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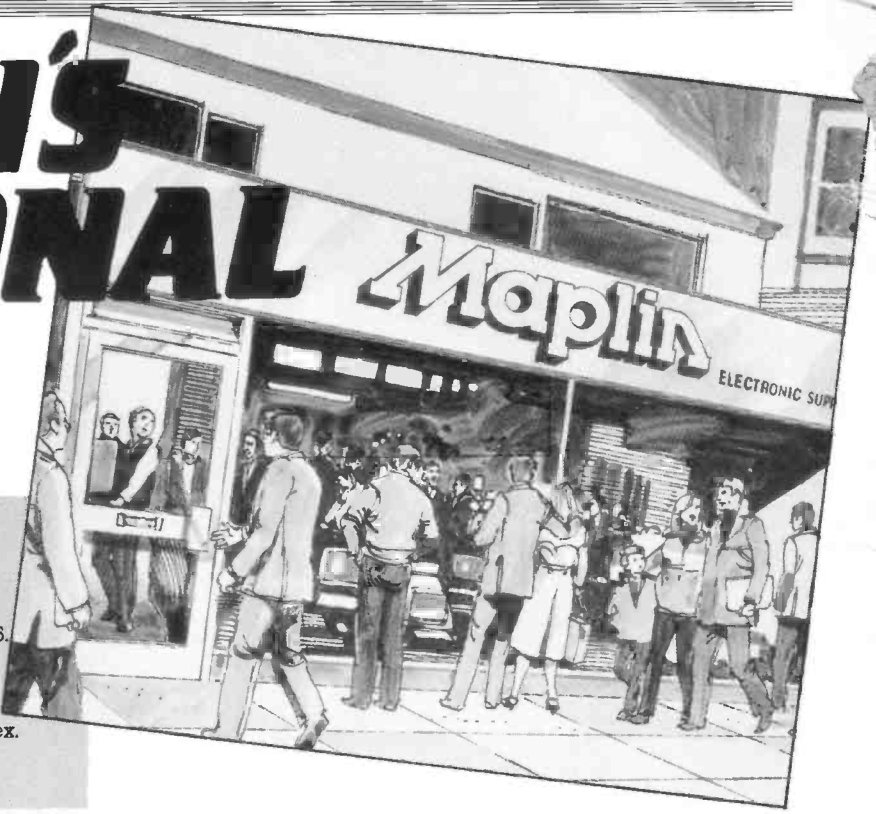

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June to August 1986
Volume 5 Number 19

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THE MAPLIN MAGAZINE

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P.O. Box 3, Rayleigh, Essex SS6 8LR.
Telephone: Retail Sales: (0702) 552911.
Trade Sales: (0702) 552961. General: (0702) 554155.
Computer Ordering: (0702) 552941.

Shops: See inside front cover.
All shops closed Mondays.

Editorial & Production
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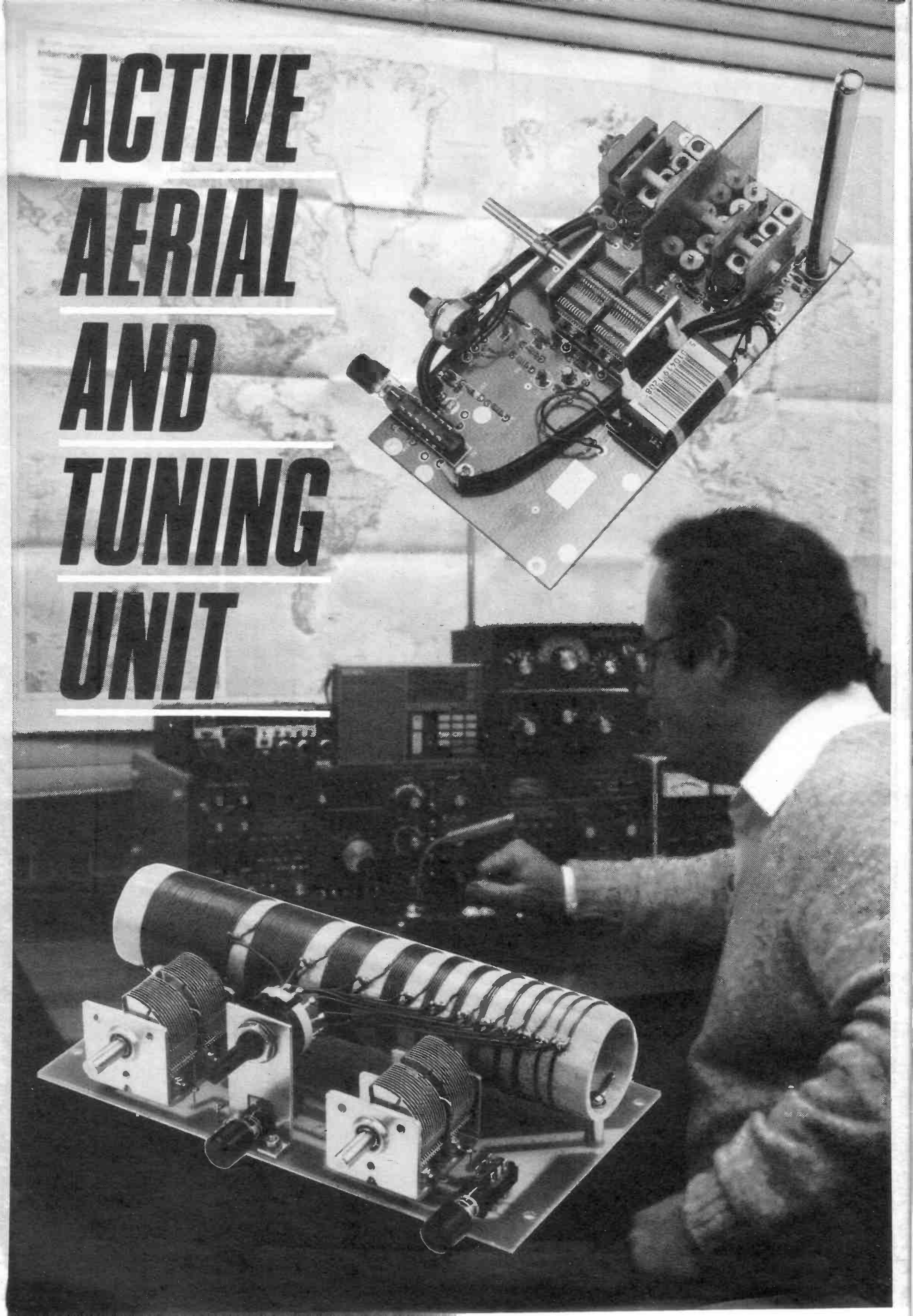
Published by Maplin Electronic Supplies Ltd.
Typesetting by Essex Process and Engraving Co. Graphic House, Stock Road, Southend-on-Sea, Essex.
Printed by Mayhew McCrimmon Ltd., Star Lane, Great Wakering, Essex.
Distributed by Spotlight Magazine Distribution Ltd., 1-11 Benwell Rd, London N7.

ACTIVE AERIAL AND TUNING UNIT



Two Devices

In the following article, two add-on devices for your receiver are described in detail for you to construct. They are designed to increase the strength of the radio signal being received over a wide range of frequencies. For broadcast and shortwave listeners using a general coverage receiver both devices will offer an improvement in reception even when used in conjunction with a small aerial system.

The first device is a simple, passive Aerial Tuning Unit. The second is the Active Aerial which incorporates a dual-gate Mosfet amplifier. The best results are achieved when both are used together with an outdoor aerial system. However, worthwhile improvements in radio reception are possible when using only one device or the other. In deciding whether to use just one or perhaps both of the units, with your particular receiving station, it is recommended that you read through each part of this article and also determine if the deficiency is due to aerial impedance mismatch or lack of receiver sensitivity.

Aerial Tuning Unit

One of the most common types of simple receiving aerials is the end-fed, long wire, its length being governed by the amount of space available within the boundaries of your property. An average length for such an aerial is between 20 and 50 metres. Its height above the ground is not critical at MW/SW frequencies, but it is far more convenient to get it up in the air out of the way, usually at around 5 to 10 metres. The main disadvantage of this system is that its impedance presented to the aerial input of a communications receiver will vary depending upon the frequency. The range of impedance values may swing from a few ohms to several thousand ohms. When looking at the frequency/impedance characteristics of your aerial system you will need to know its wavelength relationships.

The mathematical calculation is quite simple. The velocity of a radio wave, whilst travelling through free space, is constant at 186,000 miles or 300,000,000 metres per second. In the following formula, V = Velocity, and F = Frequency in Hertz (cycles). The result is the full wavelength in metres.

$$\frac{V}{F} = \frac{300{,}000{,}000}{1{,}875{,}000\text{Hz}} = \frac{300}{1.875\text{MHz}} = 160$$

The relationship between the impedance and the wavelength of the aerial will vary; at a full or half wave length it will appear to the receiver as a relatively high impedance, while at quarter-wave, or at an odd multiple of quarter-waves, it is considerably lower.

The aerial input impedance of most communications receivers is 50Ω. Unless the impedance of the aerial matches that of the input of your receiver, you will not transfer all the RF energy from the aerial to the receiver input circuit. The more extreme the mismatch the weaker the received signal will appear, and under adverse conditions it could vanish into the background noise. The answer to this problem would be an impedance matching

by C.S. Barlow & Ms M.A. McCarthy

AERIAL TUNING UNIT

SPECIFICATION OF PROTOTYPE

Frequency Range	= 600kHz to 30MHz
Input Impedance, Aerial	= Variable
Output Impedance, Receiver	= 50Ω
Transmitter Power Capability	= 10 watts

transformer which will accept a wide range of input impedances and convert them down to the 50Ω level required by the receiver. At the frequencies where the aerial impedance is close to that of the input of the receiver no amount of matching will improve the signal. Under these conditions more gain in the aerial system or in the receiver would be necessary.

Circuit Description

The circuit shown in Figure 1 consists of two variable capacitors and a tapped inductor forming a 'T' configuration. The origin of this

- ★ **Boost Radio Reception with these Super Projects**
- ★ **Both Units can be used with a Wide Range of Radios**
- ★ **Tuner is Simple to Construct, DC Power not Required**
- ★ **No Coil Winding on Aerial Project**
- ★ **Includes High Quality Telescopic Aerial**

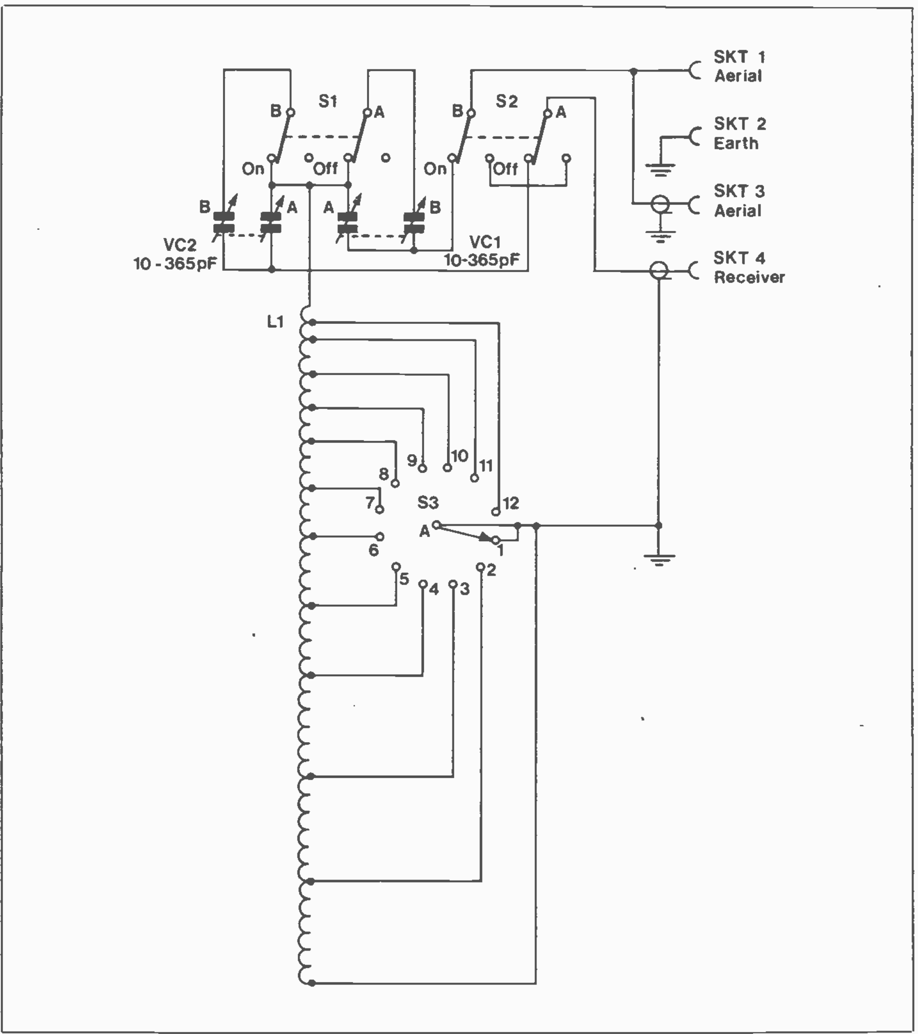


Figure 1. Tuner Circuit

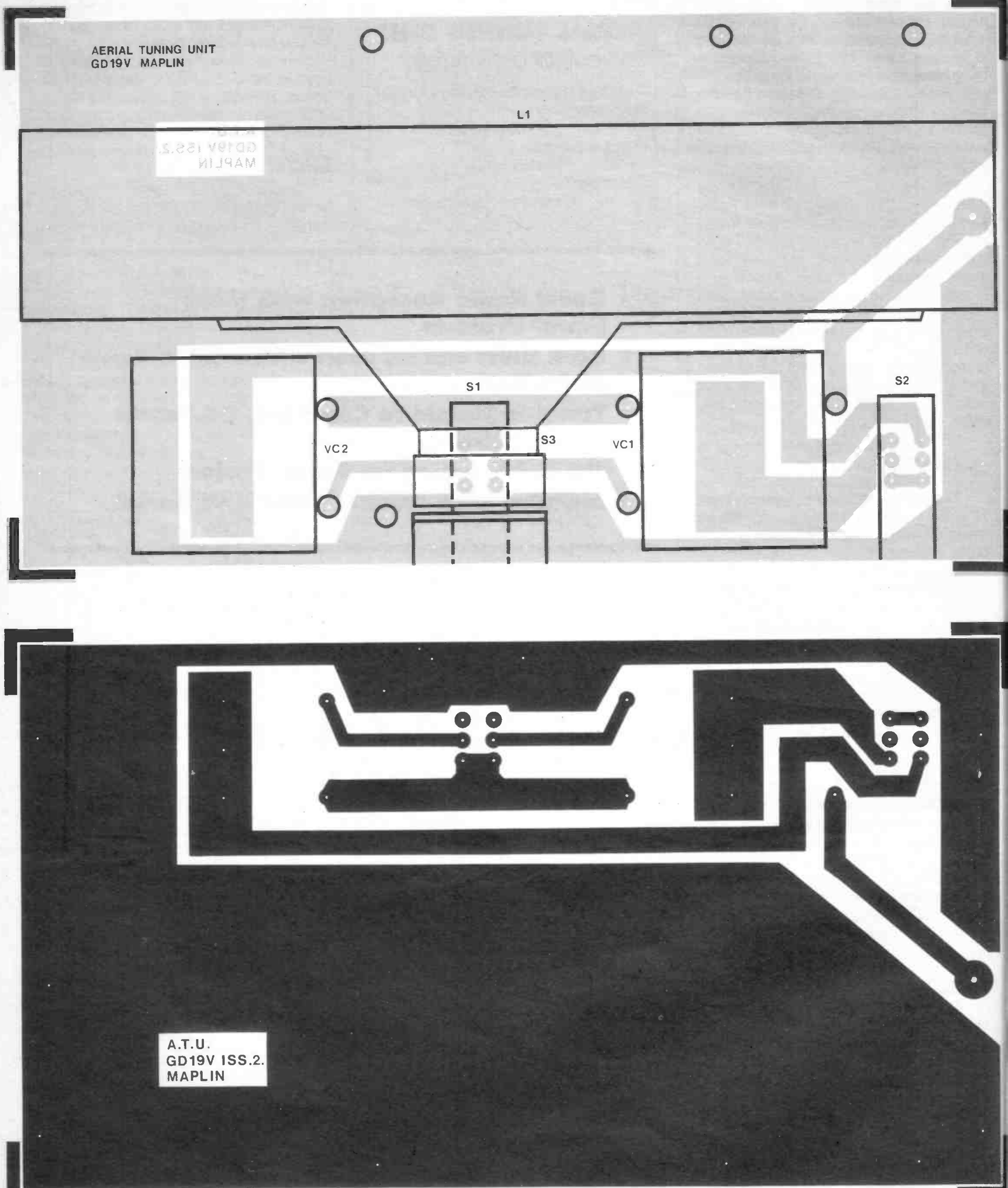


Figure 2. Tuner PCB

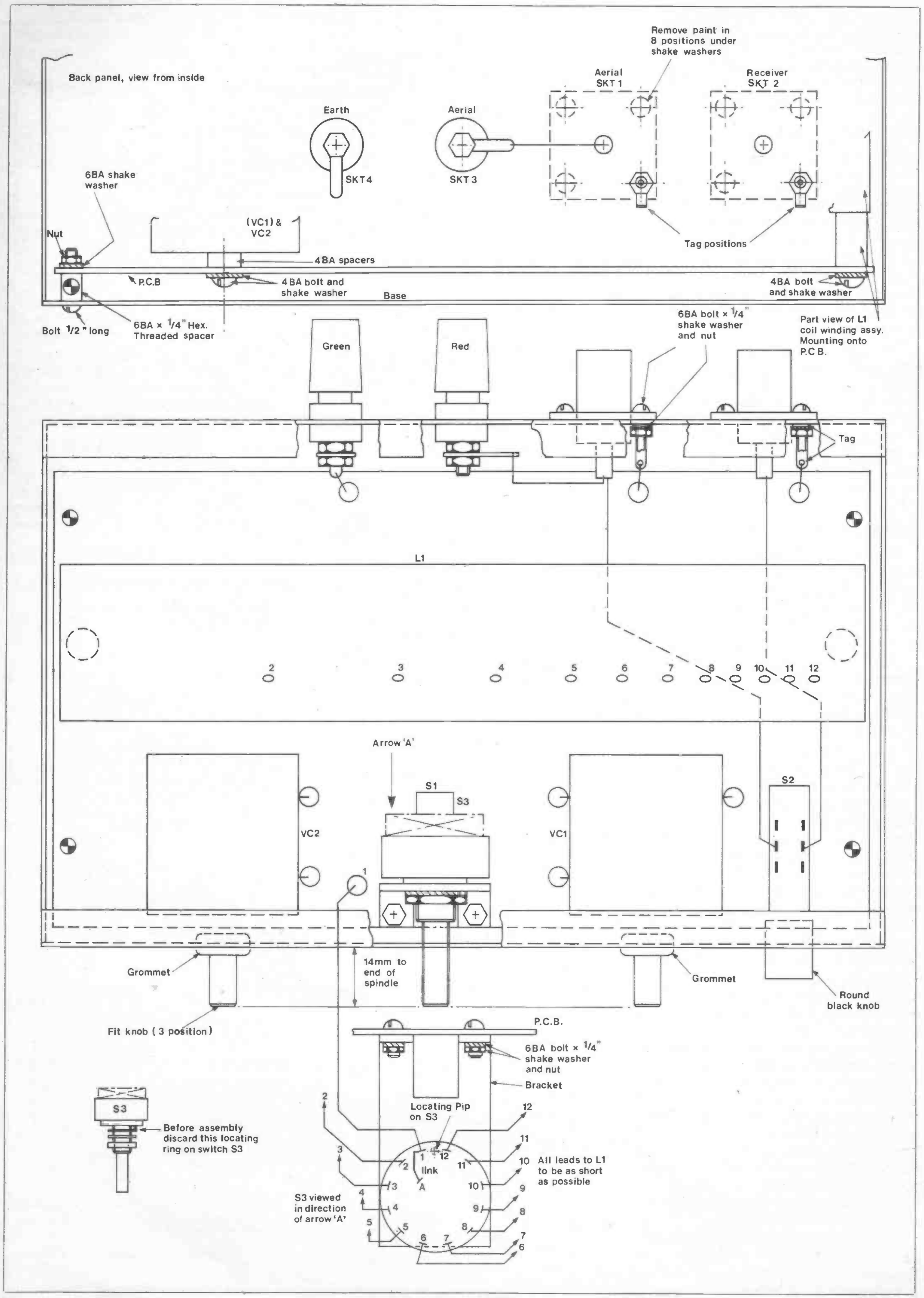


Figure 3. Wiring the Tuner

type of circuit is not clear, but it has been attributed to an American designer and is sometimes referred to as a Transmatch. The frequencies covered by the device will be determined by the values of VC1, VC2 and L1.

The prototype performed well over a range of frequencies from 600kHz to 30MHz, however this may vary fractionally depending upon the type of aerial and receiver in use. To achieve this wide range, both VC1 and VC2 are arranged so that single or dual sections (gangs) can be switched in by S1 (the 'C x 2' switch), and L1 has multiple taps switched in by S3 (the 'L' switch). The remaining switch S2 is the signal bypass, mainly used for comparing the direct signal to the improved, matched one.

VC1, the aerial capacitor, matches the aerial load impedance to the tuned circuit formed by VC2 and L1. The resonant impedance of this tuned circuit is dependant upon the combined L/C ratio of VC2, L1 and the load impedance transferred by VC1. VC2, on the receiver side, subsequently matches the output of the circuit to the 50Ω aerial input of the receiver.

Construction

The pcb has a printed legend to assist in the positioning of each component, see Figure 2. The sequence in which these components are fitted is not vitally important; however, the following instructions will aid in the easy assembly of this project.

Install the veropins at the positions indicated by the white circles on the pcb. Next insert the push switches S1 and S2, making certain that they are pushed firmly down on to the surface of the board.

When handling the variable capacitors VC1 and VC2 *always* keep the vanes fully enmeshed (fully retracted) to avoid damaging them; clearance between the vanes are very small and they can easily be bent accidentally causing a short-circuit. When mounting these capacitors use the 4BA quarter-inch bolts and spacers. Line up the capacitor so that it is square to the legend, and the side tags are in line with the holes in the pcb. Make sure that the bolts are secure, as they are the principle means of connecting the frame side of the capacitor to the rest of the circuit!

Fit the switch bracket using the 6BA hardware as shown in Figure 9. Before fitting the rotary switch S3, remove the nut and shake-proof washer to reveal the moving contacts' stop-ring, which can be positioned to select a maximum number of ways from 2 to 12. Since all 12 positions are to be used here, you can remove and discard this ring. Cut the plastic shaft of the switch to a length of 29mm from the *mounting face,* that is, the boss at the base of the threaded bush (see Figure 3). Refit the large lockwasher to S3, then attach S3 to the bracket as shown in Figure 9.

