HM31J	EB-6103-30 Semi Part	£19.95
HM34M	EB-6104 Elc Cir Text	£19.95 NV
HM35Q	EB-6104-40 Elec Wkbk	£10.95 NV
HM36P	EB6104-50 Elec Instr	£9.95 NV
HM37S	EB-6104-30 Elec Part	£34.95
HM40T	EB-6105 Test Eq Text	£19.95 NV
HM41U	EB-6105-40 Test Wkbk	£10.95 NV
HM42V	EB6105-50 Test Instr	£9.95 NV
HD67X	Heathkit EEA-3105A	£19.95
HM43W	EB-6105-30 Test Part	£29.95
HM46A	EB-6106 Commun Text	£19.95 NV
HM47B	EB-6106-40 Commn Wkbk	£10.95 NV
HM48C	EB6106-50 Comm Instr	£9.95 NV
HD69Y	Heathkit EEA-3106A	£19.95
HM49D	EB-6106-30 Comm Part	£34.95
HM52G	EB-6201 Digital Text	£24.95 NV
HM53H	EB-6201-40 Digi Wkbk	£11.95 NV
HM54J	EB6201-50 Digi Instr	£9.95 NV
HD70M	Heathkit EEA-3201	£19.95
HM55K	EB-6201-30 Digi Part	£34.95
HS23A	Heathkit EB-6001	£19.95 NV●
HS24B	Heathkit EB-6001-40	£10.95 NV
HS25C	Heathkit EB-6001-50	£9.95 NV
HS26D	Heathkit EB-6001-30	£10.95
HS27E	Heathkit EB-6002	£19.95 NV
HS28F	Heathkit EB-6002-40	£10.95 NV
HS29G	Heathkit EB-6002-50	£9.95 NV
HS30H	Heathkit EB-6002-30	£19.95
HM56L	EB-6401 Micro Text	£24.95 NV
HM57M	EB-6401-40 Micro Wbk	£11.95 NV
HM58N	EB6401-50 Micro Inst	£9.95 NV
HM59P	EB-6401-30 Micro Prt	£84.95
HM61R	EB-6402 Intface Text	£24.95 NV
HM62S	EB-6402-40 Intf Wkbk	£10.95 NV
HM63T	EB6402-50 Intf Instr	£9.95 NV
HM64U	EB-6402-30 Intf Part	£84.95
HM67X	EB-8086 16-Bit Text	£24.95 NV
HM77J	EB8086-40 16-Bit Wbk	£11.95 NV
HM78K	EB8086-50 16-Bit Ins	£9.95 NV
HM79L	EB-8086-30 16-Bit Pt	£59.95
HS73Q	Heathkit EB-6405	£24.95 NV
HS74R	Heathkit EB-6405-40	£10.95 NV
HS75S	Heathkit EB-6405-50	£9.95 NV
HS76H	Heathkit EB-6405-30	£54.95
HM81C	EB-1801 Robotic Text	£29.95 NV
HM82D	EB1801-40 Robot Wkbk	£14.95 NV
HM83E	EB1801-50 Robot Inst	£9.95 NV
HM84F	EB-1801-30 Robot Prt	£44.95
HS69A	Heathkit EB-1812	£19.95 NV
HS70M	Heathkit EB-1812-40	£10.95 NV
HS71N	Heathkit EB-1812-50	£9.95 NV
HS72P	Heathkit EB-1812-30	£49.95
HM72P	EB6100-40 BASIC Wkbk	£10.95 NV
HM73Q	EB6100-50 BASIC Inst	£9.95 NV
MD32K	Heathkit EB-6003	£19.95 NV
MD33L	Heathkit EB-6003-40	£10.95 NV
MD34M	Heathkit EB-6003-50	£9.95 NV
MD35Q	Heathkit EB-6003-30	£19.95
HE11M	Heathkit EB-601	£19.95 NV
MD41U	Heathkit EB-610-40	£10.95 NV
HE12N	Heathkit EB-601-50	£9.95 NV
HE13P	Heathkit EB-601-30	£24.95
MD18U	Heathkit EB-2001	£19.95
MD19V	Heathkit EB-2001-40	£10.95 NV
MD20W	Heathkit EB-2001-50	£9.95 NV
MD22Y	Heathkit EB-2002	£19.95
MD23A	Heathkit EB-2002-40	£10.95 NV
MD24B	Heathkit EB-2002-50	£9.95 NV
MD27E	Heathkit EB-2003	£19.95
MD28F	Heathkit EB-2003-40	£10.95 NV
MD29G	Heathkit EB-2003-50	£9.95 NV
MD30H	Heathkit EB-2003-30	£29.95

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HT63T	Heathkit HS-317-10	£995.00
MD44X	Heathkit HS-317-20	£699.95

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HG12N	Heathkit IG-5282	£59.95
HK26D	IG-5280 RF Oscilltr	£59.95
HK34M	IB-5281 RCL Bridge	£59.95

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HG13P	Heathkit IT-5283	£59.95
HG14Q	Heathkit IPA-5280-1	£39.95
HK28F	IT-2250 Capactnc Mtr	£159.95
HE95D	Heathkit IT-3120	£99.95
HS60Q	GD-1703 Bat Test Kit	£16.95

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HE89G	Heathkit IT-5230	£149.95
MD09G	Heathkit ITA-5230-1	£29.95
HE89E	Heathkit IM-4180	£179.95
HK52G	IN-3117 Resistnc Box	£69.95
HK83B	IMA-100-10 DC Probe	£16.95
HT51F	Heathkit IM-5215	£34.95

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HK54J	IM-2410 Freq Counter	£139.95
HK87X	PS2405 Hand-Freq PSU	£12.95
HK84C	SMA-2400-1 Antenna	£9.95

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HK95D	IG-4244 Osc Calibrtr	£149.95
HT52G	Heathkit IP-2760	£179.95
HK53H	IP-2718 Tri-Otpt PSU	£119.95
HK35Q	IP-2728 Low-Volt PSU	£49.95

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HG46A	Heathkit IP-2717A	£189.95
HK56L	ID-4001 Weather Cmpr	£399.95

KNOBS

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RX01B	Knob NK2	54p●

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HB28F	Knob R51	50p
HB29G	Knob R52	DIS
HB31J	Knob R54	90p
HB32K	Knob K105	DIS

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★RX29G	Spindle Coupler	98p
RX30H	Ext Spindle	£1.20

MICROPHONES

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FK43W	Omni Insert Dyn DU3	£1.10

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YB33L	Electret Casette Mic	DIS●

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YW77J	Mic Hldr Screw-Fix	DIS
YW78K	Mic Hldr Adhesive	TEMP

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YW71N	UM Tie-Clip Mic	£11.95

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YW76H	Extra Hgt Mic Stand	DIS
XB45Y	5-Foot Mic Stand	£14.95

MUSICAL & EFFECTS

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XG63E	G. Equlsr + Analyser	£139.95●

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AF99G	DE1200 Digital Delay	£224.95●

OPTO-ELECTRICAL

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FF67X	Fluted Lhldr Clear	DIS●

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WL76H	Bulb MES 3.5V	38p
WL77J	Bulb MES 6V 0.24W	38p
WL78K	Bulb MES 6V 0.6W	38p
FM99H	Reader's Light	£2.95●
YK36N	Alarm Beacon	£12.95

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★QY94F	Ultrabri LED Red Std	60p
★QY95G	Ultrabri LED Red Nar	60p

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BY65V	Red Bargraph Dsply	£2.25
YB33L	Green Bargraph Dsply	£2.25
★FT61R	5 x 7 LED Array	£3.95

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RK24B	Solar Panel 12V	£15.95

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HY19V	5KV Laser PCB	£4.98

ORGAN COMPONENTS

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YL17T	Reverb PSU Module	£4.95

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BR21X	S Tab Gedeckt 8'	DIS
BR28F	S Tab Salicional 8'	£1.20
BR32K	S Tab String 8'	DIS
BR34M	S Tab Tremulant	£1.20

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BR42V	Drawbar White	DIS
BR89G	Drawbar Blue	£1.50●
BR89H	Drawbar Green	DIS

PCB EQUIPMENT

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BK63T	Verobloc Kit	£8.45

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XG20W	CM100 PCB Kit	£74.95

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HX45Y	Transfer Sheet 1	48p
HX46A	Transfer Sheet 2	45p
HX47B	Transfer Sheet 3	45p
HX48C	Transfer Sheet 4	48p
HX49D	Transfer Sheet 5	45p
HX63T	Transfer Sheet 6	45p
HX64U	Transfer Sheet 7	45p
HX66V	Transfer Sheet 8	48p
HX66W	Transfer Sheet 9	48p
HX67X	Transfer Sheet 10	45p
HX68Y	Transfer Sheet 11	45p
HX93E	Transfer Sheet 12	45p
HX94F	Transfer Sheet 13	45p
HX44X	Transfer Kit	£4.95

PROJECTS & MODULES

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XG08G	Burglar Alarm Box	£11.95
GA46A	Break Contact PCB	£2.20
LW57M	Burglar Alarm Kit	£58.95
LW58N	Ext Horn Kit	£42.95●

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GA81C	Channel/PSU PCB	£1.80
GA82D	Extra Channel PCB	£1.20
LW75S	Radar Extr Ch Module	£4.95●
LW83E	Usonic Xceiver Kit	£10.95●
LW84F	Usonic Interface Kit	£3.45

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LK73Q	Floodlight Alarm Kit	£31.95●
LW97F	Panic Button Kit	£3.95●

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LK60Q	Explsve Gas Alrm Kit	£24.95
LK14Q	Codelock Kit	£21.95●
GB75S	Musical D.Bell PCB	£2.95●
LK57M	Musical Announcr Kit	£14.95

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GA04E	Stopwatch PCB	£2.80●
LW66V	Stopwatch Kit	£44.95
GB24B	Enlarger Timer PCB	£8.95
LK07H	Enlarger Timer Kit	£46.95
GB84U	Enlarger Exp Mtr PCB	£1.20

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GB78K	Flash Meter PCB	£1.95
GA62S	Timer Switch Board	£4.95
GA63T	Timer Relay PCB	£1.10
GA64U	Timer Front Panel	£4.50

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GA26C	Power Control PCB	£1.10

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LK34M	2.8kW Pwr Cntrlr Kit	£19.95
LK35Q	Fluor Tube Drvr Kit	£8.50

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QY25C	2716/M4	£9.95
QY60Q	2716/M5	£9.95
GB05F	Connect PCB	£4.95
GB06G	T/E Motherboard	£24.95
GB07H	T/E PSU PCB	£8.95
LW81C	Digi-Tel Connect Kit	£11.95
LW82D	Digi-Tel Main Kit	£129.95
LK37S	Digi-Tel Expdr Kit	£149.95●

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XX47B	Train Cnrl Front Pnl	£3.30
GA72P	Train Common PCB	£3.30
GA75S	Train Receiver 2 PCB	£1.20
LW61R	Train Common/PSU Kit	£31.95
LW62S	Train Control Kit	£8.50●
LW63T	Train Rcvr1 ML926Kit	£11.95
LW64U	Train Rcvr2 ML926Kit	£11.95
LW68Y	Train Rcvr1 ML927Kit	£10.95●
LW69A	Train Rcvr2 ML927Kit	£10.95●
GA84F	Remote Data Ltch PCB	£2.20
GA85G	Data Encoder PCB	£2.80
GA86T	Data Decoder PCB	£2.80
GA87U	IR Tx PCB	£1.80
GA88V	IR Rx PCB	£1.80
GA89W	27MHz Tx PCB	£1.10

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FT40T	Cntrl-A-Train Fr Pan	£1.95
LK64U	Control-A-Train Kit	£13.95
GB77J	Mains Cntrllr PCB	£2.50●

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GA19V	Batt Mon PCB	£1.30
LK42V	Car Batt Monitor	£7.50
LK79L	Car Digtl Tacho Kit	£18.95●
XX40T	Ignition PCB	£1.80
XX41U	Ign Mtg Plate	£1.10

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GA99G	Car Burglar Alrm PCB	£1.40
LW78K	Car Burglr Alarm Kit	£7.95
GA40T	Car Aerial Bster PCB	£1.60
GB93B	U/Sonic Car Alrm PCB	£3.95

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GA76H	MPG Meter Main PCB	£2.20
GA77J	MPG Meter Disply PCB	£1.80
LW67X	MPG Meter Kit	£84.95●
YQ69A	LM1871 Xmitter PCB	£1.40
LK55K	27MHz Transmittr Kit	£7.95
GB83E	4 Ch Servo Cntrl PCB	£8.95
LK61R	4 Ch Servo Cntrlr Kit	£27.95

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LK45Y	Servo & Driver Kit	£10.95
FJ54J	TU 1000 Rear Panel	£2.59
GB67X	RTTY Terminal PCB	£9.95
LK53H	TU1000 RTTY Kit	£54.95

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GB50E	TDA 7000 Radio PCB	£2.80
LK41U	80m Conv Rx Kit	£19.95●

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XG15R	Stereo Amp Chassis	£8.95
GA71N	Stereo Amp PCB	£7.95
GA78K	Stereo Amp Sw PCB	80p
LW71N	25W Stereo Amp Kit	£89.95●
LW77J	Amp Remote Cntrl Kit	£34.95

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XX03D	10-Channel G.E. PCB	£2.20
LR13P	HQ Mixer PCB No.2	£2.50

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LR15R	HQ Mixer PCB No.4	£2.20
LR34M	HQ Mixer PCB No.24	£2.80
LR16S	HQ Mixer PCB No.5	£1.80
LR35Q	HQ Mixer PCB No.25	£2.40
LR22Y	HQ Mixer PCB No.7	£2.40

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LR24B	HQ Mixer PCB No.9	£2.40
LR25C	HQ Mixer PCB No.10	£2.40
LR26D	HQ Mixer PCB No.14	£2.80

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GA00A	D.I.Box PCB	£1.10
FJ36P	Mapmix Front Panel	£4.95
LK49D	Mapmix Kit	£39.95
GA43W	Noise Gate PCB	£1.50
LK43W	Noise Gate Kit	£10.95

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GA30H	Compander PCB	£3.50
LK38R	Mk II N/R Unit Kit	£44.95
GB44X	Stereo DNL PCB	£1.98

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LK69A	Active Crssvr Kit	£19.95
LK70M	3 Channel Amp Kit	£21.95

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BY73Q	8W Amp PCB	90p
LW36P	8W Amp Kit	£5.95
YQ38R	30/2 PSU PCB	£2.20
YQ43W	15W Amp Kit	£8.50

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LW35Q	50W Amp Kit	£18.95●

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LW32K	150W Power Amp Kit	£22.95

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GA28F	100W MOSFET Amp PCB	£2.20
LW51F	MOSFET Amp Kit	£17.95
GA41U	Combo Amp PCB	£7.95
XG03D	Combo Amp Frnt Panel	£4.95
GA17T	MOS-Amp Bridge PCB	£2.95
LK03D	MOSFET Bridging kit	£11.95

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BB81C	Disco Pre-Amp Tn PCB	£5.50
BB19V	Disco PSU PCB	£2.95
BB26D	Motor Switch PCB	£1.50
BB27E	Light Mod Bd	£7.95●

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GA42V	Partylite PCB	£2.20
★XF11M	Stereo Synth Book	£1.95 NV
BB41U	Synth Mixer PCB	£8.50
BB44X	Synth VCA PCB	£2.50
BY90X	Synth Smpl & Nse PCB	£5.50
BB43W	Synth Trns Gen 1 PCB	£4.95
BB45Y	Synth Trns Gen 2 PCB	£4.95
BY82D	Synth Rvrb & Phs PCB	£4.50
BY83E	Synth VC Pn & AncPCB	£11.95
BB48C	Synth Ext I/P's PCB	£2.20
BB65V	3800 VCF PCB	£3.30
BB47B	Synth Otpt Stge PCB	£8.95

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GA03D	Spectrum PSU PCB	£2.80
GA36P	Spectrum VCO PCB	£8.95
GA55K	Spectrum Cntrllr PCB	£3.30
XH56L	Spectrum Synth Book	£1.20 NV●
LW85G	Hexadrum Kit	£22.95

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GB72P	Computadrum PCB	£2.95●
LK52G	Computadrum Kit	£11.95
GA05F	Syntom PCB	£1.10
LW86T	Syntom Kit	£13.95
LW87U	Synwave Kit	£13.95

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LK15R	Synchime Kit	£14.95
LW56K	Synclock Kit	£22.95●
LW86V	Volume Pedal Kit	£28.95

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LW89W	Auto Swell Kit	£12.95
GB54J	Auto-Wee PCB	£2.40
LK36P	Auto-Wee Kit	£13.95
GB92A	Guitar Equaliser PCB	£4.95●
LK74R	Guitar Equaliser Kit	£29.95

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BB72P	Sine/Square Gen PCB	£4.95

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LK63T	Live Wire Det Kit	£3.80
GB21X	CMOS Xtal Clbrtr PCB	£3.30
LK10L	CMOS Xtal Clbrtr Kit	£23.95

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LK06G	Sweep Osc Kit	£26.95
GB30H	Probe Upper PCB	£1.10
GB31J	Probe Lower PCB	£1.10
LK13P	Logic Probe Kit	£14.95
GB36P	Pulser PCB	£1.80

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RK30N	Freq Cnt Front Panel	£2.95
GB02C	Freqency Counter PCB	£6.95
GB03D	Freq Ctr Display PCB	£2.80
LW79L	Freqency Counter Kit	£109.95●
GB40T	Frqncy Mtr Adptr PCB	£1.80

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GB09K	Modem Main PCB	£5.95
GB10L	Modem PSU PCB	£1.80
LW99H	Modem Kit	£54.95

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GB84F	Mains Tx/Rx PCB	£2.95●
LK68Y	Mains Tx/Rx Drvr Kit	£32.95●
LK17T	RS232/TTL Cnvrtr kit	£8.50

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GB86T	Z80 CPU Module PCB	£13.95●
LK67X	Z80 CPU Module Kit	£31.95●
GB38N	BBC Motherboard PCB	£8.95●
LK47B	BBC Motherboard Kit	£27.95
GB37S	Dragon I/O PCB	£5.50
LK18U	Dragon I/O Port	£19.95

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GB45Y	Oric Talkback PCB	£4.95
LK28F	Oric Talkback Kit	£21.95
GB55K	Oric Ma-Mo I/F PCB	£4.50
LK40T	Oric Maplin Mo IFace	£11.95●
QY72P	2716/M9 EPROM Shp IF	£9.95
LK71N	Sharp Serial IF Kit	£31.95●
LK39N	Spctrm Easyload Kit	£11.95●

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QY57M	2716/M7	£9.95
LK21X	Spctrm/RS232 Intf kt	£24.95
YM29G	Spectrm RS232 IF Ass	£27.95
LK65V	Spctrm I/O Cntrlr Kt	£17.95
YM31J	Sptrm I/O Cntrl Assm	£19.95
LK72P	Spect Pallel/Srl Kit	£17.95

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LK26D	Spectrum ADC Kit	£32.95
GB34M	DAC PCB	£3.30
LK23C	Spectrum DAC Kit	£18.95
GB47B	Spectrum Kbd Pcb	£11.95
GB46C	Spectrum Kbd Con Pcb	£2.20
LK29G	Spectrum Kybd Kit	£38.95●
LK30H	Sptrm Kybd Adptr Kit	£8.95
LK16S	ZX81 1K RAM Extnsion	£7.95

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LK22Y	VIC20 Extendiboard	£34.95
GB17T	VIC 20 Talkback PCB	£3.95
GB28F	VIC20/RS232 Intfce	£3.50

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GA83E	ZX81 Ext Kyboard PCB	£3.95
LW72P	ZX81 Keyboard Kit	£27.95
GA90X	I/O Port PCB	£2.80
LW76H	ZX81 I/O Port Kit	£9.95●

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GB11M	ZX81 Sound Gen Pcb	£2.20
GB14Q	TV Snd/Inv Vid PCB	£2.95
LK02C	ZX81 TV snd/inv vid	£17.95●
GB23A	ZX81 Mod/Intface PCB	£5.50
QY52G	2716/M6	£8.95
LK08J	ZX81 Modem Intfce Kt	£34.95

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QY58N	2716/M8	£9.95
GB43W	ZX81 Hi Res Grph PCB	£14.95
LK23A	ZX81 Hi-Res Graphics	£34.95
GB90X	Trundle Sensor PCB	£2.80
FT41U	Trundle Motor Ass	£4.45●

PROTECTION

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WR93R	Fuse 20mm 50mA	18p●
WR00A	Fuse 20mm 100mA	15p●
WR94C	Fuse 20mm 160mA	12p●

RECORD, TAPE & VIDEO

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HR15R	Ctrdg Goldring G850	£10.95●
HR16S	Ctrdg Goldring G800	£13.95●

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FQ39N	Ctrdg Goldring G800E	£19.95●
FQ41U	Cdg Tenorel T2001ED	£11.95●

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★HR39N	BSR TC8	85p
★HR51F	Ronette BF40	98p
★FV27E	BSR ST4	98p
★HR25C	Acos GP91-1SC	£1.25
★HR87U	Philips AG3306	£1.25
★HR60Q	Sonotone 9TAHC	£1.25
★HR42V	BSR ST10	£1.25
★YX27E	Sony ND15P	£5.95
★FV26D	Acos GP91-1	£1.25
★HR53H	Garrard KS40A	£1.25
★HR31J	Acos GP104	£1.25
★HR47B	BSR ST17	98p
★HR74R	BSR ST21	98p
★FQ45Y	Garrard GDD1	£1.25
★HR81C	Vacco Luxor	98p
★FV19V	Shure N75-6	£8.95
★FV30H	Shure N75-ED	£15.95
★FV31J	Shure N75-EJ	£11.45
★HR45Y	BSR ST15	£1.25
★YX06G	ADC RSQ30	£5.95
★FV25C	ADC RSQ33	£14.95
★FV24B	Fuji Onkyo	£4.95
★FV22Y	Sanyo STG6	£1.25
★HR90X	Philips GP400	£3.95
★FM76H	Hitachi HN-ST6	£1.25
★FV33L	Shure N95-ED	£19.95
★FV20W	Tetrad T30MS	£1.25
★FV34M	Shure N97-HE	£38.95
★FQ51F	Tenorel 2001D	£3.95
★FQ52G	Tenorel 2001ED	£8.95
★BK19V	Stanton D5107AL	£8.95
★HR89W	Philips GP205	78p
★FM70M	Garrard GKS25	£1.25
★HR97F	Sanyo 2611K	£4.95
★HR48C	Goldring D110SR	£3.45
★HR77J	Goldring D110H	£2.95
★HR76H	Goldring D110E	£5.95
★HR49D	Goldring D120SR	£3.45
★FV29G	Panasonic EPS36	£3.50
★HR61R	Sonotone V100	£4.95
★HR95D	Sansui SN28	£3.95
★HR98H	Sharp STY717	£4.95
★FV32K	Shure N70-B	£8.50
★HR79L	Hitachi ST103	£8.95
★FV28F	Sharp STY104	£3.95
★FV23A	Panasonic EPS270	£2.95
★BK12N	Audio Tech ATS10L	£4.95
★FV21X	Audio Tech ATN3401	£5.75
★BK07H	Audio Tech ATN3400	£8.95
★FG94C	Sharp STY123	£8.95

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FR50E Gram Speed Indicator ... DIS •
YJ27E Compact Discbox ... £2.98 •

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RB07H Rota-Rack ... TEMP

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CT00A Scotch BX-C60 ... 80p •
CT01B Scotch BX-C90 ... 94p •
CT06G Scotch CX-C60 ... 98p •
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CT13P Scotch XSI-C60 ... £1.10 •
CT14Q Scotch XSI-C90 ... £1.35 •
CT21X Scotch XSII-C60 ... £1.45 •
CT22Y Scotch XSII-C90 ... £1.70 •
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CT26D TDK SA-X60 ... £1.90 •
CT27E TDK SA-X90 ... £2.95 •
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CT05F Maxell UL-C90 ... £1.05 •
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CT19V Maxell XLI-S60 ... £1.60 •
CT20W Maxell XLI-S90 ... £2.10 •
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CT25C Maxell UDII-C90 ... £1.55 •
CT28F Maxell XLII-C60 ... £1.55 •
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CT40T D Micro MC-60 ... £2.95 •
YJ46A Video Tape Hd Clnr ... £1.35
FJ06G Video Belts VSK9707 ... £2.95 •
FJ07H Video Belts VSK9808 ... £2.95 •
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FJ10L Video Belts VSK9794 ... £2.95 •
FJ11M Video Belts VSK9805 ... £2.95 •
FJ12N Vdeo Belts VSK9635 ... £2.95 •
XG59P Video Enhancer VH607 ... £34.95 •

RESISTORS

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XL06F Colour Wheel ... 45p •

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YY13P Resnet 220R ... 68p
YY14Q Resnet 470R ... 68p
YY15R Resnet 1k ... 68p
YY18U Resnet 10k ... 68p
RA24B SIL Resistor 220R ... 34p
RA25C SIL Resistor 330R ... 34p
RA26D SIL Resistor 470R ... 34p
RA27E SIL Resistor 1k ... 34p
RA28F SIL Resistor 2k2 ... 34p
RA29G SIL Resistor 4k7 ... 34p
RA30H SIL Resistor 10k ... 34p
RA31J SIL Resistor 47k ... 34p
RA32K SIL Resistor 100k ... 34p

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FW44X Sw Pot Lin 47k ... £1.35

SEMICONDUCTORS

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QB00A AA119 ... 12p •
QB19V AF139 ... 54p •
QF10L BF167 ... DIS
QF15R BF200 ... DIS
QQ20W BF495 ... DIS •
★YH95D BT149M ... 65p
QF41U BY126 ... 20p •
YH59P ICL7109 ... £29.95 •
YY75S ICL7660CPA ... £2.85
YY93B ICM7045IPI ... £16.95 •

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QH35Q LH0042C ... £9.95
YY73Q LM336Z ... £1.65
YY84F LM382 ... £1.98 •
WQ42V MCM4027 250ns ... DIS
QR58N ML927 ... £4.50 •
QY81C MV2108 Varicap ... £1.45
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RA74R DP-27GNB ... £4.50 •
RA81C SAA1099 ... NYA
QL19V TIS43 ... 64p
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QL20W uA709C ... 45p •
WQ98G VN88AF ... DIS •
QL37S W005 ... 25p
QL38R W01 ... 28p
QL39N W02 ... 32p
QL40T W04 ... 35p
QL50E ZTX304 ... 28p •
QW03D Z80A-PIO ... £2.85
QR43W 2N4058 ... DIS

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QR46A 2N4062 ... DIS
QQ32K 2SC1307 ... DIS •
QW13P 2708 450ns ... £8.50 •
★QQ08J 2732 350ns ... £3.95
QQ09K 2764 350ns ... £2.30
YH88V 27128 ... £3.45
QY75S 27256 - 250ns ... £5.50
QR52G 3N140 ... £2.95 •
QX04E 4007UBE ... 28p
QW20W 4029BE ... 68p •
QW22Y 4032BE ... 74p
QW26D 4038BE ... DIS •
QX21X 4049UBE ... 38p •
★QW34M 4051BE ... 57p
QX23A 4066BE = FD1079DS ... 28p
QW50E 4085BE ... 69p •
QW52G 4089BE ... DIS •
QW61R 40103BE ... £2.25
QW62S 40104BE ... DIS
QY74R 41256 - 150ns ... £5.50
QY55K 4419BE ... £3.20
QW82D 4508BE ... £1.45
QW83E 4510BE ... 63p
QX31J 4511BE ... 63p
QW84F 4512BE ... 63p
QW85G 4514BE ... £1.20
QQ44X 4526BE ... 80p
UF24B 4527BE ... £1.35 •
QW89W 4532BE ... 74p
QW90X 4556BE ... 57p
UF22Y 4599BE ... £1.98 •
★UF36P 4702B ... £8.95
UF33L 6116 (446) 150ns ... £1.70
UF34M (6264-150ns) ... £4.50
★QQ02C 6502 ... £7.95
QX37S 7400 ... 25p
YF00A 74LS00 ... 25p
QX38R 7401 ... 25p
YF01B 74LS01 ... 25p
★QX39N 7402 ... 25p
★YF02C 74LS02 ... 25p
YF03D 74LS03 ... 25p
QX40T 7404 ... 28p
YF04E 74LS04 ... 25p
QX41U 7405 ... 28p
YF05F 74LS05 ... 25p
QX75S 7406 ... 58p •
QX76H 7407 ... 44p
YF07H 74LS09 ... 25p
YF08J 74LS10 ... 28p
QX44X 7411 ... 38p •
YF09K 74LS11 ... 25p
YF10L 74LS12 ... 25p
QX45Y 7413 ... 40p
YF11M 74LS13 ... 34p
QX46A 7414 ... 57p
YF13P 74LS15 ... 25p
YF14Q 74LS20 ... 25p
QX48C 7421 ... DIS
YF15R 74LS21 ... 25p
YF16S 74LS22 ... DIS •
QX80B 7425 ... 37p
QX81C 7426 ... 41p
YF17T 74LS26 ... DIS
QX49D 7427 ... 34p
YF18U 74LS27 ... 25p
QX50E 7430 ... 25p
YF20W 74LS30 ... 25p
YF21X 74LS32 ... 25p
★YF22Y 74LS33 ... 28p
YF23A 74LS37 ... 28p •
YF25C 74LS40 ... 25p
QX55K 7447A ... £1.80 •
QQ52G 74LS47 ... 86p
QQ53H 74LS48 ... 86p
YF27E 74LS51 ... 25p
YF28F 74LS54 ... DIS
QX56L 7470 ... 55p
QX57M 7472 ... 48p
QX58N 7473 ... 46p
YF30H 74LS73 ... 32p
YY83E 74ALS74 ... 92p •
YF31J 74LS74 ... 32p
QX60Q 7475 ... 55p
YF32K 74LS75 ... 43p
QX61R 7476 ... 46p
YF33L 74LS76 ... 32p
QX85G 7483 ... 97p
QX84U 7486 ... 40p
YF38R 74LS90 ... 46p
QX86T 7491 ... 74p •
QX87X 7492 ... 63p
YF39N 74LS92 ... 57p
YF40T 74LS93 ... 51p
QX87U 7496 ... 82p
QX71N 74107 ... DIS •
QX88V 74109 ... 69p
YF45Y 74LS112 ... 46p
QX72P 74118 ... £1.10
WH00A 74122 ... 57p
QQ54J 74LS122 ... 62p
WH01B 74123 ... 82p
YF48C 74LS123 ... 69p
YF49D 74LS125 ... 42p
YF50E 74LS126 ... 42p
WH03D 74132 ... 69p
YF51F 74LS132 ... 60p
YF52G 74LS138 ... 40p
YF53H 74LS138 ... 55p
YF54J 74LS139 ... 55p
WH05E 74141 ... 90p
WH06G 74145 ... £1.40 •