The Coil Assembly

The coil assembly L1 must be prepared before fitting it to the rest of the circuit. The former supplied in the kit has already been cut to the length required and drilled. However, if you are not constructing from a kit, then

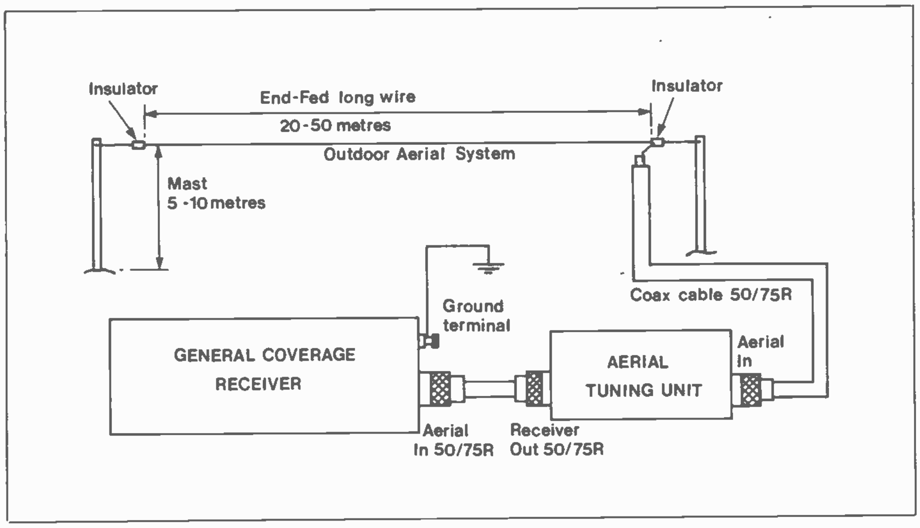


Figure 4. System Set-up

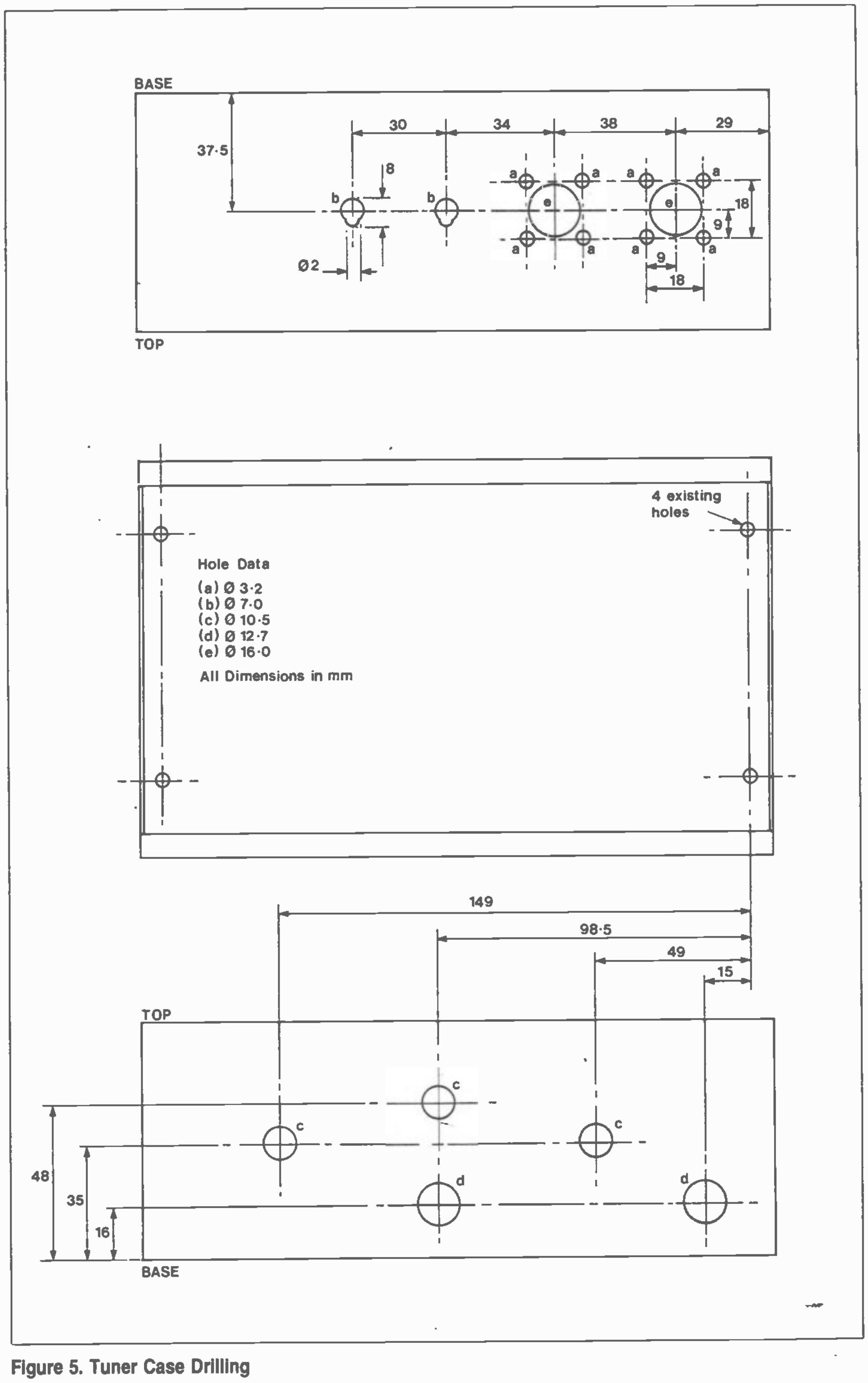


Figure 5. Tuner Case Drilling

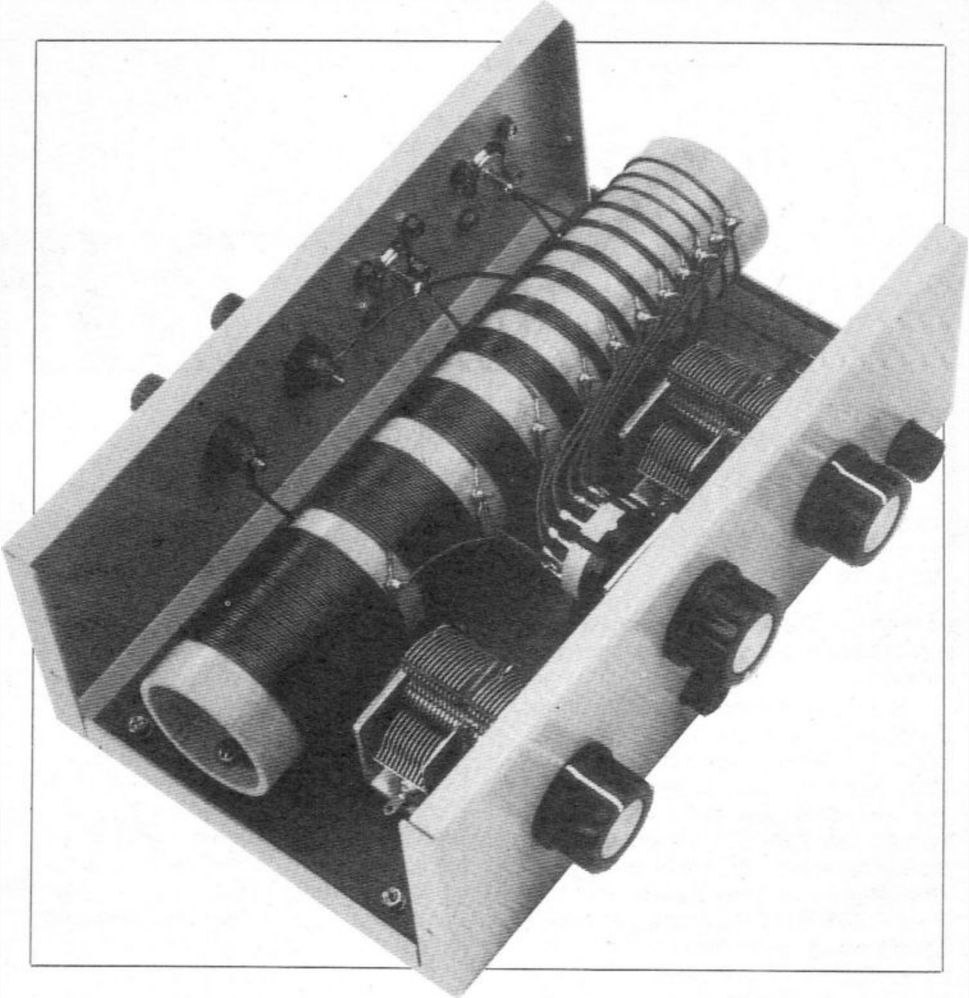
drilling and cutting information is provided in Figure 7. The small holes running along the tube are for the double-ended veropins, which form the tapping points for the finished coil, and you must use a drill bit of the correct size if you are doing this yourself.

The pins must be a tight fit so that a soldering iron can be used to insert these pins as the heat softens the material of the former, making the installation easier, and the pin solid on cooling.

When handling the 22 s.w.g. enamelled copper wire, be careful not to accidentally kink it as this will make the close winding of the coils difficult. Commence winding the coil as shown in Figure 8. Make sure that the ends of the e.c.w. to be soldered have all enamel completely removed, by scraping all around with a small knife. On reaching a veropin tapping point or a solder tag, it will be necessary to remove the enamel from the copper wire without cutting it, by scraping the area adjacent to the pin for a length of ¼ inch, or just enough to allow the wire to be soldered to the pin. Make sure that you tin the wire with a small amount of solder first to ensure a good connection. When winding the wire on the former you may discover that it has a mind of its own and will attempt to unwind itself if you relax the tension before fixing it to an anchoring point. As a means of preventing this occurence temporarily wrap insulation tape around each section of the coil before soldering. This becomes less of a problem as the number of turns required in each section decreases.

Each end of the coil has a 4BA solder tag attached to it and is secured to the threaded spacer by a bolt, as shown in Figure 3. Install the coil assembly to the pcb, using the 4BA hardware provided. Ensure all the bolts are secured firmly as they are the means of connecting the coil to the rest of the circuit.

The wiring to the coil is made by using various lengths of the solid core wire as provided in the kit. A guide showing the runs of wire from each tapping of the coil to the numbered tags on S3 is shown in Figure 3.



Typical record

RECEIVER	AERIAL	FREQUENCY	INDUCTANCE L	RECEIVER C	AERIAL C	C×2
TRIO-TS940S	Long wire	14·2 MHz	9	4	7	Out
YAESU-FRG 8800	Dipole	3·7 MHz	3	8	4	Out
ICOM-R71	Long wire	700 kHz	1	6	10	In

Figure 6. Typical Record Chart

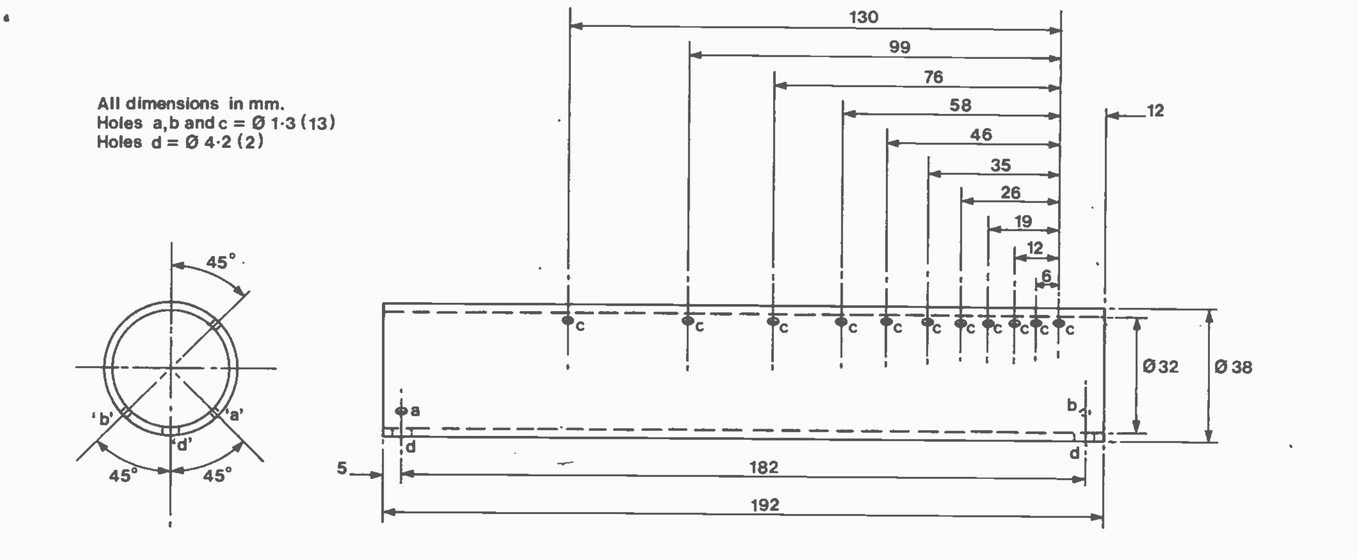


Figure 7. Coil Tube Drilling

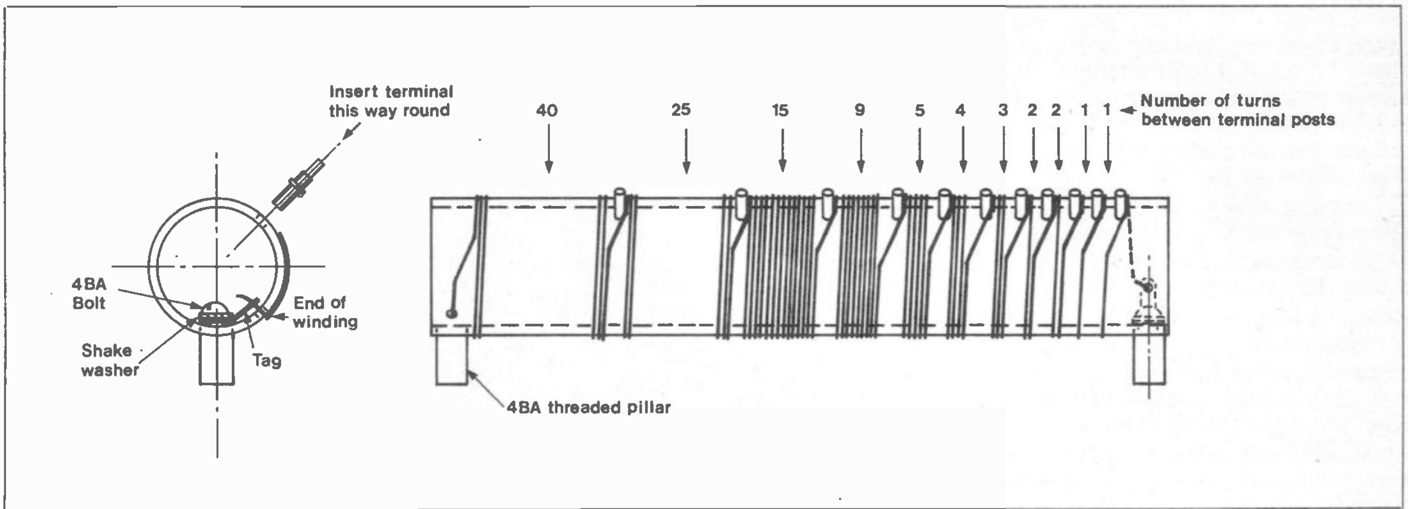


Figure 8. Coil Winding

Do make sure that the correct switch tag goes to each tapping to avoid confusion and future problems.

The cabinet for which the ATU pcb was designed is the 'Blue Case Type 222' (XY45Y) and it is painted on all its surfaces. When drilling the holes for sockets SK3 and SK4, ensure that the paint is removed from the inside of the cabinet at the positions where the 6BA solder tags will be fixed, see Figure 3. This will provide a good earth connection to the chassis, which is vital at radio frequencies. Use the drilling information shown in Figure 5 to position the holes in the front of the chassis using the self-adhesive front panel to check that the placement is correct before doing any drilling.

Having drilled the holes, at the same time clearing them of any swarf, clean the front of the case of all dirt and grease and remove the protective backing from the front panel. Carefully position and then firmly push down using a dry, clean cloth until it is securely in place. Before installing the pcb assembly, fit the grommets into the front panel at the positions shown in Figure 3. These grommets are necessary as the metal shafts of the capacitors are above ground potential and therefore if they touch the chassis they will short out the signal to earth. For this self-same reason the control knobs are made of a non-conductive material, thus preventing any unusual effects when handled by the operator.

The pcb itself is held in place by four 6BA, half-inch bolts and spacers underneath, plus four 6BA shake-proof washers and nuts on the top. The spacers are necessary to prevent the circuit from shorting out to the bottom of the metal cabinet. Now fit SK1 to SK4 on the back of the cabinet and wire them in to the circuit using the solid core wire, as shown in Figure 3.

Testing

The best way of testing the unit is to connect your aerial to the input of the ATU and your receiver to the output, as shown in Figure 4. Most communications receivers have some sort of signal strength meter, usually referred to as an 'S meter', and this is the only indication needed when tuning the ATU for a peak. If your receiver has no meter then it must be done by ear. Under these conditions, if your receiver has the facility of switching out the AGC, then the peak in signal will be more audible.

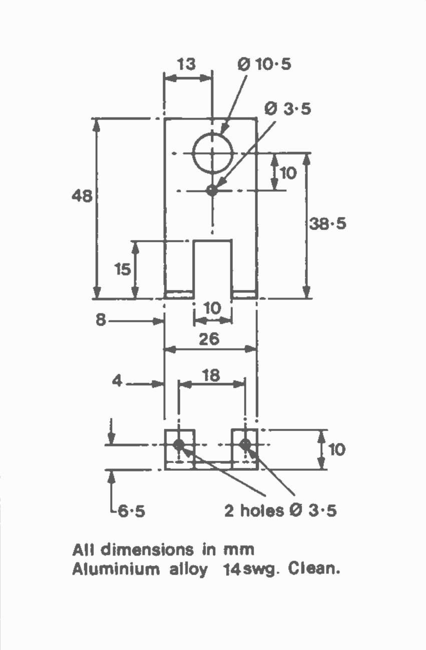


Figure 9. Tuner Bracket

When starting from a new frequency, set both variable capacitors to their halfway positions, that is at position '5' on the front panel scales. The 'C x 2' switch should be out, and the inductance switch 'L' at position one.

Push the bypass switch in. You may note, at this stage, a reduction in signal strength. Rotate 'L' until the signal peaks, then adjust the settings of the aerial and receiver controls simultaneously until no further improvement can be made. If either of the 'C' controls are at position '10' extra capacitance can be brought in by pressing in the 'C x 2' switch, and re-adjusting the controls. Sometimes the 'L' switch also requires slight modification. In general, the lower the frequency being used then the more inductance required. This corresponds to a low setting of the 'L' switch, for example '1' or '2' at MW frequencies, and '11' or '12' at 10 metres. If no improvement can be made to the signal being received, it is probably because the aerial system is presenting the correct impedance match at that particular frequency. Therefore no amount of tuning can enhance the signal.

To assist you in keeping a record of the various settings of the ATU for a given frequency and aerial system, a suggested chart for entering your observations is shown, see Figure 6.

The ATU was not designed for transmitter use, since higher voltage capacitors would have been essential and therefore much more expensive than those used here. Heavier duty switches would also have been necessary, making the entire assembly much bulkier. Therefore, this unit is definitely *not* designed for transmitters with more than 10 watts output!

Active Aerial

Aerial theory is a very complicated subject. Needless to say, to expect a good performance from 150kHz to 30MHz from just one aerial would be expecting a lot. The ideal would be a number of separate aerials each resonant to a smaller part of the frequency spectrum. However, not everyone has the space available for so many aerials, and so one must suffice for the whole of the range. This means, depending on the length of the aerial system, the performance will vary over the radio frequency spectrum. It is possible to make some improvement with the addition of an Aerial Tuning Unit. This device attempts to match the aerial impedance to the receiver; however, it is only a passive device consisting usually of a set of variable inductors and variable capacitors.

ACTIVE AERIAL

SPECIFICATION OF PROTOTYPE

Tuned Input/Output Frequency Range	= 150kHz to 30MHz
Variable Gain	= 0dB to +20dB
Input Impedance, High (Integral Telescopic Aerial)	= 50kΩ
Input Impedance, Low (External Aerial)	= 50Ω
Output Impedance	= 50Ω
Power Supply, Internal PP3 Battery or External DC	= +7 to +15 Volts
Low Voltage Indicator Threshold	< +7 Volts

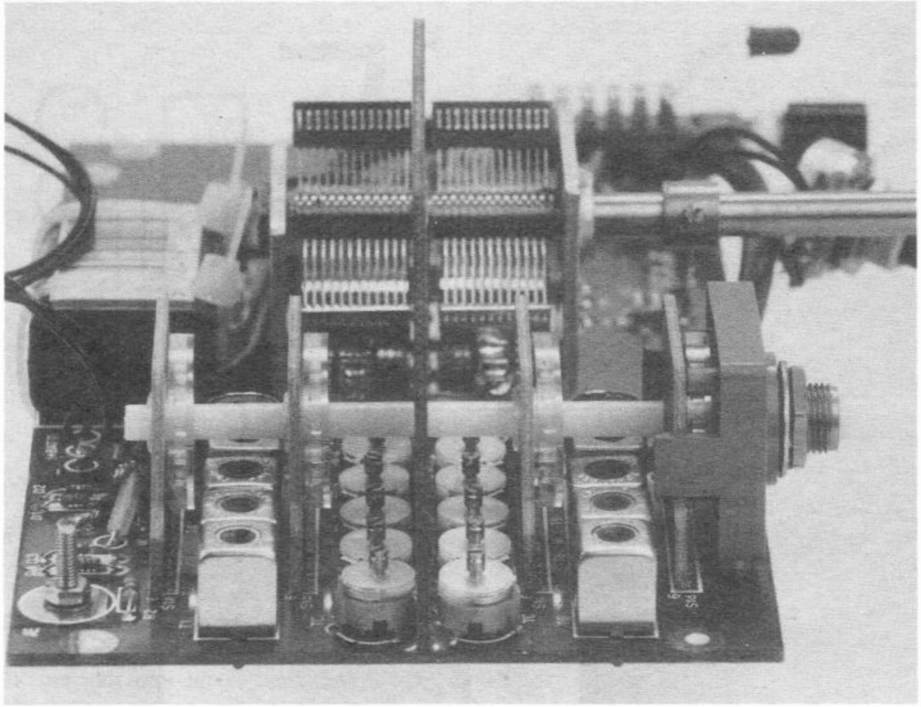
In some cases, it is not possible to have an outdoor aerial, and yards of wire trailing about the house are definitely not desirable, especially by the wife! So a small telescopic aerial is integrated into the design.

But a telescopic whip aerial at short wave frequencies, even with an aerial tuning unit, will have a very poor performance over the entire range of frequencies previously mentioned. A further complication when using an aerial that is not resonant at the frequency you wish to receive, is the possibility of a stronger signal swamping the desired signal, because of the aerial being more resonant at that frequency. This can be a minor or a major problem, depending upon the quality of the receiver.

The greater the number of tuned RF stages, and the narrower the passband, then the better the performance will be under these adverse conditions. A solution to both these problems is to use an active Tuned Aerial Amplifier. When used with an outdoor aerial system, it will offer an improvement over the entire frequency range.

The unit has its own telescopic aerial for use where a proper outdoor aerial is not practical or possible. Also it can be employed as a deliberate 'low sensitivity' option, to reduce gain as, sometimes, too much signal is as bad as too little. This again depends upon the quality of the receiver being used.

The tuning of the amplifier is very similar to that of a radio, with a band switch and tuning control. To obtain the best results, simply tune the amplifier to the same frequency as the radio for a peak in signal strength. If an aerial tuning unit is to be used in conjunction with this amplifier, then it must be connected between the input of the amplifier and the aerial. The two devices will then optimise your aerial system.



The power source for the active aerial is an internal PP3 battery or, an external DC power supply of between +7 volts and +15 volts can be used. This means the active aerial can be used virtually anywhere, i.e. at home, in the car or on a boat.

An LED indicator has been provided to give warning of low battery voltage. In this event the indicator will not light, but the active aerial will still work with reduced performance. The power drain of the unit is minimal, so the internal battery will last for quite a time when in general use. The LED operates as a 'power on' indicator while the battery is healthy, or where an external power source is used.

Circuit Description

The circuit shown in Figure 10 is a simple, single transistor RF amplifier with a tuned input and output. This is done to keep the passband to a minimum. It is not possible to tune through the entire range of frequencies with only one coil, so switched coils are used to cover the RF spectrum from 150kHz to 30MHz. These are manufactured with a low impedance winding for aerial/receiver input matching. They each have an adjustable ferrite core to permit alignment, and are encased in a metal can for screening purposes. To obtain the frequency coverage required, five switched coils are used on the

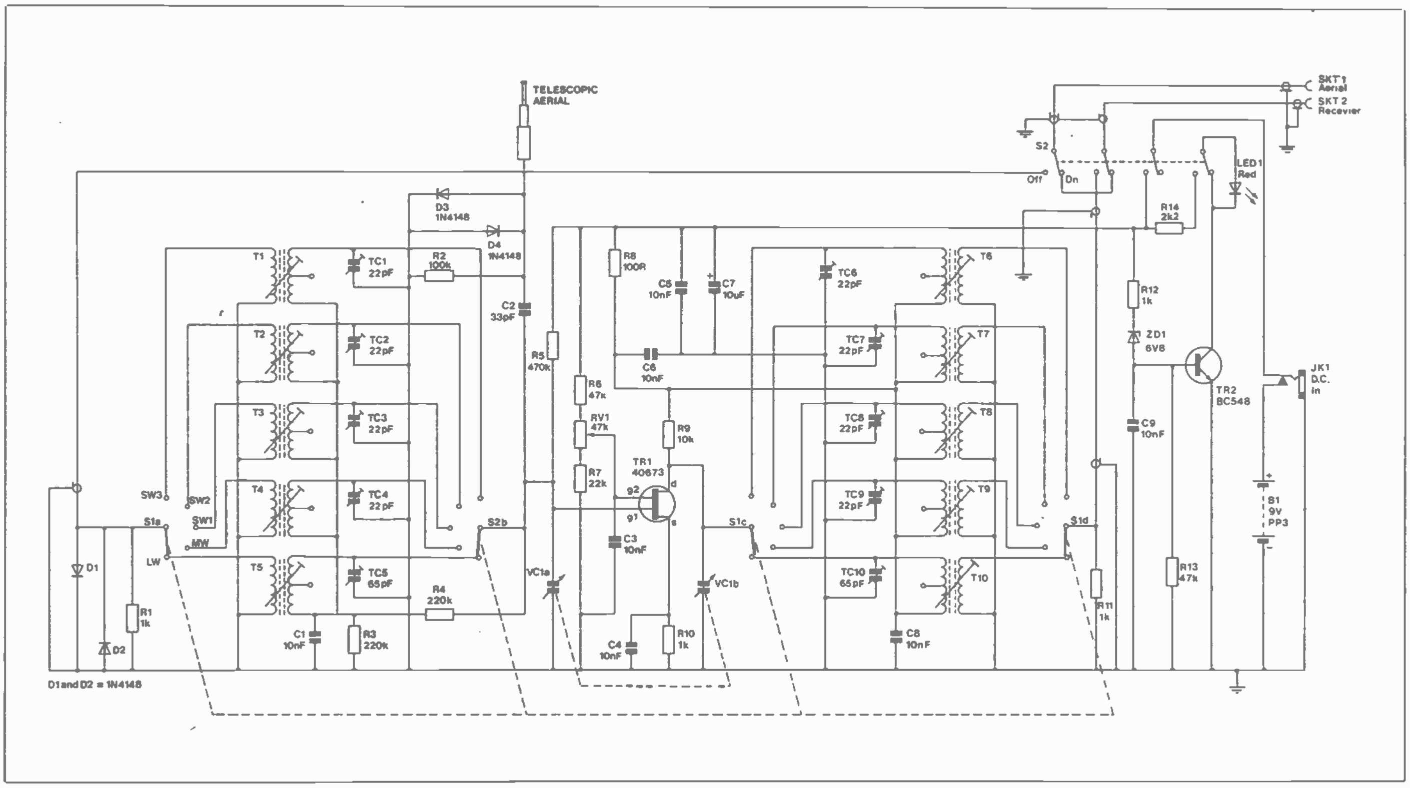
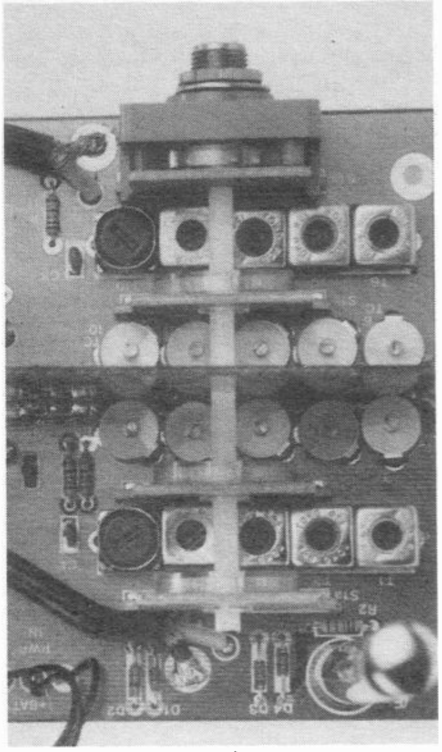


Figure 10. Aerial Circuit



input to the amplifier and a further five on the output. The bands are as follows: LW, MW, SW1, SW2, and SW3. As can be seen from the circuit diagram, the input and output of each coil must be switched. This is achieved by the multi-segment rotary switch S1. S1a connects the external aerial to the low impedance input of the desired coil; S1b switches the output of the coil to G1 (the signal input gate of TR1). G1 is at a much higher impedance than the external aerial input, and it is at this point, via ceramic capacitor C4, that the telescopic whip aerial is introduced when used. The tuning of these input stages is provided by the variable capacitor VC1a, and the DC biasing for G1 is provided by resistors R3, R5.

The required output coil is switched into the drain circuit of TR1 by S1c, and is tuned by VC1b. The low impedance output of each coil is selected by S1d and fed to the receiver via the 'ON/OFF' switch S2.

The gain of the amplifier is set by rotary potentiometer RV1, which varies the DC bias on G2 of TR1. Its limits are fixed by R6, R7.

There are several ceramic capacitors in the circuit to provide de-coupling for the prevention of instability at RF frequencies. These are C6, C8, C9, C10 and C11.

The low voltage indicator is a simple transistor switch operating a high-efficiency, red light-emitting diode (LED) to keep the power drain to a minimum. TR2 will be turned on and the LED will light as long as there are more than +7 volts applied to the cathode of ZD1. As soon as the voltage drops below +7 volts TR2 turns off and the LED will go out.

S2, the ON/OFF switch, has two functions – it applies the voltage to the circuit and switches the RF input/output, so when the active aerial is switched off, the external aerial is connected directly to the receiver.

JK1 is the external power input socket. When in use, it disconnects the internal PP3 battery from the rest of the circuit. The positive

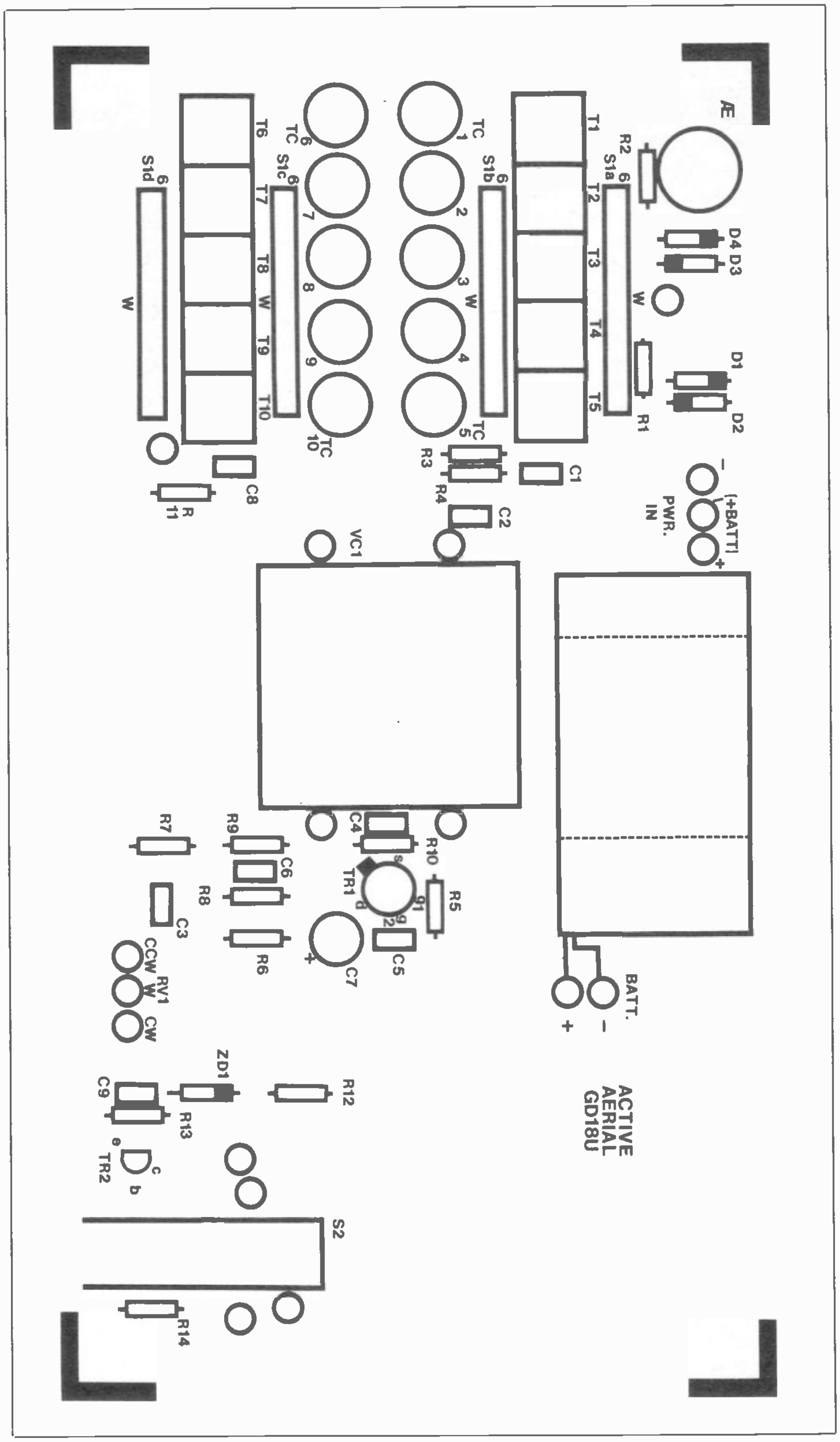


Figure 11. Aerial PCB Overlay

supply should be wired to the tip connection of the external power plug, and the negative supply to the body or 'ring' of the plug. See Figure 14.

A list of voltage readings is shown in Figure 15. These were taken from the prototype, using a high input impedance Digital Multimeter. No aerial or receiver was connected, and the telescopic aerial was fully retracted. The band switch was set to LW and the tuning control to 150kHz. The power supply was as close as possible to +9 volts and all voltage readings were positive, relative to the chassis/ground.

Construction

When dealing with RF amplification the layout of the components is critical. This is because any stray capacitive or inductive coupling between the input and output will cause oscillations and instability in the circuit. All the components are mounted in such a way as to keep their leads as short as possible for this very reason. The Printed Circuit Board has most of its top surface covered in copper to increase the stability of the circuit at RF frequencies. To further increase the stability, wherever possible, pcb mounted components have been used, for

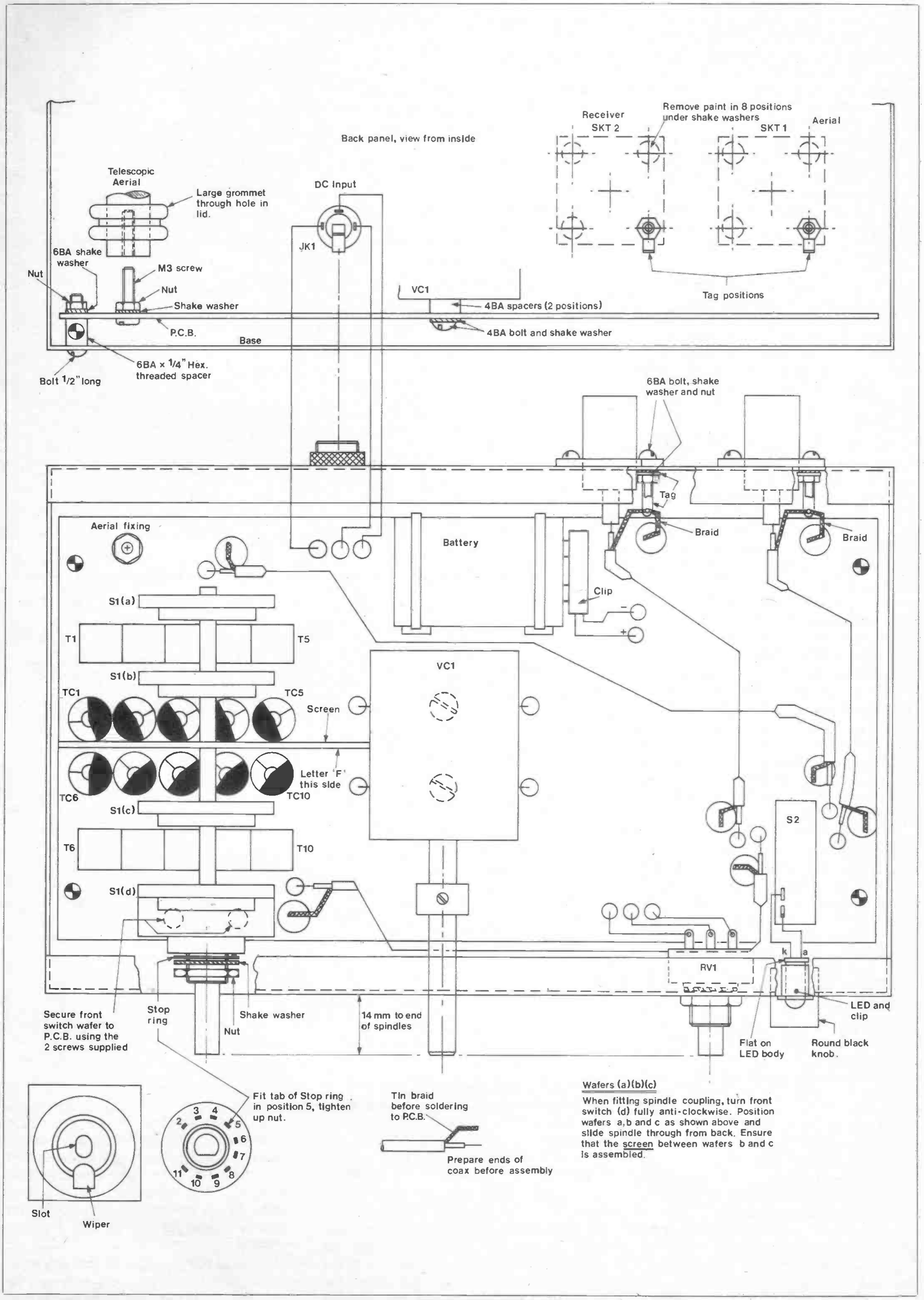


Figure 12. Aerial Wiring

example, S1a, b, c, d, and T1 to T10. S2 is mounted as close to the surface of the pcb as possible, but its position is not as critical, because it only switches DC voltage to the amplifier circuit. The wiring to and from this switch is screened 50Ω coaxial cable. This type of cable is used to prevent any stray pick-up of RF signals, and is the only way to efficiently carry such signals any distance. The voltage indicator circuit layout does not require the same amount of precision however, as it is only a simple DC transistor switch, therefore no instability problems are expected.

The gain control, RV1, supplies a variable DC reference voltage to Gate 2 of TR1. This Gate is de-coupled to RF by C7, so the positioning of RV1 can be remote from the circuit board. The finished unit is housed in a metal case for screening purposes and protection of components on the pcb.

PCB Assembly

The pcb is a double-sided, plated-through hole type. This was used for maximum reliability and stability. However, removal of a misplaced component is quite difficult with this kind of board so do double check each component type, value and its placement on the circuit board. The pcb has a printed legend to assist in the correct positioning of each item, see Figure 11. The sequence in which the components are fitted is not important, however the following instructions will be of use in making the task as straightforward as possible.

It is best to start with the smaller components first. Begin with the resistors plus the ceramic and tantalum cpacitors. Save some of the offcuts from the resistor leads as these will be used later. The diodes D1 to D4 and ZD1 have a band at one end which should be lined up with the markings on the pcb. Do not fit TR1, the dual-gate Mosfet yet, but go on to fit TR2.

Install S2, making certain that it is pushed down firmly on to the surface of the pcb. When handling the variable capacitor VC1 always keep the vanes fully meshed to avoid damaging them as this could produce a short circuit. To mount the variable capacitor use the 4BA, quarter-inch bolts and spacers. Line it up square to the legend, and with the side tags in line with the four holes in the pcb. Make sure the bolts are secure, since they are the means of connecting one side of the variable capacitor to the rest of the circuit. If you have a powerful soldering iron, for example 25 watts, you can solder the tags on the bottom of the capacitor to the pcb through the hole provided between the two 4BA fixing bolts.

The screening plate, which is formed from a prepared piece of double-sided copper-clad board, is soldered to the top of the pcb at the position shown on the legend. This is the long, bare strip of tinned copper to the left of VC1. Use the central vertical plate of VC1 as a guide to positioning. The front of the screen is denoted by the letter 'F' (and its stock code) and this must face forwards. Make sure it is upright and correctly orientated to allow the switch shaft of S1a, b, c, d to pass through it. It may be helpful to temporarily 'tie-down' the screen to the pcb with masking tape or similar, from edge to edge of the pcb and over the top of the screen to pull it into contact with the board. Then the correct position can be easily adjusted and the screen will be supported in this position for soldering. Ensure that it butts against the centre plate of VC1 and is dead centre of the strip.

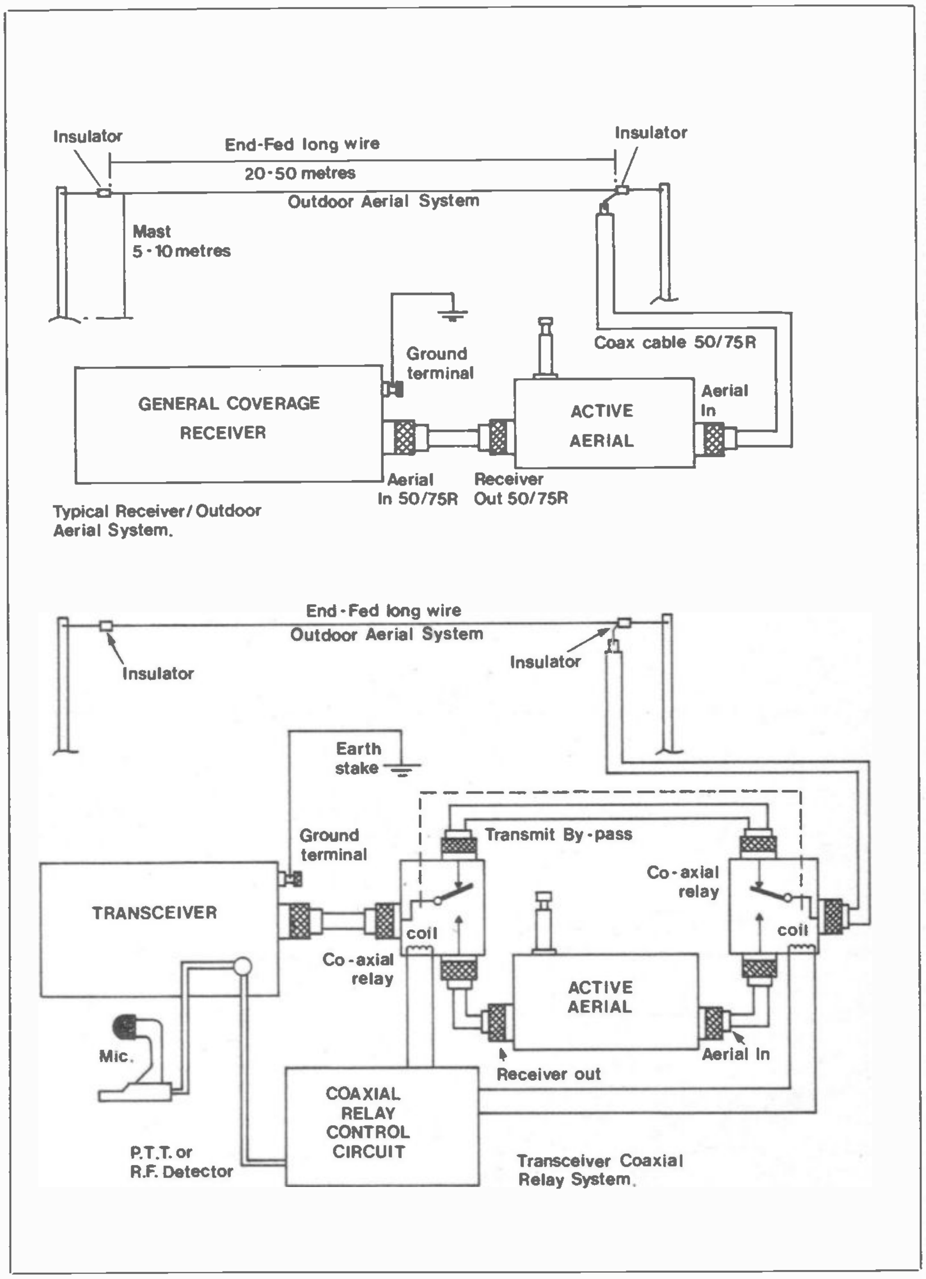


Figure 13. System Set-ups

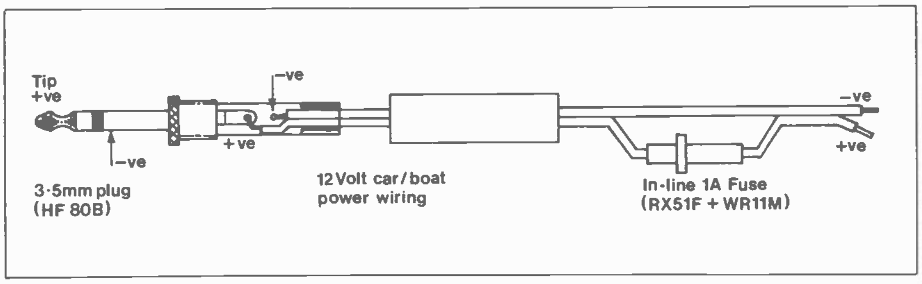


Figure 14. Power Plug

Commence soldering by making small joints at each end first. Then recheck the position to make sure the screen hasn't moved. If it has, remelt the joints and reposition. Once you are satisfied that the screen is central to the pcb strip, that it butts against VC1 and the hole for the shaft of S1 is in the right place, and that it is properly vertical, then you can complete the solder joints all along both sides of the pcb. There is a lot of copper here so allow time for the iron to heat the joint. Travel along the joint a step at a time, whilst feeding copious lengths of solder into the joint. You must ensure that the area is heated enough to form the joint properly.