Page 297
YF55K 74LS145 ... £1.00
QX89W 74150 ... £1.48
YF56L 74LS151 ... 62p
YF57M 74LS153 ... 74p
YF59P 74LS155 ... 62p
YF61R 74LS157 ... 54p
YF62S 74LS158 ... 55p
WH09K 74160 ... £1.00
YF63T 74LS160 ... 78p •
YF66W 74LS163 ... 69p
YF67X 74LS164 ... 80p
YF68Y 74LS165 ... £1.08
YF69A 74LS166 ... £1.00
YF71N 74LS169 ... £1.00
YF72P 74LS170 ... £1.35
YF73Q 74LS173 ... 90p
WH11M 74174 ... £1.10
YF74R 74LS174 ... 69p
YF75S 74LS175 ... 69p
YF78K 74LS190 ... 86p
YF79L 74LS191 ... 63p
WH12N 74192 ... £2.20
YF80B 74LS192 ... 86p
YF81C 74LS193 ... 86p
WH13P 74194 ... 90p
YF82D 74LS194 ... 80p
YF83E 74LS195 ... 69p
YF84F 74LS196 ... 86p
YF85G 74LS197 ... 86p
YF86T 74LS221 ... 74p
YF88V 74LS241 ... 92p
YF90X 74LS243 ... 92p
★QQ56L 74LS244 ... 95p •
YF91Y 74LS245 ... £1.00
YF92A 74LS251 ... 62p
YF95D 74LS257 ... 62p
YF96E 74LS258 ... DIS
YF97F 74LS259 ... £1.00
YF99H 74LS266 ... 28p
YH00A 74LS273 ... 90p
YH01B 74LS279 ... 62p
YH02C 74LS283 ... 80p
YH06G 74LS298 ... DIS •
YH11M 74LS365 ... 48p
YH12N 74LS366 ... 48p
YH13P 74LS367 ... 48p
YH14Q 74LS368 ... 48p
YH15R 74LS373 ... 90p
YH16S 74LS374 ... 90p
YH18U 74LS377 ... £1.15
YH19V 74LS378 ... DIS
YH22Y 74LS393 ... 55p
YH23A 74LS395 ... £1.15
WH02C 74LS629 = 74LS124 ... £1.35
QQ63T 74LS684 ... £3.40
QY08J 74C925 ... £8.95
★UF13P 74HC4316 ... £2.75
YH38R 8038 CCPD ... £8.95
YH50E 8255A ... £3.65

Page 305
QX37S 7400 ... 25p
YF00A 74LS00 ... 25p
QX38R 7401 ... 25p
YF01B 74LS01 ... 25p
YF03D 74LS03 ... 25p
QX81C 7426 ... 41p
YF17T 74LS26 ... DIS
YF23A 74LS37 ... 28p •
YF08J 74LS10 ... 25p
YF10L 74LS12 ... 25p
YF14Q 74LS20 ... 25p
YF16S 74LS22 ... DIS •
YF25C 74LS40 ... 25p

Page 306
QX50E 7430 ... 25p
YF20W 74LS30 ... 25p
YF07H 74LS09 ... 25p
QX44X 7411 ... 38p •
YF09K 74LS11 ... 25p
YF13P 74LS15 ... 25p
QX48C 7421 ... DIS
YF15R 74LS21 ... 25p

Page 307
★QX39N 7402 ... 25p
★YF02C 74LS02 ... 25p
★YF22Y 74LS33 ... 28p
QX80B 7425 ... 37p
QX49D 7427 ... 34p
YF18U 74LS27 ... 25p
YF21X 74LS32 ... 25p

Page 308
QX84U 7486 ... 40p
YF52G 74LS136 ... 40p
YF99H 74LS266 ... 28p
YF27E 74LS51 ... 25p
QW50E 4085BE ... 69p •
YF28F 74LS54 ... DIS

Page 309
WH03D 74132 ... 69p
YF51F 74LS132 ... 60p
QX45Y 7413 ... 40p
YF11M 74LS13 ... 34p
QX46A 7414 ... 57p

Page 310
QX40T 7404 ... 28p
YF04E 74LS04 ... 25p
QX41U 7405 ... 28p
YF05F 74LS05 ... 25p
QX75S 7406 ... 58p •
YH12N 74LS366 ... 48p
YH14Q 74LS368 ... 48p
QX21X 4049UBE ... 38p •
QX76H 7407 ... 44p
YH11M 74LS365 ... 48p
YH13P 74LS367 ... 48p
YF49D 74LS125 ... 42p
YF50E 74LS126 ... 42p

Page 311
YF90X 74LS243 ... 92p
YF88V 74LS241 ... 92p
★QQ56L 74LS244 ... 95p •
YF91Y 74LS245 ... £1.00
QX04E 4007UBE ... 28p

Page 312
YF31J 74LS74 ... 32p
YY83E 74ALS74 ... 92p •
YF75S 74LS175 ... 69p
WH11M 74174 ... £1.10
YF74R 74LS174 ... 69p
YH19V 74LS378 ... DIS
YH00A 74LS273 ... 90p
YH16S 74LS374 ... 90p
YH18U 74LS377 ... £1.15

Page 313
QX56L 7470 ... 55p
QX57M 7472 ... 48p
QX58N 7473 ... 46p
YF30H 74LS73 ... 32p
QX61R 7476 ... 46p
YF33L 74LS76 ... 32p
QX71N 74107 ... DIS •
QX88V 74109 ... 69p
YF45Y 74LS112 ... 46p
YH01B 74LS279 ... 62p
QX72P 74118 ... £1.10

Page 314
YF73Q 74LS173 ... 90p
QX60Q 7475 ... 55p
YF32K 74LS75 ... 43p
QW82D 4508BE ... £1.45
YH15R 74LS373 ... 90p
YF97F 74LS259 ... £1.00
UF22Y 4599BE ... £1.98 •
YF72P 74LS170 ... £1.35

Page 315
WH13P 74194 ... 90p
YF82D 74LS194 ... 80p
YF83E 74LS195 ... 69p
YH23A 74LS395 ... £1.15
QW62S 40104BE ... DIS
QX87U 7496 ... 82p
QX86T 7491 ... 74p •
YF67X 74LS164 ... 80p
YF68Y 74LS165 ... £1.08
YF69A 74LS166 ... £1.00

Page 317
YF38R 74LS90 ... 46p
QX87X 7492 ... 63p
YF39N 74LS92 ... 57p
WH09K 74160 ... £1.00
YF63T 74LS160 ... 78p •
YF78K 74LS190 ... 86p
WH12N 74192 ... £2.20
YF80B 74LS192 ... 86p
YF84F 74LS196 ... 86p
QW83E 4510BE ... 63p
YF40T 74LS93 ... 51p
YF66W 74LS163 ... 69p
YF71N 74LS169 ... £1.00
YF79L 74LS191 ... 63p
YF81C 74LS193 ... 86p
YF85G 74LS197 ... 86p
YH22Y 74LS393 ... 55p
QQ44X 4526BE ... 80p
QW20W 4029BE ... 68p •

Page 318
QW61R 40103BE ... £2.25
QY55K 4419BE ... £3.20

Page 319
QW89W 4532BE ... 74p
YF54J 74LS139 ... 55p
YF59P 74LS155 ... 62p
QW90X 4556BE ... 57p
YF53H 74LS138 ... 56p
WH05E 74141 ... 90p
WH06G 74145 ... £1.40 •
YF55K 74LS145 ... £1.00

Page 320
QW85G 4514BE ... £1.20
QX55K 7447A ... £1.80 •
QQ52G 74LS47 ... 86p
QQ53H 74LS48 ... 86p
QX31J 4511BE ... 63p

Page 321
YF61R 74LS157 ... 54p
YF62S 74LS158 ... 55p
YF95D 74LS257 ... 62p
YF96E 74LS258 ... DIS
YH06G 74LS298 ... DIS •
YF57M 74LS153 ... 74p
YF56L 74LS151 ... 62p
YF92A 74LS251 ... 62p
QW84F 4512BE ... 63p
QX89W 74150 ... £1.48

Page 322
★QW34M 4051BE ... 57p

Page 323
QX23A 4066BE = FD1079DS ... 28p
★UF13P 74HC4316 ... £2.75

Page 324
QQ63T 74LS684 ... £3.40
QX85G 7483 ... 97p
YH02C 74LS283 ... 80p

Page 325
QW22Y 4032BE ... 74p
QW26D 4038BE ... DIS •
QW52G 4089BE ... DIS •
UF24B 4527BE ... £1.35 •

Page 326
WH00A 74122 ... 57p
QQ54J 74LS122 ... 62p
WH01B 74123 ... 82p
YF48C 74LS123 ... 69p
YF86T 74LS221 ... 74p

Page 327
WH02C 74LS629 = 74LS124 ... £1.35

Page 328
YY67X NE5539 ... £5.95 •

Page 329
RA74R DP-27GNB ... £4.50 •
QL20W uA709C ... 45p •

Page 331
QH35Q LH0042C ... £9.95
RA70M TL081CP ... 42p •

Page 335
BR02C 5W Amp PCB ... £2.20

Page 337
BR04E LM381 PCB ... £3.45
YY84F LM382 ... £1.98 •

Page 345
RA81C SAA1099 ... NYA

Page 350
QR58N ML927 ... £4.50 •

Page 353
YY73Q LM336Z ... £1.65

Page 355
FY90X Crystal 6.5536MHz ... £2.55 •
YY93B ICM7045IPI ... £16.95 •
QY08J 74C925 ... £8.95

Page 356
★UF36P 4702B ... £8.95

Page 361
YY75S ICL7660CPA ... £2.85

Page 362
XX04E 15V Supply PCB ... 98p

Page 364
YQ39N 0.1A Reg PSU PCB ... £1.60
YQ40T 0.5/1A Reg +V PS PCB ... £1.10
YQ41U 0.5/1A Reg -V PS PCB ... £1.10
YQ54J 0.5/1A Vareg Pos PCB ... £1.10
YQ55K 0.5/1A Vareg Neg PCB ... £1.10

Page 366
★QQ02C 6502 ... £7.95

Page 367
YH50E 8255A ... £3.65
QW03D Z80A-PIO ... £2.85

Page 370
UF33L 6116 (446) 150ns ... £1.70
UF34M (6264-150ns) ... £4.50
WQ42V MCM4027 250ns ... DIS

Page 371
QY74R 41256 - 150ns ... £5.50
QW13P 2708 450ns ... £8.50 •
★QQ08J 2732 350ns ... £3.95

Page 372
QQ09K 2764 350ns ... £2.30
YH88V 27128 ... £3.45
QY75S 27256 - 250ns ... £5.50

Page 374
YH38R 8038 CCPD ... £8.95

Page 378
YH59P ICL7109 ... £29.95 •

Page 381
FG52G Clip on T0220 ... 45p

Page 382
FG63T Dip Sink 40 pin ... DIS

Page 383
YB26D Heatsink 60DN ... DIS

SPEAKERS & SOUNDERS

Page 387
YM43W SC Xtd Freq Sterophn ... TEMP
YM44X SC V/cntrl Sterophon ... TEMP

Page 389
★WY15R 25W Squawker ... £5.45

Page 391
XY79L Ceiling Speaker ... £11.95

SWITCHES & RELAYS

Page 394
FH10L Std Toggle SPST ... 98p •
FH11M Std Toggle SPDT ... £1.10 •
FH12N Std Toggle DPDT ... £1.40 •

Page 395
★FT56L PCB R/A Rotary 1x12 ... £2.50
★FT57M PCB R/A Rotary 4x2 ... £2.50
★FT58N PCB R/A Rotary 2x5 ... £2.50
★FT59P PCB R/A Rotary 3x3 ... £2.50
FH57M Rotary Mains ... 88p

Page 400
★FH67X Latchswitch 2-pole ... 40p
★FH68Y Latchswitch 4-pole ... 60p
★FH69A Latchswitch 6-pole ... 80p
★BW11M Latchsoft 2-pole ... 55p
BW12N Latchsoft 4-pole ... DIS •
★FH72P Latchdummy ... 30p
★FH74R Mains Latchswitch ... £1.95
FL36P Rd Latchbutton Chrm ... DIS

Page 401
LB91Y Flasher Unit 2-Way ... DIS

Page 403
FX24B Open Relay 12V ... £4.95
FX26D 2p Sub-Min Relay 6V ... £2.95 •
FX27E 2p Sub-Min Relay 12V ... £2.95 •
FX30H 4p Sub-Min Relay 12V ... £3.50
FX50E Reed Relay 6 to 9V ... £2.70 •
FX51F Reed Relay 9 to 12V ... £2.70 •

Page 404
FX91Y Dil Reed Relay 2p12V ... DIS •
FX93B Dil Rd Rly 1p C/O12V ... £6.95 •

TEST GEAR

Page 405
HF19V Test Prod Black ... 65p •
HF20W Test Prod Red ... DIS •

Page 407
‡XB82D Crotech 3031 ... £225.00 •
‡XB83E Crotech 3132 ... £325.00 •
YK01B RF Frequency Meter ... £74.95 •

Page 408
YB81C Signal Generator ... £34.95

Page 410
★YJ09K Multimeter M-5050E ... £34.95

Page 411
★YJ78K Push Button DMM ... £39.95

Page 412
YJ79L Multi-purpose DMM ... £84.95

Page 413
★YK81C Fluke Meter Holster ... £12.95

Page 414
LH80B Clamp Meter ... £44.95

TOOLS

Page 416
YW92A Ratchet Socket Set ... DIS

Page 417
FY21X Std Lap-joint Cutter ... £2.95

Page 419
FT44X Cutter/Stripper Tool ... £3.95 •

Page 420
★FY45Y Adjust Spanner 150 ... £4.95
★FY46A Adjust Spanner 200 ... £5.50

Page 423
★YW65V Mini Mains Drill ... £15.95

Page 424
QY66W Metric Drill 1.4mm ... 36p •
FR01B Element Type CN ... £3.75
FR02C Handle Type CN ... 95p •

Page 425
FY95D Element CS 240V ... £3.75
FY68Y CS Kit SK5 ... £8.95
FY96E Element XS 240V ... £3.75
FY69A XS Kit SK6 ... £9.25
FR13P 12V Iron MLXS ... £9.96 •
FY97F Element MLXS 12V ... £3.75
FR15R Element MLX12 ... £3.95
★FT09K Finger Hook XS/MLXS ... 20p
RK33L Sponge ST4 ... 37p

Page 426
XG55K Solder Station TCSU1 ... £65.95
FT13P 30 Watt Iron CSTC ... £21.50
FT26D CSTC Element ... £12.38
FT28F 40 Watt Iron XSTC ... £21.50
FT27E XSTC Element ... £12.38
FT10L Sponge Tray TCSU-1 ... £1.73
XG57M Solder Station TCSUD ... £94.95
FT12N 50 Watt Iron XSD ... £21.95
FT29G XSD Element ... £12.38
FT11M Sponge Tray TCSU-D ... £1.15
FT08J Sponge TCSU-D ... 35p
FR03D Bit 102 ... £1.38
FT00A Bit 103 C ... £1.38
FR04E Bit 104 ... £1.38
FR05F Bit 106 ... £1.38
FR06G Bit 820 ... £1.38
FR07H Bit 821 ... £1.38
FR08J Bit 822 ... £1.38
FT01B Bit 202 C ... £1.38
FT02C Bit 302 C ... £1.38
FT03D Bit 10 C ... £1.38
FY84U Bit 1100 ... £1.38
FY85V Bit 1101 ... £1.38
FY86W Bit 1102 ... £1.38
FY87X Bit 1103 ... £1.38
FR30H Bit 1106 ... £1.38
FR16S Bit No. 50 ... £1.38
FR17T Bit No. 51 ... £1.38
FR18U Bit No. 52 ... £1.38
FT06G Bit 14A XS ... £4.89

Page 427
FV59P Sucksolder Tiplet ... £1.60 •
FR63T Desldr Washer Type 2 ... DIS
HY13P Desldr Nozzle Type 2 ... DIS

Page 430
YJ91Y Flex Rubber Sealant ... £2.80 •
FA81C Thermalbond Compound ... £13.95 •

WOUND COMPONENTS

Page 431
LB42V Dust Core Type 6 ... 28p •

Page 432
★WH25C Choke 0.22uH ... 48p
★WH27E Choke 0.47uH ... 48p
★WH29G Choke 1.0uH ... 48p
★WH30H Choke 1.5uH ... 48p
★WH31J Choke 2.2uH ... 48p
★WH32K Choke 3.3uH ... 48p
★WH33L Choke 4.7uH ... 48p
★WH34M Choke 6.8uH ... 48p
★WH35Q Choke 10.0uH ... 48p
★WH36P Choke 15.0uH ... 48p
★WH37S Choke 22.0uH ... 48p
★WH38R Choke 33.0uH ... 48p
★WH39N Choke 47.0uH ... 48p
★WH41U Choke 100uH ... 48p
★WH45Y Choke 470uH ... 48p
★WH47B Choke 1mH ... 48p

Page 434
WB06G Min Tr 6V ... £3.10
YJ50E Min Tr 0-6 0-6 1A ... £4.50
YJ51F Min Tr 0-6 0-6 2A ... £5.75
WB11M Min Tr 9V ... £4.20
WB10L Min Tr 12V ... £3.10
YK28F Tr 12V 0.5A ... £4.50
WB25C Tr 12V 1A ... £5.75
WB26D Tr 12V 2A ... £7.95 •
LY03D Tr 10VA 15V ... £4.25
WB15R Min Tr 15V ... £3.95 •
WB16S Min Tr 20V ... £3.95 •
WB20W Min Tr 24V ... £3.10

Page 435
YJ52G PCB Tr 0-6 0-6 0.5A ... £3.75
YJ53H PCB Tr 0-9 0-9 0.3A ... £3.75
YJ54J PCB Tr 0-12 x 2 .25A ... £3.75
YJ55K PCB Tr 0-15 x 2 0.5A ... £3.75
YK07H Tr 32-0-32 4A ... DIS
LW33L Tr 240V Isotran ... £4.50

Page 436
★YK33L Toroidal 24/100V ... £14.95

Page 437
★LK76H Stppr Mtr + Drvr Kit ... £15.95

MISCELLANEOUS

Page 439
FA84F Hearing Aid ... £29.95 •

Page 440
YX86T Flow Sensor ... £22.95 •
FT30H UHF Modulator UM1233 ... £4.95 •
BK66W UM1286 Modulator ... £7.95 •

AMENDMENTS TO 1986 CATALOGUE

PLEASE NOTE that the telephone number of MPS (Maplin Professional Supplies) is 0702-552961.

VHF/UHF DIPLEXER BW51F (Page 34). Diplexer UF20 has been replaced by Diplexer UF22 which is a masthead (fastening to mast by nylon strap) or surface mounting diplexer for combining UHF/TV and VHF/FM signal from antennæ downleads. Bandwidth: (FM) 87–108MHz; (UHF) 470–860MHz. Channel isolation: (FM) 22dB; (UHF) 38dB. Insertion loss: (FM and UHF) 0.5dB.

SNAP-TOGETHER PLASTIC BOXES YK48C - YK51F (Page 68). These boxes are now supplied with the base and top sections in cream, with the two end plates now in brown.

COILED MAINS CABLES BL72P (Page 77). The extended length of Stretchflex 6 Amp is 3 metres.

AXIAL LEAD ELECTROLYTIC FB53H (Page 90). The working voltage of this 100μF axial electrolytic is now 200V not 250V.

KINGDOM GAME CASSETTE (Page 104). This cassette game for the Atari has been listed as having the stock code KB97F, whereas it should be YG55K.

SCREENED CENTRONICS PLUG FJ61R (Page 121). The 36-way contacts are *not* of the IDC type as stated in the catalogue, but are solder terminals.

EDGE CONNECTOR FOOT (CLOSED) FL91Y (Page 122). The Edge Connector End Bracket (YR58N) available for the Card Frame Edge Connectors is an open ended (slotted) type. FL91Y is now also available and is a closed type, i.e. suitable for use as a pcb guide. Price 24p.

0.1in. SERIES PCB CONNECTORS RK65V – YW30H (Page 123). Please note that although these minicon latch connectors are described as having 0.1in. spacing, the actual spacing is 0.098in. or 2.5mm.

TELEPHONE WALL SOCKETS' LOCKING PLATE FV94C (Page 131). The Small Locking Plate is for use with the Surface Mounting Jack Units 2/4A and 2/6A, and not 1/4A and 1/6A.

PRINTER CABLES FG30H & FG31J (Page 133). These 26-way and 20-way ribbon cables have had their lengths quoted as 30cm, they should be 1m as before.

STRAIN RELIEF GROMMETS LR47B - LR50E (Page 143). Please note the amended sizes of these strain relief grommets. All dimensions in millimetres:

Type	B	A	D
3P-4	9.9	11.0	10.3
5M-3	11.7	12.7	11.0
6W-1	11.8	12.7	11.0
7K-2	19.6	22.2	19.0

GRAPHIC AND PANEL TRANSFERS (Page 144). A new range of transfer sheets are available as follows: 2.5mm letters and numbers in black or white; XH73Q Transfer 2.5 Black, XH74R Transfer 2.5 White. 3.5mm numbers only in Black or White; XH75S Transfer 3.5 Black, XH76H Transfer 3.5 White. 4.2mm letters and numbers in black or white; XH77J Transfer 4.2 Black, XH78K Transfer 4.2 White. Sizes 2.5 and 3.5 are in medium typeface, size 4.2 is in light typeface.

Two new graphic panel sheets are available: XH71N Graphic Sheet Black, XH72P Graphic Sheet White. All of the above priced at 45p per sheet.

SPINDLE COUPLER RX29G (Page 184). The length of this brass coupler is 15mm and not 22.5mm.

ULTRA-BRIGHT RED LEDs QY84F, QY85G (Page 199). It is the anode and not the cathode that is denoted by the flat of the package and the shorter of the two leads.

5x7 LED ARRAY FT61R (Page 201). The dimensions of the 5x7 LED array have been erroneously omitted from the catalogue. The dimensions of the array are 53 x 38 x 8.5mm deep excluding pins.

PCB TRANSFERS (Page 222). A new range of PCB transfers are now available. There are 14 sheets in the range, some will replace existing stock, others are completely new. Old Transfer Sheets 1 (HX45Y), 4 (HX48C), 8 (HX65V), 9 (HX66W) are discontinued. To replace them new transfer sheet numbers have been allocated thus: Transfer Sheet 1 = XH66W, Transfer Sheet 4 = XH67X, Transfer Sheet 8 = XH68Y, Transfer Sheet 9 = XH69A and a new Transfer Sheet 14 = XH70M. The Transfer Kit (HX44X) now contains all 14 sheets. A brief run-down of each sheet follows:

Sheet 1: 2176 circle pads 1.6 x 0.38mm.
Sheet 2: 20 straight lines 170 x 1.61mm.
Sheet 3: 260 circle pads 2.54 x 0.45mm.
Sheet 4: 351 circle pads 3.6 x 0.79mm.
Sheet 5: 210 transistor pad sets, each circular pad is 2.4 x 0.32mm.
Sheet 6: 45 rows of 16 pad DIL IC's spaced at 0.3 x 0.1 inch, each circular pad is 2.16 x 0.38mm.
Sheet 7: 90° bend lines, fifteen bends 2.25mm wide, twelve bends 3.0mm wide.
Sheet 8: 8 rows of 68 pairs of pads with 'between-pad' tracks, pads are 2.54mm diameter.
Sheet 9: 77 sets of 8 pads 1.6 x 0.34mm with through tracks.
Sheet 10: 0.1 inch spaced edge connector fingers, 12 rows of 32 fingers. Sheet 11: 21 straight lines 170 x 0.65mm.
Sheet 12: 90° bend lines, 24 bends 0.65mm thick. 24 bends 1.61mm thick.
Sheet 13: 33 sets of DIL IC pads with leads and offset holes.
Sheet 14: 7 straight lines 170 x 3.0mm, 8 straight lines 170 x 2.25mm.
XH67X to XH70M are priced at 45p each.

STEREO SYNTH BOOK XF11M (Page 253). Please note that details of metalwork and cabinet are no longer available and are not shown in the book.

THERMAL FUSE RA18U (Page 274). Note that the Thermal Fuse 169C is no longer being manufactured. It is replaced with type 167C which for most purposes is suitable for the same applications as type 169C.

REPLACEMENT STYLI (Page 279). The prices for the styli shown on pages 279 and 280 of the 1986 catalogue have been omitted. For prices refer to a copy of the current price list.

CASSETTE CARE KIT BK28F (Page 282). Please note that the cleaning head of the cassette in this Cassette Care Kit no longer includes a demagnetiser.

ALL ROTARY POTENTIOMETERS (Page 290, 291). The shaft length of all types (single, single with switch and dual gang) is 50 ±0.5mm minimum. Also the thread length of the single and dual gang is 9mm and not 7mm. Note that the body length of the switched types is 22mm not 20.8mm, and that the switch rating is 4A at 250V AC and not 2A.

4702B PROGRAMMABLE BIT RATE GENERATOR (Page 296). The order code for this device is UF36P, *not* UF35Q.

74HC4316 UF13P (Page 297). In the semiconductors index on page 297, the 74HC4316 IC has been listed as being described on page 328, it is in fact to be found on page 323.

THYRISTOR BT149M YH95D (Page 302). Replacement device TAG 84 may be supplied, please note that the anode and cathode are reverse of that shown for the BT149M.

BT149F YH94C (Page 302). Please note that thyristor BT149F is now no longer in manufacture, and has been replaced by this device BT149B. The specifications are identical except that PIV is rated at 200V instead of 50V. The specifications are: Case T092f, PIV 200V, $I_{T\ (rms)}$ 1A, $I_{T\ (av)}$ 0.64A, $V_{GT\ (max)}$ 0.8V, $I_{GT\ (max)}$ 0.2mA, $I_{H\ (max)}$ 5mA.

7402, 74LS02, 74HC02 AND 4001BE, 4001UBE QX39N - QL03D (Page 307). The captions for the pin-out diagram of the TTL devices have been accidentally transposed with those for the CMOS diagram.

74LS244, 74HC244, 74HCT244 OCTAL BUFFERS QQ56L, UB65V, UB66W (Page 311). In the pin-outs diagram for these octal buffers note that the control input via pin 19 should have an inverting input symbol at the control input buffer.

4040BE, 74HC4040, 4060BE, 74HC4060 RIPPLE COUNTERS (Page 318). The pin-outs diagrams for these ICs have the wrong captions. The 4060BE and 74HC4060 devices are actually the 14-stage ripple counter with oscillator, and the 4040BE and 74HC4040 devices are the 12-stage ripple counter.

4051BE, 74HC4051, 74HC4351 (Page 322). The captions on the pin-out diagrams for these 1-pole 8-way analogue switches should be transposed.

AUDIO POWER AMP IC's QH39N, WQ33L, WQ66W, WQ67X, YY70M (Pages 335 – 337). Please note that although these devices are described as having heatsink mounting tabs that do not need to be electrically insulated from a chassis, this is on the condition that the chassis is the same potential as the most negative supply pin of the IC. The mounting tab is connected to the IC substrate, and it is required that this be equal to or up to 0.6V more negative than the negative supply pin voltage. If chassis = IC 'ground' potential, then the omission of an insulating kit will satisfy this condition, but do not overlook the possibility of earth related instability problems. If you intend to use a split-rail power supply, you *must not* bolt the tab direct to chassis without an insulating kit!

TEMPERATURE COMPENSATED TWO STEP LEAD ACID BATTERY CHARGER (Page 364). In the circuit diagram a value is missing for R14, it should be 4k7.

6502 MICROPROCESSOR QQ02C (Page 366). The device being supplied is the 6502A.

2732 EPROM QQ08J (Page 371). The programming voltage V_{pp} at pin 20 of this IC should be 21 volts, not 25 volts.

MID-RANGE SPEAKER WY15R (Page 389). This mid-range unit is for use in systems up to 25W and not 40W.

RIGHT-ANGLED PCB ROTARY SWITCHES FT56L, FT57M, FT58N & FT59P (Page 395). The specifications of these switches should be amended as follows – FT56L is 1-pole 12-ways, FT57M is 4-pole 2-ways (4-pole changeover), FT58N is 2-pole 5-ways, and FT59P is 3-pole 3-ways.

PUSH BUTTON LATCHSWITCHES FH67X – FH74R (Page 400). The operation of these switches has changed slightly. For push-on/push-off locking action the switches operate as before, but for momentary push-on non-locking, or for interlocking action with the use of a latchbracket, the locking/retainer clip must be replaced with the nylon retainer provided with each switch, otherwise the moving portion containing the moving contacts will entirely withdraw from the switch body. This may be useful for contact cleaning purposes.

ELECTRONIC MULTIMETER M-5050E YJ09K (Page 410). In that part of the description relating to measurements from centre zero scale, it should read 'In addition the meter pointer can be positioned to the centre of the scale so that + and – DC readings may be taken,'. In the table, the line 'DC volts' etc. should be followed with 'From centre zero ±f.s.d; ±150mV, ±0.6, ±1.5, ±6, ±15, ±60, ±150, ±600'.

PUSH BUTTON DIGITAL MULTIMETER M6000 YJ78K (Page 411). Note that the table of resistance ranges has been erroneously omitted from the catalogue. The resistance ranges for the M6000 are as follows, written as 'Range, Resolution, Accuracy':
200Ω, 100mΩ, ±(0.5% of rdg + 1d); 2kΩ, 1Ω, ±(0.3% of rdg + 1d); 20kΩ, 10Ω, ±(0.3% of rdg + 1d); 200kΩ, 100Ω, ±(0.3% of rdg + 1d); 20MΩ, 10kΩ, ±(1.5% of rdg + 1d). Max open circuit voltage drop across probes, <3V. Overload protected to 250V DC or rms AC.

FLUKE METER HOLSTER YK81C (Page 413). This holster no longer has a neck strap.

ADJUSTABLE SPANNERS FY45Y, FY46A (Page 420). The dimensions of these spanners have changed slightly. The small adjustable is now 150mm in length with a maximum jaw opening of 19mm, and the large adjustable has an overall length of 200mm with a maximum opening of 24mm.

BOX SPANNERS FY41U & FY42V (Page 420). Please note that these box spanners are no longer 4BA and 6BA respectively as stated in the catalogue, but are now metric M4 and M2.5.

SATURN MAINS DRILL YW65V (Page 423). Please note that the specifications in the catalogue are not quite correct. The mains supply voltage range is actually 220 – 250V, the off-load speed is 12,000 r.p.m, and the 3-jaw pin chuck has a maximum capacity of 2.9mm and not ⅛in.

SOLDERING IRON HOOK FT09K (Page 425). This clip-on hook/finger guard will fit the XS and MLXS soldering irons only, and not the CS type.

RF CHOKES WH25C - WH47B (Page 432). Please note that due to a change of supplier these RF chokes will be supplied with colour code bands to denote the value, as stocks of the black bodied types become exhausted. The colour codes operate in the same way as the resistor 3-band colour codes, except that the unit value is the microhenry and not the ohm. For example: Red, Red, Silver = 20 + 2 x 0.01 μH; Brown, Black, Gold = 10 + 0 x 0.1 μH; Orange, Orange, Gold = 30 + 3 x 0.1 μH; Brown, Green, Black = 10 + 5 x 1 μH; Brown, Black, Brown = 10 + 1 x 10 μH; Brown, Black, Red = 10 + 2 x 100 μH; etc. A fourth band is always silver.

TOROIDAL TRANSFORMER YK33L (Page 436). In the case of the toroidal transformer with 0–24, 0–24, 0–100V secondaries, the wire colour codes for the 100V secondary have been omitted. They are: start of winding, Black. Finish of winding, White.

TRANSFORMER KITS (Page 436). The turns ratio quoted for the 20, 50, and 100 watt transformer kits are in the wrong order. Correct turns/volts ratios are as follows:-
20VA – 6.04 turns per volt, +1% for each multiple of 10VA loading.
50VA – 4.8 turns per volt, +1% for each multiple of 10VA loading.
100VA – 4.16 turns per volt, +1% for each multiple of 10VA loading.

STEPPER MOTOR KIT LK76H (Page 437). This kit now includes a pcb, GD14Q.

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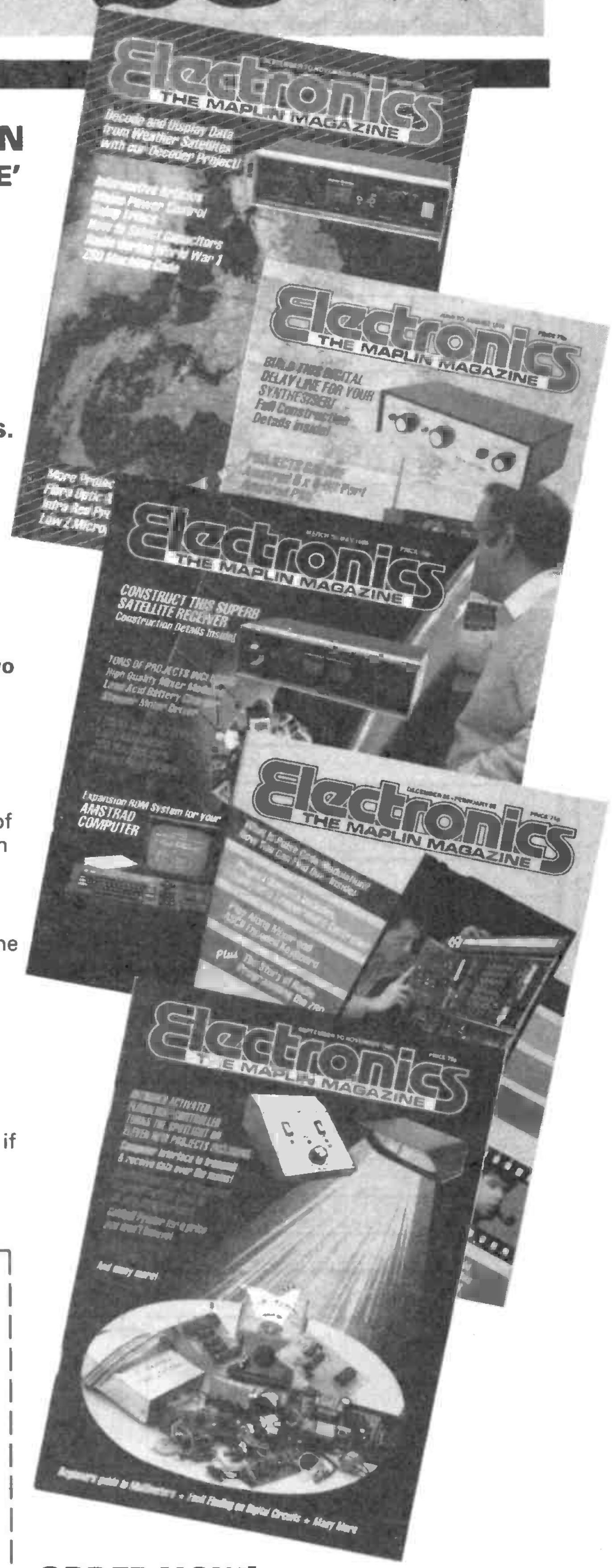

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The Fibre Optic Audio Link serves as an interesting alternative to the traditional pair of wires carrying audio signals from one point to another. Fibre optics are used extensively these days in the fields of communications, TV and Radio, computer data transmission, medicine and even motor vehicles – to name but a few!

Optical Fibre

The light guide itself may consist of many strands of fine, drawn, glass fibres or a single, solid fibre made from polymethyl-methacrylate and enclosed with a polymer cladding and protective sheath. Unlike cables and wires, the fibres do not carry an electric current, but instead reflect light waves along their length.

Therefore electrical signals must be converted into light and sent along the guide. At the far end, the light waves are re-converted back into electrical signals, closely resembling the original. Unfortunately, fibres exhibit the luminal equivalent of resistance which increases proportionately with length and limits the maximum length of guide which can be used in any particular system. Attenuation effects can be measured at 1.2dB per metre, or approximately a 20% reduction with the light guide recommended for use with this project (XR56L).

The maximum useable range of these modules is limited to 20 metres (65 feet approx) provided that the fibre ends are 'polished' for optimum light transfer.

Characteristics

Frequency Response	– 50Hz to 20kHz (–6dB) Flat from 150Hz to 3kHz
Max I/P and O/P Levels	– 0dB (775mV rms) @ 1kHz
Minimum I/P Level	– –28dB (30mV rms) for rated O/P
Noise Level	– 10mV
Signal to Noise Ratio	– 35dB
T.H.D. @ 1kHz	– 1.0%
P.L.L. Carrier Frequency	– 95 to 120kHz (110kHz nom)
PSU (Tx)	4.8 to 6V DC @ 30 to 50mA (Average) Recommended, +5V DC @ 38mA
PSU (Rx)	4.8 to 12V DC @ 5 to 12mA Recommended, +9V DC @ 8mA

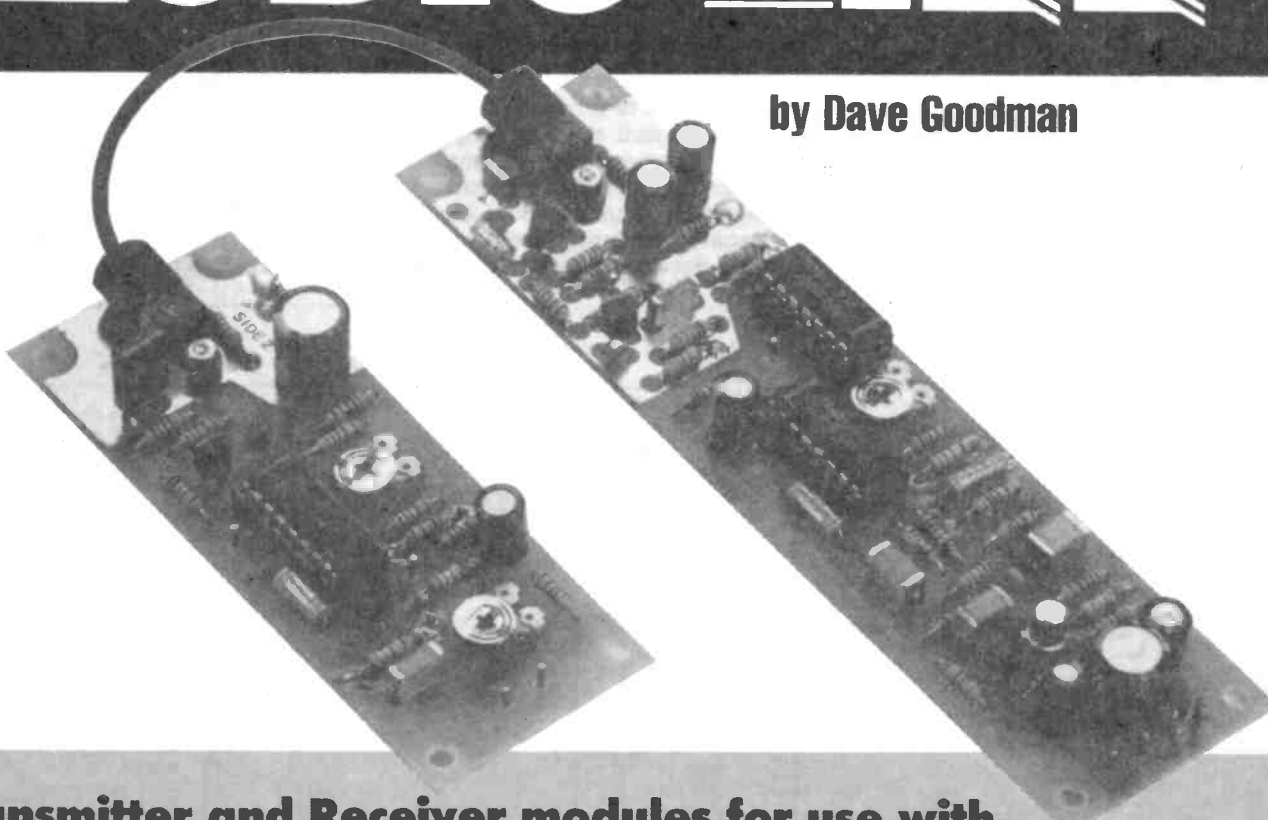
All specifications apply to the prototypes and may vary between different modules. Use recommended supplies for optimum performance.

Fibre Optic Couplers

A simple system for connecting the light guide to each module is shown in Figure 1. Both Emitter and Detector units contain an Infra Red PIN Diode and lens contained in the FLCS housing. Prepared light guide ends are inserted through the cap, which is then screwed onto the housing, up to finger tightness. The cap contains a compression ring which grips the light guide tightly and prevents it from being easily pulled out, see Figure 2.

FIBRE OPTIC AUDIO LINK

by Dave Goodman



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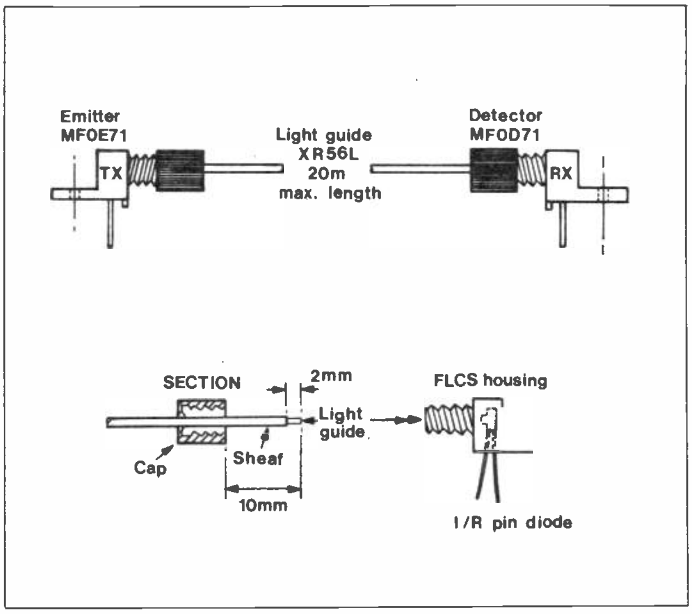


Figure 1. Connecting Light Guide.

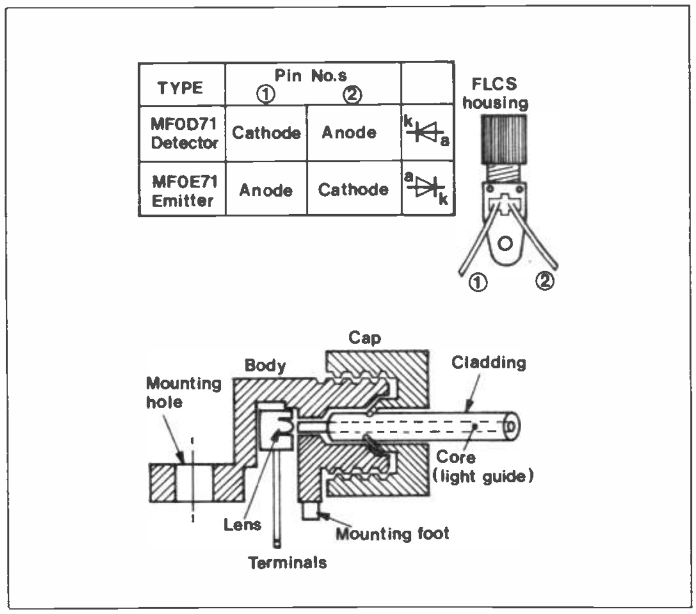


Figure 2. Emitter and Detector Pin-out and Construction.

Preparation of Light Guide

Both FLCS couplers are designed for use with 1000 micron (1mm) core plastic fibre, which can be found in our catalogue or parts list (XR56L). Remove a short piece of sleeving from one end of the light guide, as shown in Figure 3, by gently cutting around the circumference, or by using 18 gauge wire strippers. Great care should be taken when cutting through the covering sheath, to prevent scoring the fibre core inside!

Remove the end covering and cleanly cut the fibre core two millimetres long. Try to make a single, straight cut thus keeping the end as smooth as possible, this being important for maximum light transfer to the couplers. Use a sharp knife for this. Very fine emery paper, or the striking edge of a matchbox (but not glasspaper types!) can be gently rubbed, *squarely* across the cut fibre end to polish the surface. Liquid metal polish also helps to develop a smooth finish and could also be used to finish off.

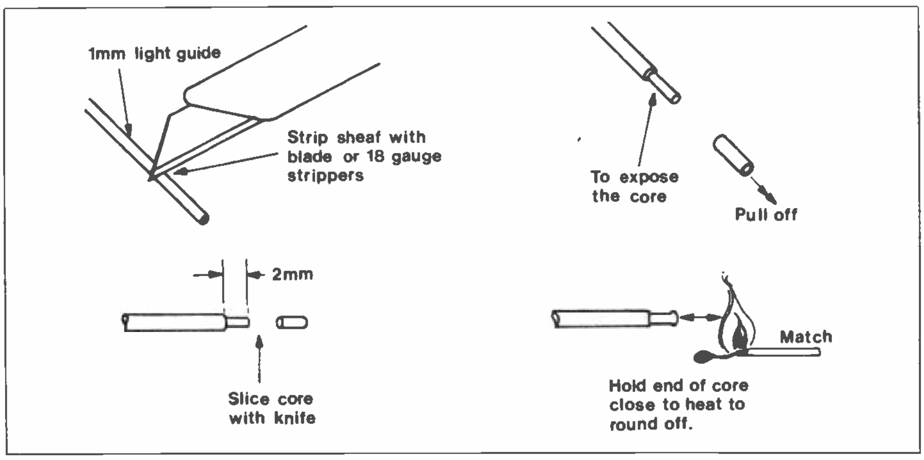


Figure 3. Preparing the Light Guide.

Alternatively, the cut fibre end could be placed close to a naked flame for a few seconds until the end begins to round off. Excessive heat will melt the fibre completely, and this should be avoided. This latter method has the advantage of producing a near perfect finish and develops a 'lens' in the fibre – ideal for good light transfer. Whichever method is employed, aim for a mirror-like finish on the fibre end if maximum range is required.

Circuit Description

The system has been developed for use with audio signals of a reasonably

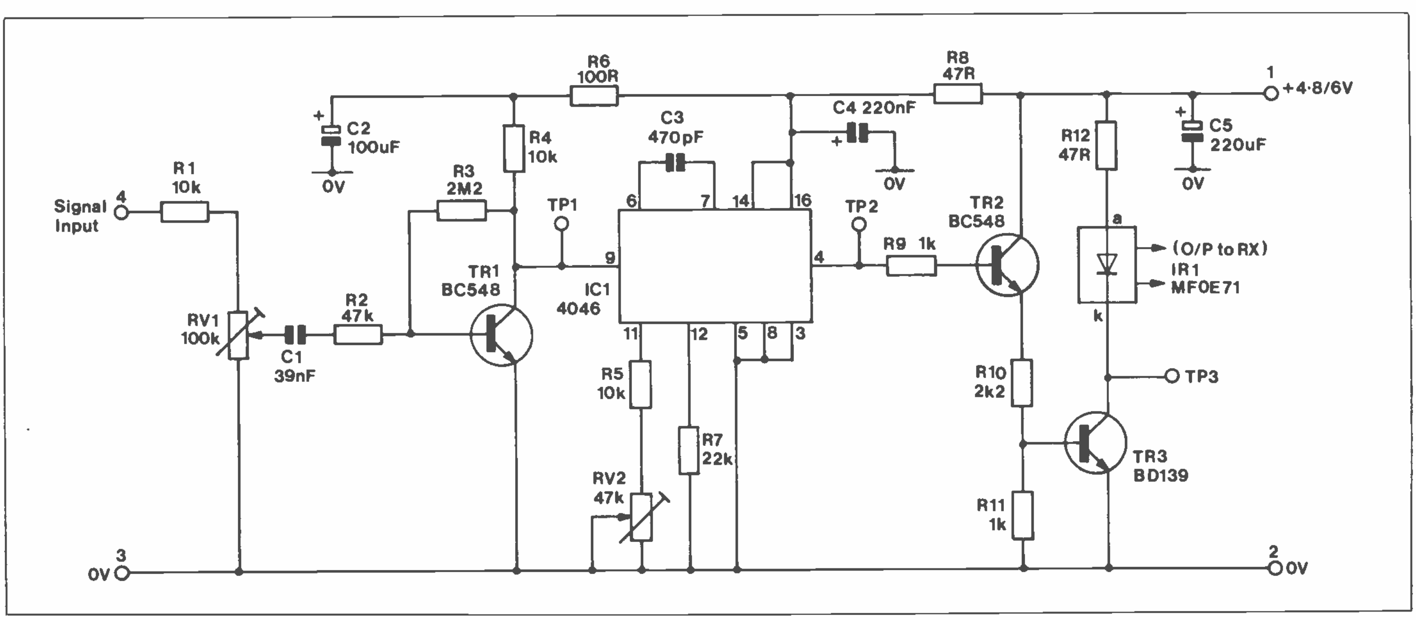


Figure 4. Transmitter Circuit.

high level to begin with. High impedance microphones could be coupled directly to the input of the Tx module, as could cassette or amplifier line outputs.

TR1 on the transmitter module (Figure 4) pre-amplifies the incoming signal and RV1 is adjusted to suit the input signal level from Pin 4. Because a low voltage supply is used here (4.8 – 6V) the input range dynamics are somewhat limited and C1 has been chosen to roll off low frequency signals, which would otherwise produce distortion from the receiver output.

The low power, CMOS, Phase Locked Loop device, IC1, is used as a voltage controlled oscillator, operating at a centre frequency of 110kHz. Audio signals from TR1 collector swing the VCO each side of the 110kHz centre frequency, thus frequency modulating the 'carrier' signal. At test point TP2, a 5V square wave representing the modulated carrier is available, this being buffered by an emitter follower TR2 to the current switch TR3.

The Light Guide Emitter MF0E71 is an infra-red PIN diode, which is switched on and off, at the carrier frequency, by transistor TR3. R12, of 47Ω, limits current through the PIN diode at an average 40mA. The diode is capable of taking up to 100mA, made possible by reducing the value of R12 down to 22Ω or so, but power supply demands are then greater. If using a 4 cell nicad pack (5.2V) then the lower 40mA current drain is preferable for longer battery life. The advantage of increasing current through the PIN-diode comes from an increased light output; the signal to noise ratio is improved and greater transmission distances are possible, although by only a few metres, but this is only practicable given the appropriate power supply.

Hence R12 is here optimised at 47Ω for a 40mA collector current. Timing components C3 and R7 determine the VCO centre frequency and RV2, R5 allow a 25kHz adjustment approximately over a 95kHz to 120kHz range. Light transmitted from the MF0E71 is in the infra-red band at a peak, spectral wavelength of 820nM; the full bandwidth extends from 400 to 1000nM (nano-metres) with an 80% reduction in output power.

Receiver

Audio signals in the form of frequency modulated, infra-red light now have to be amplified, detected, demodulated and filtered to reconstitute the original waveform. A matching infra-red detector, MF0D71, is used in reversed-bias mode with current limiting resistor R1 (see Figure 5). Output current to TR1 is extremely small, so the front pre-amplifing stages have a very high gain. TR1 and TR2 are configured as a DC coupled amplifier, self biased by R2. C3 is the main AC feedback component, and this stage has a frequency response of up to 0.5MHz.

With such a high gain, wide band pre-amplifier, noise levels are increased,

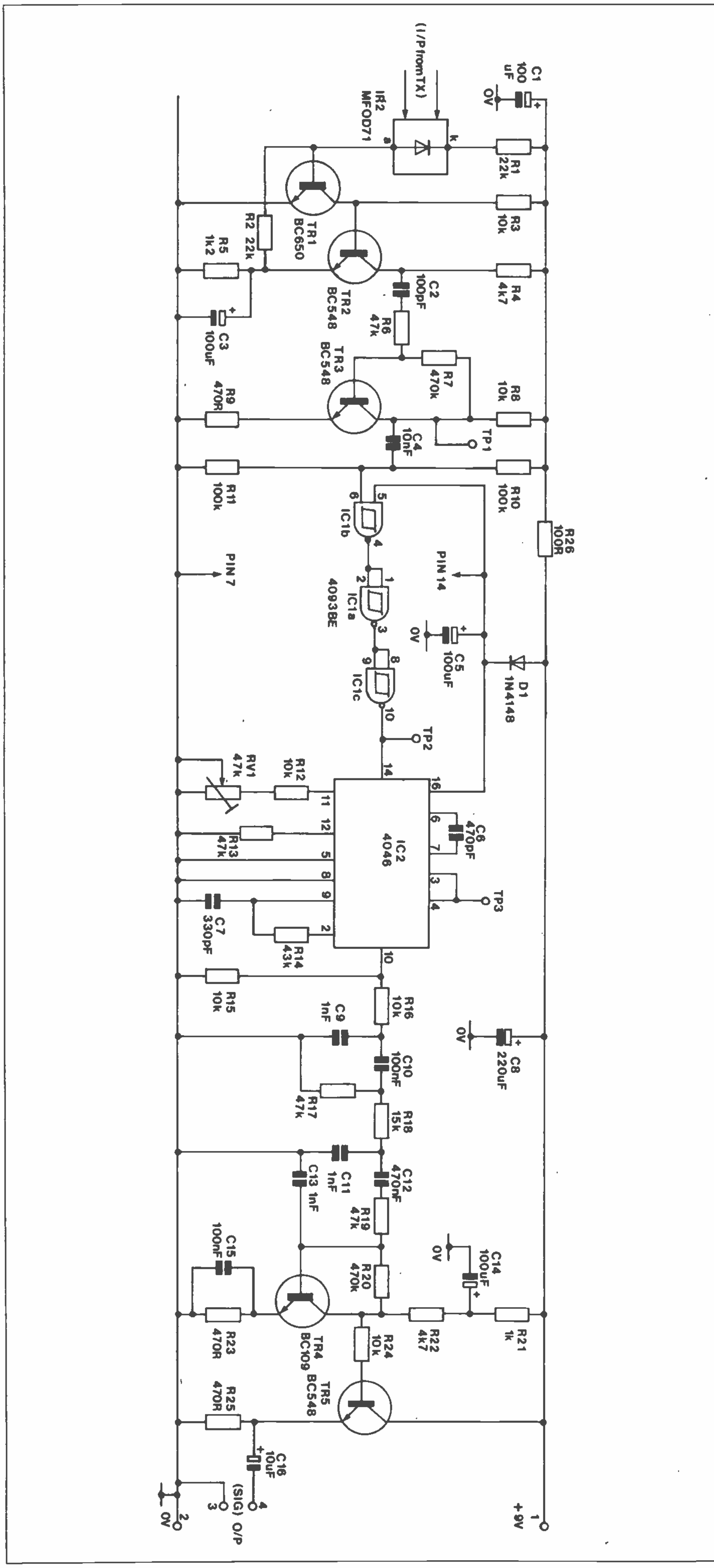


Figure 5. Receiver Circuit.

originating from the optical fibre itself, in addition to self-generated noise – therefore buffering amplifier TR3 is coupled by C2 and R6, which filter out much of the lower frequency noise signals. IC1 is a schmitt trigger-NAND package used for 'cleaning up' the pre-amplified carrier signal, and the supply for this and IC2 is separated from the main supply rail by reversed supply protection diode D1 and C5.

The carrier square wave is made available at TP2, which is also one of the Phase Locked Loop's phase comparator inputs. The comparator output controls a voltage controlled oscillator, via R14 and C7 which filter out harmonics and maintain a 90° phase shift at the VCO centre frequency. VCO timing components are C6, R13 and RV1. With no carrier signal applied to the receiver input, the VCO is free running at 110kHz; this frequency can be varied by RV1. The VCO square wave output from pin 4 feeds back to a second phase comparator input at pin 3.

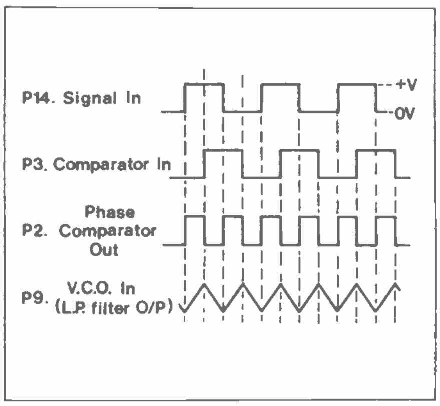


Figure 6. Waveforms.

With a 110kHz carrier signal present on Pin 14, a digital error signal is output to the filter and VCO input Pin 9 (Figure 6). Signals well outside of the carrier frequency do not produce the error signal, and the loop (VCO-comparator) does not 'lock on'. The values of R14 and C7, therefore, are important and determine the loop capture range and bandwidth.

The low pass filter output is taken from Pin 10, which is a buffered output from Pin 9. R15 serves the internal FET buffer source load and R16, C9 form a first stage filter for the audio and carrier output. A further two stages of low pass and high pass filters are necessary to reconstitute the audio waveforms and remove much of the 110kHz carrier signal. TR4 amplifies the filtered signal and TR5, emitter follower, buffers the signal for a low impedance output at Pin 4.

Transmitter Construction

For information regarding component identification, assembly methods and soldering, please refer to the 'Constructors Guide' supplied with this kit (if you do not intend to purchase the complete kit then see the Parts List for the order code of the Constructor's Guide, price 25p). Begin construction by referring to Figure 7 and inserting seven vero pins, pins 1 to 4 and TP1 to 3. Pin 2 (0V – PSU) should be soldered to both side 1 and side 2 of the pcb in order to connect the screening earth plane on both sides. Referring to Figure 8, mount the emitter coupler MF0E71 on side 2.

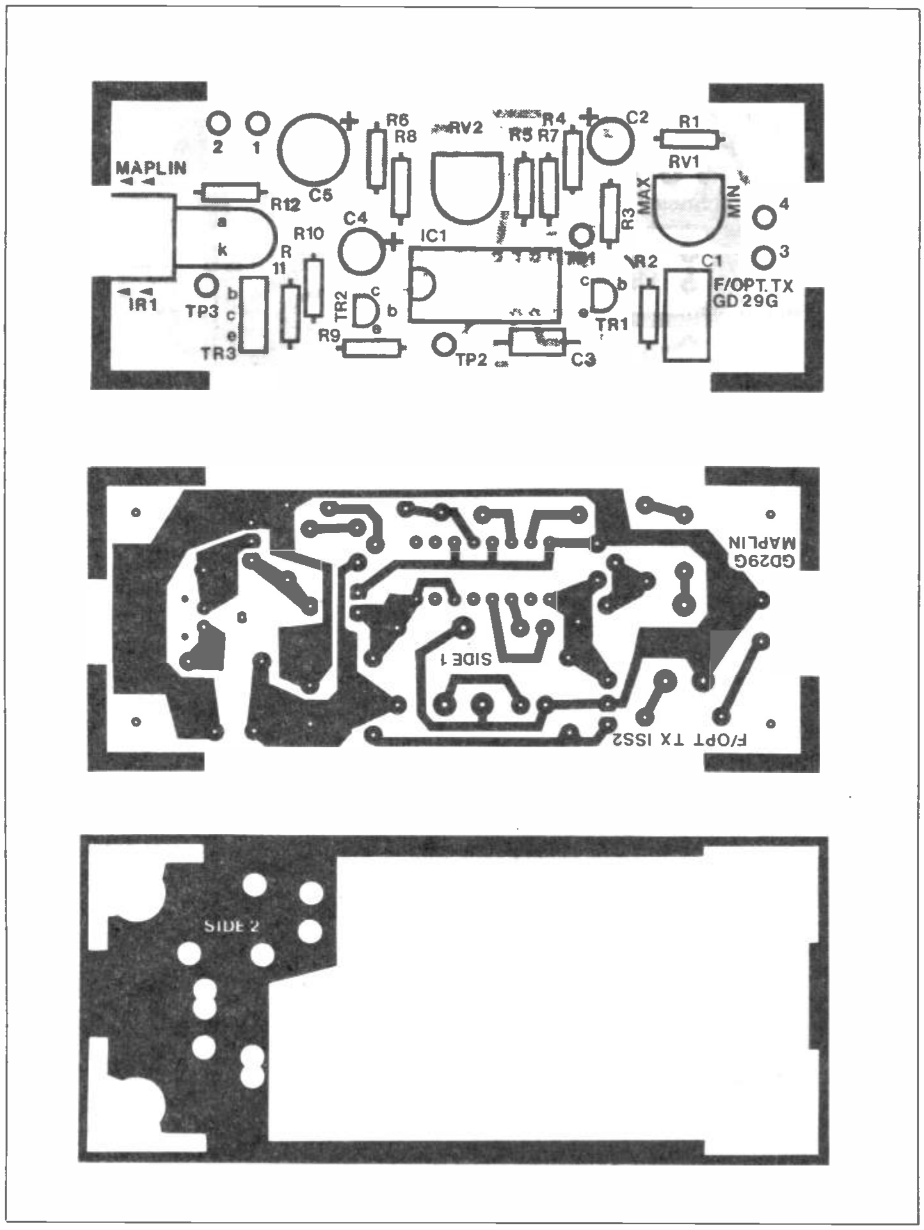


Figure 7. Transmitter Track and Legend.