Repeat the procedure for the other side. When you have finished, the work can be inspected and any suspect spots touched up, and the tape, if used, removed. If any pcb holes in the immediate vicinity have become filled in the process, then you will have to clear these using a pcb drill of the correct size. As a guide, the seventh hole of each position for the four elements of S1 can be used as a centre line corresponding to the position of the coupling shaft.

The trimmer capacitors TC1 to TC10 and the coils T1 to T10 are now installed. The trimmers are colour coded as Green = 22pF, and Yellow = 65pF.

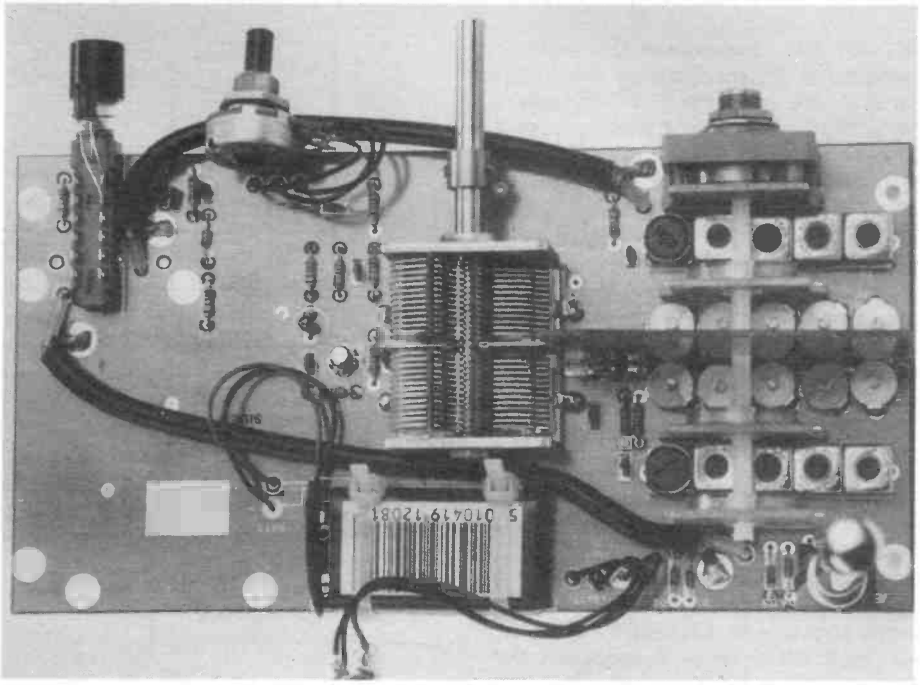
When fitting the coils T1 to T5 and T6 to T10, note that they are all tightly packed together in two rows on the pcb. When installing these be very careful not to stress the terminal pins; the internal wire ends of the windings are extremely fine and are easily broken if the pins are twisted for example. It may be a good idea to insert T1 to T5, and T6 to T10 one at a time consecutively, and to only solder the screening can pcb tab on the *opposite* side to that against which the next coil will be inserted. Only this one solder joint at this stage allows some sideways flexibility until all coils in the row have been installed. The next coil to be inserted is likely to be a tight fit against the previous, so press the coil down to the pcb while soldering. This joint will include the screening can tabs of this *and* the previous coil. The last two coils are likely to be the tightest fit and may have to be supported in position while soldering.

Complete soldering the screening can tabs, and then go on to solder all the pins of all the coils. Repeat the procedure for the row comprising T6 to T10.

The band switch, S1a, b, c, d is installed by first fitting the main switch unit at the position shown, using the bolts and spacers provided. The switch has a nut and shake-proof washer on it. If these are removed, a metal ring which governs the number of positions in which the switch can be set (the stop-ring), is revealed. This ring must be set to allow the switch a maximum of five positions. First remove the stop-ring, which will usually fall out easily, and then count four rectangular holes in a clockwise direction from the start (The first position is always for two-way operation). Replace the stop-ring with its tab in the fourth hole position. Hold it in place and check that the switch does actually rotate to only five positions, then put the washer and nut back on to prevent the ring from moving, then rotate the switch fully anti-clockwise to the first position (LW).

When installing the remaining three switch segments, make sure they are in the position shown in Figure 12, and that the transparent plastic part is facing the main switch assembly previously installed. It is also important that the segments are upright and pushed fully into the holes in the pcb to ensure the plastic coupling shaft passes through each switch segment without jamming. Upon inserting the shaft, ensure that the wiper of each segment is at the bottom and that the main switch assembly is at position 1. Then gently feed the plastic coupling shaft through all the segments, keeping them upright and turning as necessary to allow the coupling to enter each segment, until it is pressed home into the main switch assembly.

Use the off-cuts of wire from the resistor leads for wiring in the four tags on the variable capacitor to the corresponding holes in the pcb.



TR1	GAIN MINIMUM	GAIN MAXIMUM
G1	+2·8V	+2·8V
G2	+1·7V	+5·2V
D	+8·6V	+8·3V
S	+1·6V	+2·9V
CURRENT DRAIN	8·3mA	11mA

Figure 15. Voltage Chart

The telescopic aerial is held in position by the metric nut and bolt size M3, as shown in Figure 12. Do not fit the telescopic aerial at this stage, as it makes the pcb difficult to handle.

The final position of the red LED indicator will depend upon its location in the front panel of the finished boxed unit, so leave the leads of the LED at their full length when soldering them to the tags on the top of S2, as seen in Figure 12. Fit TR1 on to the pcb at the position shown ensuring that the metal tag matches the legend. The reason for leaving TR1 until the last possible moment is simply because it is a MOS device and can be sensitive to stray static charges. These may damage the device but, once in the completed circuit, its gate inputs are at a much lower impedance, so the possibility of damage is greatly reduced. This leaves the fitting of the coaxial cable. Care should be taken when preparing the ends of the cable and a guide is given in Figure 12. Four pieces are required in the following lengths:-

One at 6in. (150mm); One at 7in. (180mm); Two at 4in. (100mm).

The two 4in. pieces of cable connect S2 to the input and output sockets SK1 and SK2. Extra braiding is required at the socket end of the cable for connecting the solder tags to the top of the pcb, at the position shown on the legend. The 7in. length connects the input of the amplifier to S2, and the remaining 6in. piece connects the output to S2.

The case which the unit is designed to fit is the 'Blue Case Type 222' (XY45Y), and is painted on all its surfaces. When drilling the holes for sockets SK1 and SK2, ensure that the paint is removed from the inside of the case at the positions where the 6BA solder tags are fitted, see Figure 17. This will ensure a good earth connection to the chassis, which is very important at radio frequencies. Follow the drilling instructions in Figure 17 when preparing the front of the case. The self-adhesive front panel can be used as a guide for checking the positioning of the holes. Having drilled the holes at the same time clearing them of any swarf, clean the front of the case and remove the protective backing from the self-adhesive front panel. Carefully position and firmly push down using a dry, clean cloth until it is securely in place.

Before installing the pcb assembly, fit the brass tuning shaft through the front of the case, as shown in Figure 12. Please note that the afore-mentioned shaft is cut to 36mm in length *overall* . The pcb assembly is held in place with four 6BA, half-inch bolts and spacers underneath, plus four 6BA shake-proof washers and nuts on the top surface of the assembly. The spacers are necessary to prevent the circuit from shorting out on the bottom of the metal case.

Before fitting the gain control, RV1, cut the shaft to a length of 17mm from the mounting face. Mount RV1 on to the front of the case using the nut and shake-proof washer provided. Wire into the circuit as shown in Figure 12.

Fit the LED clip to the front panel and position the LED, previously installed, so it rests inside the clip. Next install the two coaxial sockets, SK1 and SK2 using the 6BA hardware shown in Figure 12. The remaining socket is the external DC input, JK1, which is mounted in the position shown in Figure 12.

The three sockets are then wired into circuit. The coaxial cable from S2 going to

SK1 and SK2. The external DC socket is connected to the main pcb via three short pieces of wire. Install the PP3 battery clip at the position shown. The battery is held in place by two re-usable cable ties which pass through the holes in the pcb and around the battery to secure it in place.

Finally, fit the knobs on to the shafts of the controls and check that they all move freely, not scraping the front panel. This completes the construction of the unit. After carefully checking to ensure that there are no errors, you are now ready to move on to DC testing and RF alignment procedures.

DC Testing

The circuit can be treated as two separate parts, TR1 and RF amplifier, and TR2 the low voltage indicator. VC1a and b should be fully meshed, that is, set to 150kHz LW. Set the band switch to LW and the gain control to maximum. Connect a multimeter, selected to show current, in series with the positive supply of the 9 volt battery. Turn the power switch to on. If all is well then you should observe a reading of approximately 12mA and the LED indicator should be lit. If you reduce the gain control of the amplifier then you should notice a reduction in supply current to approximately 8mA. Remove the meter from the positive battery supply and reconnect the battery to make the voltage tests. A chart showing all the voltage and current readings expected from the tests is shown in Figure 15.

If your circuit readings are close to those given in the chart then you can begin the RF alignment procedure. However, if there are any major discrepancies it is likely that you have a fault in the circuit. In this instance check all your soldering and component orientation. If everything checks out then start a more detailed series of tests to establish whether there is a faulty component in the circuit. If you are lacking the necessary test gear to determine the nature of the fault, then Maplin can offer a repair service, the terms of which have been published in the magazine on numerous occasions. It is hoped however, that this will be a final resort and that most problems will be minor and therefore easily corrected with the basic equipment usually found in most amateur electronics enthusiasts homes.

RF Alignment

After the DC testing procedure it will be necessary to adjust the input/output coils T1 to T10, for their correct frequency tuning points. Each coil contains a ferrite tuning slug. Adjusting its position in the coil will increase or decrease the inductance and so affect the tuning point. Ferrite is a very brittle material and should be handled with great care as, if broken, it may jam up inside the coil, rendering any further adjustments impossible. For this reason a proper trimming tool is recommended, *not* a screwdriver! The one most suited to this task in the Maplin range of trimming tools, is the pot-core type BR51F. This tool has two blades, one at either end. The wider blade being suitable for adjusting the LW and MW coils T4, T5, T9 and T10, the

STEP	BAND SWITCH	ACTIVE AERIAL AND RADIO TUNING	ADJUST FOR PEAK SIGNAL READING INPUT	OUTPUT
1	LW	150kHz	T5	T10
2	LW	500kHz	TC5	TC10
REPEAT	STEPS	1 and 2		
3	MW	500kHz	T4	T9
4	MW	1·5MHz	TC4	TC9
REPEAT	STEPS	3 and 4		
5	SW 1	1·5MHz	T3	T8
6	SW 1	4 MHz	TC3	TC8
REPEAT	STEPS	5 and 6		
7	SW 2	4 MHz	T2	T7
8	SW 2	10 MHz	TC2	TC7
REPEAT	STEPS	7 and 8		
9	SW 3	10 MHz	T1	T6
10	SW 3	30 MHz	TC1	TC6
REPEAT	STEPS	9 and 10		
END				

Figure 16. Alignment Chart

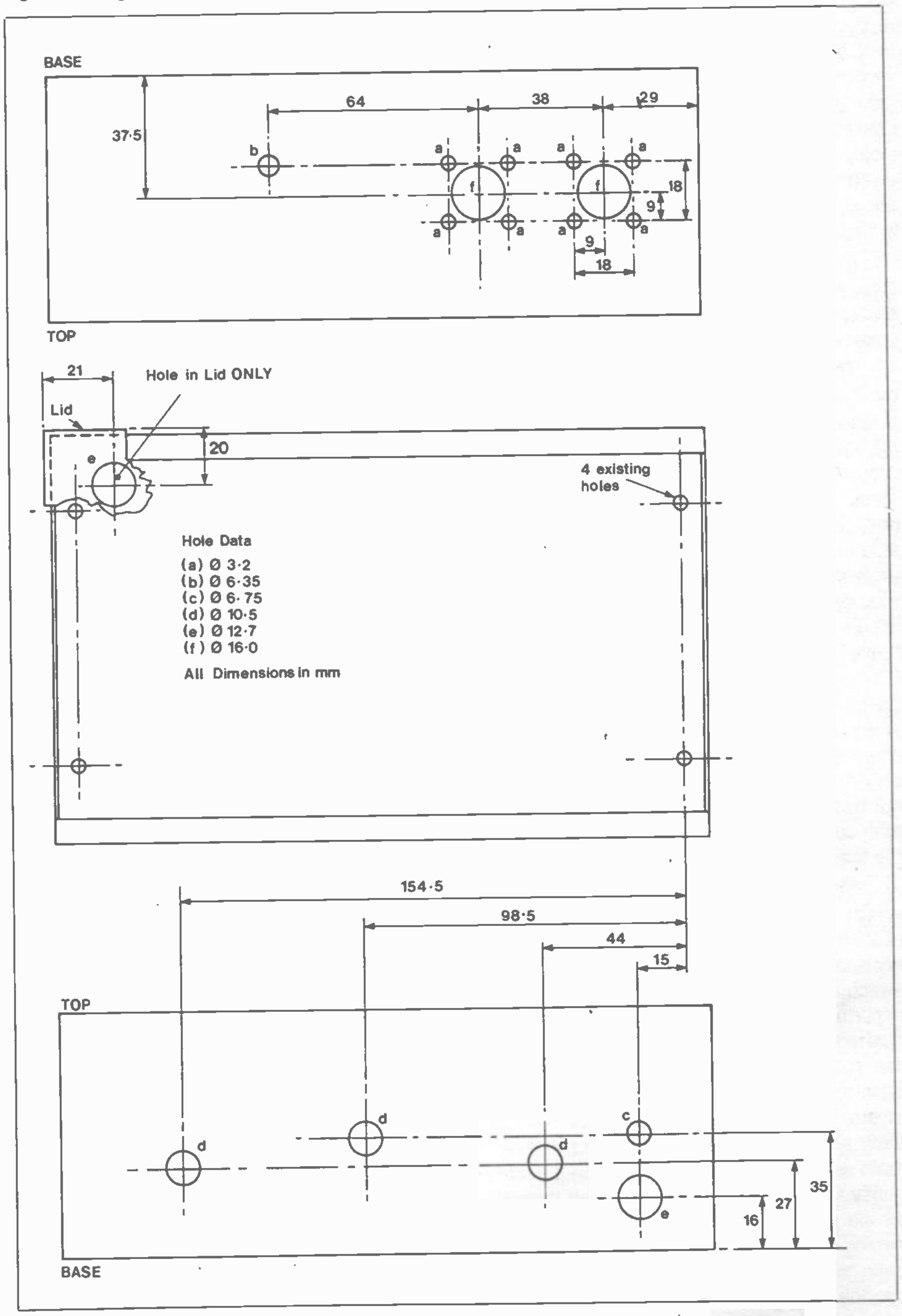


Figure 17. Aerial Case Drilling

ACTIVE AERIAL PARTS LIST

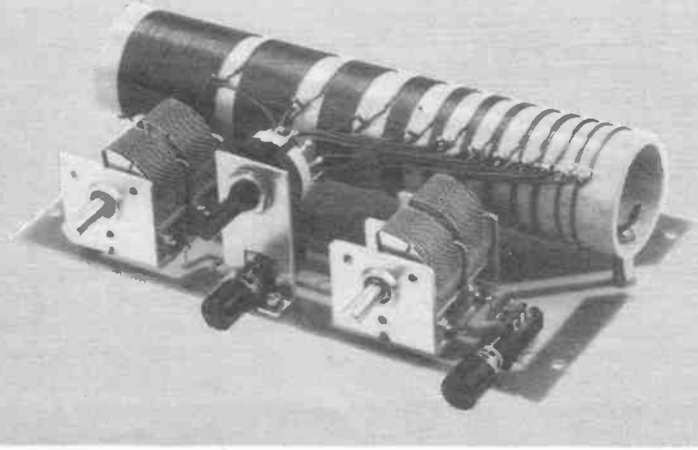
RESISTORS: All 0.6W 1% Metal Film			
R1,10,11,12	1k	4	(M1K)
R2	100k	1	(M100K)
R3,4	220k	2	(M220K)
R5	470k	1	(M470K)
R6,13	47k	2	(M47K)
R7	22k	1	(M22K)
R8	100Ω	1	(M100R)
R9	10k	1	(M10K)
R14	2k2	1	(M2K2)
RV1	47k Potentiometer Linear	1	(FW04E)
CAPACITORS			
C1,3,4,5,6,8,9	10nF Ceramic	7	(WX77J)
C2	33pF Ceramic	1	(WX50E)
C7	10µF 16V Tantalum	1	(WW68Y)
VC1	10-365pF Variable	1	(FF40T)
TC1,2,3,4,6,7,8,9	Trimmer 22pF	8	(WL70M)
TC5,10	Trimmer 65pF	2	(WL72P)
SEMICONDUCTORS			
D1,2,3,4	1N4148	4	(QL80B)
ZD1	BZY88C6V8	1	(QH10L)
TR1	40673	1	(QX34M)
TR2	BC548	1	(QB73Q)
LED1	High Bright Red LED	1	(WL84F)
MISCELLANEOUS			
SKT1,2	Socket SO239	2	(BW85G)
JK1	Jack Socket 3.5mm	1	(HF82D)
	PP3 Clip	1	(HF28F)
	Telescopic Aerial	1	(LB10L)
S1a,b,c	Wafer 1-pole 12-way	3	(FA97F)
S1d	PCB Rotary 1-pole 12-way	1	(FT56L)
S2	Latchswitch 4-pole	1	(FH68Y)
T1,6	KANK3335R TOKO Coil	2	(FD04E)
T2,7	KANK3334R TOKO Coil	2	(FD03D)
T3,8	KANK3333R TOKO Coil	2	(FD02C)
T4,9	RWR331208 TOKO Coil	2	(FD01B)
T5,10	CAN1A350EK TOKO Coil	2	(FD00A)
	Knob K7B	3	(YX02C)
	Extension Spindle	1	(RX30H)
	Round Button Black	1	(FL31L)
	Grommet Large	1	(FW60Q)
	LED Clip	1	(YY40T)
	ISO Bolt M3 x 12mm	1 Pkt	(BF52G)
	ISO Nut M3	1 Pkt	(BF58N)
	Active Aerial PCB	1	(GD18U)
	Coax Cable Low C	1 mtre	(XR19V)
	Bolt 6BA x ½ inch	1 Pkt	(BF06G)
	Nut 6BA	2 Pkts	(BF18U)
	Washer Shake Proof 6BA	2 Pkts	(BF26D)
	Solder tags 6BA	1 Pkt	(BF29G)
	Bolt 4BA x ¼ inch	1 Pkt	(BF02C)
	Spacer 4BA x ⅛ inch	1 Pkt	(FW30H)
	Hook-up Wire 7/.02mm	1 Pack	(BL00A)
	Plastic Wafer Shaft	1	(FA98G)
	Screen Plate	1	(GD26D)
	Bolt 6BA x ¼ inch	1 Pkt	(BF05F)
	Washer 4BA Shakeproof	1 Pkt	(BF25C)
	Tapped Spacer 6BA x ¼ inch	1 Pkt	(FD10L)
OPTIONAL			
	Case Blue 222	1	(XY45Y)
	Front Panel	1	(FA99H)
	PP3S Silver Seal Battery	1	(FK62S)
	AC Adaptor Regulated	1	(YB23A)
	Re-usable Cable Tie	2	(RK59P)

A complete kit of all parts, but excluding optional items, is available:
Order As LM05F (Active Aerial Kit) Price £44.95
The following are also available separately, but are not shown in the 1986 catalogue:
Active Aerial PCB **Order As GD18U Price £11.95**
Aerial Screen Plate **Order As GD26D Price £1.10**
Toko Coil CAN1A350EK **Order As FD00A Price 88p**
Toko Coil RWR331208 **Order As FD01B Price 55p**
Toko Coil KANK3333R **Order As FD02C Price 55p**
Toko Coil KANK3334R **Order As FD03D Price 55p**
Toko Coil KANK3335R **Order As FD04E Price 55p**
Plastic Shaft **Order As FA98G Price 50p**
1 Pole 12-Way Wafer **Order As FA97F Price £1.45**
Aerial Front Panel **Order As FA99H Price £3.95**
6BA Tapped Spacer x ¼in. (Pack of 10)
Order As FD10L Price 88p

AERIAL TUNING UNIT PARTS LIST

CAPACITORS			
VC1	10-365pF Variable	2	(FF40T)
MISCELLANEOUS			
S1,2	Latchswitch 2-pole	2	(FH67X)
S3	Rotary SW12B	1	(FF73Q)
SK1	Terminal Post Red	1	(HF07H)
SKT2	Terminal Post Green	1	(HF06F)
SKT3,4	Socket SO239	2	(BW85G)
	Round Button Black	2	(FL31J)
	Knob K7B	3	(YX02C)
	Aerial Tuner PCB	1	(GD19V)
	Plate (Rotary Switch Mtg)	1	(FD07H)
	Veropin 2140	1 Pkt	(FL20W)
	Bolt 6BA x ¼ inch	1 Pkt	(BF05F)
	Bolt 6BA x ½ inch	1 Pkt	(BF06G)
	Nut 6BA	2 Pkts	(BF18U)
	Washer Shakeproof 6BA	2 Pkts	(BF26D)
	Solder Tag 6BA	1 Pkt	(BF29G)
	Solder Tag 4BA	1 Pkt	(BF28F)
	Washer Shake 4BA	1 Pkt	(BF25C)
	Bolt 4BA x ¼ inch	1 Pkt	(BF02C)
	Spacer 4BA x ⅛ inch	1 Pkt	(FW30H)
	Spacer 4BA x ½ inch	1 Pkt	(LR71N)
	Tapped Spacer 6BA x ¼ inch	1 Pkt	(FD10L)
	Grommet Small	2	(FW59P)
	Bell Wire White	1 Pack	(BL94C)
	Wire EC 22 swg	2 Rolls	(BL27E)
	Tube drilled	1	(YM61R)
OPTIONAL			
	Case Blue 222	1	(XY45Y)
	Front Panel	1	(FD11M)

A complete kit of all parts, excluding optional items, is available:
Order As LM06G (Aerial Tuner Kit) Price £29.95
The following are also available separately, but are not shown in the 1986 catalogue:
Aerial Tuner PCB **Order As GD19V Price £3.50**
Aerial Tuner Plate **Order As FD07H Price 78p**
Tuner Front Panel **Order As FD11M Price £3.95**
Pre-drilled Tube **Order As YM61R Price £3.95**
6BA Tapped Spacer x ¼in. (Pack of 10)
Order As FD10L Price 88p



Continued on page 19.

REFRIGERATION
THE PRODUCTION OF COLD

by P. Bateman

In general, some of the most misunderstood pieces of domestic equipment are the refrigerator and the deep freeze. We all know that they keep foodstuffs cold or frozen and in doing so, slow down the rate of growth of bacteria and therefore keep food from deteriorating over a variable period of time, but few people understand how they work. It is the intention of this article to try to explain in simple terms what happens in the sealed system, that produces cold within the insulated space, and heat on the outside of the box.

Introduction

Firstly, the most popular method of refrigeration is the vapour compression system and this is the system we will concentrate on. A simple circuit diagram is shown in Figure 1. At the heart of the system is a hermetically sealed motor compressor, which is a compressor (generally reciprocating) with an electrical motor fixed on the compressor, supported on springs (to reduce vibration) put in a metal can, with oil being added for lubrication purposes. An outlet is provided for the electrical wiring, with a copper pipe outlet for the discharge of refrigerant vapour and a copper pipe inlet for the refrigerant return or suction line. In addition the can is welded to produce a sealed system.

Through a system of valves in the valve plate of the compressor, compressed refrigerant vapour is forced out into the discharge line at high pressure and high temperature. This enters the condenser (the black wire and pipe grid at the back of the refrigerator), where heat is lost from the refrigerant to the surrounding air.