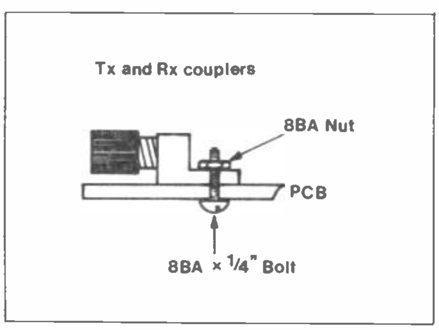


Figure 8. Coupler Mounting.

Ensure both terminal leads pass completely through the pcb and both locating pegs enter their holes. Insert an 8BA x ¼in bolt through the tab provided and tighten down with an 8BA nut. *Do not* overtighten, as excessive force is not necessary and the plastic body may be damaged.

Refer to Figure 9 and fit power transistor TR3 (BD139). This device must be fitted correctly, with the metal heatsink mounting surface facing toward TP3 and the front edge of the pcb. Push all three leads down into the holes leaving a clearance of 3mm between pcb and the base of the package of TR3. Solder all these five leads in place and cut off excess ends.

Now identify and insert resistors R1 to R12, and capacitors C1 to C5. When fitting C1, take care not to damage the leads on each end of the device, as they are very easily broken off. Note polarity markings on electrolytic and tantalum capacitors and insert correctly (consult the Constructor's Guide if in difficulty). Solder these components and again, remove excess wire ends.

Mount the 16-pin IC socket and TR1, TR2. Bend a few legs of the socket over beneath the pcb to prevent it from falling out. Mount RV1 and RV2 – note that their values are not identical so be sure to put the correct value in the required position – finally solder all remaining component leads, remove excess wire ends and clean the pcb tracks, before inserting the P.L.L. device, IC1.

Transmitter Testing

A few checks can be made at this stage to ensure that the transmitter module is operating properly. Connect a 5V power source to Pin 2 (0V) and +Ve via a milliammeter to Pin 1. Set the wiper of RV2 to approximately half travel, and turn on the power source.

A current reading of approximately 30 to 40mA should be obtained. Any readings well outside of this may well point to a fault, unless the test meter is not connected properly or the wrong range selected; double check and repeat the procedure. If the error is genuine and a frequency counter or oscilloscope is available, connect either to test point TP2. Adjust RV2 for 110kHz, which will be some 45° displacement of the wiper of RV2 from its central position. The output stage can be monitored with a 'scope on

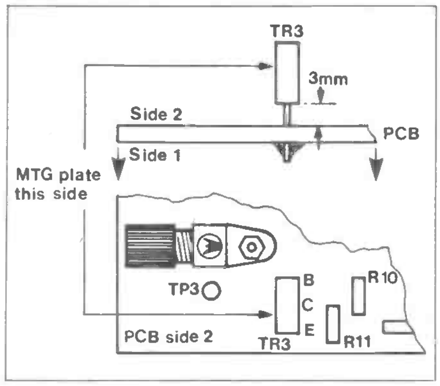


Figure 9. Mounting TR3.

TP3, where a 9μs square wave of 3.25V amplitude is present. The lower edge of the square wave will be approximately 0.7V above 0V, and the upper edge at +4V.

If this waveform is not present and the VCO *is* running, then it is possible that the actual infra-red coupler devices could have been mixed up! Both devices look the same, except for an identification code printed along one side of the body housing – if it turns out to be the wrong device then swop it for the other and repeat the testing procedure.

With testing completed switch off the power source and continue with the Receiver.

Receiver Construction

In similar fashion to the transmitter module, refer to Figure 10 and insert 7 vero pins in the holes marked with white rings, and mount the infra-red detector coupler, as Figure 8. Identify and insert resistors R1 to R26, then solder their leads on side 1 of the pcb. Three of these resistors, R5, R9 and R11, additionally have one of their leads soldered on side 2, the component side, of the pcb, see Figure 11. Do not omit this as it extends the earth plane to 0V.

Insert diode D1, taking care *not* to damage the glass case, and semiconductors TR1 to TR5. TR2, TR3 and TR5 are identical devices and look similar to TR1, but *must not* be mixed as TR1 has a different leadout configuration. TR4 has a silver, metal case with a marker tab against the emitter lead; push these devices down to within 3mm clearance between pcb and base of the package.

Next, fit capacitors C1 to C16, noting polarity markings on electrolytic types.

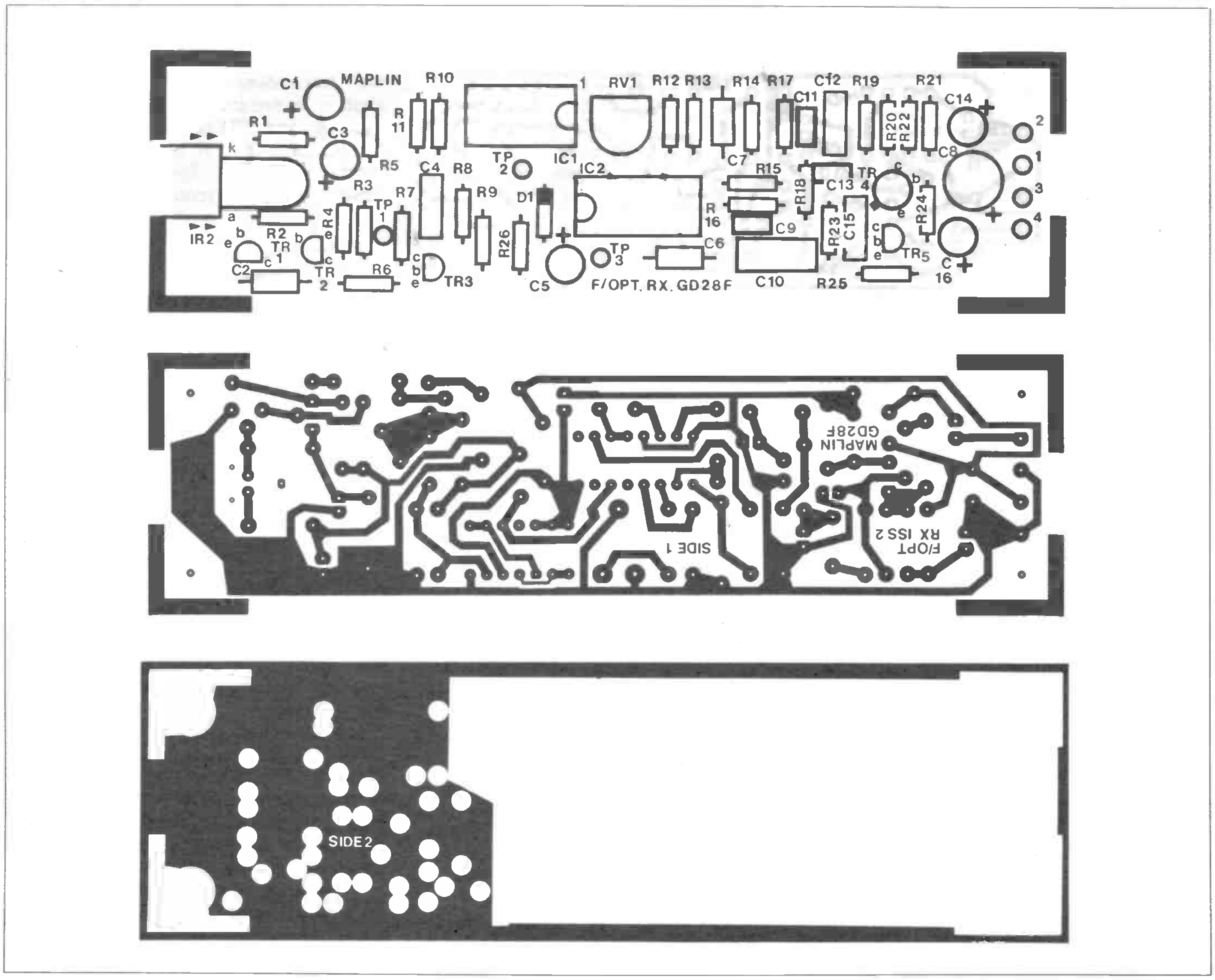


Figure 10. Receiver Track and Legend.

Poly-layer capacitors should be handled carefully to avoid their leads breaking off, as this is easily done.

Mount preset RV1 and a 14-pin IC socket at IC1 position, and 16-pin socket at IC2 position. Solder all components and leads and remove excess wire ends before inserting IC1 and IC2 into their sockets.

A careful inspection of all resistors and track areas is advisable at this stage, and cleaning side 1 of the pcb is recommended.

Receiver Testing

Basic checks and adjustments can now be made on the receiver module. Connect a 9V power source with 0V to Pin 2 and +V via a milliammeter to Pin 1. A PP6 9V battery pack is useful for this. Set the wiper of RV1 to approximately half travel, and turn on the power source.

A current reading of 7 to 9mA should be obtained. With a frequency counter or oscilloscope, monitor the test point TP3, and adjust RV1 for a frequency of approximately 110kHz. The exact setting is not that critical, since the PLL will lock onto the transmitter signal (once detected) and pull the VCO within range. If monitoring TP3 with a 'scope, then a square wave form (≃50% duty cycle) should be evident of at least 8V in amplitude with a 9μs period. Check that TP2 is at logic 0 (0V) whilst no carrier signal is present, and TP1 is at approximately +2 to +4V.

Monitoring the audio output, Pin 4, may produce a certain amount of carrier

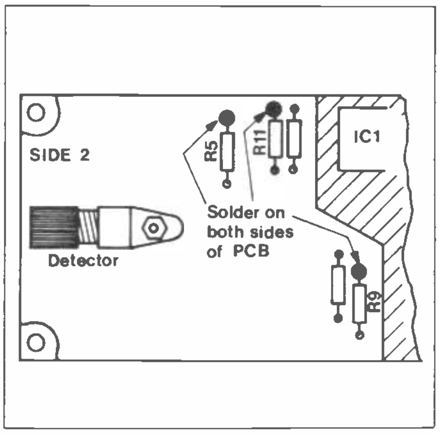


Figure 11. Some resistors are soldered both sides.

'breakthrough' signal (at 110kHz) which can be reduced by turning RV1 clockwise. The signal is present due to a lack of input carrier to the receiver and is removed when the PLL locks onto the incoming signal. Remove the 9V test power source.

Connecting the System

Figure 12 details both modules and should be referred to for the following. If the Fibre Optic Light Guide has not yet been prepared, then refer back to the Preparation of Light Guide section and Figures 1 to 3.

Slide a fluted cap from the coupler over the light guide – it will be quite a tight fit – leaving about 1cm of prepared end protruding. Push the prepared end into the coupler, and offer up the cap. Tighten the cap with fingers only – do *not* use any tools to do this! Repeat the procedure on the opposite end so that both Tx and Rx modules are secured to the light guide. It must be emphasised that careful preparation of the light guide core end is of vital importance if maximum range is required. Poorly prepared ends will produce noisy Rx output and may well limit useable cable length to below 10 metres or less!

When installing fibre optic light guide in a permanent position, be careful with bends, see Figure 13. The absolute minimum *radius* of any bend in the fibre should not be less than 20mm. Exceeding this limit will result in cracking of the fibre, which will completely refract light and result in zero throughput. If using clips to hold the guide in position, be careful not to pinch or damage the outer sheath in any way. Light will escape and/or enter from pierced sheathing and again poor results are inevitable. Excessive heat and some chemical solvents will also damage the guide and should be avoided.

Final Testing

Apply power sources to both modules and connect a suitable signal source to the transmitter input Pins 4 and 3 (0V). Turn RV1 clockwise to approximately one-quarter of its travel and monitor the receiver output Pins 4 and 3 (0V). RV2 on the transmitter should be adjusted slightly for optimum signal level from the receiver, and RV1 on the Rx pcb can be turned clockwise if background noise level is excessive. The Tx input attenuator can be turned clockwise to increase the audio signal level through the system, but too high a level will produce a distorted audio output from the receiver.

Input signal levels to the transmitter should be kept as high as possible (at least 250mV to 500mV) for best signal to noise performance if using long (20 metre) lengths of light guide, although a fair amount of gain is available from the Tx input pre-amp.

Tests on the prototype produced quite good results using a Hi-Fi cassette player line output as the signal source, and the line/Aux input of a Hi-Fi tuner amp for the output of the receiver, with approximately 500mV average signal

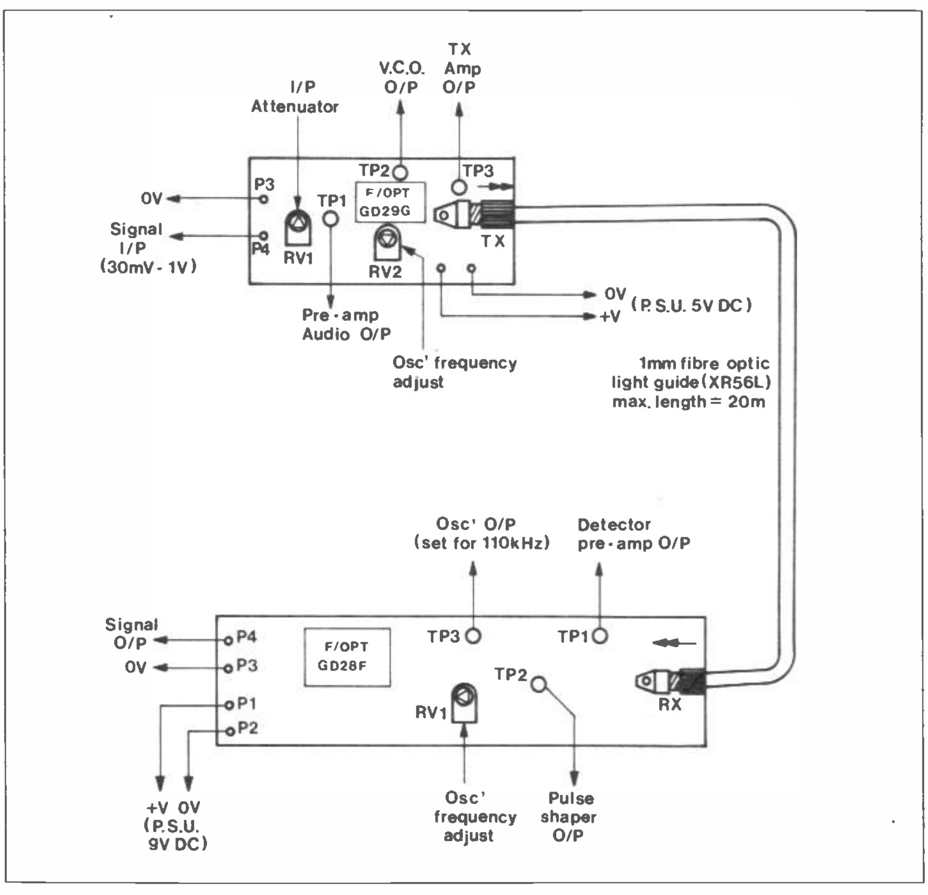


Figure 12. Connecting up the System.

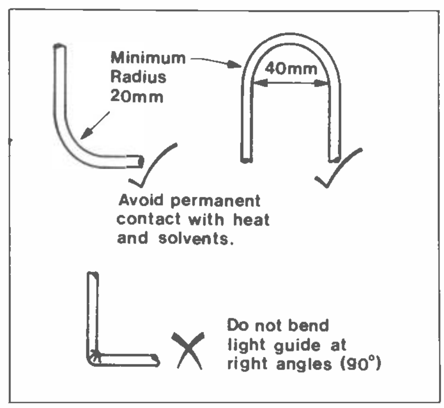
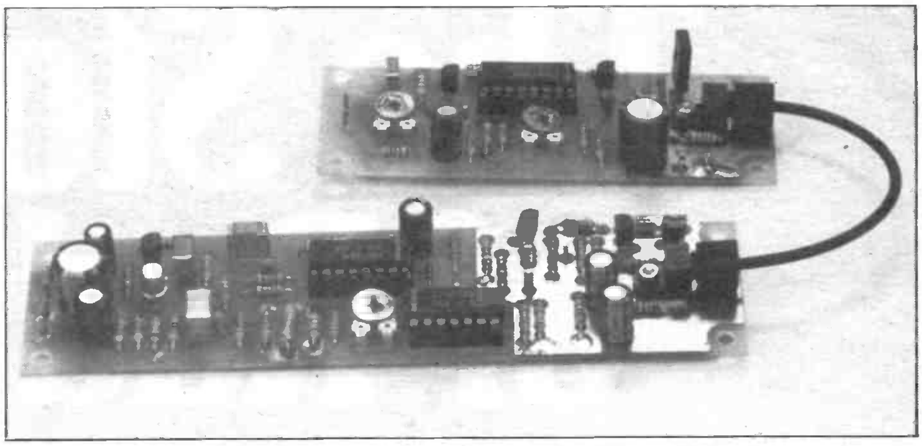


Figure 13. Bending the Light Guide.

level applied. Very low frequency transients are limited by the input stage filtering, middle and upper ranges are reproduced very well.

The modules are not designed to Hi-Fi standards, but as a fairly low cost introduction to fibre optics for personal and educational uses. Really useful practical applications would be in communications through environments plagued with electrical noise and powerful electro-magnetic fields to which conventionally carried screened signals cannot remain immune. Much scope exists for the enthusiast to improve on the basic system. For example, an audio compressor could be used to limit and average-out applied signals to the transmitter. The pre-amp gain could then be increased for better signal to noise performance, especially if an expander is used at the receiver output.



Another application could include computer data transmission. The system bandwidth will not allow very high baud rates, but this could be improved on by removing much of the receiver output filtering components as required, and is a matter for some further experimentation by the enthusiast.

FIBRE OPTIC LINK Rx PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,2	22k	2	(M22K)
R3,8,12,15,16,24	10k	6	(M10K)
R4,22	4k7	2	(M4K7)
R5	1k2	1	(M1K2)
R6,13,17,19	47k	4	(M47K)
R7,20	470k	2	(M470K)
R9,23,25	470Ω	3	(M470R)
R10,11	100k	2	(M100K)
R14	43k	1	(M43K)
R18	15k	1	(M15K)
R21	1k	1	(M1K)
R26	100Ω	1	(M100R)
RV1	47k Hor S-min Preset	1	(WR60Q)
CAPACITORS			
C1,3,5,14	100µF 10V PC Electrolytic	4	(FF10L)
C2	100pF Polystyrene	1	(BX28F)
C4	10nF Polylayer	1	(WW29G)
C6	470pF 1% Polystyrene	1	(BX53H)
C7	330pF 1% Polystyrene	1	(BX51F)
C8	220µF 16V PC Electrolytic	1	(FF13P)
C9,11,13	1nF Ceramic	3	(WX68Y)
C10,15	100nF Polylayer	2	(WW41U)
C12	470nF Polylayer	1	(WW49D)
C16	10µF 50V PC Electrolytic	1	(FF04E)
SEMICONDUCTORS			
D1	1N4148	1	(QL80B)
TR1	BC650	1	(QB74R)
TR2,3,5	BC548	3	(QB73Q)
TR4	BC109C	1	(QB33L)
IC1	4093BE	1	(QW53H)
IC2	4046BE	1	(QW32K)
IR2	F/Optic Detector MFOD71	1	(FD12N)
MISCELLANEOUS			
	F/Optic Rx PCB	1	(GD28F)
	Veropins 2145	1 Pkt	(FL24B)
	DIL Socket 14-pin	1	(BL18U)
	DIL Socket 16-pin	1	(BL19V)
	8BA x ¼in Bolt	1 Pkt	(BF08J)
	8BA Nut	1 Pkt	(BF19V)

A complete kit of all parts is available for this project:
Order As LM11M (Fibre Optic Rx Kit) Price £8.50
The following items in the above kit list are also available separately, but are not shown in the 1986 catalogue:
Fibre Optic Detector MFOD71 **Order As FD12N Price £1.98**
Fibre Optic Rx PCB **Order As GD28F Price £1.80**

FIBRE OPTIC LINK Tx PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,4,5	10k	3	(M10K)
R2	47k	1	(M47K)
R3	2M2	1	(M2M2)
R6	100Ω	1	(M100R)
R7	22k	1	(M22K)
R8,12	47Ω	2	(M47R)
R9,11	1k	2	(M1K)
R10	2k2	1	(M2K2)
RV1	100k Hor S-min Preset	1	(WR61R)
RV2	47k Hor S-min Preset	1	(WR60Q)
CAPACITORS			
C1	39nF Polylayer	1	(WW36P)
C2	100µF 10V PC Electrolytic	1	(FF10L)
C3	470pF 1% Polystyrene	1	(BX53H)
C4	220nF 35V Tantalum	1	(WW56L)
C5	220µF 16V PC Electrolytic	1	(FF13P)
SEMICONDUCTORS			
TR1,2	BC548	2	(QB73Q)
TR3	BD139	1	(QF07H)
IR1	F/Optic Emitter MFOE71	1	(FD14Q)
IC1	4046BE	1	(QW32K)
MISCELLANEOUS			
	F/Optic Tx PCB	1	(GD29G)
	DIL Socket 16-pin	1	(BL19V)
	Veropins 2145	1 Pkt	(FL24B)
	8BA x ¼in Bolt	1 Pkt	(BF08J)
	8BA Nut	1 Pkt	(BF19V)
	Constructor's Guide	1	(XH79L)
OPTIONAL			
	F/Optic Light Guide	As req	(XR56L)

A complete kit of all parts, excluding optional item, is available for this project:
Order As LM12N (Fibre Optic Tx Kit) Price £6.50
The following items included in the above kit list are also available separately, but are not shown in the 1986 catalogue:
Fibre Optic Emitter MFOE71 **Order As FD14Q Price £2.35**
Fibre Optic Tx PCB **Order As GD29G Price £1.25**
Constructor's Guide **Order As XH79L Price 25p *NV***

The Story of Radio

by Graham Dixey
C.Eng., M.I.E.R.E.

Part Four– The First World War

In 1899, Marconi gave a demonstration of wireless telegraphy on Salisbury Plain. Present at this event were representatives of the Post Office, the Royal Navy and the Army, the latter including an officer of the Royal Engineers. As a result, some wireless sets were despatched to South Africa to help in the Boer War, which they failed to do and so were transferred to ships. The early military attitude to wireless was lukewarm; at best it might be considered an adjunct to the cavalry. Consequently, at the outbreak of war in 1914, the British Army was not particularly well equipped with the new technology.

By 1903, all ships of the Royal Navy had been fitted with Marconi wireless equipment.

The situation in the Royal Navy was much better. Some of their ships had been fitted with wireless as early as 1899 and, in 1900, a contract with the Marconi Company was signed for the supply of two shore stations and twenty-six shipboard installations. By 1903, all ships of the Royal Navy had been fitted with Marconi wireless equipment. The use of wireless had also become universal in the U.S. Navy, and quite widespread in the German Kriegsmarine.

Wireless with Wings

There was of course, in Britain at least, no separate air force prior to World War One. But experiments had been carried out to take wireless equipment aloft. The Royal Engineers, from which the Royal Flying Corps and, later, the Royal Air Force, emerged carried out some tests with their balloons. In 1907, Lieutenant C.J. Ashton ascended in a captive balloon and became the first person to receive signals from the ground. In the following year, two-way communication was established with a free balloon, the Pegasus, when signals were received from Aldershot, twenty miles away.

From balloons to airships was a natural step and, in 1911, the airship Beta was used, equipped with a transmitter and receiver. Captain Leroy of the Royal Engineers went up in her and made contact with the ground at distances up to thirty miles. A slight snag was that the airship's engines had to be stopped during reception! However, the value of the 'eye in the sky' was shown during exercises in 1912, when the airship Gamma reported consistently on the movements of the 'enemy' below. It pointed the way for the value of wireless in the conflict to come, though during the Great War the Army used aeroplanes in the spotting role, as airships close to the ground were far too vulnerable.

The feasibility of equipping an aeroplane, as opposed to an airship, with wireless had been shown quite recently, in 1910 in fact. The demonstrations had taken place on both sides of the Atlantic. McCurdy in a Curtiss had effected two-way communication at Sheephead Bay, New York, while the well known British actor, Robert Loraine, had taken up a transmitter in his Bristol during the Salisbury Plain manoeuvres, and made contact with a receiver on the ground.

In 1907, Lieutenant C.J. Ashton ascended in a captive balloon and became the first person to receive signals from the ground.

Message transmitted from an aircraft to the ground, September 1910 over Salisbury Plain.

Photo supplied by The Marconi Co. Ltd.

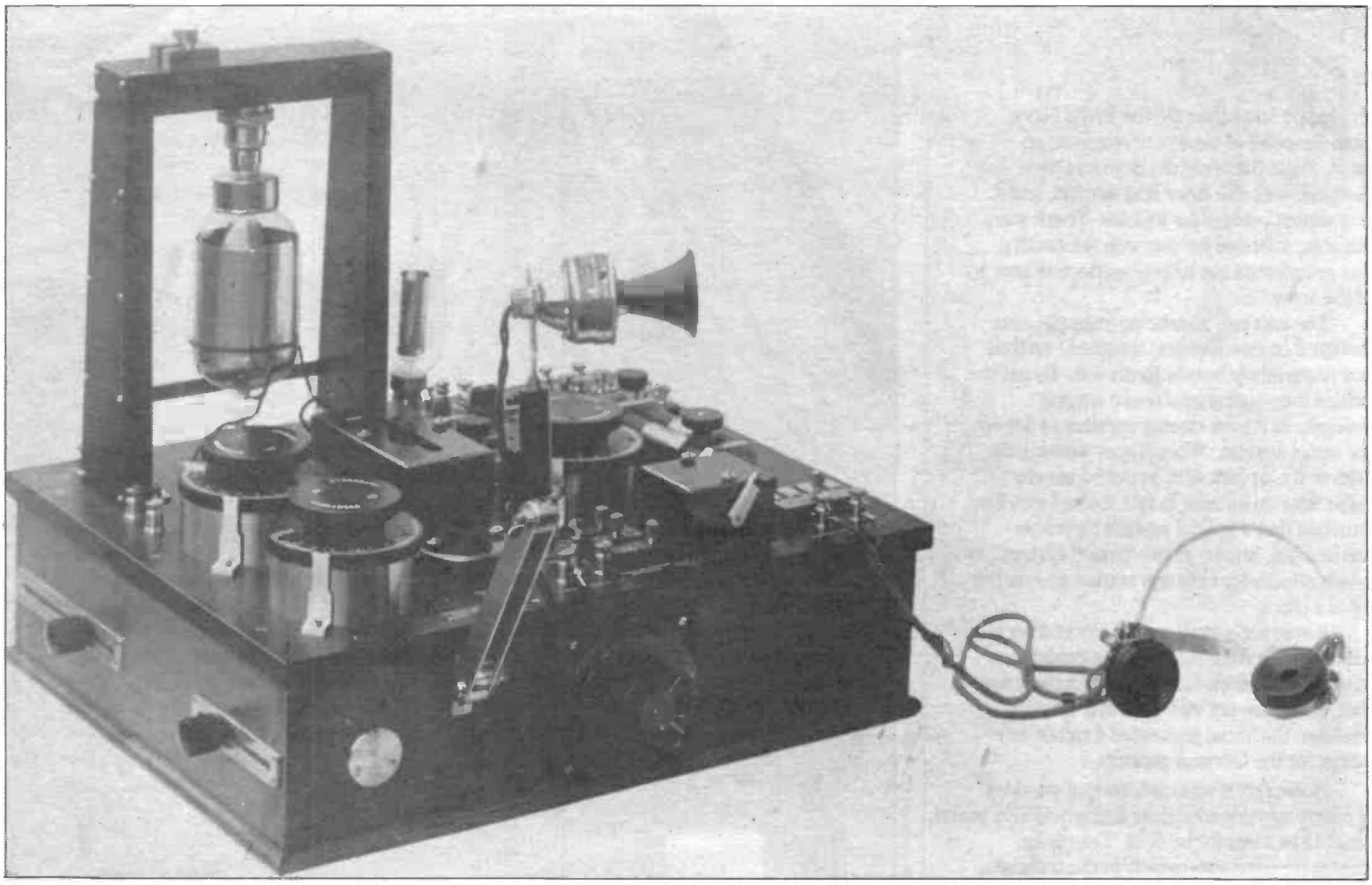


Photo supplied by The Marconi Co. Ltd.

Set used by Marconi during telephone experiments between vessels at anchor 10 kilometres apart in Italy 1914.

Not to be left out of the picture, the Royal Navy were busy putting wireless sets into some of their aircraft and, in 1912, there occurred the first instance of the rescue of an aircrew downed in the drink, as a direct result of wireless. This came about when Lieutenant Fitzmaurice and Commander Samson suffered an engine failure in their Short seaplane and had to put down on the sea. Because of the signals they sent when the trouble developed, they were soon rescued by the ship Hermes.

In the Beginning

During the opening months of World War One, the whole country was caught up in the most incredible spy mania. Most people, including those in positions of authority, had little idea of the potentialities of wireless and there was the fear that anyone who owned anything remotely connected with this 'dark art' was likely to be a German agent. As a result, everyone was required by law to register any equipment in their possession, even a simple crystal set! One young man who was an avid experimenter was found to have a roomful of apparatus and so languished in gaol for nine months because he hadn't registered it!

By the outbreak of war in August 1914, wireless had not developed sufficiently for Britain to possess transmitters with a world wide range. But, she did have an Empire and a number of cables. The combination of the two made communication with the Royal Navy possible, wherever the ships were to be found. So it was that, on August 3rd 1914, the following messages were received by ships of the Royal Navy.

'Admiralty to all ships – Urgent message. The war telegram will be issued at midnight authorising you to commence hostilities against Germany but in view of our ultimatum they may decide to open fire at any moment. You must be ready for this.'

Followed by a few hours later:

'Commence hostilities against Germany.'

Both the Royal Navy and the German Kriegsmarine had full wireless contact with their ships at sea. Cipher was used in the passing of messages of course but, right at the beginning of the war, the British gained an enormous advantage over their enemy by the most incredible stroke of luck.

At the beginning of September 1914, the German light cruiser, Magdeburg, was wrecked in the Baltic. The body of an unteroffizier was hauled out of the sea by the Russians a few hours later and, clasped firmly in his arms, held there by rigor-mortis, were the German Navy's cipher and signal books, together with detailed maps of the North Sea and the Heligoland Bight!

The value of the 'eye in the sky' was shown during exercises in 1912, when the airship Gamma reported consistently on the movements of the 'enemy' below.

The whole country was caught up in the most incredible spy mania; most people had little idea of wireless and there was the fear that anyone who owned anything remotely connected with it was likely to be a German agent.

The Russians felt that Britain, as the leading naval power, should have the use of these important documents and so they were handed over to us.

As a result, we were able to monitor all communications between Germany and her warships for the early part of the war (until it was realised why we always knew where the German ships were!) and decipher them at ease. Then the Germans changed their codes.

Find the Direction

However, by the time that had happened, wireless was being applied in a new role, that of direction finding. DF stations were set up on the east coast, for example at Aberdeen, Flamborough and Lowestoft, and with them it was possible to pinpoint the activities of enemy vessels. This could only be done if the ships were actually transmitting, of course, but as it happened the Germans had not learnt the value of wireless silence.

In fact, the battle of Jutland came about because the British could follow the passage of the German High Seas Fleet and so were able to put to sea to intercept it.

Submarines were also equipped with wireless in order to maintain contact with their bases and, although the transmissions were brief, they were sufficient to allow the DF stations to plot the course of the German U-boats. By co-operating with the aircraft of the Royal Naval Air Service, it was possible to vector a seaplane or flying boat onto the enemy, with a fair chance of finding and destroying it.

Field Radio

As already mentioned, the British Army entered World War One in a much less happy state than did the Royal Navy, from the point of view of wireless equipment. What the army did have had been designed with the Boer War in mind, and it was almost useless for its task. There were ten sets, supplied for use with the cavalry, that prestigious but largely ineffective arm of the army.

The cart set, to take an example, was mounted on two limbers, weighed two tons and required six horses to draw it. To get the station fully operational was a lengthy process, as it took twenty minutes to set up the aerial system. When it *was* working the selectivity, or lack of it, imposed severe limitations on its use. In fact, so bad was the situation that a special system had to be worked out, known as the 'period system', in which effectively only one station was on the air at a time!

It was not a system that worked very well and so it did little to inspire confidence in the use of wireless. Another problem was that, when the set was used in a 'forward' position, the aerial presented a rather nice target for the German gunners.

However, it was obvious that wireless properly developed and applied would be a useful asset to an army in the field. Telephone lines were used extensively in the trenches, but they were easily cut, and could also be tapped into. What was required was a short-range portable set so, in August 1915, the British field wireless set was ordered.

These were first used at the Battle of Loos and actually worked very well. This set had a range of 4000 yards when it was used with a 180 foot long aerial, supported on 12 foot high masts, but gave a better range on a *longer* aerial! A crystal detector was used. It is interesting to note that, in London where Dr. W.H. Eccles was working on the use of the thermionic valve for wireless, he was able to pick up the transmissions from the Western Front in Flanders.

The early transmitters were of the spark type but when later, in 1917, it became possible to generate continuous oscillations (called CW for Continous Wave), CW transmitters appeared on the Western Front which gave a range of 6000 yards with an aerial system only 30 feet long and 2 to 3 feet high.

The big problem with wireless in the army was not the equipment as such, but the general attitude to its use. It simply wasn't trusted by those in command and, consequently, was never employed to the extent that it could or should have been. Nevertheless, it did have one particular use which was exploited effectively, and that was for artillery observation. In this application aircraft were used as spotters for the artillery, directing the fall of shot.

Wireless Aeroplanes

Two wireless sets were designated for aircraft use, known as the type L and L1 respectively. The former weighed 50lb and had a range of 15 miles for a power rating of 40W; the latter had the very much greater range of 80 miles, achieved using an aerial power of 500W, but weighed 200lb, which made it an unlikely proposition for the typical artillery observation aeroplane whose payload was very limited. However, of a number of methods tried for communicating the desired information to the ground, the use of wireless telegraphy turned out to be the most effective.

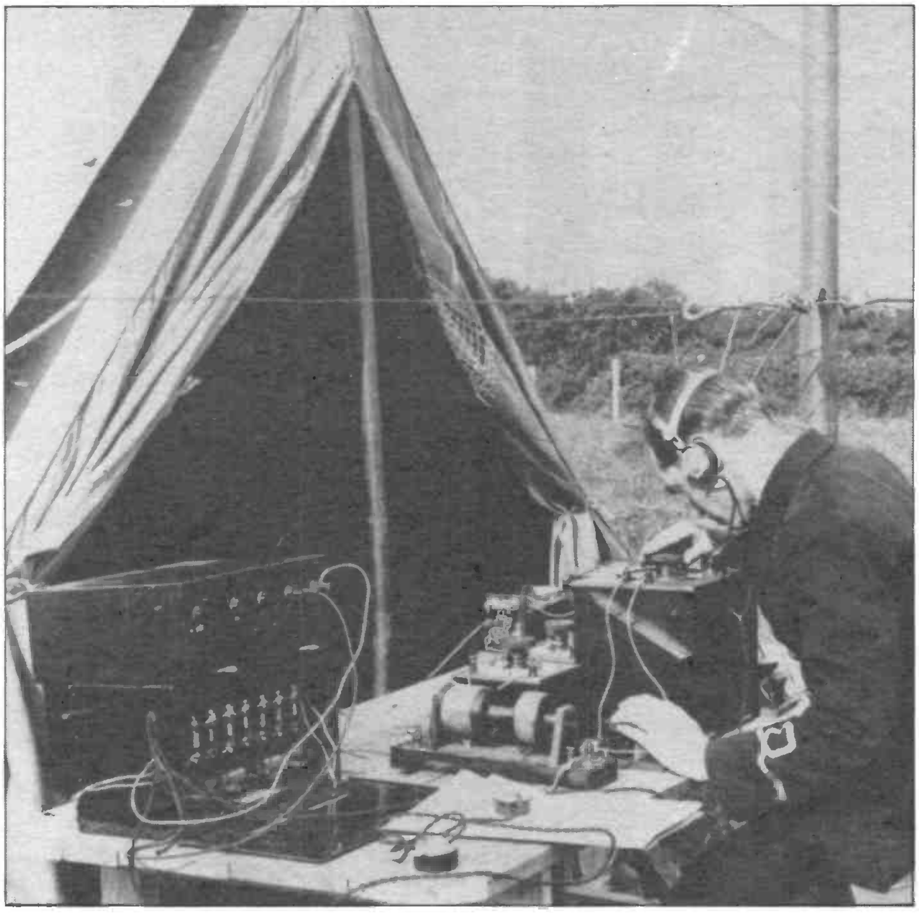


Photo supplied by The Marconi Co. Ltd.

Mobile wireless set 1916.

There were still some of the old problems though of mutual interference due to lack of selectivity. The answer was to use sets of low power and a minimum spacing of about 2000 yards between adjacent 'wireless aeroplanes'. An example of this type of set was the Sterling, which was manufactured by the Sterling Telephone Co Ltd to the designs of Lt. Leroy, an RNVR officer serving with the RNAS. It weighed only 20lb, which made it possible for an observer to be carried, who could deal with its operation, leaving the flying to the pilot. Hitherto the pilot had had to handle the aeroplane, observe the effects of the artillery bombardment and pound out the relevant information in morse code at the same time!

It took twenty minutes to set up the aerial system . . . When the set was used in a 'forward' position, the aerial presented a rather nice target for the German gunners.

A special wireless unit was built up, which later became No.9 Squadron, Royal Flying Corps. Later still every battery of guns had its own spotting plane. By the end of the war about 600 British aircraft were fitted with wireless telegraphy equipment, and there were some thousand or so ground stations.

Wireless 'telegraphy' meant, of course, morse code. However, there were experiments with radio telephony (RT) as early as 1914. A Captain Dowding, later Lord Dowding of Battle of Britain fame, while with No. 9 Sqdn. RFC, took a Maurice Farman biplane aloft, which was fitted with a telephony transmitter. He was assisted by a professional wireless engineer, one C.E. Prince, and was able to lay claim to being the first person in England to receive an airborne radio telephone transmission. The War Office decreed that such impracticable experiments must cease, but evidently relented later because, by 1915 a working RT set had been put into service which had a special microphone capable of working close to the aeroplane's engine.

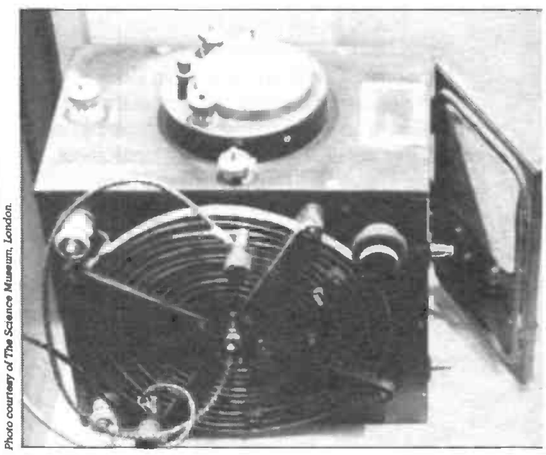


Photo courtesy of The Science Museum, London.

Trench spark transmitter and receiver, 1916. The receiver aerial is laid along the floor of the trench while part of the transmitting section was hoist on a bayonet in the Parapet.

For a long time transmission was a one-way affair, because the high noise level in the air made it difficult to understand messages received from the ground. However, by shouting into his microphone the operator could get a good enough

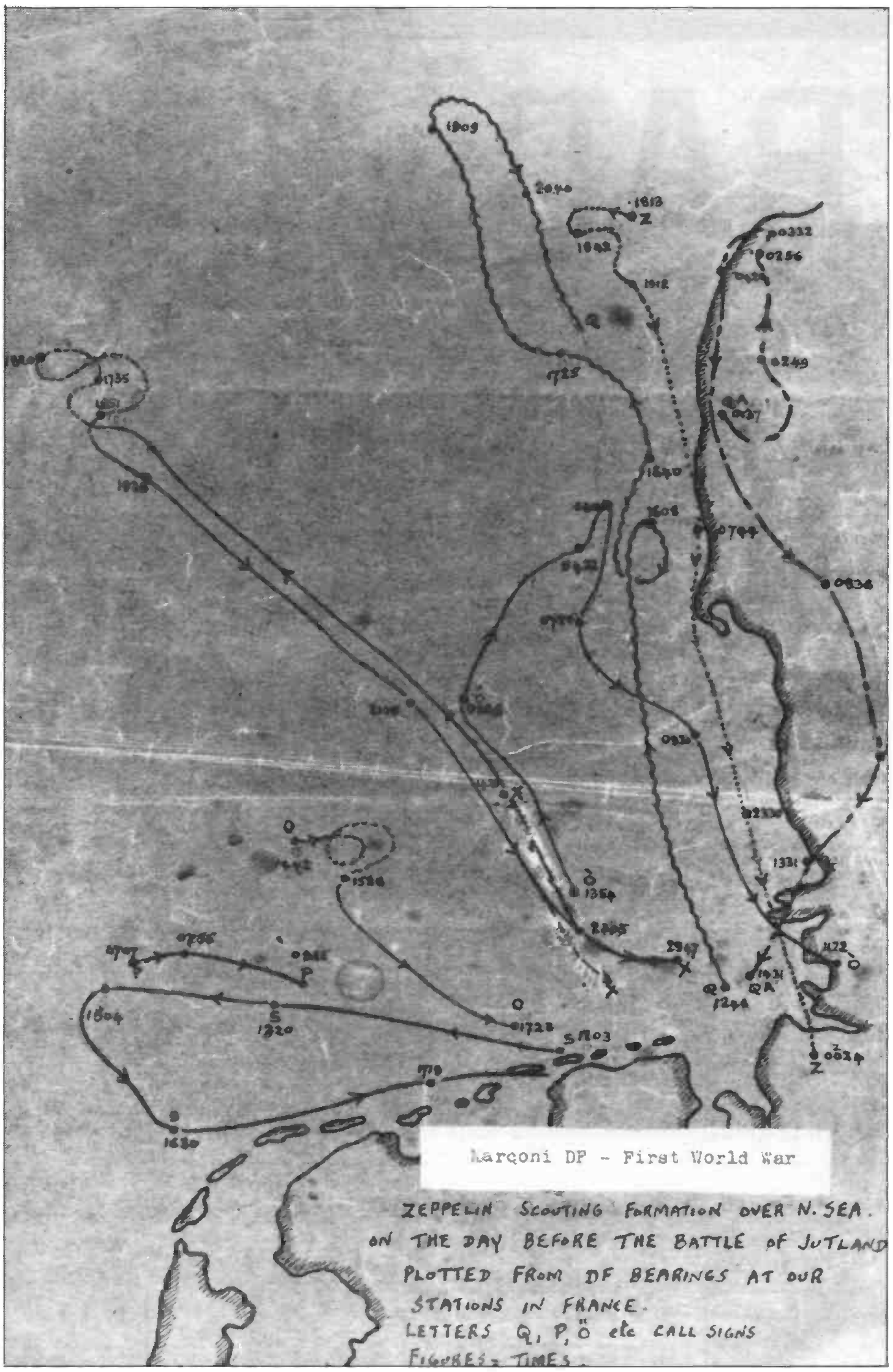


Photo supplied by The Marconi Co. Ltd.

DF bearings of Zeppelins over the North Sea.

The body of an unterofficier was hauled out of the sea by the Russians a few hours later and, clasped firmly in his arms, were the German Navy's cipher and signal books

signal/noise ratio to make one-way working practicable. The other problem with airborne reception was the way in which the vibration of the airframe affected the stability of the contact between the 'cat's whisker' and the crystal. The introduction of balanced carborundum crystals improved this situation.

Another weapon of war appearing at this time was the tank. To direct the tank force effectively also meant control from the air. RT was tried, but the range was too limited to be effective. WT was much better but here there was also a slight snag. The tank had to stop and set up an aerial whenever it wanted to communicate! There is much we take for granted today.

Signal Corp

Throughout the various theatres of operations of World War One, wireless was employed with a greater or lesser degree of usefulness, but it seems that the former was more prevalent because, by the middle of 1918, the army 'brasshats' realised that a separate organisation was needed to control the use of wireless, both WT and RT. Though too late to see service in the First World War, the Royal Corps of Signals was formed in 1920.

For the first time the civilians, well away from the battle lines, became involved in a major conflict between combatant powers. This was one of the less desirable by-products of the new age of aerial transportation. The Germans, as well as the British, built some heavy bombers with a moderate war load and respectable range. However, the Germans, just across the Channel had an advantage, which they followed up.

While a substantial number of air raids were carried out on English towns, with the consequent loss of life and extensive damage to property, it is the Zeppelin that has captured the public imagination rather than the Gotha and Friedrichshafen bombers. Perhaps it is their immense size that accounts for this, the huge gas-filled envelopes droning above the cloud cover, dropping their explosive cargoes indiscriminately.

WT was much better but here there was also a slight snag. The tank had to stop and set up an aerial whenever it wanted to communicate!

Wireless was used by both sides in this form of warfare. The Zeppelins could only be attacked if the element of surprise could be achieved. This meant knowing sufficiently well in advance the likely course and height of the intruders. Thus, DF was used to plot the enemy's course and the use of wireless communication directed the defending fighters onto him. Although the little single-seater scouts used for air defence were nimble, the giant airships could rise very rapidly out of range, just by jettisoning ballast, carried in the form of water. It was very much a 'cat and mouse' game, but in the end the Zeppelins were too vulnerable. Although 'radar' had to wait for another war to bring it into existence, wireless played a similar and vital role during the Great War.

The Germans used wireless for communication between airships (and aeroplanes), for communication with their bases and also for navigation. For the latter purpose, the Germans set up a network of DF stations, able to take bearings on signals transmitted from an airship, that could provide a fix for an airship commander. It was, of course, this very provision that allowed the British to plot the enemy's incoming track and so scramble the defending fighters in time!

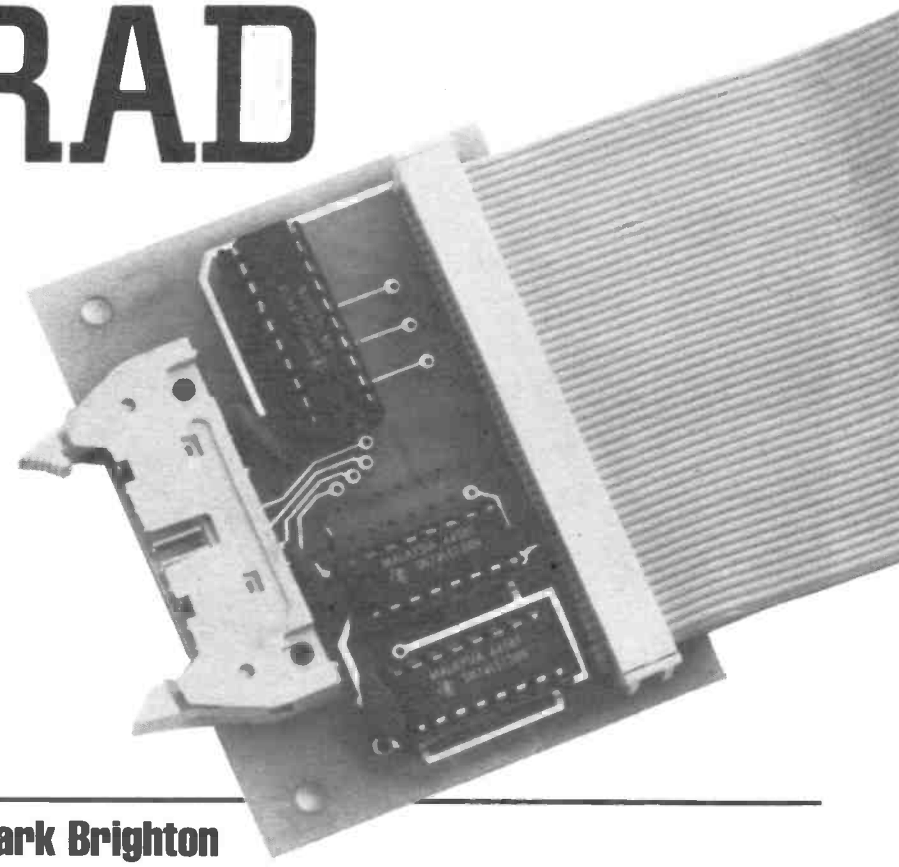
The Germans set up a network of DF stations, able to take bearings on signals transmitted from an airship, that could provide a fix for an airship commander.

As wireless had assisted the purposes of war, in the end it was used to announce to a tired and waiting world the most welcome news of all.

On top of Marconi House in London a constant vigil was kept to listen out for the transmissions of the French station FL on the Eiffel Tower in Paris. At 0500 hours on November 11th, the following message was received and despatched to Downing Street.

'From Marshal Foch to All Allied Commanders – Hostilities will cease at 11.00 o'clock.'

AMSTRAD 8 BIT INPUT PORT



by Mark Brighton

★ Inexpensive - Easy to Build and Fit
★ Compatible with BBC User Port Socket

This article describes a simple 8-bit input port which plugs into the expansion connector on the rear of the Amstrad CPC 464/664/6128 range of computers and allows information from the outside world to be read and stored by the computer. It may be used, for example, to interface the weather satellite decoder described elsewhere in this issue with the Amstrad computers.

Circuit Description

In Figure 1, IC1 decodes $\overline{IORQ}$ and A5 - A7 to produce $\overline{IOSEL}$, which is active for any valid external I/O address, enabling IC2 when $\overline{RD}$ is active and A4 is high.

This locates the port within the second block of 16 addresses in the valid external I/O area starting at $F8E0, although the constraints imposed on the design complexity by the low cost specification precluded complete address decoding, so there are 'ghost images' of the port in the other I/O areas. For this reason, the port address may also be located at any two addresses within the block of sixteen by fitting one of the eight links as shown in Table 1.

By carefully choosing the link required, it should be possible to avoid overlapping the port with any other external I/O mapped device used within the system.

Finally, IC3, when enabled via the link fitted, gates any data present on P_0 - P_7 onto the data bus to be read by the processor.

Construction

Referring to the Parts List and the legend, as shown in Figure 2, fit and solder the IC sockets, ensuring that the notch on each socket aligns with the legend. Locate and solder the three

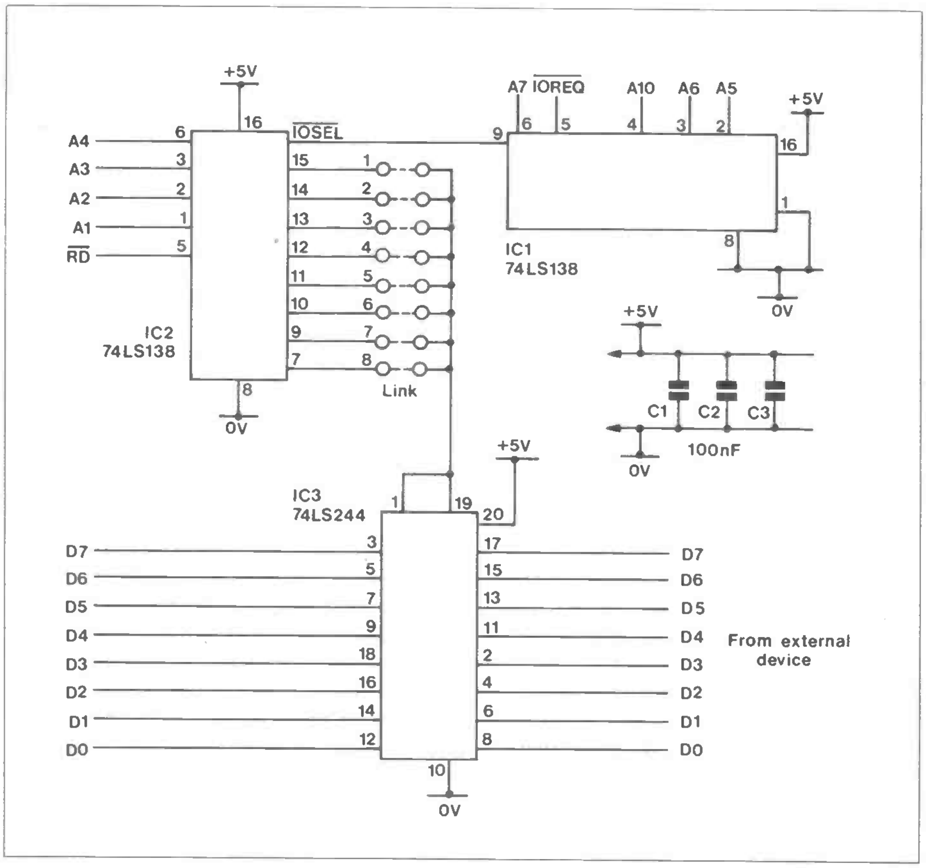


Figure 1. Circuit Diagram.

0.1μF decoupling capacitors. Then fit PL1 and the IDC cable of your choice, with the stripe on the cable at the pin 1 end of the legend! Lastly, fit the link previously selected from Table 1, and proceed to solder all connections and check the PCB for dry joints, short circuits, etc. Fit all IC's into their sockets, noting correct orientation. Figure 3 shows PL1 pin connections looking into the connector, onto the pins.

Testing

There is a choice of cables given in the Parts List, but you will probably use cable FD22Y for most applications. Plug the IDC cable into the expansion connector on the Amstrad, with the stripe on the left side when viewed from the *front* of the computer. If an external disk drive or other peripheral is to be used, plug this into the socket mid-way along the alternate IDC cable (FD24B) which must be used in conjunction with our Reversiboard (GD37S) to ensure that the peripheral is connected correctly, see Figure 4.

Switch the computer on, switching off again immediately if the computer fails to initialise in the normal way of displaying the 'ready' prompt.

If all is well, reading the address chosen with an 'INP' command should return the number set-up on the port inputs (if nothing is connected to the port, 255 will be read).

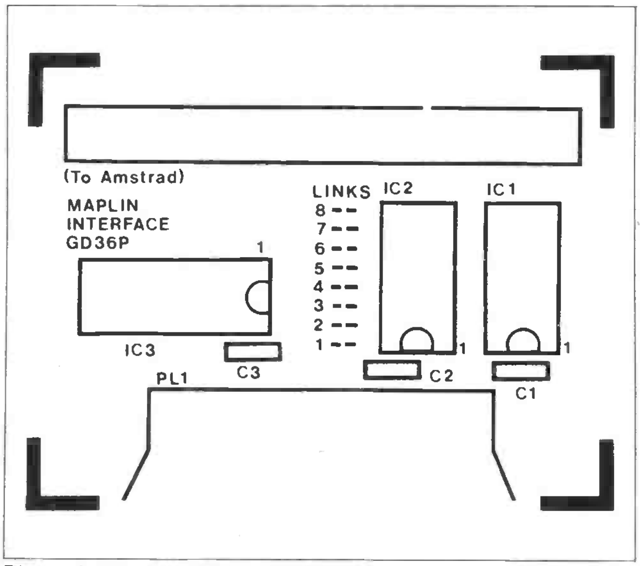


Figure 2. Board Layout.

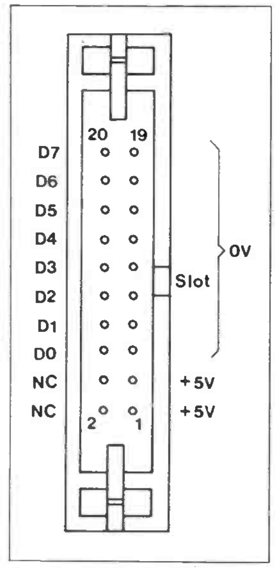


Figure 3. Header Plug.

LINK	ADDRESS
1	F8E0 - F8E1
2	F8E2 - F8E3
3	F8E4 - F8E5
4	F8E6 - F8E7
5	F8E8 - F8E9
6	F8EA - F8EB
7	F8EC - F8ED
8	F8EE - F8EF

Table 1.

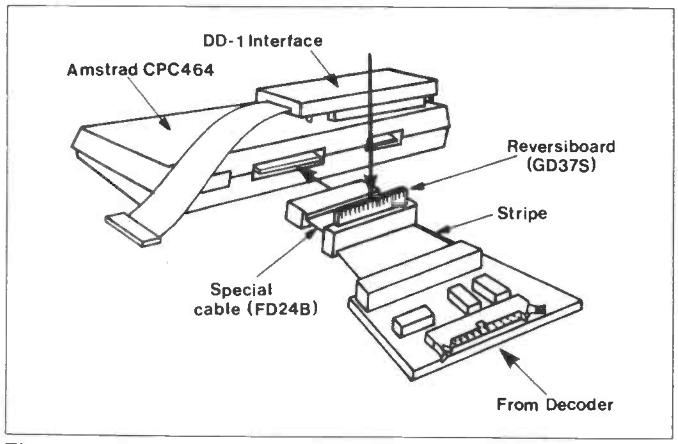
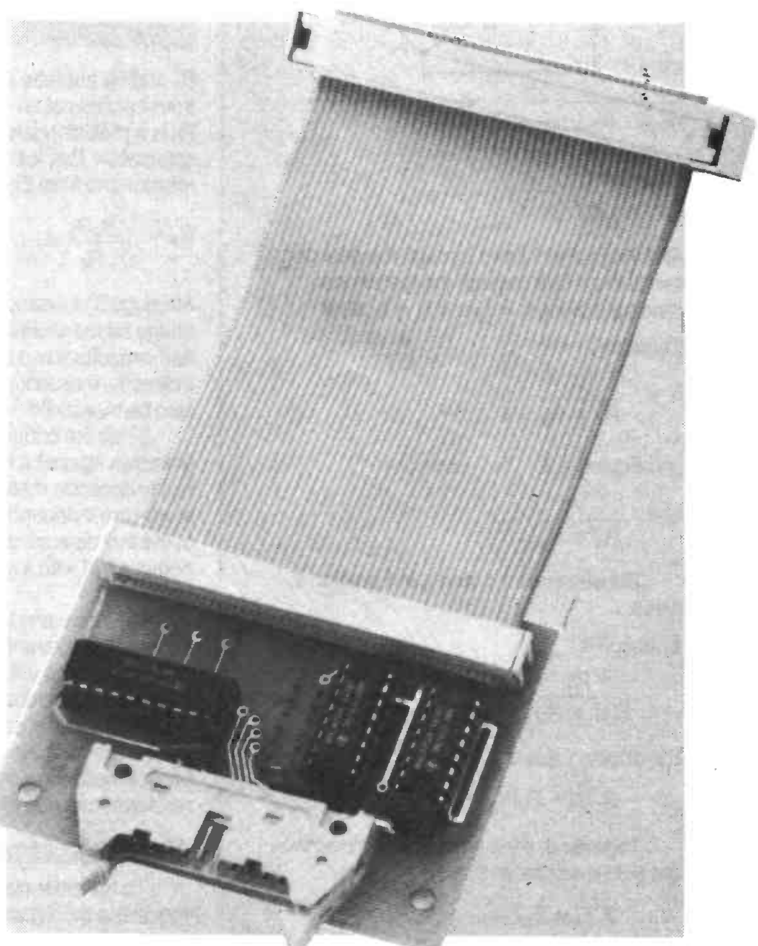


Figure 4. Alternate cable.

AMSTRAD 8-BIT I/P PORT PARTS LIST

CAPACITORS			
C1-3	100nF Minidisc	3	(YR75S)
SEMICONDUCTORS			
IC1,2	74LS138	2	(YF53H)
IC3	74LS244	1	(QQ56L)
MISCELLANEOUS			
	Amstrad Interface PCB	1	(GD36P)
PL1	20-way IDC Header R/A	1	(FT72P)
	DIL Socket 16-way	2	(BL19V)
	DIL Socket 20-way	1	(HQ77J)
	Bolt 6BA x ½"	1 Pkt	(BF06G)
	Nut 6BA	1 Pkt	(BF18U)
OPTIONAL			
	Cableform Amstrad/Interface	1	(FD22Y)
	Cableform Amstrad/Disc/Interface	1	(FD24B)

A complete kit of all parts, excluding optional items, is available for this project:
Order As LM14Q (Amstrad 8-bit I/P Port Kit) Price £9.50
The following items included in the above kit list are also available separately, but are not shown in the 1986 catalogue:
Amstrad Interface PCB **Order As GD36P Price £5.95**
Amstrad/Interface Cable **Order As FD22Y Price £7.20**
Amstrad/Disk/Interface Cable **Order As FD24B Price £12.15**
Reversiboard **Order As GD37S Price £2.50**



TEST GEAR AND MEASUREMENTS

by Danny Stewart
Part 2

Having established some internationally recognised standard units of measurement in Part 1 of this series, we shall now take a look at some actual practical methods of measuring electrical properties.

Wheatstone Bridge

A basic bridge circuit is shown in Figure 1, where D is a detector, usually a galvanometer or any other sensitive current meter. The bridge is balanced when the voltage across the detector is zero volts and there is no current flowing through it. This can be expressed as:

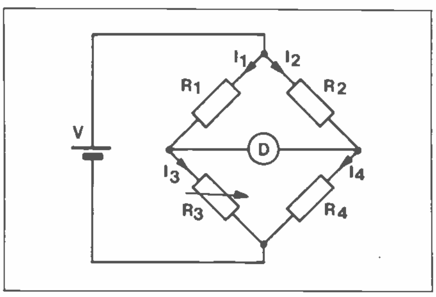


Figure 1. Basic Bridge.