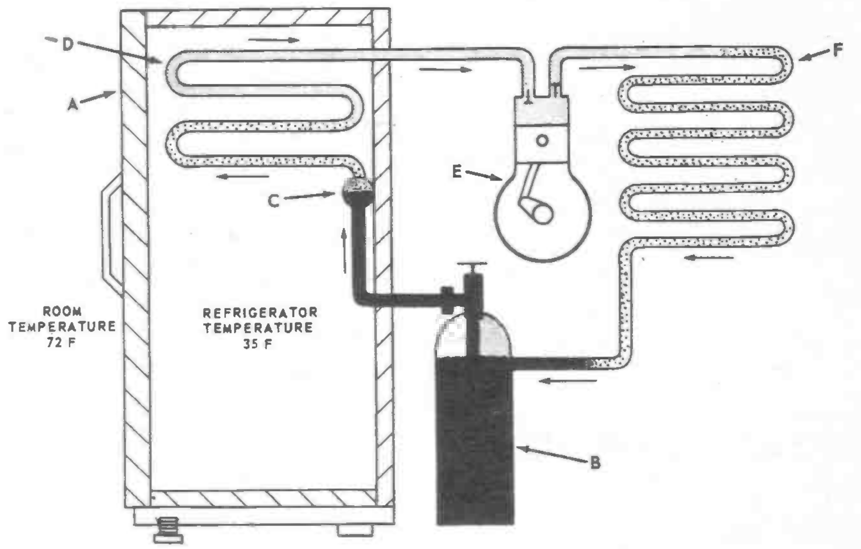


Figure 1. An elementary mechanical refrigerator. A – Refrigerator. B – Liquid refrigerant receiver. C – Refrigerant control. D – Evaporator. E – Motor-driven compressor. F – Condenser. In this refrigerator, the refrigerant is not allowed to escape, but is recycled, as necessary, to get the desired temperature.

In losing heat to the outside air, the refrigerant inside the condenser changes to a liquid at the same temperature and pressure. In other words, the refrigerant vapour condenses to a liquid in the condenser.

As shown in Figure 1, this liquid collects in a liquid receiver which in domestic refrigerators is omitted for reasons of cost. From the liquid receiver, the liquid refrigerant passes to a refrigerant flow control, which is a length of coiled fine bore copper-tubing, called a capillary control in a domestic refrigerator or freezer.

Here, the refrigerant, still in liquid form, loses some of its high pressure and leaves the capillary tube at a lower pressure and enters the evaporator (the aluminium embossed box generally covered in ice and with a spring flap on it) inside the insulated box. On entering the evaporator, the liquid refrigerant picks up heat from the surrounding air causing the refrigerant to change to a vapour, and finally leaving the evaporator as a vapour having removed heat from the air in the refrigerated space, and continues to the suction side of the compressor where the vapour is compressed and pushed out into the discharge line of the system, to repeat the process already explained.

Principles of Refrigeration

The principles of condensing and evaporating are not always clearly understood, especially in the case of a fluid in an enclosed space, so let's look a little closer at the subject.

Water boils at 100°C at atmospheric pressure (1.013 Bar or 14.7lb/in^2) and changes to vapour at the same temperature and pressure due to the water absorbing 970 British Thermal Units, or 416 J (Joules), of Heat Energy for every 1lb of water in the form of latent heat to change its state.

If the pressure on the water is increased or decreased, above or below atmospheric pressure, then not only does the temperature at which boiling or evaporation occurs, but the *latent heat* value, to enable the change from liquid to vapour to occur, also changes. Condensation is the opposite of evaporation, whereupon latent heat is removed to change the state of the refrigerant from a vapour to a liquid. Again, the amount of heat to be removed varies with the pressure of the refrigerant.

The refrigerants used in refrigerating systems since the 1930's are in the main derivatives of either Methane or Ethane, and are of the Halogenated Fluorocarbon types. These are considered safer to use than Methyl Chloride, Methylene Chloride, Sulphur Dioxide and Ammonia which were used many years ago. One of the most popular refrigerants used in domestic refrigerators is Dichlorodifluoromethane, internationally known as R12. Some of its properties are: Boiling Point at Atmospheric Pressure, −29°C (−21.7°F). It has a pressure of 26.5lb/in^2 (absolute) or 1.83 Bar at −15°C, or a pressure of 108lb/in^2 (absolute) or 7.5 Bar, at 30°C. Latent Heat of R12 at −15°C is 68.2 B.Th.U./lb (159 Joules/gram). R12 is inert at ordinary temperatures, it is non-toxic, non-corrosive, non-irritating and mixes with oils used in a refrigeration compressor.

Filling the System

Before adding the refrigerant to a sealed system, care must be taken to ensure no air, moisture, metal swarf, or dirt enters the system or else unreliable performance will occur and the motor may burn out as a result of overloads caused by blockages in the system etc. It is customary to pull a vacuum on the system before introducing a measured charge of refrigerant, under or over charging of the refrigerant can result in malfunctioning of the system.

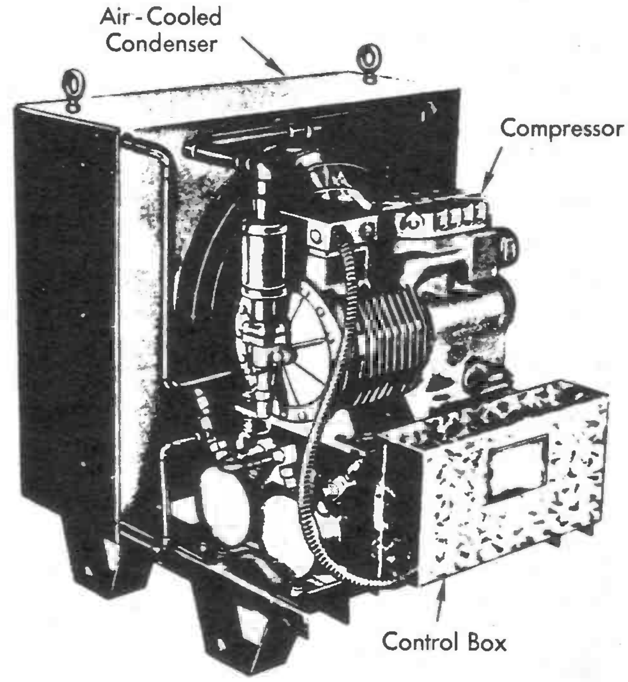


Figure 2. Commercial hermetic condensing unit with air-cooled condenser.

In most refrigeration systems, it is customary to fit a liquid line drier between the liquid receiver and flow control, a device which when filled with an absorbent such as Silica Gel, or Molecular Sieve, will trap small quantities of water, which may have entered the system by accident. If this water is not trapped, then it will circulate with the refrigerant, with the result that with evaporators operating at temperatures below 0°C, it will freeze in the pipe, usually at the flow control, thus blocking with ice the flow of refrigerant. The evaporator defrosts since no refrigerant can flow, eventually this plug of ice melts from the heat in the refrigerant and the refrigerant flows again, providing cooling at the evaporator. It may be gathered from this that intermittent refrigeration is a typical symptom of water in the system.

On most domestic refrigeration systems an accumulator is placed in the pipe line from the evaporator, and before the compressor. It is generally an enlarged cylinder, tapered at each end to suit the sizes of pipe used, and its function is to act as a reservoir, to prevent liquid refrigerant returning to the compressor and only allowing vapour to be compressed.

Precautions

1. Do not block the flow of warm air from the condenser.
2. Do not defrost the evaporator with a sharp pointed knife, danger of puncturing the evaporator is real, and of losing the charge of refrigerant.
3. Do not smoke in an atmosphere charged with refrigerant as the refrigerant passing through a heated cigarette end produces Phosgene, a poisonous gas,
4. Occasionally clean the condenser of dust/debris and more frequently remove the ice from the evaporator. Both of these measures ensures good heat exchange and reliable refrigeration.
5. In hot weather, *do not* turn the thermostat setting to a lower temperature than usual; if anything raise the temperature setting to stop the compressor working so hard.
6. Always follow the manufacturers guide lines on siting, cleaning and levelling.

A Big Freeze

In larger refrigeration systems, additional items of equipment and different types of compressor and flow controls are used with larger condensers, evaporators and pipe sizes. The compressors for these applications are larger, using in the main the reciprocating principle, although Centrifugal, Screw and Rotary types are used to a lesser degree. The compressors are either of a semi-hermetic or open nature, the semi-hermetic is in fact a serviceable hermetic compressor, whilst the open type uses an external drive from a power source (usually an electric

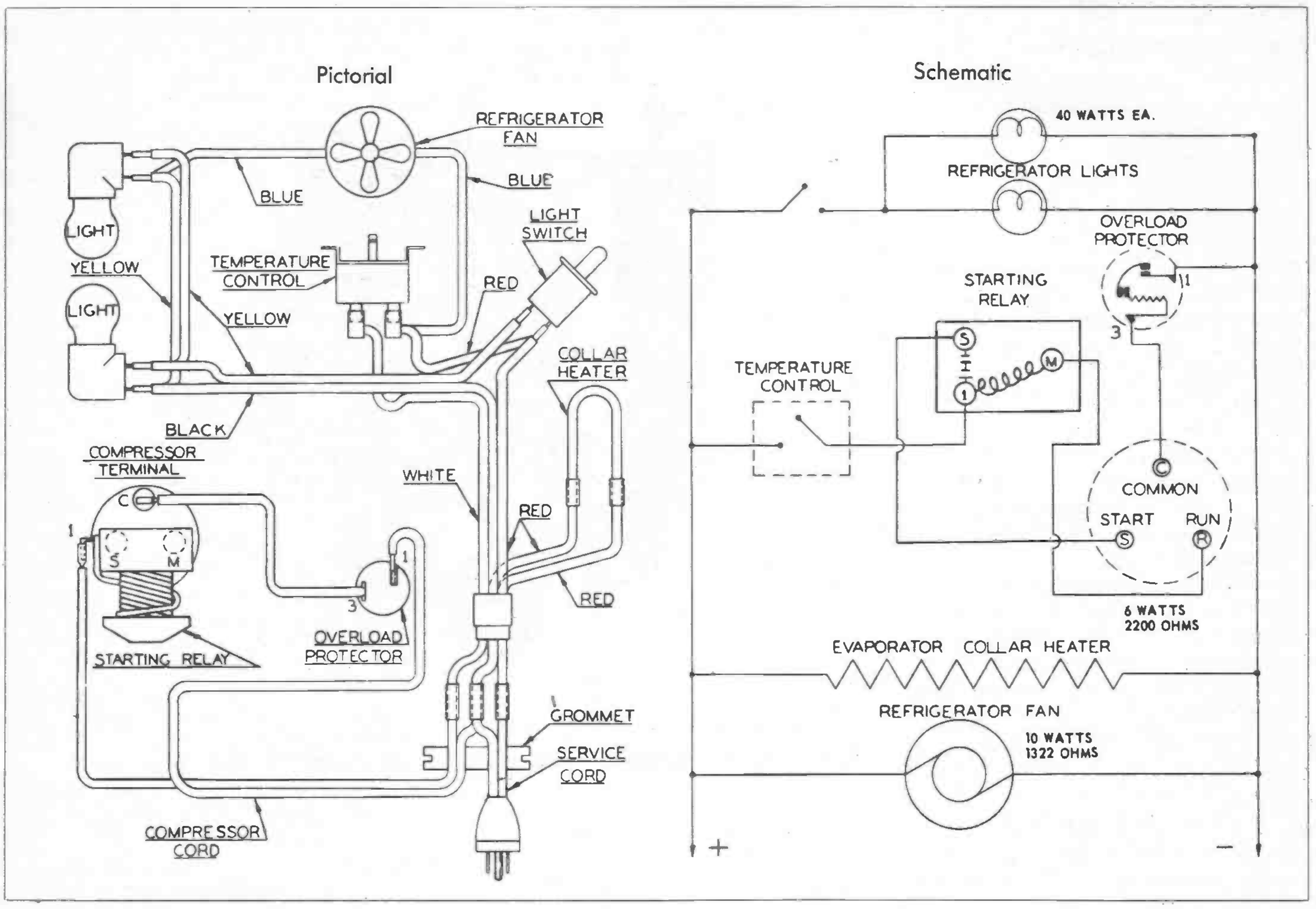


Figure 3. Typical wiring diagram of a refrigerating system.

motor), either via a belt drive or a flanged coupling.

Sometimes an oil separator is used in the discharge line, placed between the compressor outlet and the condenser inlet, its function is to remove excessive quantities of oil from the refrigerant and return it to the compressor sump.

The condenser may have many configurations, using either water or air as the cooling medium. The air cooled condenser will most certainly have fan assistance, where air is drawn across the coils and fins of the condenser. The warm air from the condenser can be used to provide some cooling of the compressor. This arrangement is used in a condensing unit, where the condensor, fan compressor and liquid receiver are mounted on a common chassis, see Figure 2.

Other types of condensers may be: (a) Shell and Tube, (b) Shell and Coil, (c) Skin Condenser, (d) Convective, (e) Evaporative Condenser.

The flow control will generally be of the Thermostatic Expansion Valve (T.E.V.) type, which gives a range of adjustment, the operating principle of which is based on measuring the heat in the refrigerant that leaves the evaporator by means of a phial, which is sealed and contains a refrigerant charge, and which has a length of capillary tubing connecting the phial to the top of the T.E.V. body. The sensing phial will be subject to a change in pressure for a corresponding change in temperature, and communicates this change via the capillary to a diaphragm in the valve body, which in turn controls the valve allowing more or less refrigerant into the evaporator. For example, a lowering of temperature lowers the pressure in the phial and closes the valve, shutting off or restricting the refrigerant flow into the evaporator. In this way the temperature can be regulated.

In addition, other equipment such as Back Pressure valves, Crankcase protector valves, water regulating valves, Crackcase heaters, Defrost heaters, Reverse cycle valves, Solenoid valves, etc., are also used for specific functions to maintain the automatic operation that is expected of a refrigeration system.

Electrical Control

So far little has been mentioned of the electrical supply and controls, so here we will look at a simple wiring diagram for a domestic refrigerator, see Figure 3. We will take the starting

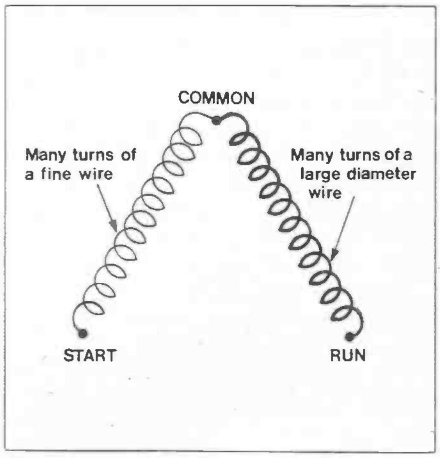


Figure 4. Compressor Pins.

point as the hermetic compressor, which has 3 circular pins from the windings within the compressor and these pins are labelled Start, Common and Run, as shown in Figure 4. We can see that a connection is made from the Start pin to the S connection on a starting relay. The other connection M on the start relay goes to the Run connection. The purpose of the start relay is to start the motor on the start winding which provides a high start torque, but switch it out of circuit before it overheats and burns out via a start relay to the Run winding.

The next connection is the motor winding protector, where a connection is made from the Common Pin on the compressor to position 3 on the motor winding protector. This connection passes through a small heater which, providing the current is not too excessive, will not produce sufficient heat for the bimetallic connector to distort and break the supply. The other connection is made to the negative mains supply. The start relay and overload protector are mounted in a plastic housing with three mating sockets for connection to the compressor pins. The next connection is to the thermostat or temperature controller, where one connection is taken from connection 1 on the starting relay to the positive mains supply.

The operation of either the temperature control switch or the overload protector will cut the supply to the compressor and stop refrigeration. The refrigeration lights are mounted in parallel via a door switch, with the compressor control relay and overload protector. A defrost heater is mounted in parallel but, for simplicity, a time switch is not shown. To control the heater, an evaporator fan is also mounted in parallel (and again a switch is not shown) to cut out the fan when the defrost heaters come on.

One must remember that automatic control of refrigeration equipment has been around for a long time, and price competitive equipment has been developed on electro-mechanical principles. However, electronic and semiconductor devices are being developed to produce better and more effective control equipment. In particular, a P.T.C. device, which senses the temperature in the motor windings and cuts the supply to the compressor more effectively than the overload protector, which unfortunately, takes time for the heat generated to distort the bimetallic strip and cut off the supply. Already, electronic devices coupled to a computer can give temperature and pressure readings of equipment sited remotely as in a chain of supermarkets, giving an indication of possible troubles in refrigeration equipment.

ACTIVE AERIAL *Continued from page 15.*

narrower blade for S1, 2, and 3, coils T1, T2, T3 and T6, T7, T8.

Set each coil so that its ferrite tuning slug is approximately halfway through its range of movement within its screening can. This will provide a good starting point for the alignment of each coil. There are small trimming capacitors installed to compensate for any tracking errors in the main tuning control. When starting the alignment procedure set all these trimmers TC1 to 10 to their halfway position. The same trimming tool used to set the coils will fit the slots in the tops of the trimmers.

The easiest method of alignment is to use a radio receiver which has a signal strength meter, sometimes referred to as an 'S meter'. However, if you possess more sophisticated test gear, by all means use it! The first method will be quite sufficient to produce good results from the unit but may take longer to achieve, as you may have to wait for favourable band conditions to find a stable signal to align with. You can use the inbuilt telescopic aerial or an external one when aligning the unit. When using an external aerial or setting up with test gear it is better to have the telescopic aerial folded down to its shortest length.

The connection to the receiver or test gear should be made with a short length of good quality, 50 or 75Ω coaxial cable, such as XR19V or low loss coax XR29G. Also use a good quality PL259 plug, with reducer if necessary, to ensure good connections throughout the system.

The alignment procedure is the same for each band and is in two main stages. First the low frequency end of the band with VC1a, b almost fully meshed, where you adjust the input/output coils for a peak in signal reading. The second stage at the high frequency end of the band with VC1a, b virtually fully open, where you adjust the input/output trimmer capacitors for a further peak in signal strength. This procedure is then repeated until no further improvement can be achieved on that band. The next band is then given the same treatment and so on, until all the bands have been aligned. A chart showing the frequency points plus the coil and trimmer references is shown in Figure 16.

Until the unit is properly aligned on each band you can not expect it to perform at its optimum and therefore, under adverse conditions, it may give an unstable result. If instability occurs during alignment it can usually be rectified by reducing the gain of the unit until the problem clears and alignment can be resumed. If the alignment has been carried out correctly no instability should occur, even with the gain control set at maximum.

In Use

The active aerial must never be directly connected to a transmitter or transceiver as any RF power transmitted through the unit will result in damage to the amplifier circuit and possible damage to the external equipment. If the unit is to be used in conjunction with such a device, an automatic bypass circuit would have to be added, as shown in Figure 13. The change-over action of the coaxial relays is controlled by the push-to-talk (PTT) line or by detecting some of the transmitted RF output.

With general use and a good quality PP3 battery a long period of service can be expected. Once the battery is exhausted it must be removed as soon as possible as even the modern types of battery will sometimes leak corrosive chemicals which will damage the circuit board and components. A battery which is left unused over a long period of time will decay to its discharged state; therefore if the unit is not to be used, or stored over a long period of time, it is good practice to remove it.

When using an external power source make sure the polarity is correct! Most small battery eliminators will be adequate but it is advisable to use one which has a regulated voltage output. The reason for this is the low current consumption of the unit which on an unregulated supply will allow the voltage to go much higher than its stated output.

If using the unit from the +12 volt supply of a car or boat make sure that you have a small fuse, for example 100mA, in line with the power supply cable and make the connection to the unit via the 3.5mm jack plug before connecting the +12 volt supply.

When no external aerial is available, the telescopic whip of the active aerial, fully extended, will give reasonable results over the whole of the tuning range. However, if there is an external aerial connected the whip is still active and can be more effective on certain frequencies. This, of course, depends on the type of external aerial in use and also whether or not an aerial tuning unit is being used. There are various types of external aerial to choose from, so for more detailed information refer to an aerial construction handbook. Maplin supply a number of these handbooks which cover the LW through to 10 metres SW. Normally when using an external aerial system, the telescopic whip should be folded down thus enabling you to assess the improvement of the signal when the unit is switched in and out.

The tuning of the active aerial is quite simple. First set the band switch so that the tuning control covers the same frequency range as that of the receiver. The incoming radio signal will peak in strength when the tuning of the unit matches the frequency of the receiver. You will soon obtain a good working knowledge of the tuning and gain settings suitable for your receiver and aerial system.

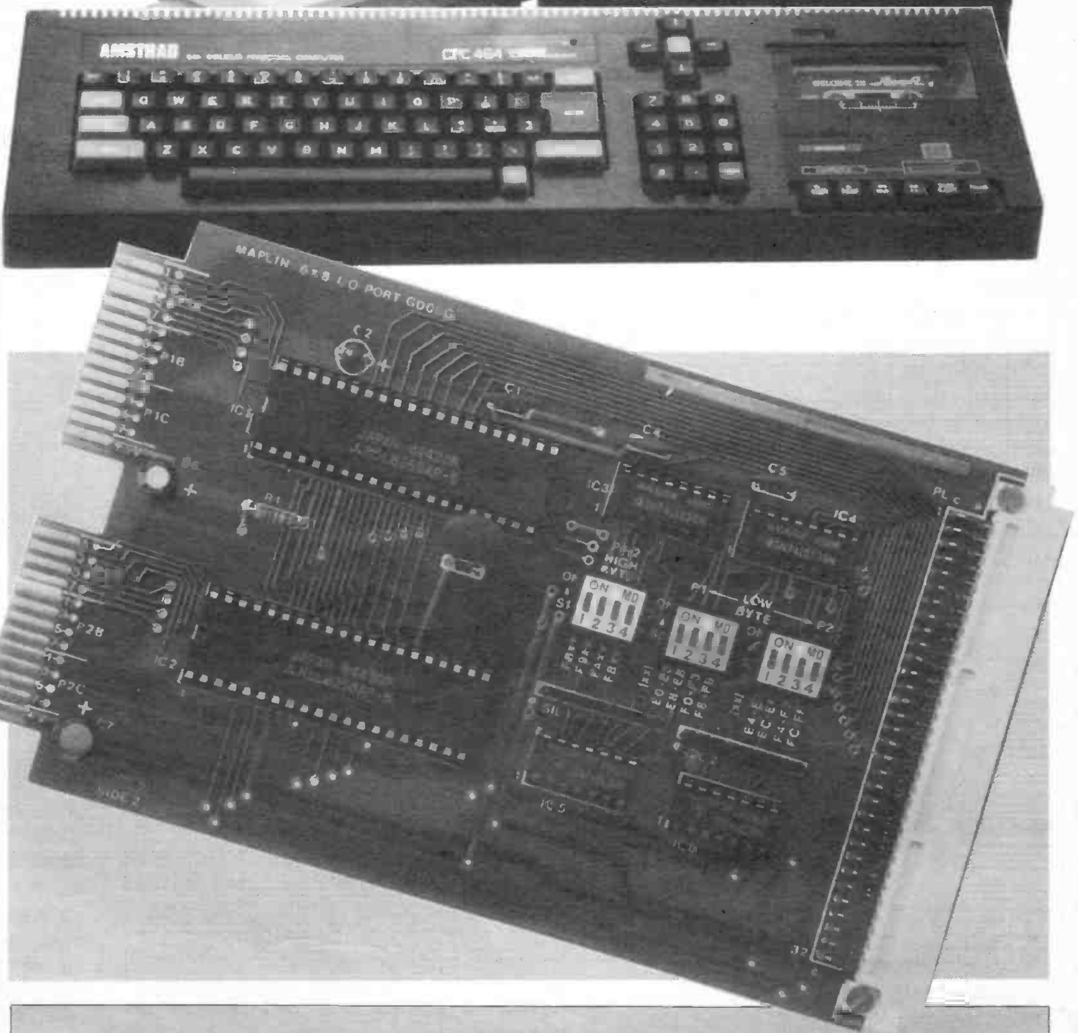
In Conclusion

Having matched the aerial impedance with the aid of the ATU and amplified the signal using the active aerial, you can do no more to improve the performance of your particular aerial/receiver system at the RF level. Improving the aerial system significantly could be difficult depending upon your location and the amount of space available to you. Improving your receiver would mean either extensively modifying the circuit of your current model or replacing it with a far more expensive alternative. However, at the audio level, sharp filtering can give further improvements in station readability by removing those annoying whistles and noises that come in with weak or low-powered stations. Such a device is currently being developed and will appear in a later issue of this magazine. The combination of all three devices should be quite spectacular and stations that were previously unintelligible will be dragged out of the background noise or QRM!