Equation 1.

$$I_1R_1 = I_2R_2$$

And if no current flows through the detector, then it must flow through the resistance dividers making $I_1 = I_3$ and $I_2 = I_4$, also:

Equation 2.

$$I_1 = \frac{V}{R_1 + R_3}$$

and Equation 3.

$$I_2 = \frac{V}{R_2 + R_4}$$

Substituting for I_1 and I_2 in Equation 1 gives:

Equation 4

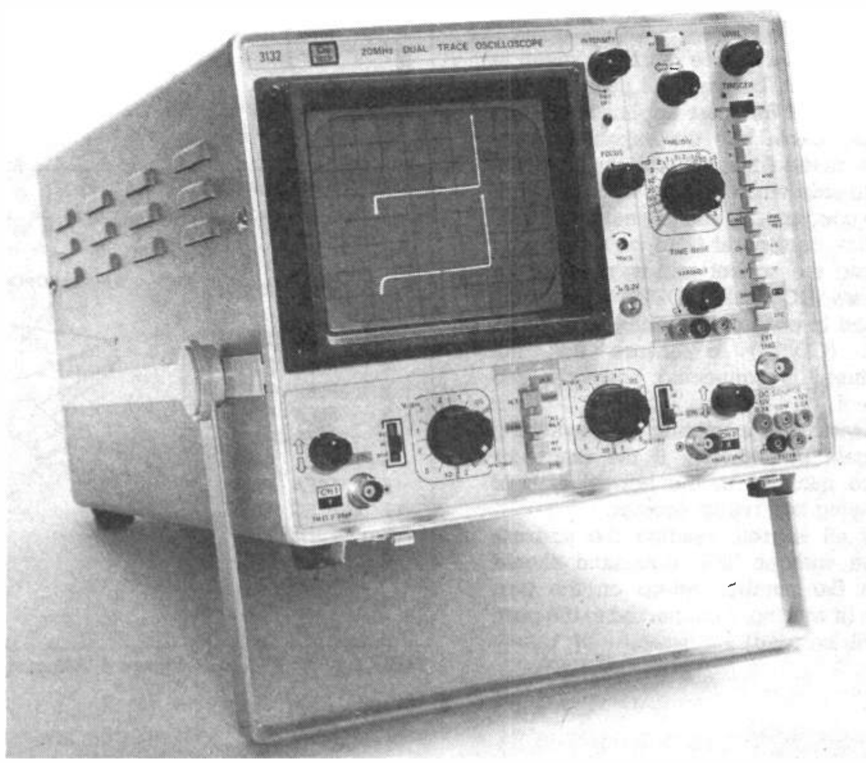
$$\frac{R_1}{R_1 + R_3} = \frac{R_2}{R_2 + R_4}$$

Simplifying Equation 4 gives Equation 5:

$$R_1R_4 = R_2R_3$$

In general, if the arms of the bridge are not pure resistances then:

$$Z_1Z_4 = Z_2Z_3$$



R_1 and R_2 are ratio arms and are switchable from fractions of an ohm to several megohms. R_3 is a precision standard which is also selectable. This leaves R_4 as the unknown resistor and from Equation 5, Equation 6:

$$R_4 = \frac{R_3R_2}{R_1}$$

Although this example illustrates the use of a bridge for measuring resistance, inductors and capacitors can also be measured. Indirectly, frequency and phase angle can also be measured.

Since the bridge method compares the unknown against a fixed standard, this is a highly accurate method. Also the measurements are independent of the characteristics of the null detector as long as the detector can detect a null with a reasonable degree of sensitivity.

Therefore any lack of accuracy will be attributed to tolerance of the three resistors and any *heating effect* of the current through the resistors, particularly for low values of resistance. Inaccuracy can also be due to an insensitive null detector. Inspite of all this, the basic Wheatstone Bridge is used to measure resistors from one ohm to one Megohm.

Kelvin Bridge

To measure resistor values below 1 ohm requires a modification to the basic Wheatstone Bridge. Figure 2 shows the problem. The resistance of the leads become significant in measuring the unknown resistance.

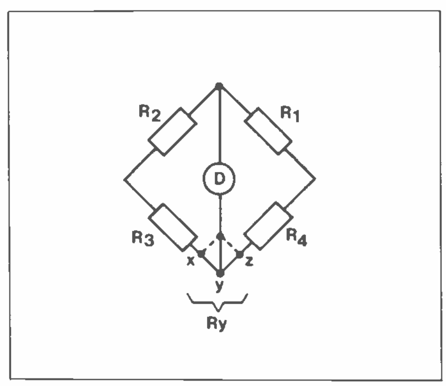


Figure 2. Measuring Resistor Values below 1Ω.

Connecting the detector to either x or z means increasing the resistance in the respective bridge arms. But if the detector is connected to point y such that:

$$\frac{Rxy}{Ryz} = \frac{R_2}{R_1}$$

then the bridge balance conditions are met and:

$$R_4 = \frac{R_1}{R_2} R_3$$

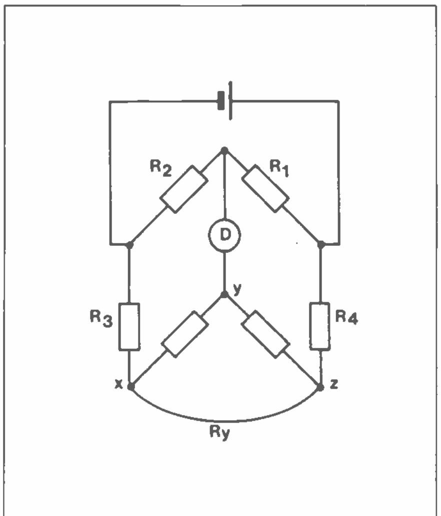


Figure 3. Kelvin Double Bridge.

where R_4 could be the unknown resistor.

Figure 3 shows a Kelvin double bridge, so called because it contains an additional pair of ratio arms to eliminate the effect of wire xz. As before:

$$\frac{R_{xy}}{R_{yz}} = \frac{R_2}{R_1}$$

The Kelvin Bridge can be used to measure resistors down to 0.00001 ohm. If R_3 is the standard resistor then it could be arranged in steps of 0.001 ohm, as shown in Figure 4. A manganin bar of 0.0011 ohm provides a sliding contact for small adjustments and for good accuracy as much of the standard resistance must be included in the circuit. This depends on the ratio of R_1 to R_2. As for the Wheatstone Bridge, R_1 and R_2 are switchable in decade steps.

Murrary Loop Test

A modified form of the Wheatstone Bridge is used to detect wires shorting to earth in a telephone cable.

If a wire is shorting to earth at point x, Figure 5, it is connected to a good wire at the far end and both wires connected to a Wheatstone Bridge. In this way both wires will contribute towards two arms of the bridge, with point x the dividing point. The balance condition is given by:

$$\frac{R_1}{R_2} = \frac{R_L - R_X}{R_X}$$

where R_L is the total resistance of the two wires, R_X is the resistance from the bridge to point x.

$$\text{Therefore, } R_x = \frac{R_2 \cdot R_L}{R_1 + R_2}$$

length is proportional to resistance, so we can replace R_X and R_L above.

$$L_x = \frac{R_2 (L_1 + L_2)}{R_1 + R_2}$$

Also $L_1 = L_2$

$$\text{Hence } L_x = \frac{R_2}{R_1 + R_2} \cdot 2L$$

and the distance to the faulty point can be calculated.

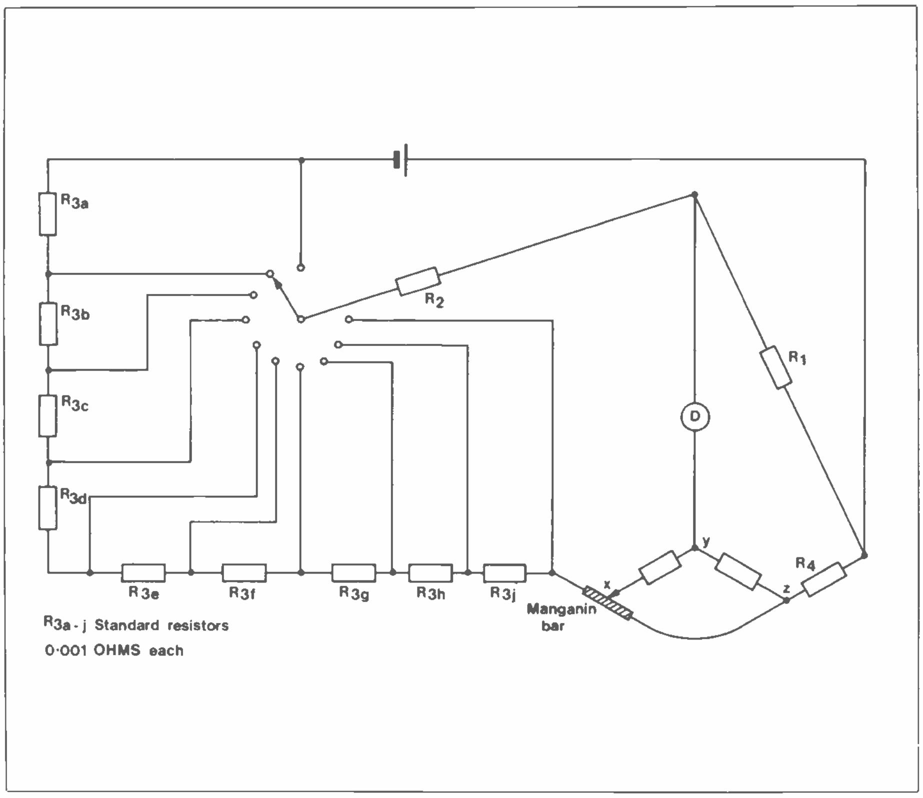


Figure 4. Stepped Resistors.

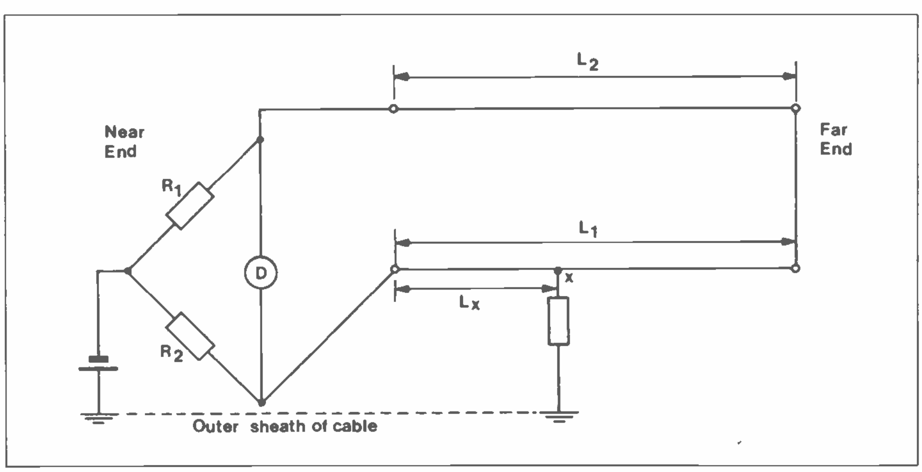


Figure 5. Murrary Loop Test.

Varley Loop Test

This is a further modification of the Wheatstone Bridge and is also used to detect cable faults, e.g. crossed connections, short circuits or earth faults. This test is usually used to locate a fault down to a cable section and is capable of locating within 500 feet in a 50 mile section. The Murray test can then be used to locate within the section, therefore the Murray test set is usually of the portable variety, employing batteries.

The Varley test is a more complex test than the Murray test and employs three wires with different connection arrangements, see Figure 6a, b, c.

Compared to the Murray Bridge, the Varley has resistors in three arms instead of two and the variable resistor is placed in the third arm. The ratio arms R_1 and R_2 are varied by a dial to give a ratio from 0.001 to 1,000 in decade steps.

Analysis of the circuits in Figure 5 yield:

$$Lx = \frac{R_1 \cdot (B-A)}{R_1 + R_2}$$

$$(L_1 - Lx) = \frac{R_1 \cdot (C+B)}{R_1 + R_2}$$

Substituting the results of the measurements in the above two equations gives the distance to the fault. It can be seen that one equation provides a check on the other.

A.C. Bridges

An a.c. bridge will require an a.c. power source and an a.c. detector, and is used for measuring inductors , capacitors, frequency, i.e. anything other than resistance which is the domain of d.c. bridges.

An a.c. bridge then, will have the general format of Figure 7, where the Z values are capacitors or inductors with their associated resistive components. the detector can be a pair of headphones or magic eye (electron ray tube).

At low frequencies, the domestic mains supply is an adequate source but at higher frequencies an oscillator must be used at the frequency for which the component is designed.

For bridge balance, the potential difference across the detector has to be zero, as for d.c. bridges. This will occur when the potential difference across Z_1 is the same as that across Z_2 in both magnitude and phase.

i.e. $I_1Z_1 = I_2Z_2$

also $$I_1 = \frac{V}{Z_1 + Z_3}$$

and $$I_2 = \frac{V}{Z_2 + Z_4}$$

Substituting for I_1 and I_2 gives:

$$Z_1Z_4 = Z_2Z_3$$

or using admittances

$$Y_1Y_4 = Y_2Y_3$$

In complex rotation, the magnitudes are multiplied and the phases angles added:

$$Z_1Z_4 \angle(\Theta_1 + \Theta_4) = Z_2Z_3 \angle(\Theta_2 + \Theta_3)$$

and for balance, not only must $Z_1Z_4 = Z_2Z_3$ but $\angle(\Theta_1 + \Theta_4)$ must equal $\angle(\Theta_2 + \Theta_3)$.

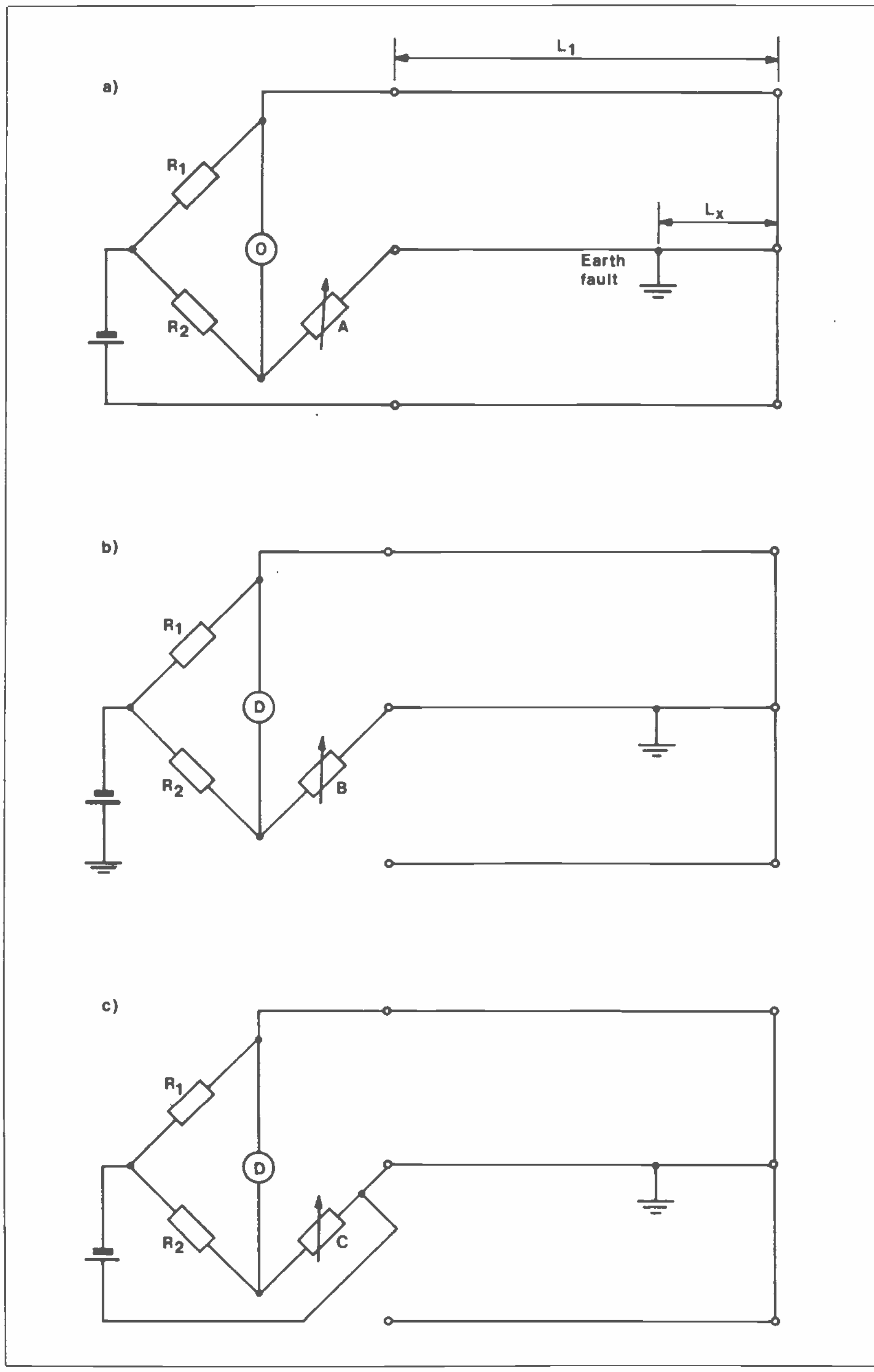


Figure 6. Varley Loop Test.

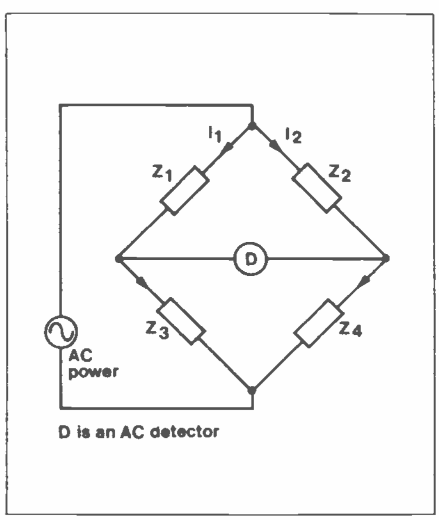


Figure 7. A.C. Bridge.

Capacitance Bridge

Figure 8 shows a bridge arrangement for measuring capacitance where Cx is the unknown capacitor and Rx its associated leakage resistance. These two components are reflected on the other side of the equation by standard capacitor Cs and a variable resistor Rs.

Now $Z_1 = R_1, Z_2 = R_2,$

$$Z_3 = R_S - \frac{j}{wC_S}, \quad Z_4 = Rx - \frac{j}{wC_X}$$

Substituting in $Z_1Z_3 = Z_2Z_4$

$$R_1\left(\frac{Rx - j}{wC_X}\right) = R_2\left(\frac{R_S - j}{wC_S}\right)$$

$$R_1R_X - R_1\frac{j}{wC_X} = R_2R_S - R_2\frac{j}{wC_S}$$

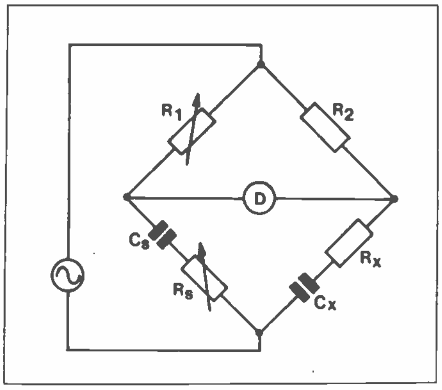


Figure 8. Bridge for Measuring Capacitance.

Such equations are solved by equating real and imaginary expressions separately. Equating real terms:

$$R_1R_x = R_2R_S$$

Equation 7.

$$Rx = \frac{R_2R_S}{R_1}$$

Equating imaginary terms:

$$\frac{jR_1}{wC_X} = \frac{jR_2}{wC_S}$$

Equation 8.

$$C_X = \frac{C_S\,R_1}{R_2}$$

C_X is a precision standard capacitor that cannot be adjusted and since R_S does not appear in Equation 8, it can be made adjustable. One other variable component is required in order to balance the above two equations. Unfortunately, the choice is between R_1 and R_2 which appear in both equations.

If R_1 is chosen, then R_1 and R_S need to be changed alternately for minimum sound in the headphones until balance is obtained. This is called convergence.

Schering Bridge

Figure 9 shows a Schering Bridge which is one of the popular bridges for measuring capacitors and insulators.

For measuring insulation (phase angle nearly 90°), C_S is an air dielectric capacitor. Otherwise, C_S is a mica capacitor which also has low loss and therefore, a phase angle of 90°.

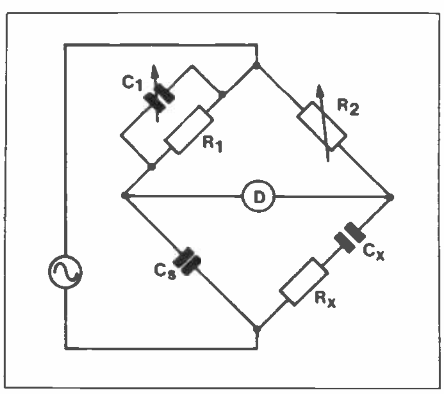


Figure 9. Schering Bridge.

Substituting in the balance equation

$$Z_x = \frac{Z_2\,Z_3}{Z_1}$$

$$R_X - \frac{j}{wC_2} = \left(R_2 - \frac{j}{wC_S}\right)\left(\frac{1 + jwC_1}{R_1}\right)$$

$$R_X - \frac{j}{wC_X} = \frac{R_2\,C_1}{C_S} - \frac{jR_2}{wC_SR_1}$$

Equating real terms $R_X = \dfrac{R_2\,C_1}{C_S}$

Equating imaginary terms $C_x = \dfrac{C_S\,R_1}{R_2}$

Inductance Bridge

The general form of an inductance bridge is shown in Figure 10 where Lx is the unknown inductor and Rx its resistive component. To balance these on the other side of the equation, the standard is in two parts, Ls and Rs.

Circuit analysis yields:

$$Rx = \frac{Rx \cdot R_2}{R_1}$$

$$Lx = \frac{Ls \cdot R_2}{R_1}$$

In an inductor, the resistive component is larger than that in a capacitor, so the resistive adjustment must be made first.

When measuring inductors, Q values must be taken into account. The Q of a coil is $\frac{wL}{R}$ and the Q of a capacitor $\frac{1}{wCR}$. For Q values above 10, a Hay bridge is used and for Q between one and ten, a Maxwell bridge is used. The reason for this will become clear below.

Hay Bridge

Figure 11 shows a Hay bridge. The impedances of the arms are:

$Z_1 = R_1 - \dfrac{j}{wC_1}$,

$Z_2 = R_2$, $Z_3 = R_3$, $Z_x = Rx + jwLx$.

Substituting in $Z_1Z_x = Z_2Z_3$

$$\frac{(R_1 - j)}{wC_1}(Rx + jwLx) = R_2R_3$$

$$R_1\,Rx = jwLxR_1 - \frac{jRx}{wC_1} + \frac{Lx}{C_1} = R_2R_3$$

Equation 9.

Equating real terms $R_1Rx + \dfrac{Lx}{C_1} = R_2R_3$

Equation 10.

Equating imaginary terms $wLxR_1 = \dfrac{Rx}{wC_1}$

Equations 9 and 10 each contain both Rx and Lx, therefore these equations need to be solved as simultaneous equations, yielding:

Equation 11.

$$Rx = \frac{wC_1{}^2R_1R_2R_3}{1 + w^2C_1{}^2R_1{}^2}$$

Equation 12.

$$Lx = \frac{C_1R_2R_3}{1 + w^2C_1{}^2R_1{}^2}$$

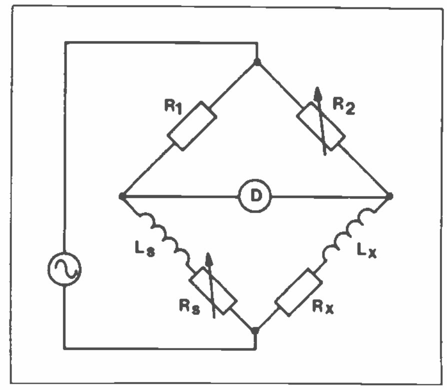


Figure 10. Inductance Bridge.

Substituting $Q = \dfrac{1}{wCR}$ in Equation 12:

Equation 13.

$$Lx = \frac{C_1R_2R_3}{1 + \left(\frac{1}{Q}\right)^2}$$

If Q = 10 then $(1/Q)^2 = 0.01$ and is insignificant and Equation 13 reduces to: $Lx = C_1R_2R_3$.

This final equation is the same as that for a Maxwell bridge, which has a different component arrangement.

Maxwell Bridge

A Maxwell bridge is suitable for coils with a Q between one and ten. Figure 12 shows the arrangement of components in a Maxwell bridge.

$$\text{Now } Z_1 = \frac{R_1\left(\frac{1}{jwC_1}\right)}{R_1 + \frac{1}{jwC_1}}$$

$$= \frac{\frac{R_1}{jwC_1}}{\frac{jwC_1R_1 + 1}{jwC_1}} = \frac{R_1}{jwC_1R_1 + 1}$$

$Z_2 = R_2$, $Z_3 = R_3$, $Zx = Rx + jwLx$

Substituting in $Z_1\ Z_x = Z_2Z_3$

$$\left(\frac{R_1}{jwC_1R_1 + 1}\right)(Rx + jwLx) = R_2R_3$$

Equating real terms:

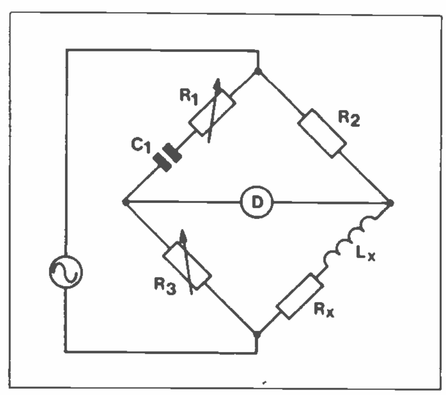
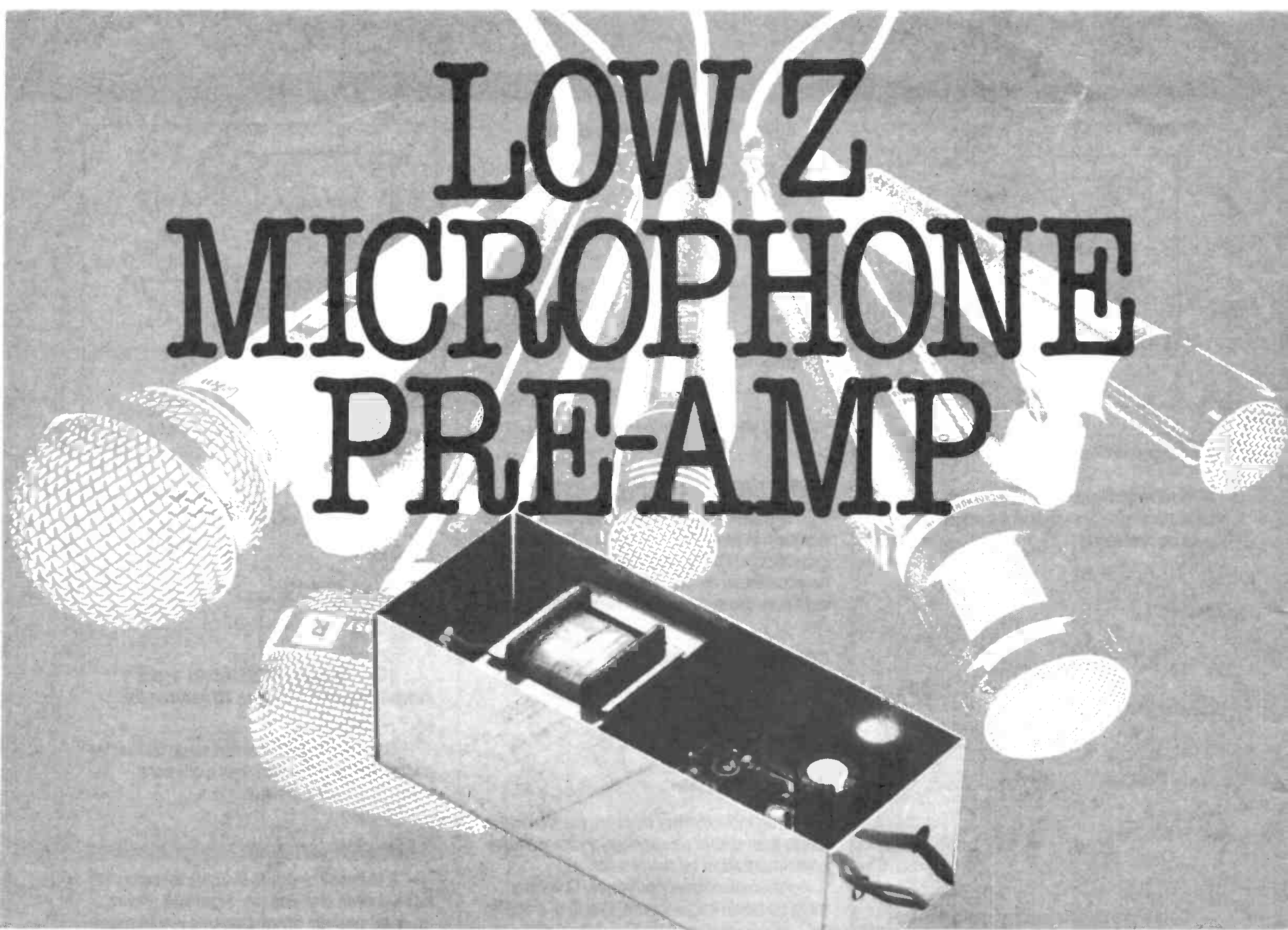


Figure 11. Hay Bridge.

Continued on page 62.

LOW Z MICROPHONE PRE-AMP



by Dave Goodman

- ★ ***Use with Balanced and Unbalanced Microphones***
- ★ ***300 - 600Ω Low Level Input, High Level Output***
- ★ ***Very Low Noise and Distortion***
- ★ ***Low Supply Current Drain***

General purpose microphones are usually supplied as either high impedance or low impedance versions and occasionally, both. In the past, high Z (where 'Z' represents 'impedance') microphones have been the most commonly used in non-studio applications, especially for stage mixing and PA amplification. Modern technology has allowed for very high quality Low Z microphones to be more readily available at much lower prices.

Matching these devices to High Z system inputs poses a problem, due to the inherent low signal levels, and resulting lack of high frequency response. In the absence of Low Z input facilities on amplification equipment, a pre-amplifier is required to match the mic' output impedance and amplify signals to a level suitable for driving into high Z inputs.

The Low Z mic' pre-amp module is intended for this purpose, and is available either in kit form, for home constructors, or as a ready-built module complete with its own screening case.

Impedance

The term impedance, abbreviated to 'Z', is commonly used in electronics and the expression describes the joint opposition to the flow of current, caused by the presence of resistance and reactance, in the circuit. With microphones, be they dynamic or condenser types, it is necessary to know the capabilities of the transducer, under specific operating conditions.

For instance, if a microphone output is designed to deliver 10mV of signal into a 47kΩ load, then decreasing the load to 100kΩ or more (remembering that a larger resistance is a lighter load) would allow a higher signal voltage, greater than 10mV, to be developed. Alternatively, increasing the load to 600Ω or less would greatly reduce the signal level developed.

To standardise these variations, microphone specifications typically state voltage (signal) levels with a particular impedance value; usually 47kΩ for high Z mic's and 600Ω for low Z mic's. With high impedance microphones, frequency is important when driving into a *reactive* circuit. Inductive and capacitive reactances effect the microphone signal level dramatically, and specifications often apply to voltage and impedance values at a frequency of 1kHz.

Low Z Mic Pre-amp Module

MODULE SPECIFICATIONS

Input Impedance	–	600Ω Balanced (300 – 0 – 300Ω)
Typical Signal Levels	–	1.25V out for 1mV in
Maximum Output Level	–	2V r.m.s (5.6V Pk)
Input/Output Gain	–	30 to 50dB Variable
Signal to Noise Ratio	–	80dB
Distortion (@ 1kHz)	–	0.02%
Frequency Response	–	50Hz to 30kHz (–1dB)
PSU Requirement	–	9V @ 3mA

Low Z Balanced Lines

Figure 1 shows two typical configurations for balanced and unbalanced line connections to this module. Because Low Z mic signal levels are very low, in the order of 100 to 500μV, induced noise and hum becomes a very real problem especially where long connecting cables are used. Not all microphones have the facility for balanced line connection

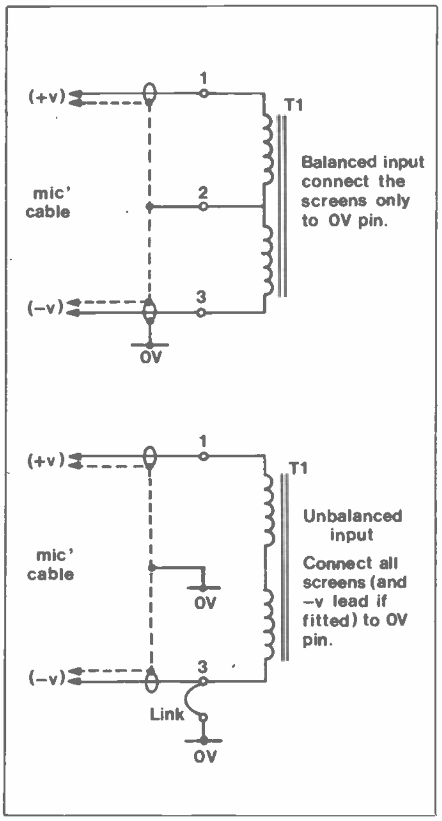


Figure 1. Balanced and Unbalanced Lines.

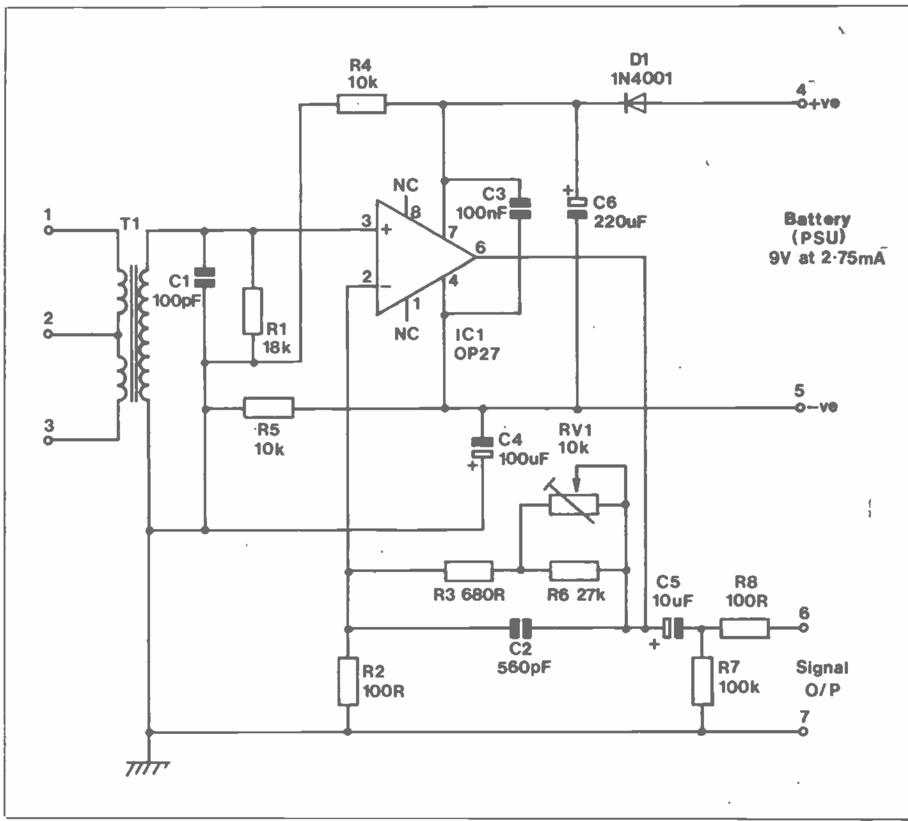


Figure 2. Circuit Diagram.

however, and in this case the unbalanced system must be adopted, although with degraded noise performance. The step up transformer, T1, can be used in either balanced or unbalanced systems with 600 and 300Ω microphones. 200Ω unbalanced lines can also be used, although output signal levels will be reduced by a few dB.

Circuit Description

Figure 2 shows IC1 which is a very low noise, instrument grade op-amp offering wide bandwidth, high slew rates and reduced low frequency noise performance.

For improved component noise figures, gain determining components, R2 and R3, have low values of resistance and C2 prevents RF breakthrough problems associated with local radio transmissions. Capacitor C1 limits HF response and R1 with T1 secondary determine the input impedance for optimum performance of IC1.

The preset potentiometer RV1 allows gain adjustment over a 20dB range, with resistor R6 selected at 27kΩ. The signal output impedance is approximately 600Ω, but at a much amplified level, making for compatibility with high impedance equipment inputs, and DC isolation is maintained by C5. Diode D1 prevents circuit damage in the event that the power supply connections may be reversed, and the divider made up from R4, R5 provides a local '0V' central to the positive/negative supply rails, for the purpose of biasing the inputs of IC1. Input and output signals are consequently referenced to this 0V tap, and *not* the negative rail, which is connected to a top earth plane of the PCB to ensure stability.

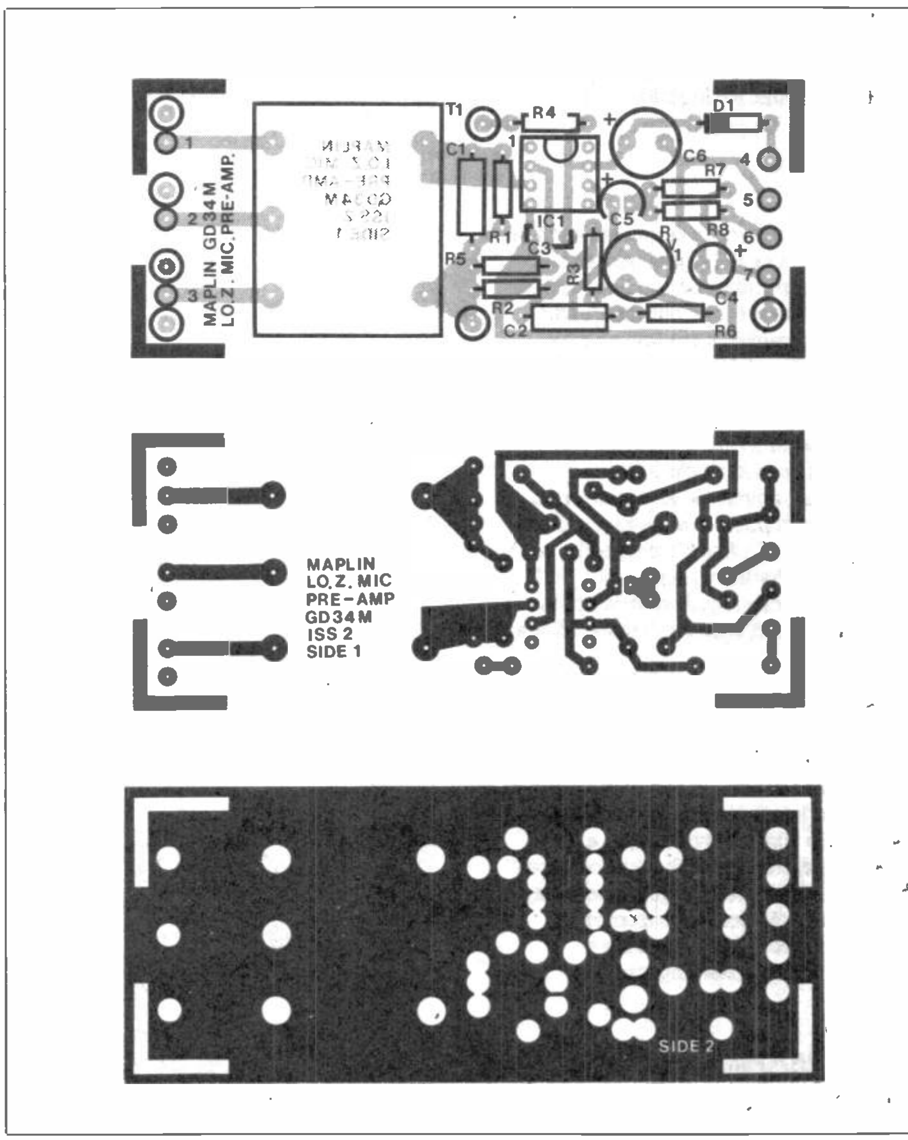


Figure 3. Track and Overlay.

Construction

Reference should be made to the 'Constructor's Guide' supplied with this kit (if you do not intend to purchase the complete kit then see the Parts List for the order code of the Constructor's Guide, price 25p), and Figure 3 which shows the PCB track and legend.

Component assembly is quite straight forward and is best begun by inserting 14 vero pins as detailed in Figure 4. Fit each pin into holes marked with a circle, from track side 1 and solder all pin heads. Seven of these pins require to be soldered on *both* sides of the PCB for connection to the earth plane.

Identify and insert resistors R1 to R8, and capacitors C1 to C6. Observe the polarity rules with electrolytics, and ensure there is adequate clearance between the leads of these components and the earth plane areas on top of the PCB.

Fit diode D1 and solder these components in position, removing excess wires. Mount IC1 directly into position on the board and insert RV1. Carefully solder these components and mount transformer T1 firmly onto the board and solder in place. Do ensure that the five terminating posts on T1 do not touch the earth plane or short across to any components. Clean the track areas and inspect all joints, looking for short circuits, etc.

Testing

A signal source is required, such as a microphone or AF signal generator, and also an amplifier or oscilloscope for monitoring the module output. Power supply requirements are low so a 9V battery, such as a PP3 can be used for this project. Connect the negative supply to Pin 5 (Figure 4) and positive supply via a milliammeter to Pin 4. With 9V applied, the current consumption is approximately 3mA; any large deviation from this figure will point to a fault condition such as D1 or IC1 fitted incorrectly, so switch off immediately and recheck. If all is well, connect a signal source across Pins 1 and 3, and wire Pin 3 to an adjacent 0V terminal.

Take the signal output from Pin 6 to a 'scope, or to an amplifier. Pin 7, connected to 0V, is the ground return connection for the 'scope or amp' cable screen/earth return. When using a signal generator, keep the peak-to-peak signal level at 5 to 10mV maximum, to avoid excessive distortion of the audio output. Turn RV1 clockwise for increased output signal or anticlockwise to decrease. When satisfied that the module is working, fit the screening case as follows.

Case Mounting Details

With reference to Figure 5 place a layer of insulating material cut to the size of the PCB (85 x 33mm) over the inside

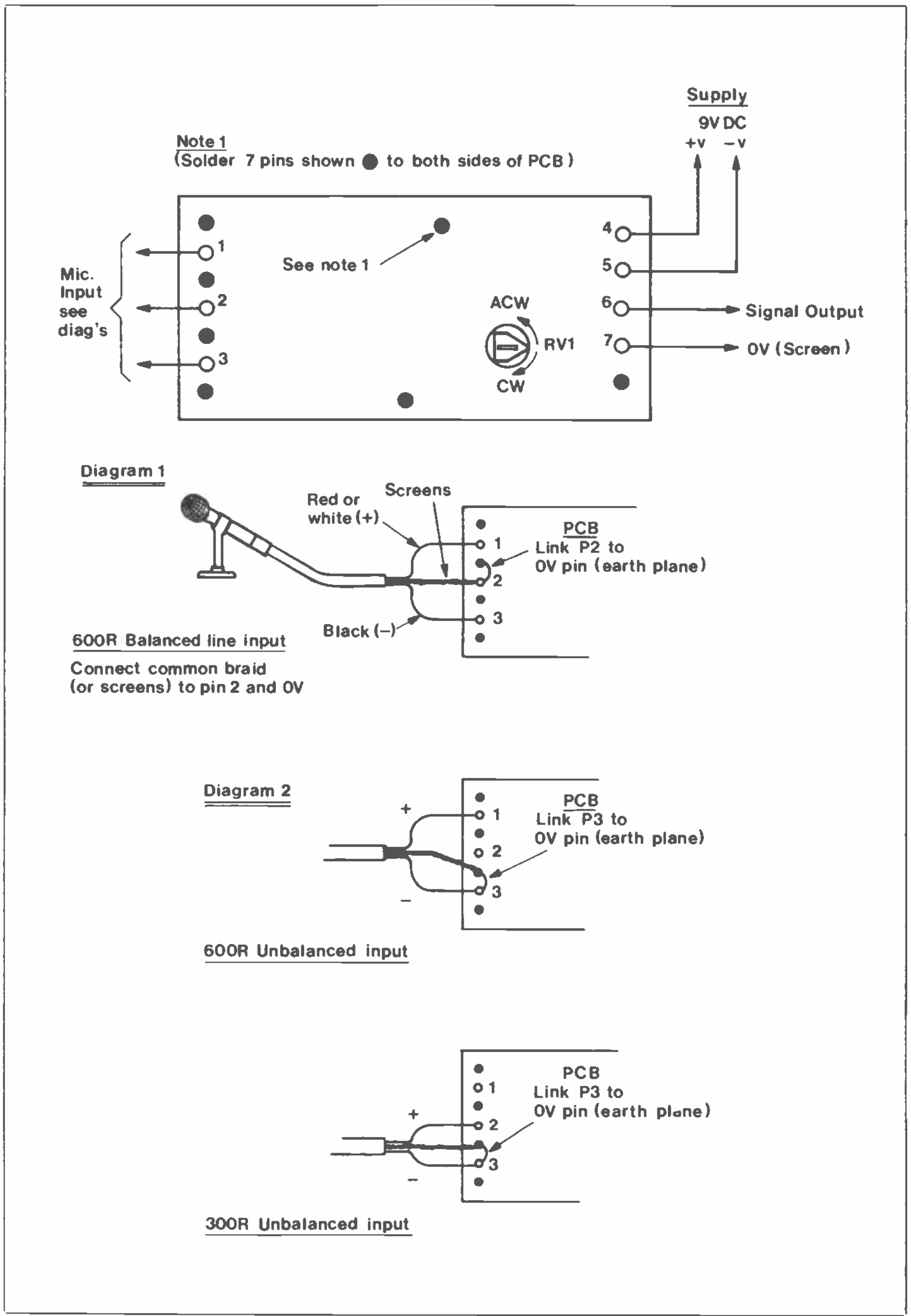
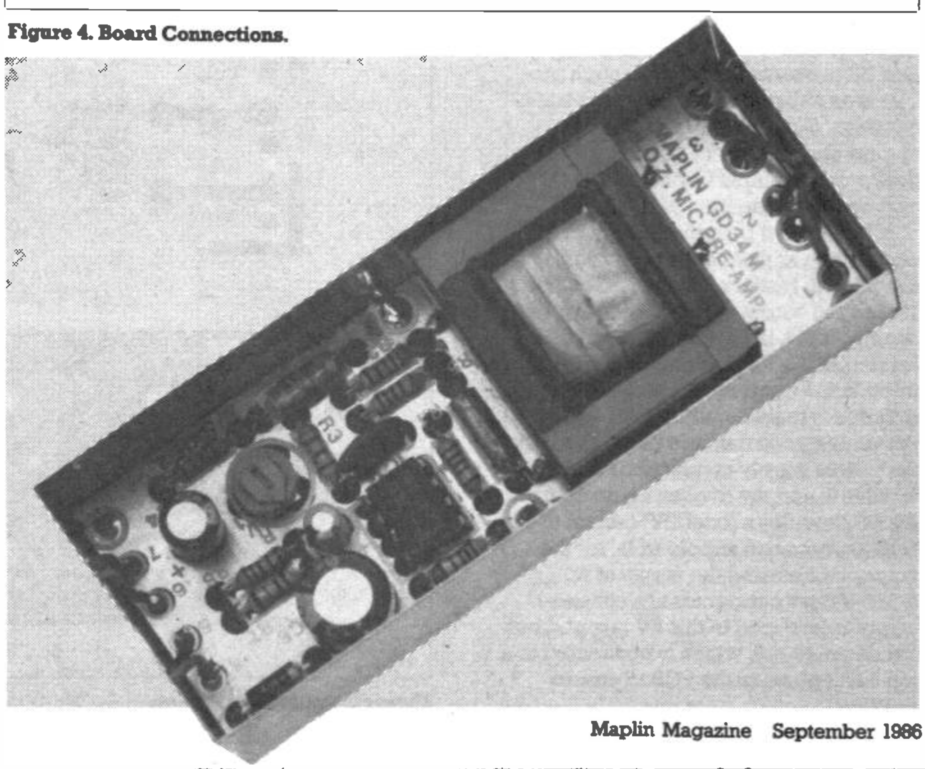


Figure 4. Board Connections.



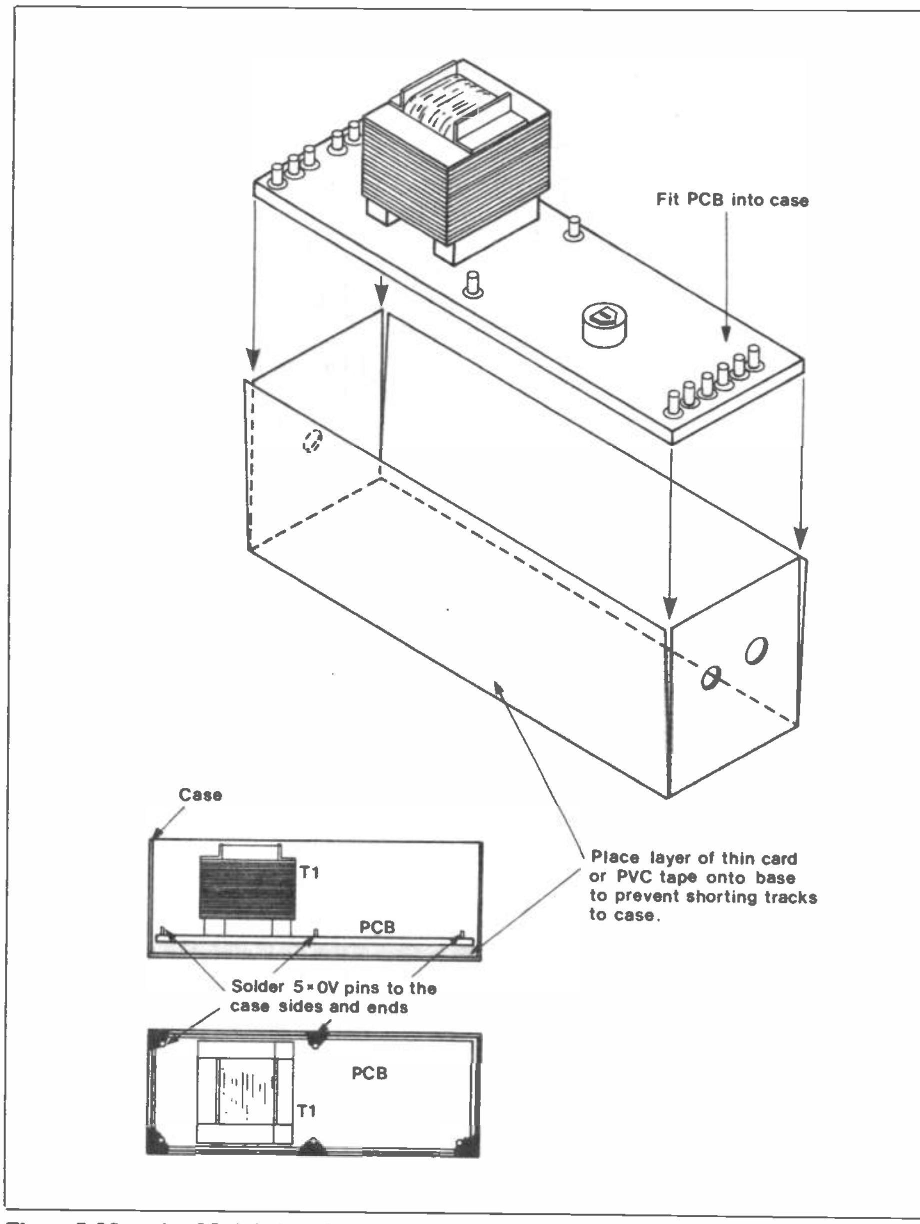


Figure 5. Mounting Module into Case.

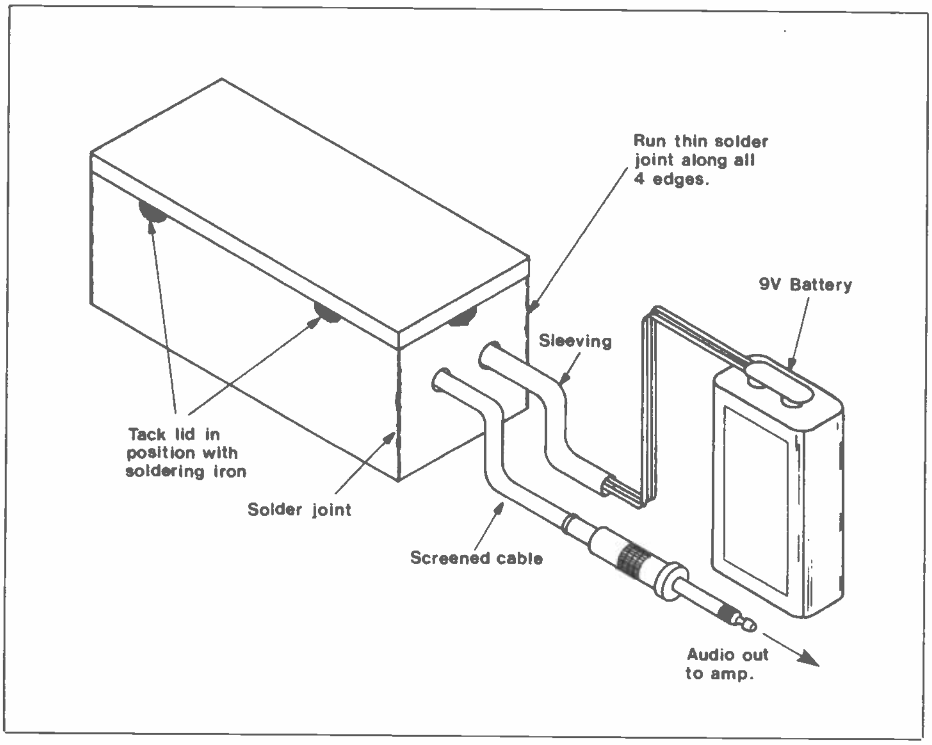


Figure 6. Final Assembly.

base area of the case. The material could be thin card, polythene or a few layers of PVC insulating tape. This insulation prevents the PCB tracks and joints from shorting to the case bottom. Insert the working module into the case with Pins 1 to 3 facing the case end panel that is drilled with a single hole only. If the module is a tight fit then the side plates can be spread apart or the PCB sides may be filed slightly to remove high spots, to help with this operation.

Push the module down towards the base until the transformer T1 just clears the top of the case, and does not obstruct the lid. Test that the module is still working correctly, and then apply small solder joints between all the 0V pins and the case sides as shown. *Do not* overheat the earth plane area, *or* put excessive amounts of solder onto the board. All that's required is a few small joints connecting the case to 0V, and to hold the PCB in position. The four corner edges can have a thin film of solder run along them, but electrically, this should not be necessary, especially if the module is required to be removed from the case later on.

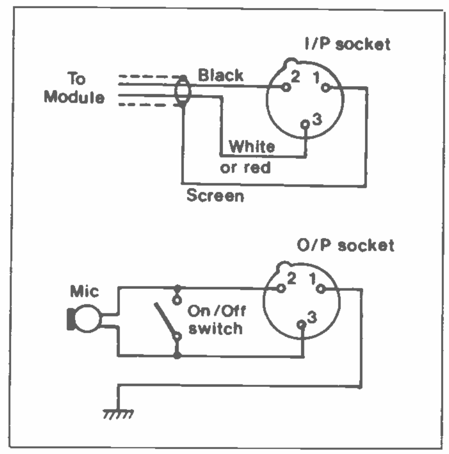


Figure 7. Wiring XLR Connectors.

Final Assembly

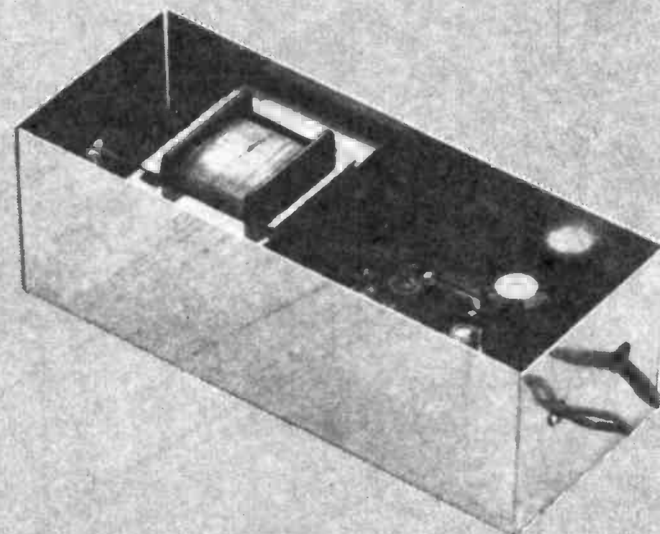
Input/output cables and battery/PSU connections can be made through the end panel holes of the case. Heat shrink sleeving can be fitted over thin wires to prevent them from chafing on the hole edges. Be careful when soldering wires to the PCB pins, as solder can run down onto the earth plane and cause a short circuit.

The input cable (from the microphone) screening braid can conveniently be soldered directly to the outside of the case as can the screened output cable from module to amplifier. Once wiring has been completed, fit the lid in position and distribute a few solder joints around the edges to seal the case, see Figure 6.

Figure 7 details various XLR plug and socket wiring arrangements for reference purposes; the terminals shown are standardised for most microphone/ mixer systems, and these connectors are recommended where small signal, low noise terminations are required.

LOW-Z MIC PRE-AMP PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	18k	1	(M18K)
R2,8	100Ω	2	(M100R)
R3	680Ω	1	(M680R)
R4,5	10k	2	(M10K)
R6	27k	1	(M27K)
R7	100k	1	(M100K)
RV1	10k Cermet	1	(WR42V)
CAPACITORS			
C1	100pF Polystyrene	1	(BX28F)
C2	560pF 1% Polystyrene	1	(BX54J)
C3	100nF Minidisc	1	(YR75S)
C4	100μF 10V PC Electrolytic	1	(FF10L)
C5	10μF 16V Minelect	1	(YY34M)
C6	220μF 16V PC Electrolytic	1	(FF13P)
SEMICONDUCTORS			
IC1	OP-27GNB	1	(RA74R)
D1	1N4001	1	(QL73Q)
MISCELLANEOUS			
T1	Mic Transformer 600/20	1	(FD23A)
	Low-Z Mic Pre-amp PCB	1	(GD34M)
	Low-Z Mic Pre-amp Case	1	(FD20W)
	Veropins 2145	1 Pkt	(FL24B)
	Constructor's Guide	1	(XH79L)
OPTIONAL			
	2mm Systoflex Black	As req	(BH06G)
	PP3 Battery Clip	1	(HF28F)



A complete kit of all parts, excluding optional items, is available for this project:
Order As LK80B (Low-Z Mic Pre-amp Kit) Price £14.95
The following items included in the above kit list are also available separately, but are not shown in the 1986 catalogue:
Low-Z Mic Pre-amp PCB **Order As GD34M Price £1.80**
Low-Z Mic Pre-amp Case **Order As FD20W Price £1.50**
Mic Transformer 600/20 **Order As FD23A Price £5.95**
Constructor's Guide **Order As XH79L Price 25p *NV***
A ready-built version of this Kit is available:
Order As YM14Q (Low-Z Mic Pre-amp Assem) Price £16.95

The Maplin Voyagers' Bounty is Shared

Pictured below on the right is Mr S. Grimmer of Middleton in Manchester, who is the lucky winner of the recent Maplin shop customer competition. Seen shaking hands with Keith Evans, the Manchester Shop Manager, Mr Grimmer was surprised to find that his entry had been judged as the most accurate. He was nevertheless very pleased to accept the prize voucher saying that he may use it to get an upmarket home computer, something he has been wanting for some time.

Mr Grimmer was a regular Maplin mail order customer until Maplin opened a shop in Manchester. It was on one of his recent visits, getting parts to complete the Maplin burglar alarm project, that he was able to stake his claim in the competition. The solutions to the competition questions were as follows:

1. The Maplin Voyager was heading in a North Easterly direction.
2. There were 200 crew on board.

3. The treasure was found at the South Polar Zone.
4. Hebroth IV is 58 light years away from Earth.

Mr Grimmer was correct on the first three questions and only 2 light years out on the fourth!

Second Prize was won by Mr J.E. Cousin of Highgate in London.