AMSTRAD EXPANSION SYSTEM

by Dave Goodman and John Attfield

Part 2



6 x 8 bit I/O Port

Part 1 of this series featured an External ROM Card and Motherboard system. The ROM Card can hold up to 8 ROMs with each ranging in size from 2K to 16K. A Motherboard module connects to the ROM Card, and can take up to six plug-in eurocard projects.

One such project is a 48-bit Input/Output Port card, another is a power supply module which drives the ROM Card buffer components and Motherboard cards, and it is these that we shall deal with in this issue.

Circuit Description

Figure 1 shows two 8255A (P.P.I.) devices, IC1 and IC2. Both devices are fully programmable for a variety of I/O functions, and contain four main registers each. In each case address lines A0 and A1 determine which 8255 register is accessed, with the RD and WR lines controlling data flow into or out of the register via data bus D0 to D7. IC3 and IC4 decode address blocks allocated by the Amstrad, and enable IC1 and IC2 at the correct time. $\overline{IOSEL}$, A8 and A9, are decoded by IC3 to produce upper byte values (Hex) F8, F9, FA and FB. Any combination of values can be selected by switch S1, to produce a negative or active low ($\overline{E}$) pulse from IC5 to IC4 pin 4. Similarly, IC4 decodes lower byte values from A2, A3 and A4, being selected by switch S2 and switch S3. Again, any combination of 1 to 4 switches can be selected to produce a negative ($\overline{CS}$) select pulse from IC6 to IC1 and IC2. R1 and C2 produce a short positive pulse when the supply is first connected. This pulse RESETs both PPI's by clearing their control registers, thus setting all ports to the input

★ **Six 8-bit Input/Output Ports**
★ **Address Select Facilities**
★ **Plugs directly into Maplin Motherboard**
★ **Power Supply Card available**

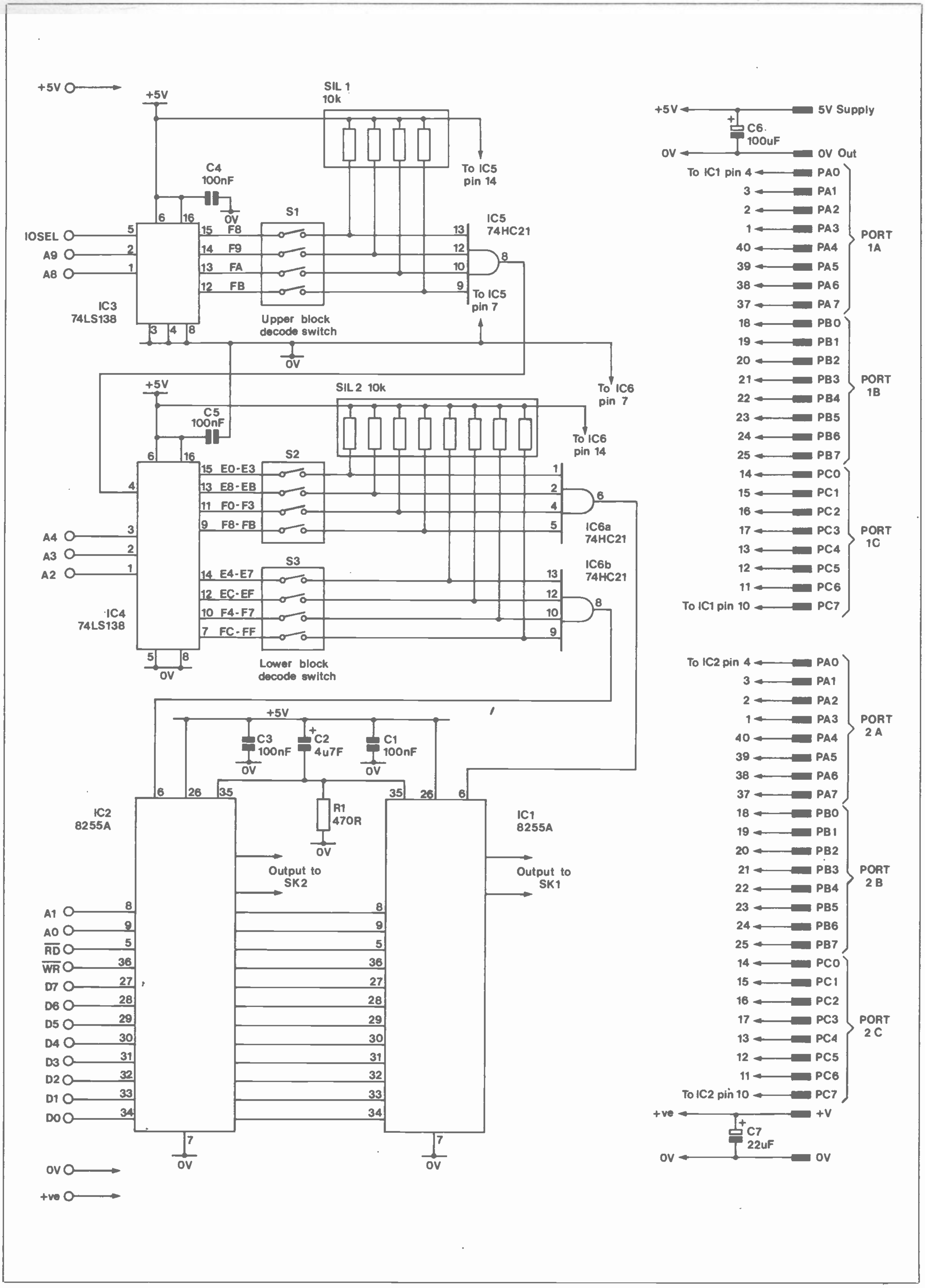


Figure 1. 6 x 8-bit Port Circuit

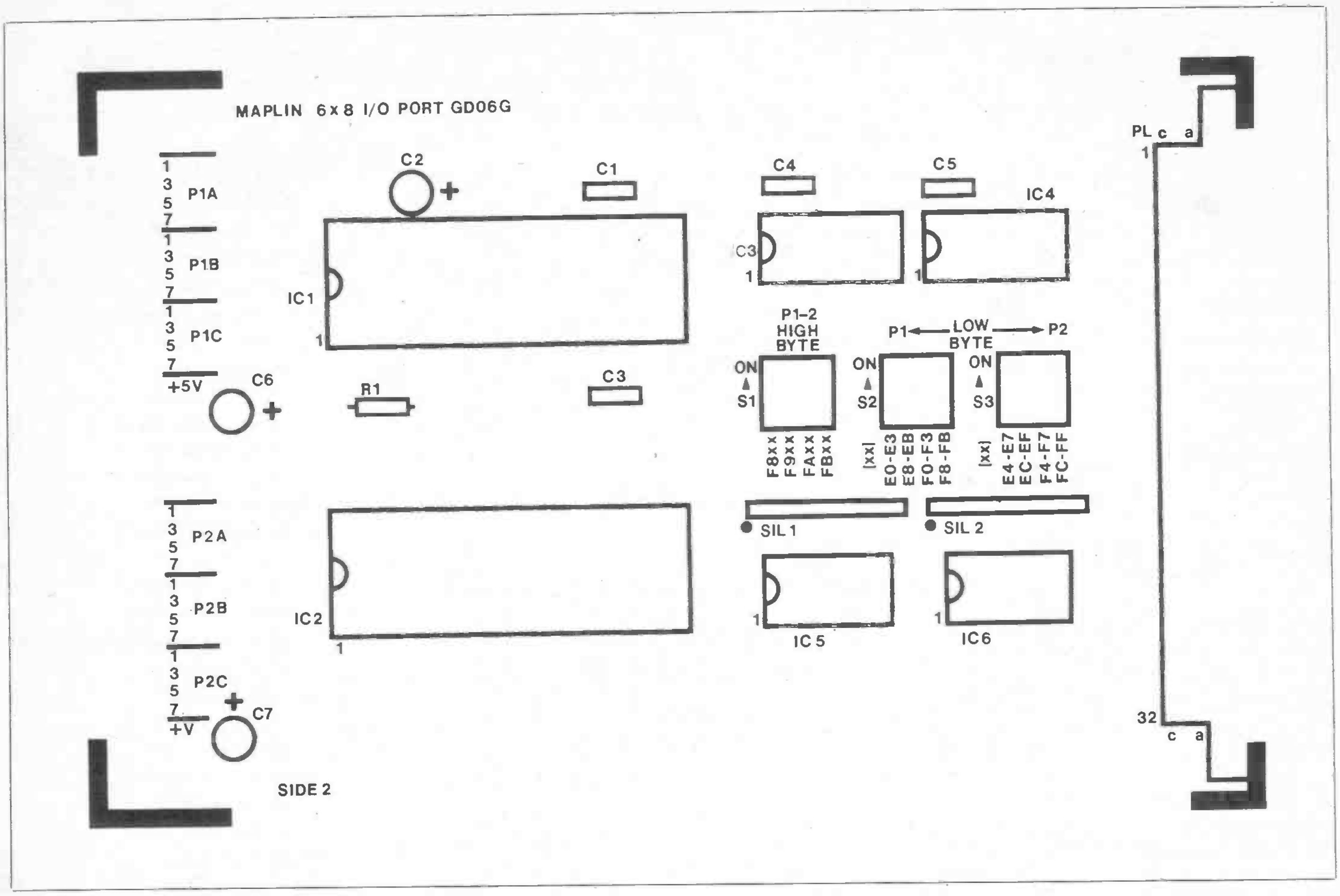


Figure 2. 6 x 8-bit Port PCB Overlay

mode. IC1 ports have been designated as P1A, P1B and P1C and IC2 ports are P2A, P2B and P2C. Each port has its own 8-bit bus, giving a total of 6 ports x 8 bits or 48 bits. Bits can be set to output data or input data in different configurations or modes, as will be explained later.

This project is designed to be plugged into our motherboard, and must not be connected to the Amstrad Expansion socket. For further details, please refer to Part 1 of this series.

Construction

Commence construction on the 6x8-port pcb (GD06G), where side 2 is the component side. With reference to the parts list and Figure 2, begin construction by inserting the IC sockets. Those for IC1 and 2 are 40-pin sockets, IC3 and 4 are 16-pin sockets and IC5 and 6 are 14-pin types.

Press them down onto the board, with the end notch or indent in-line with the white marker block on the legend. Bend a few of the legs on each socket to help keep them in position and solder in place. Do not fit any ICs until preliminary tests have been completed.

Fit the 4-way DIL switches S1, S2 and S3 in like manner and solder them in place. The two SIL resistor packs can now be inserted with the white dot, at one end of the body, matched with the white dot on the pcb legend. It is important to fit these two components correctly, as a SIL pack contains eight resistors, all commoned together at one end; this common pin is marked with the small white dot.

Fit electrolytic capacitors C6 and C7, taking note of lead polarity, and also the tantalum capacitor C2. This capacitor has its +V lead marked on the body. Insert the four remaining disk capacitors C1, C3 to C5 and also resistor R1.

Carefully solder all components in place on side 1 of the pcb, and remove excess leads and wire ends using side cutters. The 2 x 32-way right-angled plug is inserted in position PL1, from side 2, making sure that all 64 terminal pins pass through the board before soldering, see Figure 3. It might be advisable to secure this to the pcb using ½in. x 6BA screws and nuts first. Do ensure all components are fitted correctly before soldering, as the pcb track pads are plated-through the board from side 1 to side 2, thus making component removal difficult if necessary at a later date.

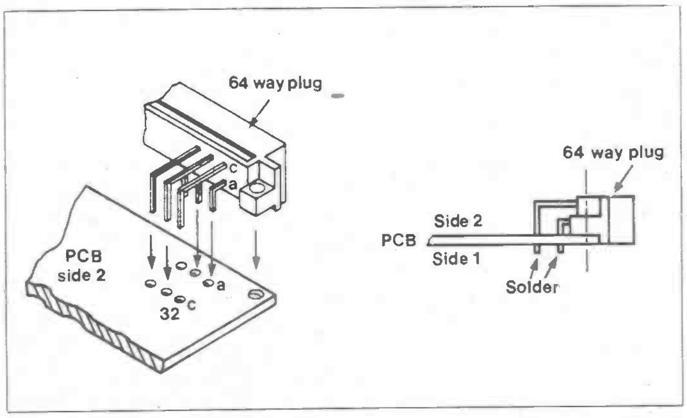


Figure 3. Fitting the 64-pin plug

Testing

Plug the I/O card into any socket position on the Motherboard. If you do not have 64-way receptacles fitted onto the mother-

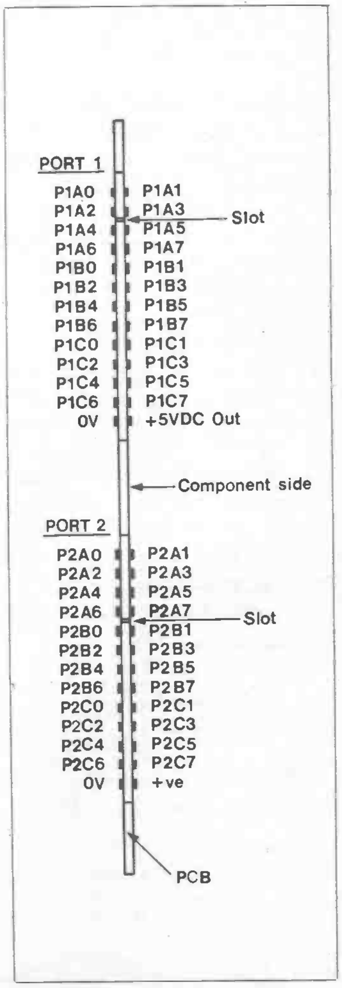
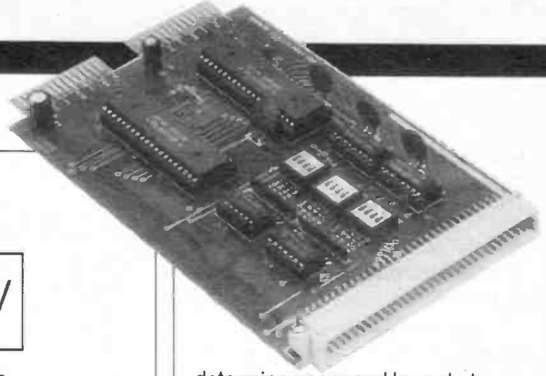


Figure 4. Edge Connections



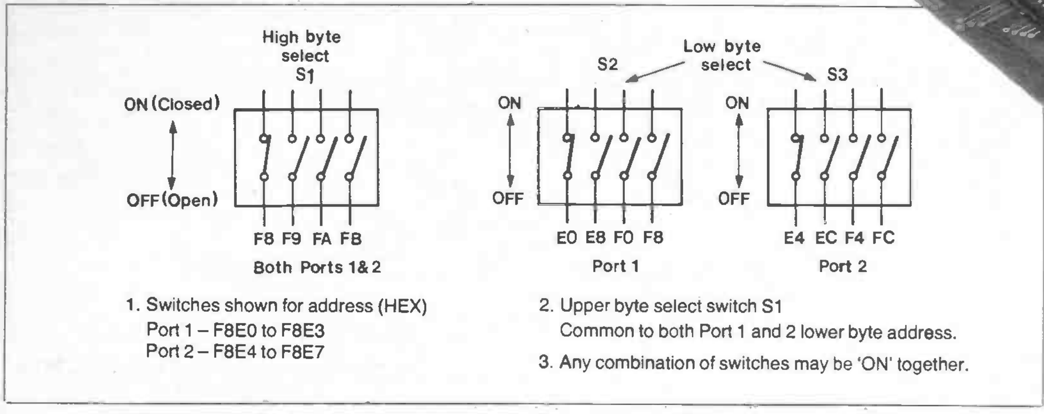


Figure 5. Address selecting

board, then these will have to be purchased and mounted first (see the Amstrad ROM Card leaflet).

Check the ROM Card extension IDC cable is fitted correctly onto the Motherboard, and that the ROM Card buffer components have been inserted and tested. The Amstrad PSU is not capable of supplying the plug-in cards, so a separate PSU is required. A suitable PSU project is available and details follow later in this article.

If you have a +5V DC regulated supply already, connect it to the Motherboard +5V and 0V terminal pins. The ROM Card buffer components also receive their supply from the Motherboard PSU. With I/O Card, Motherboard, PSU and ROM Card connected to the Amstrad, turn on both PSU and computer power. Refer to Figure 4 and measure the voltage across 0V and +5V terminals on Port 1 card edge-connector with a meter. If wrong, then recheck PSU wiring. Remove the I/O Card from the Motherboard and insert the six IC's.

Address Selection

There are 128 possible I/O addresses available on the Amstrad. Unfortunately, these addresses are not consecutive, as certain combinations of bits serve different functions. Addresses available are as follows:

HEX

F8E0 to F8FF
F9E0 to F9FF
FAE0 to FAFF
FBE0 to FBFF

The lower byte in each case (E0–FF) is common to all, but the upper or higher byte changes in blocks, see Table 1.

I/O addresses for external use require A10 low only. A11 to A15 must be high as other devices use these bits. This also applies to A5, A6 and A7, which are low for disk and communication channels only. As a point of interest:

A15 low selects the video gate array.
A14 low selects the CRT controller.
A13 low selects expansion ROMs.
A12 low selects printer port.
A11 low selects the PPI-8255 I/O chip.

Note that only one of bits A10 to A15 should be used at any time, so for I/O use, A10 is always low. Seven of the bits referenced as 'X' determine upper and lower byte values. A0 to A7 is the lower address byte and A8 to A15 the upper address byte. Any 'X' bit can be set high or low for a total of 128 addresses (7 bits) where A8 and A9 determine upper byte addresses F8, F9, FA, FB (Hex) and A0 to A4 determine lower byte addresses from E0 to FF (Hex). Hence the non-consecutive address range in use on this card.

BINARY

A 15				A 11	A 10	A 9	A 8	A 7		A 5	A 4				A 0
1	1	1	1	1	0	X	X	1	1	1	X	X	X	X	X

Table 1

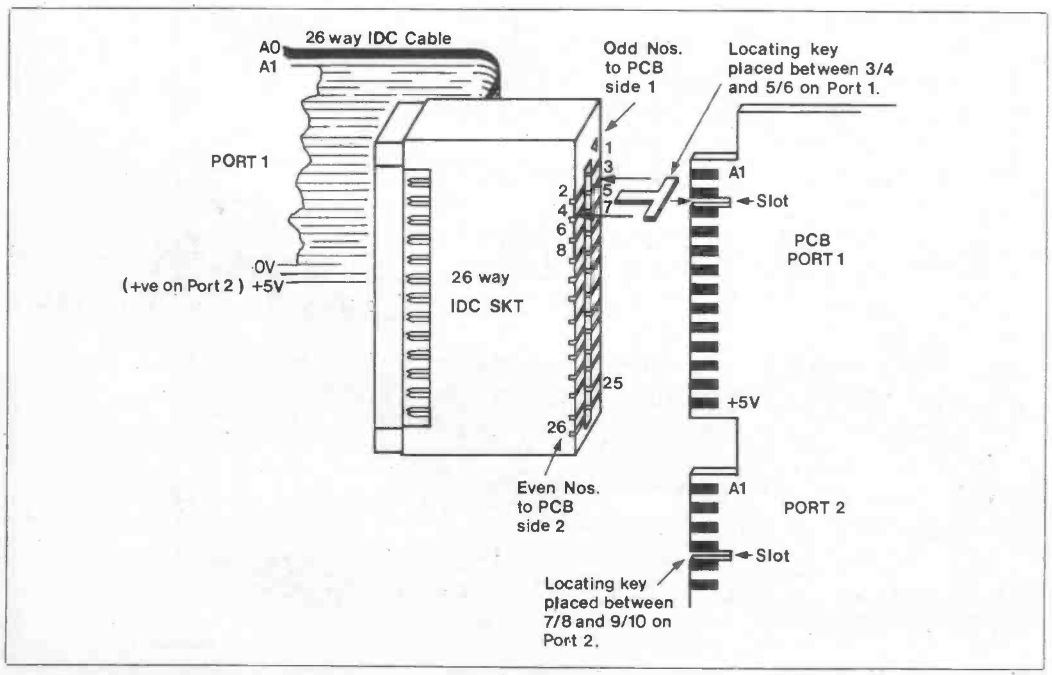


Figure 6. Connection to the 6 x 8-bit PCB

To increase flexibility in use, address blocks can be selected on the card as required, shown in Figure 5. The 4-way switch bank S1 allows for selection of the upper byte address, which is common to all ports, and S2 selects the lower byte addresses in 4 byte blocks from E0 to FF, for Port 1 only.

Similarly, switch bank S3 selects 4 byte block addresses for Port 2. If this addressing method seems strange then it must be understood that Port 1 and Port 2 PPI chips have four internal registers selected by address lines A0 and A1. These register addresses are sequential, so for Port 1, address E0, E1, E2 and E3 can be selected (switch 1 on S2), and Port 2 address E4, E5, E6 and E7 selected by switch 1 on S3. If so desired, all twelve switches can be set 'ON' so that any of the 128 addresses will access the Ports, but doing so will cause problems if more than one I/O card is fitted on the Motherboard!

Test Routines

Set all twelve (S1 to S3) switches down to 'OFF', and select F8 (S1), E0–E3 (S2) and E4–E7 (S3) switches to 'ON' only. The remaining nine switches should not be in the 'ON' position!

Port 1 enable addresses are now F8E0 to F8E3, and Port 2 addresses are F8E4 to F8E7. Plug the I/O card into the Motherboard, and turn on the PSU and the Amstrad. Type in and RUN program 1.

Lines 20 and 40 ask for Port address and data to be sent using the BASIC OUT (port), data command.

P.P.I. Programming

The Programmable Peripheral Interface IC has four internal registers as shown in Table 2.

The Control Register has data written to it to determine various functions of Ports A, B and C, see Table 3.

For example, to set I/O Registers A, B, C on Port 1, to output mode: OUT (F8E3), 80. Another example is to set I/O Register A to output, B to input, C (upper) to output and C (lower) on to input on Port 2: OUT (F8E7), 83.

Note that register C of both Ports can be 'split' into two half bytes or nibbles. The lower half bus (C0 to C3) and upper half bus (C4 to C7) can be set to *different* I/O modes, as shown in Table 3. Mode 0 operation is the most commonly used method of passing data to and from the Ports, although there are a further two operating modes for the 8255A PPI. Further information is available on data sheets (see Parts List).

To continue with the testing using program 1, enter F8E3 in response to 'address =', and 80 after 'data ='. Both address and data values will be printed, and Control Register 1 (Port 1) will be programmed for Ports 1A, 1B and 1C to assume mode 0 output mode.