The five Runners-Up, who each receive a Maplin Digital Multimeter were:

Mr S.R. Flooks of Hedge End in Southampton; Mr A. Dance of Springfield, Chelmsford in Essex; Mr C.P. Morrison of Harlesden in London; Mr K. Burford of Great Barr in Birmingham; Mr J. Houghton of Warrington in Cheshire.

MACHINE CODE PROGRAMMING WITH THE Z80

Z80

by Graham Dixey C.Eng., M.I.E.R.E. Part Four

More Jumps

The true jumps are JR and JP, discussed last time, but a number of related operations are included for convenience in the same table.

There is the CALL instruction, which is used when you want to access a sub-routine. In assembly language, the operand for CALL is the label or symbolic address by which the sub-routine is known. For example, a sub-routine that develops a fixed time delay might be known simply by the label DELAY, and be located at an address &5CC0. In assembly language we get:

CALL DELAY which, in machine code, is CD C0 5C.

However, CALL is much more useful than just that. The CALL to the sub-routine can be made unconditionally (as in the above example) or subject to one of a number of conditions (carry, non-carry, zero, non-zero, etc.) just as for the jumps JP and some JRs. This raises an obvious question. If there is so much similarity between CALL and JP, what's the real difference? It's an important question and the answer is as follows.

When a jump, whether JP or JR, is made, the contents of the program counter PC are simply replaced by the address of the destination for the jump. The old PC contents are lost and thus there is no provision for returning from whence you came. Usually this doesn't matter otherwise jumps would be of little use. The CALL instruction, on the other hand, recognises the fact that the main program is only being left temporarily (to execute the sub-routine) and a return is intended. Thus, CALL does two things. It changes the PC contents to access the area of memory where the sub-routine resides and saves the old PC by 'pushing' it onto the 'stack'. This provides an opportunity to introduce another instruction from the set, RET (obviously short for RETURN), which must be included at the end of the sub-routine for, when it is executed, it 'pops' the old PC off the stack and the program continues from right after where it left originally when told to by the CALL instruction. Incidentally, the RET instruction is unconditional or subject to exactly the same choice of conditions as the CALL instruction. Figure 1 shows the use of CALL and RET.

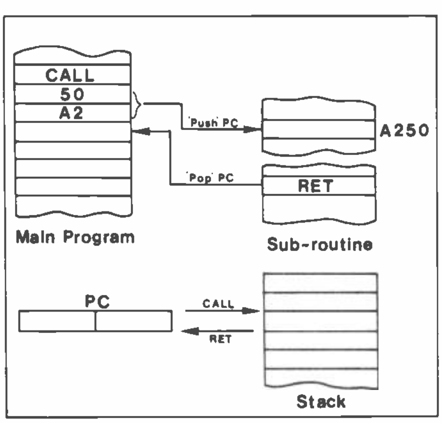


Figure 1. Use of the CALL and RET instructions.

There is a particularly useful instruction in this group, which has the mnemonic DJNZ (Decrement and Jump if Non-Zero). Decrement what? The answer is the B register. This register can be set up as a counter, loaded with any value from &00 to &FF that determines how many times the loop is to be executed. DJNZ is included within the loop and acts as a relative jump back to the beginning of the loop as long as B is not zero. Since, every time that DJNZ is encountered, B is automatically decremented, the program will eventually exit the loop when B becomes zero. Here's an example.

```
       LD    B,&0A    Load B with
                      ten (&0A)
       LD    C,&0C    Load C with
                      twelve (&0C)
       LD    A,&00    Set A register to zero
LOOP:  ADD   A,C      Add C to A
       DJNZ  LOOP     Decrement, jump
                      if B not zero
       LD    DUMP,A   Send result out
```

This simple program causes A to increase in value by a fixed amount (twelve) each time it goes round the loop. Thus, by going round the loop a given number of times (in this case ten), the product of these two numbers is obtained. Obviously the application is limited but it does illustrate the way in which the DJNZ instruction works.

There are just two instructions left in this set, RETI and RETN, which are both return instructions similar to RET discussed previously. However, they relate to 'return from interrupt' rather than from a sub-routine.

So just what is an interrupt? In brief, it's a way of getting the computer to run a particular program and yet be able to handle peripherals, apparently at the same time. Suppose there are three peripherals, known as A, B and C, as in Figure 2. Each of these is connected via a wired-OR configuration to an 'interrupt pin' on the CPU. Each of these peripherals has a flag which is connected to an input port line on the computer. Suppose the latter is happily working away on some task and peripheral A has some data that it wants to send to the computer for processing. How can it let the computer know this? By interrupting!

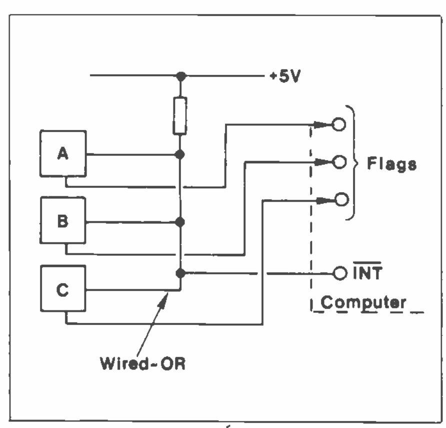


Figure 2. Three peripherals A, B and C connected to a common interrupted line.

It takes the interrupt line low and this initiates a sequence of events that includes pushing the PC (and usually other registers as well) onto the stack and going to an Interrupt Service Routine. But the computer has to decide which of the peripherals actually interrupted, which it does by testing the flags, since the peripheral that interrupted will have its flag 'high'. Then having identified the interrupting peripheral, it will go to a service routine for that peripheral. The sequence is very much like that when a sub-routine is called. But there are important differences. The manner in which it is initiated is quite different. Also the peripherals can be assigned different priorities, thus ensuring that if two or more interrupts occur at once, the most important will be serviced first. Once the service routine is complete a return must be made to the original program. This is accomplished by using the RETI instruction, which 'pops' the PC and other registers off the stack.

However, this hasn't explained what the RETN instruction does. Well, it does the same thing as RETI but for what are called 'non-maskable interrupts'. The term 'mask' is used here in the sense of inhibiting an action, i.e. preventing an interrupt from having any effect on the CPU. Does this seem a strange thing to want to do? Not at all. If there are several peripherals, one of which has interrupted and is being serviced and another, less important one, decides to interrupt also, it shouldn't be allowed to until the previous peripheral has finished. Thus a mask bit is set to prevent this. However, if there is an emergency situation, this must be given top priority, which is done by assigning it to a non-maskable interrupt. The Z80 has two separate interrupt pins. Pin 16, $\overline{INT}$, is where the regular interrupt line is connected. Pin 17, $\overline{NMI}$, is used for the high priority non-maskable interrupts. The rule is, use RETI for $\overline{INT}$ interrupts, and RETN for $\overline{NMI}$ interrupts.

Skew Operations

This group of operations includes the 'shift' and 'rotate' instructions. The first four rotations are RLC, RRC, RL and RR. Rotations may be made to the left or to the right, and may be 'through the carry' or 'with the branch carry'. Figure 3 shows how the operations are carried out. There is a general pattern about them so, once one is understood, the rest follow easily enough.

Taking the rotations first, RLC is a 'circular left rotation', in which all bits shift left and bit 7 goes into the carry flag CY as well as 'round the loop' into bit 0. RRC is simply a rotation in the opposite direction with bit 0 ending up in the carry flag. These rotations may be compared with the next two, RL and RR, in which the carry flag is 'in series' with the rotation. In RL, whatever is in the carry flag goes into bit 0 and bit 7 goes into the carry flag; in RR the exact reverse happens. There are four instructions RLCA, RRCA, RLA and RRA that duplicate the four just described but act on the A register only. They are a hangover from the 8080 from which the Z80 was developed. The Z80 instructions allow all of the registers to be operated upon as well as memory locations addressed by HL, IX or IY.

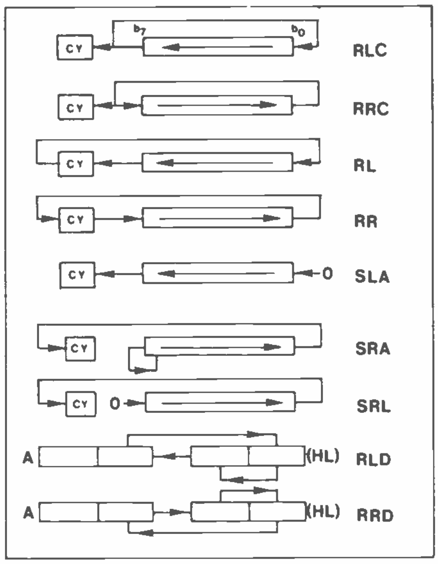


Figure 3. Effects of the 'skew' operations.

Now for the shifts. These may be to the left or the right and also involve the carry flag. However, there is no closed loop, just a series chain. For example, SLA is the Arithmetic Shift Left; all bits shift left one position, bit 7 is 'caught' by the carry flag and a zero enters bit 0.

The carry flag CY is often called a 'carry link' because it allows one register to be linked to another and data passed serially between them. For example:

```
        LD    A,&00
        LD    C,&0FF
        LD    B,&08
LOOP:   SLA   C
        RL    A
        DJNZ  LOOP
```

This program will serially shift the contents of register C into register A with eight consecutive left shifts determined by the DJNZ instruction. However, serial shifting between registers (which includes memory locations) is not all that can be done. Every left shift multiplies a number by two, as the following sequence shows.

Original byte –
00001011 = 11 (denary)

1st shift left
00010110 = 22
2nd shift left
00101100 = 44
3rd shift left
01011000 = 88
4th shift left
10110000 = 176

At which point the carry flag must be used to link this byte to another register to avoid the m.s.b. falling off the end!

SRA is the Shift Right Arithmetic instruction, which is not a simple reversal of SLA. The difference lies in that, instead of a zero entering bit 7, the current value of this bit remains unchanged, thus preserving the 'sign' of the number. The remaining seven bits can be transported across to another memory location, via the carry link, but using the RR instruction on the other location. Each successive shift right divides the number by two, for positive numbers only and only if no ones fall off the rightmost bit position - a simple but limited means of performing binary division.

The difference between SRA and SRL is that the latter is a Logical Shift Right, and a zero enters bit 7 when shifting.

The two instructions RLD and RRD stand for Rotate Digit Left and Right respectively. They are used in Binary Coded Decimal (BCD) arithmetic, in which the digits 0-9 are encoded as four-bit binary groups (0000-1001) or 'nibbles'. They act on data in the A register and a memory location pointed to by HL. Figure 3 clearly shows the re-arrangement of nibbles that occurs for each RLD or RRD instruction, all data moving simultaneously.

Bit Manipulation Group

The instructions in this group allow bits in various registers or indirectly addressed memory locations to be tested for their value (BIT), set to logic 1 (SET) or reset to logic 0 (RES). This is done by specifying the bit number (0-7) and the register. For example:

```
SET   2,C
```

Will set bit 2 of register C to logic 1.

```
RES   5,A
```

Will reset bit 5 of the A register (to logic 0), while:

```
LD    HL,&A200
BIT   3,(HL)
```

Will test bit 3 of memory location &A200 and will set the zero flag in the flags register F if the bit is found to be zero.

The ability to manipulate or test bits in registers or memory locations on an individual basis is a very useful one.

General Purpose AF Group

There are just five instructions in this group, which are concerned solely with the A register or the flags (F) register.

The first of these, Decimal Adjust A register (DAA) is used when arithmetic is to be done in BCD. The problem arises because the CPU can only work in binary and special provision must be made to compensate for errors that may arise when working in another system. As we know, BCD uses four bits to encode the denary digits 0-9, i.e. uses the groups 0000 to 1001. But what about the remaining possible groups, 1010 - 1111? These can obviously occur in binary addition and subtraction yet have no meaning in BCD - they are 'illegal' codes.

It is possible to skip over these six illegal codes by adding six to the result whenever such a code occurs. Consider the following BCD addition of 35 and 22.

```
  0011 0101  (35)
+ 0010 0010  (22)
  ---------
  0101 0111  (57)
```

The answer 57 is obviously correct.

Now see what happens with the sum of 35 and 25.

```
  0011 0101  (35)
+ 0010 0101  (25)
  ---------
  0101 1010  (5?)
```

The second nibble of the result is one of the illegal codes.

Now add 6 to the result and see what happens.

```
  0101 1010
+      0110
  ---------
  0110 0000  (60)
```

The corrected result is now right. Fortunately we don't have to worry about when to add six or whether it should be added to the low nibble or the high one, or even both. On receipt of DAA, the CPU tests the flags and decides for itself what to do.

The DAA instruction should follow when operating in BCD with any of the following instructions, ADD, ADC, INC, SUB, SBC, DEC, NEG.

CPL is a useful single-byte instruction which complements the contents of the A register, that is swaps 1s for 0s and vice-versa.

```
LD    A,&2C
CPL
```

The above example means that the A register is loaded with 00101100 (2C) which, after the CPL instruction, becomes 11010011 (D3).

NEG means 'negate the A register', e.g. if the number held is a positive one, then form the two's complement of it.

&0F (+15) becomes &F1 (−15)
&E2 (−30) becomes &1E (+30)

The final instructions in this group are CCF (Complement Carry Flag) and SCF (Set Carry Flag). CCF inverts the value of the carry flag, while SCF forces it to logic 1.

Restarts

This group of eight instructions is a special set of sub-routine calls, whose origin addresses are &00, &08, &10, &18, &20, &28, &30 and &38. Commonly used sub-routines can be called from these addresses and require only a single-byte instruction.

For example, RST 20 calls the sub-routine whose origin is at the address &0020. Somewhat confusingly these restarts are sometimes referred to by their denary values, i.e. RST 32 may be used instead of RST 20.

Control Instructions

The first instruction in this group is NOP, which stands for No OPeration, meaning that the CPU does precisely nothing during the time of this instruction. It can be useful, however, to insert a few NOPs into programs sometimes, so that program changes can be accommodated more easily by changing them to active instructions. They can also be put into a loop to act either as a short time wasting program, or where an interrupt is anticipated and the machine must be idle, such as in keyboard input routines, thus:

```
WAIT:   NOP
        JR    WAIT
```

The CPU obediently cycles back and forth between the two lines until the interrupt breaks into the loop. HALT could be used instead, since this will stop the operation of the CPU until either an interrupt is received or the reset pin (pin 26) is taken low. The remaining five instructions are all concerned with interrupts and work as follows:

DI and EI stand for 'Disable Interrupts' and 'Enable Interrupts' respectively. Earlier it was said that various interrupts can have different priorities. Thus, if a high priority interrupt wishes to ensure that it cannot be over-ridden by one of lower priority, the first thing it does when it goes into its Interrupt Service Routine is to disable further interrupts with the DI instruction. Then, when it has completed its routine it will issue the EI instruction to allow further interrupts to be acknowledged by the CPU. The last three instructions are concerned with the interrupt modes of the Z80 and require more detailed discussion.

IM0 sets mode 0. This can be referred to as the 8080 mode, since it is compatible with the older 8080 CPU. In this mode, when an interrupt is received, the PC is pushed onto the stack and the Z80 passes control of the data bus to the interrupting peripheral. The latter responds by placing an instruction on the data bus, which is usually a sub-routine call to execute the service routine for that particular peripheral. One of the restart instructions may be used for this.

IM1 sets mode 1, which is the 'polled response mode'. When an interrupt is received the CPU calls a sub-routine located at the restart address &0038. This will then poll the various peripherals to ascertain which one interrupted and then will service that peripheral.

IM2 is the most powerful of the Z80 interrupt modes. It uses a register, the I or Interrupt Vector register, which has to be loaded with the high byte of the interrupt vector. The low byte is supplied by the interrupting device itself. This complete vector then points to two consecutive locations that give the start address for the service routine. This is not as complex as it may sound and is illustrated in Figure 4.

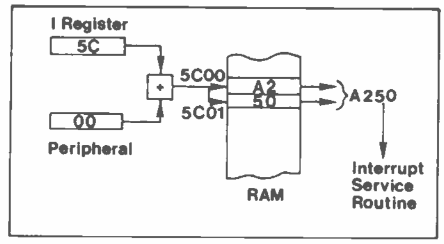


Figure 4. The Z80 Mode 2 interrupts.

The Input-Output Group

And so to the final set of instructions for the Z80, those that deal with the transfer of data between the CPU and the outside world through interface chips such as the Z80 PIO.

Unlike the 6502, the input/output ports on a Z80 system are not memory-mapped, i.e. they do not have memory addresses on the main memory map of the computer. Instead they are identified by 'port addresses', which are usually in the range &00 – &FF (which allows for 256 separate ports). In theory it is possible to have 65536 individual ports – the mind boggles! This is done by combining the number held in the A register (the high byte) with the operand of the instruction (the low byte) to give an address range for the ports from &0000 – &FFFF.

To fetch data from a port, the IN instruction is used together with the destination register and the port address, thus:

```
IN    A, &02
```

Will fetch the data at port &02 and place it in the A register.

Data is sent to the port by using the OUT instruction, the port address and the destination register, so that:

```
OUT   &02, A
```

Will send the contents of the A register to port &02. The other general purpose registers can also be the subject of IN and OUT instructions, but by means of register indirect addressing, using the C register. Thus, to send data from the D register to port &02 and then input data from port &03 into the E register, the following program could be used.

```
LD    C, &02
OUT   (C), D
INC   C
IN    E, (C)
```

There is also a range of block transfers for IN and OUT, that work in essentially the same way as the block transfers described in Part Three. INI is used to fetch data from a port and load it into a block of sequential memory locations and vice-versa for OUTI. In both cases the I stands for Increment. If, instead, the instruction INIR or OUTIR is issued the process of transferring data and incrementing to the next address is done automatically until the whole block has been transferred. In this type of transfer HL is first loaded with the start address of the block, B with the number of bytes to be transferred and C with the port address. Consider the following program:

```
LD    HL, &A200
LD    B, &32
LD    C, &02
INIR
```

This will load the block of memory &A200 – &A231 with the fifty bytes of data, specified by the B register, from port &02.

If INI is used instead of INIR only one byte is transferred, but HL is incremented and B decremented ready for the next INI.

In both cases the transfer is complete when B = 0 though, in the case of INI, this must be ascertained by testing the Z flag after each transfer to see if it now equals 1.

Analogous to INI, INIR, OUTI and OTIR are IND, INDR, OUTD and OTDR. The D, of course, stands for Decrement and refers to the fact that at each transfer HL is 'decremented' instead of being incremented. As a result, HL initially holds the 'top' address of the memory block, which is then loaded 'downwards'.

Some of the descriptions may have been fairly brief, but all of the Z80 instructions have now been discussed. This means that future articles can deal entirely with the writing of a variety of programs in Z80 code, on the assumption that all mnemonics may now have some meaning, even if it does sometimes mean a quick look back to earlier issues.

TEST GEAR & MEASUREMENTS *Continued from page 53.*

Equation 14.

$$Rx = \frac{R_2R_3}{R_1}$$

Equating imaginary terms:

Equation 15.

$$Lx = C_1R_2R_3$$

Since R_3 is common to both Equations 14 and 15, adjustment of R_3 to balance the inductor, upsets the resistive balance. Using R_1 and R_3 in turn results in successive balance points such that convergence is obtained towards final balance.

The other bogey man of bridge circuits is stray capacitance between bridge arms. Up to now we have assumed that the arms of the bridge contain lumped impedances. In practice, stray capacitance couples the various arms and upsets the balance giving a false reading.

One way out of this is the Wagner ground where all the arms are shielded and the screens connected to ground. This does not get rid of the capacitances but does make them constant in value enabling them to be included in the calculation.

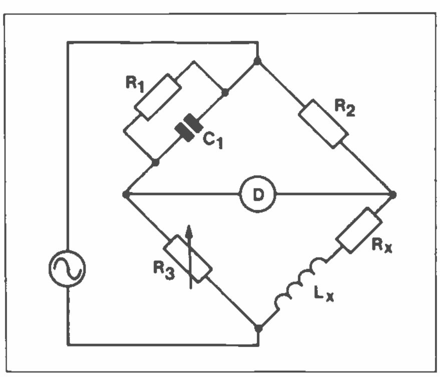


Figure 12. Maxwell Bridge.

Wien Bridge

This is a very useful bridge for measuring frequency, Figure 13. One of the drawbacks is that it requires a pure sinusoid, and any harmonics tend to upset the balance.

The Wien bridge is versatile and has been used in modified forms in oscillator circuits as well as notch filters in frequency analysers for extracting a particular frequency.

$$Z_3 = \frac{R_3}{jwC_3R_3 + 1}$$

$$Z_2 = R_2$$

$$Z_4 = R_4$$

$$Z_1 = R_1 + \frac{1}{jwC_1}$$

Substituting in $Z_1Z_4 = Z_2Z_3$

$$\left(R_1 + \frac{1}{jwC_1}\right) R_4 = R_2 \left(\frac{R_3}{jwC_3R_3 + 1}\right)$$

$$R_1R_4 + \frac{R_4}{jwC_1} = \frac{R_2R_3}{jwC_3R_3 + 1}$$

$$R_1R_4(jwC_3R_3 + 1) + \frac{R_4}{jwC_1}(jwC_3R_3 + 1) = R_2R_3$$

$$jwC_3R_3R_1R_4 + R_1R_4 + \frac{R_4}{jwC_1} + \frac{R_4R_3C_3}{C_1} = R_2R_3$$

Equating imaginary terms:

$$w^2C_3C_1R_1R_3R_4 = R_4$$

$$w^2C_3C_1R_1R_3 = 1$$

$$w^2 = \frac{1}{C_3C_1R_1R_3}$$

if $C_1 = C_3$ and $R_1 = R_3$

then $w^2 = \frac{1}{C^2R^2}$

$$w = \frac{1}{CR}$$

Equation 16.

$$f = \frac{1}{2\pi CR}$$

Equating real terms:

$$R_1R_4 + \frac{R_4R_3C_3}{C_1} = R_2R_3$$

$$\frac{R_1R_4}{R_3} + \frac{R_4C_3}{C_1} = R_2$$

$$\frac{R_1}{R_3} + \frac{C_3}{C_1} = \frac{R_2}{R_4}$$

As before, if $C_1 = C_3$ and $R_1 = R_3$

Equation 17.

then $\frac{R_2}{R_4} = 2$

This means that if R_2 is twice the value of R_4, then R_1 and R_3 can be ganged together and altered in equal steps to achieve balance. Therefore only one control is sufficient, and can be calibrated in frequency according to Equation 16.

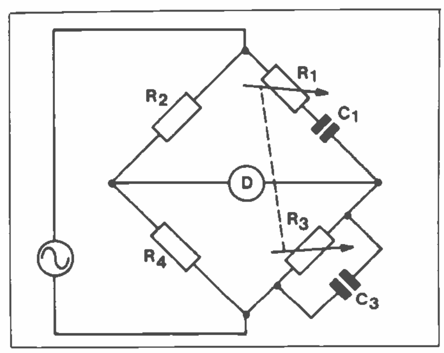


Figure 13. Wien Bridge.

A Universal Bridge

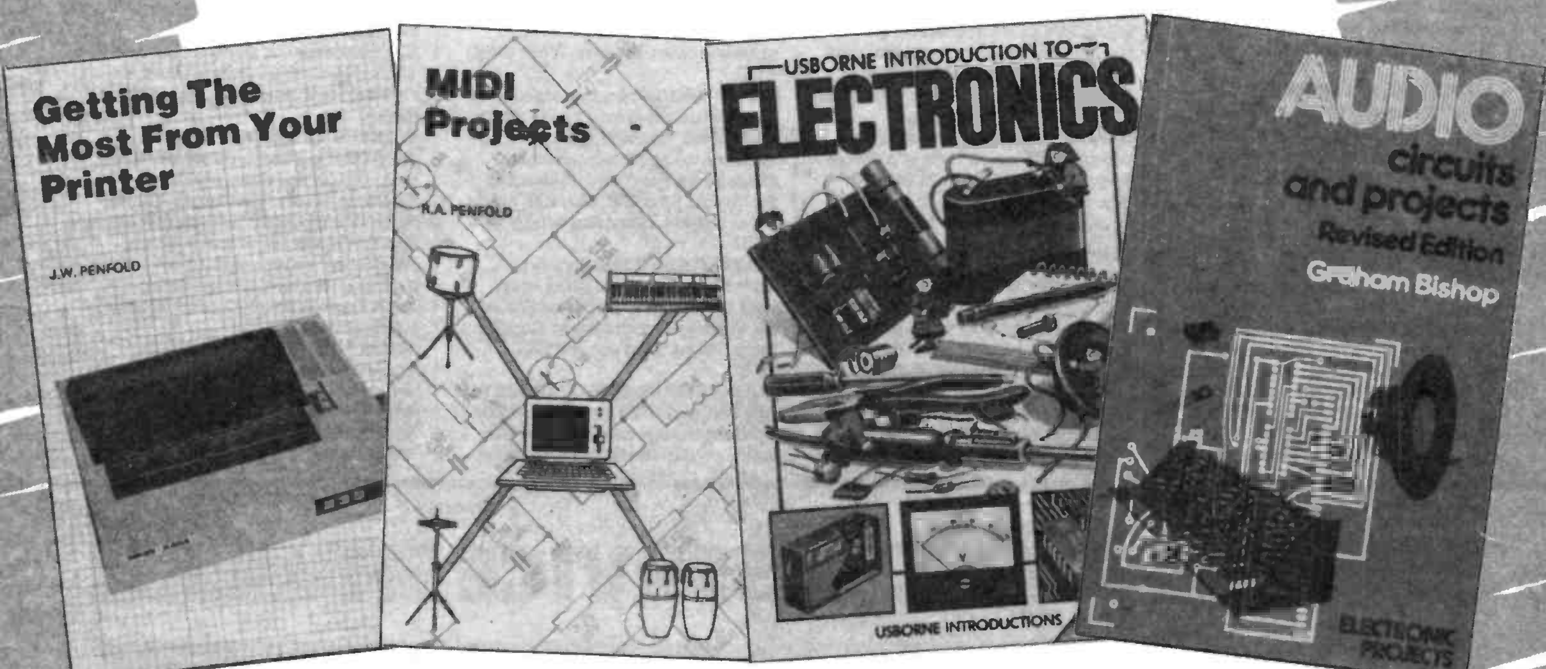
A portable impedance measuring instrument complete with handle and lid is standard in most development laboratories. In order to measure resistance, inductance and capacitance, such an instrument needs d.c. and a.c. power supplies as well as d.c. and a.c. detectors.

For a d.c. power supply, battery packs are used, and a.c. is supplied from an oscillator via RC networks to select the frequency. A frequency of 10kHz is the usual standard.

A suspension galvanometer with a sensitivity of 0.5μA per division is used as a d.c. detector in resistance measurements. An electron ray tube (magic eye) is used as an a.c. detector. There is usually an external facility for connecting headphones, as well as an a.c. mains power supply input.

Now to the actual measurements themselves. What is the minimum number of bridges we can get away with? For inductance measurements, both the Hay and Maxwell bridges are required for Q above ten and less than ten respectively. For resistance measurements a Wheatstone bridge is adequate and a bank of standard capacitors is required for capacitance measurements. So about half a dozen different bridges will serve most requirements.

New Books



Getting the Most from Your Printer

by J.W. Penfold

It is probable that a large majority of dot-matrix printer owners only ever use a fraction of the possible features offered by their machines. Often this is because the manual supplied tends to be a bit on the technical side and lacking in really helpful explanations of the printer's capabilities.

This book has been written for dot-matrix printers commonly in use with most popular home computers including the BBC and Acorn Electron, Amstrad, Sinclair Spectrum and QL, Commodore, Memotech, MSX and Enterprise. It will help the user to realise more of the afore-mentioned capabilities of his dot-matrix by illustrating exactly how to achieve given effects in word processing, using printed listings as an aid to program design (it is said by many users who dabble in program writing of their own that they wouldn't like to think about how they would have managed in the days before the printer was eventually added into the system), as a peripheral used by the user's own programs, and how to print graphics effectively.

178 x 112mm, 88 pages, illustrated.

Order As WP48C (Get Most from Your Printer) ***Price £2.95 NV***

MIDI Projects

by R.A. Penfold

MIDI interfacing enables any so equipped instruments, regardless of manufacturer, to be easily interconnected and used as a complete, sophisticated system. The MIDI interface also permits easy computer control of such a system, and a few MIDI compatible instruments together with a suitable computer and interface can provide the user with what is virtually a programmable orchestra.

The major part of this book provides details of how to interface most of the popular home computers with MIDI systems, including all circuit diagrams with operational detail, plus examples of programming used to drive the interface. Machines catered for include the Amstrad CPC464 and 6128, CBM 64 and VIC-20, BBC Model B, MTX and MSX computers, and the Sinclair QL, Spectum and ZX81.

The book also includes examples of interfacing MIDI equipment to analogue and percussion synthesisers.

178 x 112mm, 103 pages, illustrated.

Order As WP49D (MIDI Projects) ***Price £2.95 NV***

Introduction to Electronics

by Pam Beasant

This book is an introduction to the basic principles of electronics, and ideal for the younger beginner. Many introductory text books deal mainly with the electronic theory alone, with little, if any, really useful, down to earth practical illustration of how a soldering iron should be used. For the new amateur enthusiast as well as for the professional student, the gulf between the calculations and diagrams on paper, and assembling (and making work!) the real hardware itself is always a shock. Here a host of hitherto unforeseen problems, sometimes of a more 'mechanical' nature, lie in wait. Electricity is ever fickle, and at the outset the book states its purpose to show how this energy must be *controlled*.

The bulk of the book comprises many simple, practical experiments copiously illustrated in full colour. Each experiment is designed to illustrate an important principle of electronics and demonstrate how each different component works. This ranges from the very basic using light bulbs and batteries, through an introduction to transistors, choice and use of tools and how to solder, to circuit assembly on veroboard. A potted history of the science is also included. A must for anyone totally unfamiliar with real electronic components, and a useful supplement to the text books.

240 x 170mm, 48 pages, illustrated in colour.

Order As WP50E (Intro Elec) ***Price £2.25 NV***

Audio Projects and Circuits

by Graham Bishop

No matter how sophisticated your audio system, there are circuits here that will improve it – if not in sound quality, then in convenience. There are projects to cater for the musician too. A whole series of tested projects, easy and inexpensive to build, are shown together with full constructional details.

The first part of the book includes projects for audio amplifiers, preamplifiers and signal correction/processing, with designs ranging from single transistor circuits to a 100W power amp design. The second part covers musical instruments such as synthesisers, rhythm generators and organs, including effects devices such as sound to light modulation and other 'fun circuits'.

All the projects can be built onto veroboard, and components lists and relevant semiconductor information is included. Even if you do not wish to build all or any of the designs as they are, the book certainly contains many thought provoking ideas.

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