Refer to Figure 4 for the I/O edge connections, and connect a voltmeter to 0V and P1 A0 (the top connector). The reading should be 0V or very close.

Now enter address F8E0 and data 01, and the reading on Port 1A, bit 0 should be high (+4 to +5V). Using the same address (F8E0), enter data values 02, 04, 08, 10, 20, 40 and 80 (Hex), and check that all outputs P1 A0 to A7 each go high in turn.

Repeat this test on Port 1 B0 to B7, using address F8E1, and Port 1 C0 to C7, using address F8E2. Any bits that do not change indicate a fault and should be investigated. Data codes written out to all ports are 'latched' permanently within the IC until 'Reset' or overwritten by new data codes.

At any time, the Control Register can be accessed to change the status of Ports A, B and C. Please note that this particular register can be *written to only*, and status codes cannot be read from it.

Port 2 registers can be checked in the same way by entering data code 80 at address F8E7 to set P2 A, B and C registers to output mode. F8E4 will be Port 2A, F8E5 is Port 2B and F8E6 is Port 2C. Write data codes 00 to FF to each of these ports and check for appropriate bit conditions as before.

In Program 2, Ports 1A to 1C are set for output and Ports 2A to 2C are set for input modes. If Port 1 A0 to A7 is connected to Port 2 A0 to A7, Port 1 B0–B7 to Port 2 B0–B7, and Port 1 C0–C7 to Port 2 C0–C7, then the program will test each one of 48 bits and display errors, if any, as they are found.

I/O Connector

The 2 x 13-way card edge connections may be terminated with a 26-way IDC edge connector and cable (see Parts List). Polarising keys for these connectors can also be fitted, and the card slots are in different positions. Figure 6 shows these particular IDC sockets and terminal/cable connections.

When using the card, note that Port I/O signals should be at TTL levels of 0V to +5V. Current sourcing is low and relays, etc., cannot be driven directly. 0V,

```
10 CLS
20 INPUT"ADDRESS = ",a$
30 a=VAL("&"+a$)
40 INPUT"DATA = ",d$
50 d=VAL("&"+d$)
60 OUT(a),d
70 CLS
80 PRINT "ADDRESS = ";a$,"DATA = ";d$
90 GOTO 20
```

Program 1

REGISTER TYPE	A1	A0	PORT 1	PORT 2
CONTROL REGISTER	1	1	E3, EB, F3, FB	E7, EF, F7, FF
I/O REGISTER PORT C	1	0	E2, EA, F2, FA	E6, EE, F6, FE
I/O REGISTER PORT B	0	1	E1, E9, F1, F9	E5, ED, F5, FD
I/O REGISTER PORT A	0	0	E0, E8, F0, F8	E4, EC, F4, FC

Table 2

Mode 0 Port Definitions

DATA (HEX)	PORT A	PORT B	PORT C (UPPER)	PORT C (LOWER)
80	OP	OP	OP	OP
81	OP	OP	OP	IP
82	OP	IP	OP	OP
83	OP	IP	OP	IP
88	OP	OP	IP	OP
89	OP	OP	IP	IP
8A	OP	IP	IP	OP
8B	OP	IP	IP	IP
90	IP	OP	OP	OP
91	IP	OP	OP	IP
92	IP	IP	OP	OP
93	IP	IP	OP	IP
98	IP	OP	IP	OP
99	IP	OP	IP	IP
9A	IP	IP	IP	OP
9B	IP	IP	IP	IP

Table 3

```
10 MODE 2
20 CTREG1=&F8E3 : CTREG2=&F8E7
30 PORT1A=&F8E0 : PORT2A=&F8E4
40 PORT1B=&F8E1 : PORT2B=&F8E5
50 PORT1C=&F8E2 : PORT2C=&F8E6
60 OUT(CTREG1),&80 : OUT(CTREG2),&9B
70 PORT1=PORT1A : PORT2=PORT2A
80 FOR i%=0 TO 255
90 OUT(PORT1),i% : in%=INP(PORT2)
100 LOCATE 1,1
110 PRINT"PORT 1=";HEX$(PORT1);",";HEX$(i%,2),
130 PRINT"PORT 2=";HEX$(PORT2);",";HEX$(in%,2)
150 IF in%<>i% THEN GOSUB 1000:IF INKEY$="" THEN 150
170 NEXT
180 PORT1=PORT1+1:PORT2=PORT2+1
190 IF PORT1<>CTREG1 THEN 80
200 PRINT : PRINT"TEST COMPLETE"
999 END
1000 LOCATE 17,3
1005 PRINT"ERROR!"
1010 PRINT HEX$(PORT1,4);"=";HEX$(i%,2),,
1020 PRINT HEX$(PORT2,4);"=";HEX$(in%,2)
1030 RETURN
```

Program 2

+5V and +V PSU rails are extended out to the edge connector, and these terminals may need decoupling if currents greater than 500mA are envisaged.

PSU Module

Figures 7 and 8 show the circuit diagram and overlay of a small PSU module for driving the Motherboard buffer circuitry (ROM Card) and plug-in cards. A regulated +5V and unregulated +V are available for wiring to the associated Motherboard terminals, and maximum current is 1 Amp @ 5V DC, depending on the transformer used.

For general low current, low voltage use, a mains adaptor (see Parts List) can be fitted to the module. The particular adaptor specified requires a socket to be fitted (SK1) on the pcb for connecting one of the 4, 2.5mm plugs moulded onto the adaptor cable.

Alternatively, a mains transformer can be wired directly to the AC inputs on the PSU module. If a 30VA, 12V toroidal is used (YK10L), then the unregulated (≃30V DC) is connected from the +V output to +V terminal on the Motherboard. This transformer is necessary when fitting the EPROM Programmer module on to the '6 x 8 I/O CARD' as voltages of +21V to +25V are required for programming EPROMs.

The PSU module comprises a simple bridge/smoothing circuit, 5V regulator, decoupling capacitor and indicator LED. REG1 is fitted onto a vaned heatsink before mounting on the pcb (see Figure 9) using ¼in. x 6BA bolt and nut and washer as shown. The BR1 rectifier package *must* be inserted correctly, with the + symbol on the package adjacent to the + on the legend. There may also be two ~ symbols on the package which denote the input AC terminals.

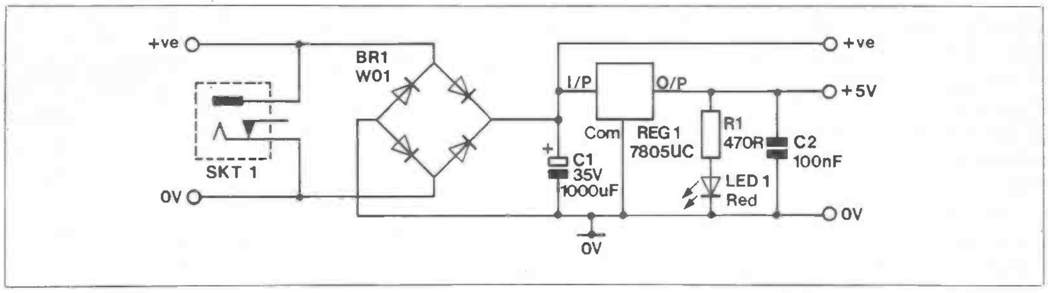


Figure 7. PSU Circuit

C1 must be fitted correctly. Note that it is the −V lead that is marked on the body, and *not* the +V lead. Insert the +V lead into the hole marked '+' on the legend.

When mounting LED1, note that the cathode lead (k) is the shortest of the pair, and is also the lead directly beneath a flat edge on the package skirt. Carefully solder all components, but note that it might be a good idea to install the regulator IC1 complete with heatsink and bolted in position on the pcb, thus ensuring correct location before soldering – bend the 3 leads to 90° according to the pattern of the pcb holes, and insert these whilst laying the IC flat onto the heatsink.

Insert three vero-pins in the +5V, +V and 0V positions from the *track side* of the pcb. Push each pin onto its pad with a hot iron and apply solder.

Using the PSU Module

Insert SK1 and solder to the board if you intend using the mains adaptor supply. One of the adaptor's four multiplugs fits the socket correctly. If using a 12–0–12V transformer, such as a toroidal, then bare and tin the RED and GREY secondary wires, and insert into the two holes marked 'AC' on the pcb. Solder these in place of SK1.

The remaining two second-

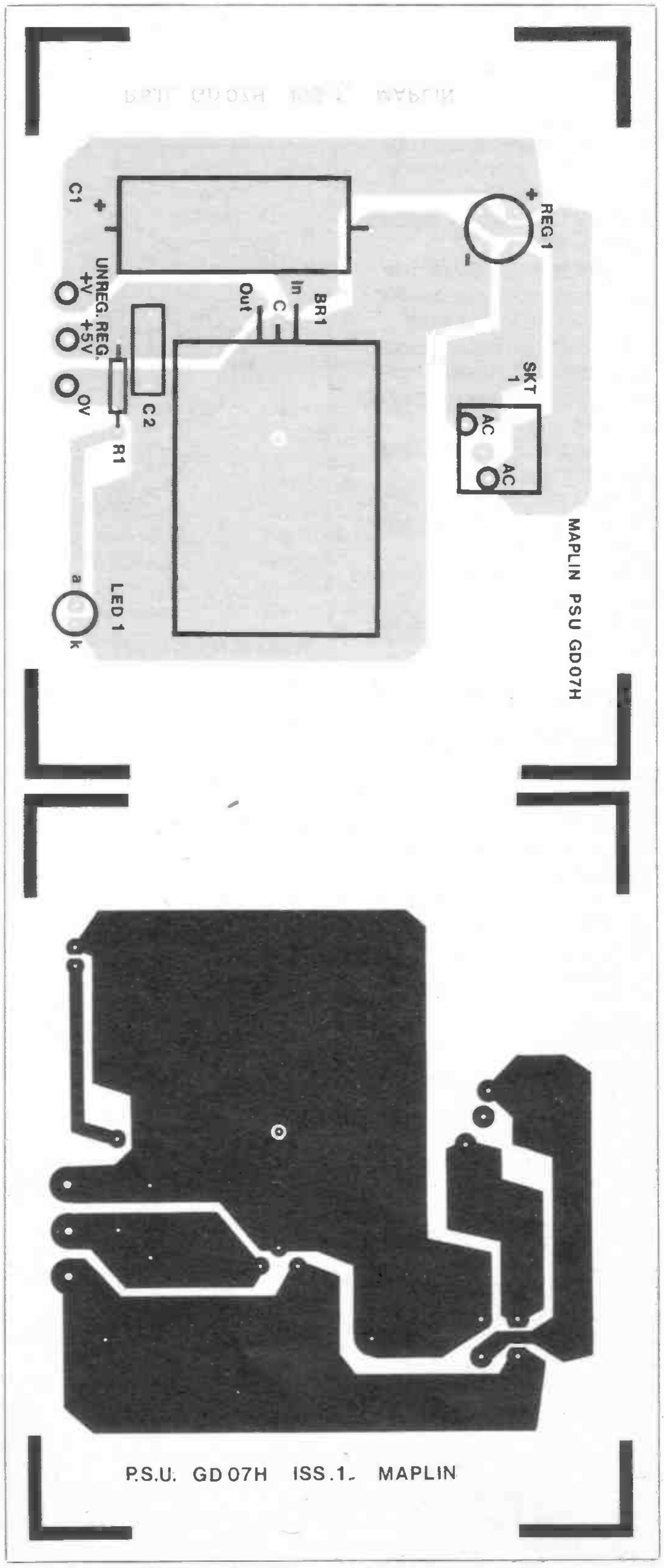
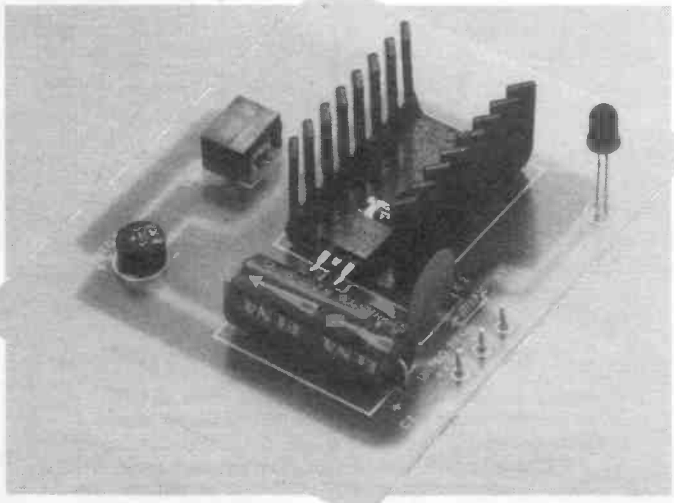


Figure 8. PSU PCB Track and Legend



aries, BLUE and YELLOW, are joined together by twisting the prepared ends and soldering. Insulate this termination with sleeving and/or insulation tape to prevent short circuit problems (see Figure 10).

Apply mains power to the supply source and check with a voltmeter connected between the 0V pin and +5V pin for 4.8 to 5.1V DC. The 0V to +V pin will be +15 to 18V with the adaptor connected (selector switch set to 12V), or 35V DC approximately with the 12V torroidal transformer fitted. Check that LED1 glows brightly with the power supply on. This LED may also glow dimly once connected to the Motherboard and ROM Card, with the Amstrad supply on only.

Wire all three PSU module terminals to each corresponding terminal on the Motherboard. ROM Card buffer circuitry tests are covered in the booklet supplied with that module, so they will not be repeated here.

Standard 'Euro-Card' sizes have been adopted for the Motherboard system which allows PSU, I/O card and Motherboard to be fitted to Euro-Card rack frames. The PSU circuit board has been enlarged for this reason, and will fit vertically in rack guide rails if required.

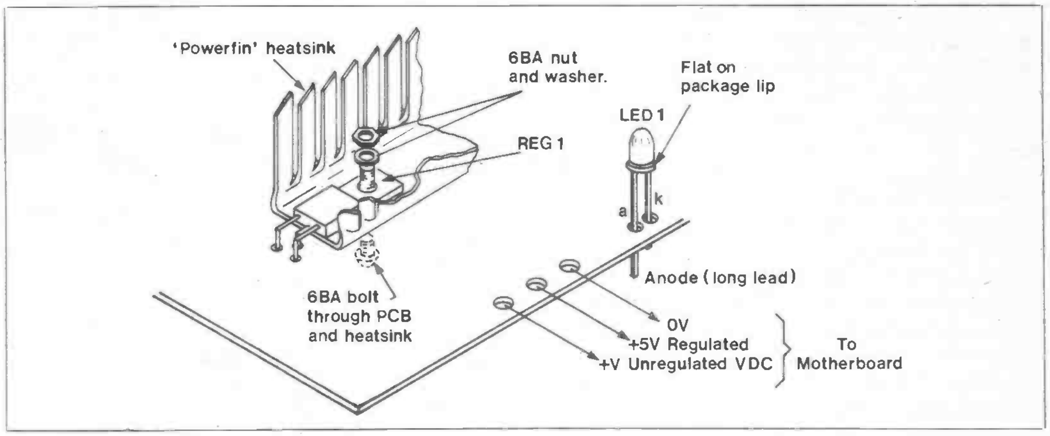


Figure 9. Fitting LED1 and REG1

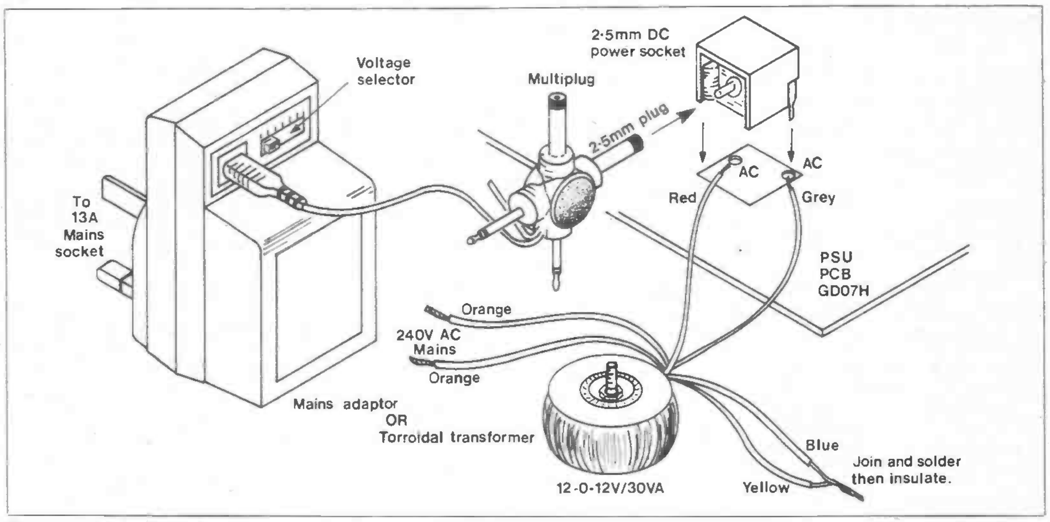


Figure 10. Mains Supply

EXPANSION SYSTEM PSU PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	470R	1	(M470R)
CAPACITORS			
C1	1000μF 35V Axial Electrolytic	1	(FB83E)
C2	100nF Disc ceramic	1	(BX03D)
SEMICONDUCTORS			
BR1	W01	1	(QL38R)
REG1	μA7805UC	1	(QL31J)
LED1	LED Red	1	(WL27E)
MISCELLANEOUS			
SK1	PCB 2.5mm DC Pwr Skt	1	(FK06G)
	Expansion PSU PCB	1	(GD07H)
	Powerfin plastic Heatsink	1	(FG55K)
	Bolt 6BA x ¼in.	1 Pkt	(BF05F)
	Nut 6BA	1 Pkt	(BF18U)
	Veropin 2145	1 Pkt	(FL24B)
OPTIONAL			
	AC adaptor Unregulated	1	(XX09K)
	Mains Tx as required (see text)	1	(YK10L)

A complete kit of all parts, excluding optional items, is available for this project:
Order As LM03D (Expansion PSU Kit) Price £4.95
The following item included in the above kit list is also available separately, but is not shown in the 1986 catalogue:
Expansion PSU PCB. **Order As GD07H Price £2.95**

6 x 8 BIT PORT PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	470R	1	(M470R)
SIL 1,2	10k SIL Resistor	2	(RA30H)
CAPACITORS			
C1,3,4,5	100nF Minidisc	4	(YR75S)
C2	4μ7F 16V Tantalum	1	(WW64U)
C6	100μF 10V PC Electrolytic	1	(FF10L)
C7	22μF 63V PC Electrolytic	1	(FF07H)
SEMICONDUCTORS			
IC1,2	8255A	2	(YH50E)
IC3,4	74LS138	2	(YF53H)
IC5,6	74HC21	2	(UB12N)
MISCELLANEOUS			
	6 x 8 Bit Port PCB	1	(GD06G)
S1,2,3	DIL Switch SPST Quad	3	(FV43W)
	DIL Socket 14-pin	2	(BL18U)
	DIL Socket 16-pin	2	(BL19V)
	DIL Socket 40-pin	2	(HQ38R)
	PCB Plug Gold 64-way	1	(FJ51F)
OPTIONAL			
	26W IDC Edge Connector	2	(FT88V)
	Polarising Key IDC	2	(QY73Q)
	Flat IDC Cable 26-way	As req	(XR75S)
	PCB Receptacle Gold 64-way	1	(FJ47B)
	Colour coded IDC Cable 26-way	As req	(XR82D)
	8255A PPI Data Sheet		

A complete kit of all parts, excluding optional items, is available for this project:
Order As LM02C (6 x 8 bit Port Kit) Price £24.95
The following item included in the above kit list is also available separately, but is not shown in the 1986 catalogue:
6 x 8 bit Port PCB. **Order As GD06G Price £10.95**

The Story of Radio

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

Part Three – The Birth of the Valve

Dr. J.A. Fleming

Photo supplied by Marconi Co. Ltd

One of the difficulties facing anyone who attempts to describe the history of a particular technology is the fact that development does not follow a single, clearly defined path, but proceeds along a number of parallel ones. The significance of what is found on any one of these paths may not always be apparent until much later.

Thus, while Marconi was experimenting with the transmission and reception of wireless waves at the end of the 19th century, other contributions were being made by scientists on both sides of the Atlantic. These initially quite unconnected experiments would culminate in a device that would eventually make the crude spark transmitters and coherer-type receivers obsolete. Instead, there would be a whole new technology, that today we would

When the cathode ray struck the paddle-wheel, the latter moved along the rails. This proved that the ray was composed of physical particles able to do work.

identify as ‘electronics’. This new device was the ‘thermionic valve’, which would be developed through many forms for many uses, before it too was overtaken by another innovation, born in the Bell Telephone Laboratories in 1948, namely the transistor. And so it is now necessary to return for a while to the Victorian age.

Cathode Rays

Conduction of electricity through gases had concerned many scientists in the late 19th century, including the eminent Sir William Crookes. Experiments had shown that electricity could cross a gap in the conductor if the voltage was high enough – this being the well known spark. Crookes investigated this phenomenon further by sealing the two conductors into a glass tube, which he could evacuate with a pump, so lowering the air pressure within.

The effect, visually, was remarkable. Apart from the current flowing more easily, which in itself was something of a surprise, the crackling blue snap of the spark was tamed, to become a beautiful stream of light, which particularly surrounded one wire (the cathode) in a violet glow. Crookes had discovered discharge lighting but, for the science of wireless still to come, he had found much more.

As the quantity of air within the tube was decreased further, the light stream changed to a series of alternate dark and light bands. Then there appeared a dark space near the cathode, which increased in size until it filled the whole tube; finally the current stopped completely. This ‘dark space’ was of interest because it coincided with a glow that appeared at the opposite end of the tube, as if a ray was leaving the cathode and causing luminescence when it struck the far end. To investigate this further, Crookes placed a metal screen in the path of the ‘cathode ray’, and found its image projected as a shadow on the luminescent area.

Taking it a stage further, he next installed a small paddle-wheel on rails within the tube and along its axis, so that when the cathode ray struck the paddle-wheel, the latter moved along the rails. This proved that the ray was composed of physical particles able to do work. These particles were, of course, what were later known as ‘electrons’.

Fleming had worked with Marconi on the wireless experiments and realised that the Edison effect could be used to detect the radio-frequency currents in a wireless aerial

In fact, the name ‘electron’ was suggested in 1891 by Dr. Johnstone Storey, who applied it to a particle of electricity that he, correctly as it turned out, predicted existed. In 1897 Sir J. J. Thomson, accepting Dr. Storey’s theory, made an announcement to the Royal Society about the ‘cathode ray’ observed by Sir William Crookes. He said that it was composed of a stream of charged particles, which arose out of the disintegration of gas atoms in the tube.

In the years that followed, the modern theory of atomic construction was developed by people such as Thomson, Rutherford, Moseley, Bohr and others, until the picture emerged that electrons had a positive counterpart, the proton, so that when a cathode ray travelled to the anode within Crooke’s partially evacuated tube, a positive ray travelled in the opposite direction.

These are some of the principle experiments that were to lead ultimately to the birth of the thermionic valve or, as the Americans have always called it, the 'vacuum tube'. But now it is necessary to go back again in time to 1883, where there is yet another parallel path, a very significant one.

The Edison Effect

In this year Thomas Edison, in the United States, was experimenting with incandescent lamps. At the time he was using carbon as the filament material. Unfortunately, this had the decided disadvantage of blackening the bulb. As an experiment, Edison fitted a metal plate inside the bulb, bringing out a connection through a seal in the glass. To this extra electrode he tried connecting potentials, first positive, then negative. What he observed was later known as the 'Edison effect', which was that when the plate was made positive with respect to the filament, a galvanometer connected in series with it registered a current. However, when the potential of the plate was negative, no current flow was observed.

Totally unaware of its true significance, what he had produced was an elementary 'diode' valve. He demonstrated the effect to others but actually made little use of it himself. But one person who did see it was a British physicist, Ambrose Fleming, who

If a positive plate was now brought near, electrons would be drawn from the space charge and would flow through space to the plate

had once studied under the great James Clerk Maxwell in the Cavendish Laboratories in Cambridge. About twenty years later Fleming put Edison's observations to good use when he invented the first practical wireless valve.

It may be remembered that Fleming had worked with Marconi on the transatlantic wireless experiments. As a result of this work, Fleming realised that the Edison effect could be used to detect the radio-frequency currents in a wireless aerial. He, therefore, carried out some experiments with modified Edison lamps. He connected a lamp in series with a galvanometer and the secondary winding of a transformer, whose primary winding was energised from the

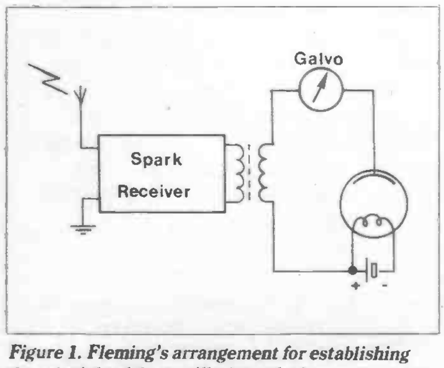


Figure 1. Fleming's arrangement for establishing the principle of the 'oscillation valve'.

Fleming's Experimental Diode 1904

output of a spark receiver (Figure 1).

Switching on a spark transmitter, he was gratified to find his predictions confirmed. Each pulse of energy was transformed and then rectified by this elementary diode valve, so producing a deflection on the pointer of the galvanometer. This made it possible for a 'visual' output to be obtained, a matter of some importance to Fleming, whose hearing was now rather poor.

Fleming's Valve

On November 16th 1904, Fleming took out a patent for what he called his 'oscillation valve'. The name arose, not because it generated oscillations (which of course it couldn't), but because it detected them, and he called it a valve because of its 'one way' property of conducting electric current.

The filament was metal and was heated by a battery to white heat. This high temperature caused the electrons in the filament to become so agitated that they actually left the material – an effect known as 'thermionic emission'. Since the filament was now positively charged, the electrons were immediately attracted back by the universal law of attraction between opposites. However, the process was continuous, with electrons being emitted and recaptured all the time. At any instant,

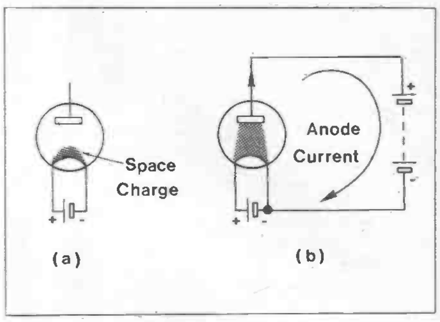


Figure 2.
(a) Formation of space charge by heated filament.
(b) Current flow when anode is positively charged.

however, the filament was surrounded by a cloud of electrons – called the 'space charge' (Figure 2a).

If a positively charged plate was now brought near, electrons would be drawn from the space charge, and would flow through space to the plate (anode). The connection of a battery between anode and filament would create a path for continuous current flow, by allowing the electrons given up by the filament to be replaced from the negative terminal of the battery (Figure 2b). Reversing the anode supply meant no current flow, since a negatively charged anode would repel rather than attract electrons. This was the basic principle of Fleming's diode valve.

To apply this principle to a wireless

Thus, the valve produced an output that was both unidirectional and followed the signal amplitude changes

receiver, it is only necessary to imagine that the anode supply is not a battery (DC), but is a high frequency oscillation (AC). The anode is now alternately positive and negative on each successive half-cycle of the r.f., and since anode current only flows on positive half-cycles, the alternating signal is converted to a unidirectional output (Figure 3). Furthermore, since the strength of the anode current depends upon the potential on the anode, strong signals would produce large anode currents and weak signals, small ones.

Thus, the valve produced an output that was both unidirectional *and* followed the signal amplitude changes, a process known as detection and which is still in use in modern radio receivers.

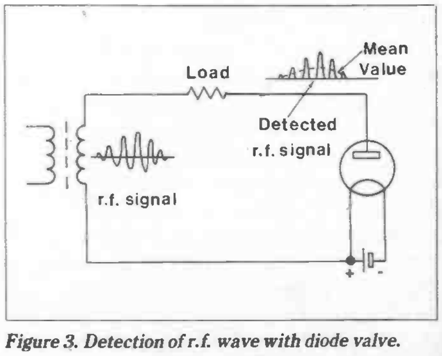


Figure 3. Detection of r.f. wave with diode valve.

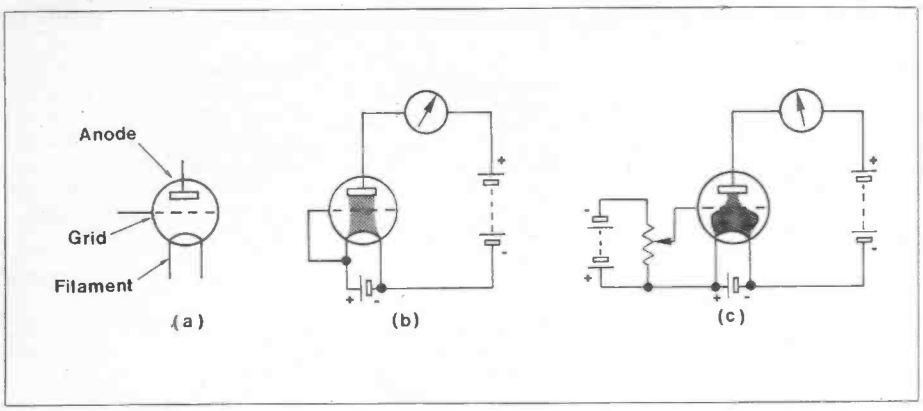


Figure 4. (a) The 'audion' or first triode valve.
(b) The grid has little effect when taken to filament potential.
(c) Anode current is reduced when the grid is made negative with respect to the filament.

The Audion Valve

As often happens once a new device appears, it is soon modfied or improved by someone else. This happened in the case of Fleming's diode valve when, in 1906, an American, Dr. Lee de Forest, produced his 'audion' valve. This was more a development than an improvement, since each still had its own, rather different, application. The audion had an extra electrode, known as the 'grid', inserted between the filament and the anode, with an external connection made to it (Figure 4a). This electrode was an open metal mesh, so it did not form a physical barrier to the electron stream. If it was connected to the filament potential it had no influence on the anode current; the electrons simply flowed through it (Figure 4b). But, if it was connected to a negative potential (with respect to the filament potential, that is), it was then able to repel some of the electrons and return them to the filament (Figure 4c). The more negative it was made, the more electrons it repelled until eventually the anode current was 'cut off' completely. Therefore, the value of the anode current could be controlled either by varying the positive anode voltage, *or* by varying the negative voltage on the grid. But, because the grid was so much nearer to the cathode than it was to the anode, it had a much greater effect on the anode current than the latter.

Like many another good idea, the theory was ahead of the current technology. In this case the process that was lacking was the large scale evacuation of glass tubes

Without labouring the point further, the practical significance of this was of immense importance. Because the audion valve could take a small input voltage (at the grid) and develop a much larger output voltage (at the anode) if a load was placed in series with the changing anode current, it became possible to amplify oscillatory voltages to any required level merely by following one valve amplifier with another, and so on. The problem was that, like many another good idea, the theory was ahead of the current technology. In this case the process that was lacking was the large scale evacuation of glass tubes to the required degree of vacuum. It was left to the First World War, and the impetus that war always gives to new technology, to make the valve the powerful component that it was to become, and remain for the next few decades.

A Titanic Disaster

Now to return to the world outside of the experimental laboratory. Wireless was now a reality, a commercial proposition that allowed the transmission of messages across the wide Atlantic, that allowed ships to maintain contact with shore stations, of which there were many, and to 'talk' to each other. The potential for saving lives was enormous. A ship in difficulties could, if she had wireless, call for assistance with a good chance of getting some if there was other shipping within a reasonable distance. However, it required a major tragedy at sea to pinpoint the weaknesses in the system and to produce the legislation needed to ensure greater safety at sea in the future.

This tragedy occurred on Sunday, April 14th 1912, when the 'unsinkable' Titanic struck an iceberg and went down with the loss of 1,517 lives. It is interesting to see the part played by wireless in this disaster and what it ultimately led to.

At 7.15 pm on that fateful Sunday, another vessel in the vicinity, the Californian, wirelessed a warning of local icebergs. Several other ships also reported similar conditions. To these messages, the Titanic responded with a routine acknowledgement but maintained high speed. At 10.30 pm that evening, the conditions were so bad that the Californian sent out the message that she was stopped in thick ice. Again the Titanic acknowledged but added curtly, "Shut up, I am busy with Cape Race" (the Newfoundland shore station). At 11.40 pm the Titanic struck an iceberg which ripped open her underwater hull for a length of about 300ft. Bulkhead failures meant that the subsequent flooding could not be contained and, recognising that the end was inevitable, distress signals were sent out.

The Californian was nearby, and equipped with wireless and clearly in a position to help, but her sole wireless operator had just gone off watch, so no calls were received.

However, the Titanic's distress calls were picked up by a number of other vessels, including the German steamer Frankfurt (153 miles away) and the Carpathia (58 miles away). In the latter case, the wireless operator was also off-duty but, by chance, had returned to his equipment to handle some routine calls. At 12.20 am he picked up the distress signals from the Titanic. As a direct result of wireless, some half a dozen vessels raced to the scene of the disaster and 712 people were plucked from the water that night and saved.

What this tragic incident highlighted was not the number of lives that were saved by the intervention of wireless, but the number that had been lost largely because of the inadequacies of the system.

Another rather alarming situation that occurred a few hours after the tragedy, but which would have been absolutely disastrous had it happened during it, was the almost total jamming of the aether by enthusiastic American amateurs, who joined in with the already intense wireless traffic associated with the incident. During this period, intelligible communication became almost impossible.

As a result of the Titanic sinking, an International Conference on Safety of Life at Sea was eventually held in London on January 20th 1914. An agreement was signed by the sixteen participating nations in which a number of clauses relating to Wireless Telegraphy appeared, including:

Californian sent out the message that she was stopped in thick ice. Again the Titanic acknowledged but added curtly, "Shut up, I am busy with Cape Race". At 11.40 pm the Titanic struck an iceberg

That all merchant ships, carrying 50 or more persons, must be equipped with wireless. In practice, this covered most sea-going vessels. Certain classes of vessel must maintain continuous watch and there were laid down standards regulating the minimum range of the equipment, and also covering emergency equipment, which should be able to operate from batteries for at least six hours.

The allocation of wavebands for specific purposes was effected in order to avoid the possibility of chaos in the future.

Also established, under the responsibility of the United States, was the wireless reporting service known as the Ice Patrol, a highly effective operation.

Among those called to give evidence at the original Board of Trade enquiry into the loss of the Titanic was Marconi himself. He placed before the Board the idea of the 'auto-alarm' system, in which an alarm was sounded on immediate receipt of a distress signal. But before it could be implemented, another event was to occur that was to give another spur to the new technology. In August 1914, Europe went to war.

1986 CATALOGUE PRICE CHANGES

The price changes shown in this list are valid from 12th May 1986 to 9th August 1986. Prices charged will be those ruling on the day of despatch.

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

Price Changes
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 17th February 1986) are marked '•' after the price.
A complete Price List is also available free of charge – order as XF08J.

Key

NYA	Not yet available.
DIS	Discontinued.
TEMP	Temporarily unobtainable.
FEB	Out of stock; new stock expected in month shown.
‡	An additional £5.50 carriage charge must be added.
NV	Indicates that item is zero rated for VAT purposes.
★	See 'Amendments To Catalogue'. Note that not all items that require amendments are shown in this list.

1986 Catalogue Page No.		VAT Inclusive Price

AERIALS

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XQ23A	Mushkiller FM1083	£14.50
XQ25C	Mushkiller FM1085	£22.30
‡XQ27E	Mushkiller FM1087	£29.50
XQ29G	Trucolour TC10 Grp A	£11.25
XQ30H	Trucolour TC10 Grp B	£11.25
XQ31J	TrucolourTC10 GrpC/D	£11.25
XG23A	Trucolour TC10 Grp E	£11.25
XQ32K	Trucolour TC13 Grp A	£13.35
XQ33L	Trucolour TC13 Grp B	£13.35
XQ34M	TrucolourTC13 GrpC/D	£13.35

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XQ35Q	Trucolour TC18 Grp A	£15.85
XQ36P	Trucolour TC18 Grp B	£15.85
XQ37S	TrucolourTC18 GrpC/D	£15.85
XG24B	Trucolour TC18 Grp E	£15.85
XQ38R	Extragain XG5	£20.95
XQ39N	Extragain XG8 GroupA	£27.50
XQ40T	Extragain XG8 GroupB	£27.50
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XY30H	Toptenna	£4.95

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BW46A	Masthead UP1300/W	£14.95
BW49D	Masthead UP1300/V	£14.95
BW50E	Power Unit PU1240	£18.95

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YX73Q	Amp XB1U	£23.50
BK06G	Amp VX1B	£23.50
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★BW51F	Diplexer UF22	£7.75•

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FK54J	Blue Seal R03B	24p•
FK55K	Blue Seal R6B	20p•
FK56L	Blue Seal R14B	33p•
FK57M	Blue Seal R20B	37p•
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FK61R	Silver Seal R20S	53p•
FK62S	Silver Seal PP3S	99p•
FK63T	Gold Seal LR03	55p•
FK64U	Gold Seal LR6	55p•
FK65V	Gold Seal LR14	99p•
FK66W	Gold Seal LR20	£1.10•
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FK68Y	Gen Purpose No.8	41p•
FK69A	Gen Purpose 1289	85p•
YJ18U	Gen Purpose PJ996	£2.55•
YJ19V	Gen Purpose 991	£7.26•
YJ20W	Gen Purpose 993	£3.28•
YJ21X	Gen Purpose AD28	£3.00•
YJ22Y	Gen Purpose HP1	£11.58•
YJ23A	Gen Purpose HP992	£3.75•
FK70M	Gen Purpose 126	£2.24•
FK71N	Gen Purpose FLAG	£4.32•
FM02C	Trans Pwr PP1 6V	£1.83•
FM03D	Trans Pwr PP6 9V	£1.54•
FM04E	Trans Pwr PP7 9V	£1.54•
YJ24B	Trans Pwr PP8 6V	£5.55•
FM05F	Trans Pwr PP9 9V	£1.56•
FM06G	Trans Pwr PP11 4.5V2	£3.25•
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FM07H	Photo Batt BLR121	£2.98•
FM08J	Photo Batt BLR122	£3.98•
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QY67X	Photo-Test PX28	£3.98•

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FM20W	Merc Batt PX675	68p•
FM21X	Merc Batt RM13H	45p•
FM22Y	Merc Batt BP401	£1.25•
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FM26D	Zinc Air A675	78p•
FM27E	Zinc Air A13	65p•

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HF27E	Clips PP9	27p•
HF28F	PP3 Clip	12p•

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WP28F	Data Communications	£10.95 *NV*•
WM59P	Linear Electronics	£8.50 *NV*•

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RL06G	Book NB0740	£5.50 *NV*•
RH05F	Book BP7	95p *NV*•
RH21X	Book BP27	95p *NV*•
RH53H	Book BP160	£2.50 *NV*
WA10L	TI Linear Circuits	£10.00 *NV*•
WA14Q	TI TTL Data	£10.00 *NV*
WP31J	TTL Data BDDK	£9.00 *NV*•
WG58N	Book FT1199	£14.20 *NV*
WA15R	TI 9900 Data	£12.00 *NV*•

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WA06G	TI MOS Memory Data	£8.95 *NV*•
WA13P	TI Interface Data	£10.50 *NV*•
WG87U	Book BP101	95p *NV*•
RR27E	Book NB2026	DIS•

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WM60Q	Mastering Electronic	£3.95 *NV*

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RQ29G	Book BP49	£2.50 *NV*
RH25C	Book BP32	DIS
XW52G	Book BP76	£2.50 *NV*

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WG18U	Book HD748	DIS

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XW07H	Book BP57	DIS
RH18U	Book BP24	£1.75 *NV*•

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RF12N	Book BP42	£1.95 *NV*•
WG43W	Book BP87	£1.35 *NV*
WP00A	Fib Op Laser Handbk	£18.20 *NV*
WA08J	TI Opto Data	£5.00 *NV*
LY05F	Book BP45	£1.95 *NV*
RH38R	Book BP205	DIS

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WG69A	Book AG602	£10.95 *NV*•
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WA90X	Book NB112	DIS
RF18U	Book BP43	DIS•

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RQ33L	Book BP52	DIS
WA61R	Book FT1409	DIS
XW32K	Book BP70	95p *NV*•
WM86T	Elect Servicing	£7.95 *NV*

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WM88V	Fault Diag Dig Syst	£6.00 *NV*•
RQ01B	Book Sybex C201	£19.95 *NV*•
WG24B	Book HD165	£13.55 *NV*•

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XW98G	Book FT1070	£14.20 *NV*

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XW81C	Book D302	£13.95 *NV*•
XW70M	Book M3	£19.95 *NV*
WK30H	Programming 6809	£8.95 *NV*•

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XW72P	Book C280	£16.95 *NV*•

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WG48C	Book HD162	£15.25 *NV*
WG80Q	Book HD762	£12.75 *NV*•
WK65V	BBC Assembly Lang	£8.95 *NV*•
WM53H	DIY Robotics BBC	DIS•

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WM71N	Atari 600XL Prog Bk	DIS•

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BQ64U	Ghost Hunter	DIS•
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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●
UF24B	4527BE	69p●
Page 326		
WH00A	74122	57p
QQ54J	74LS122	82p
WH01B	74123	82p
YF48C	74LS123	69p
YF86T	74LS221	74p
Page 327		
WH02C	74LS629=74LS124	£1.35
Page 331		
QH35Q	LH0042C	£9.95●
Page 335		
BR02C	5W Amp PCB	£2.20
Page 337		
BR04E	LM381 PCB	£3.45●
Page 345		
RA81C	SAA1099	NYA
Page 353		
YY73Q	LM335Z	£1.65
Page 355		
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	£4.50
★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	£6.95●
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 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	80p●
★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	£2.55●
FX27E	2p Sub-Min Relay 12V	£2.55●
FX30H	4p Sub-Min Relay 12V	£3.50●

TEST GEAR

Page 407		
‡XB82D	Crotech 3031	£239.95
‡XB83E	Crotech 3132	£374.95
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	£64.95
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 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	20p
FR01B	Element Type CN	£3.75●
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
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	£12.36●
FT28F	40 Watt Iron XSTC	£21.50●
FT27E	XSTC Element	£12.36●
FT10L	Sponge Tray TCSU-1	£1.73●
XG57M	Solder Station TCSUD	£94.95●
FT12N	50 Watt Iron XSD	£21.95●
FT29G	XSD Element	£12.36●
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●
FY64U	Bit 1100	£1.38●
FY65V	Bit 1101	£1.38●
FY66W	Bit 1102	£1.38●
FY67X	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		
FR63T	Desldr Washer Type 2	DIS●
HY13P	Desldr Nozzle Type 2	DIS
Page 430		
FA81C	Thermalbond Compound	£11.95●

WOUND COMPONENTS

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		
WB08G	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	£8.20●
LY03D	Tr 10VA 15V	£4.25●
WB15R	Min Tr 15V	£3.10●
WB16S	Min Tr 20V	£3.10●
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

NEW ITEMS PRICE LIST

The following is a list of all items introduced since our 1986 catalogue, excluding new items in this issue.

AERIALS
YM56L Hi-Tech TV Aerial — Price £10.95

BOOKS
WP35Q LIN CMOS Design Book. — Price £5.60 *NV*
WP36P Radio Stations Guide. — Price £2.95 *NV*
WP37S Comp Progs Running. — Price £2.50 *NV*
WP38R Comptr Music Projcts. — Price £2.95 *NV*
WP39N Digital IC Equivalents. — Price £4.95 *NV*
WP40T Linear IC Equivalents. — Price £4.95 *NV*
WP41U Proj in Microelect. — Price £4.95 *NV*
XW30H Cost Effective Construction. — Price £5.95 *NV*
XW31J Projects for Car/Garage. — Price £5.50 *NV*

BOXES
YM51F Instrument Case NM2H. — Price £14.95

CAPACITORS
UF71N Fltr 10.7MHz/50kHz. — Price 95p

CONNECTORS
FA87U 2x25 way Edge Con. — Price £4.95
FA90X PCB 6 pin DIN Skt. — Price 58p
FA93B Gold Phono Line Skt. — Price 65p
FA94C Adaptor W. — Price 95p

OPTO ELECTRICAL
FA95D Plastic Lens. — Price 48p
UF72P Ultrabri Red LED Min. — Price 54p

PROJECTS AND MODULES
FA85G Temperature Controller Front Panel. — Price £1.80
FA86T 50 way Amstrad Cable. — Price £7.99
FA88V Amstrad Front Panel. — Price 55p
FA89W Amstrad Rear Panel. — Price 45p
FA91Y Mapsat Front Panel. — Price £3.95
FA92A Mapsat Bracket. — Price 80p
GB96E ASCII Keyboard PCB. — Price £8.50
GB97F IBM Golfball Printer I/F PCB. — Price £19.95
GB99H Amstrad Extendiboard. — Price £1.95
GD00A Hobbyist's Temp. Controller PCB. — Price £2.95
GD01B High Volts PCB. — Price £2.95
GD02C Digitiser PCB. — Price £11.95
GD03D Digitiser Controller PCB. — Price £11.95
GD04E Amstrad Motherboard. — Price £9.95
GD05F Amstrad Controller PCB. — Price £11.95
GD10L Play Along Mixer PCB. — Price £1.95
GD11M Hi-Z Mic (Mono) PCB. — Price £1.95
GD13P Lead Acid Bat Charger PCB. — Price £1.75
GD14Q Stepper Motor PCB. — Price £1.45
LK78K ASCII Keyboard Kit. — Price £19.95
LK81C General Purpose Input Kit (Mono). — Price £2.95
LK82D General Purpose Input Kit. (Stereo). — Price £4.50
LK83E Tone Control Kit (Mono). — Price £3.30
LK84F Tone Control Kit (Stereo). — Price £5.75
LK85G Peak Overload Detector Kit. — Price £2.20
LK86T Mixer Amp Kit. — Price £4.75
LK87U Line Amp Kit. — Price £3.95
LK88V VU Meter Kit. — Price £8.95
LK89W Headphone Monitor Kit. — Price £6.95
LK91Y Hi-Z Mic Stereo Kit. — Price £8.50
LK92A Hi-Z Mic (Mono) Kit. — Price £4.95
LK93B Play Along Mixer Kit. — Price £13.95
LK94C Hobbyist's Temperature Controller Kit. — Price £24.95
LK95D Video Digitiser Kit. — Price £41.95
LK96E Digitiser Controller Kit. — Price £29.95
LK97F Amstrad ROM Card Kit. — Price £39.95
LK98G Amstrad Motherbd Kit. — Price £29.95
LK99H Sat Receiver Kit. — Price £59.95
LM00A Sat Aerial Kit. — Price £10.95
LM01B L/Acid Bat Chrgr Kit. — Price £39.95
RA98G Programmed Golfball EPROM 2716/M10. — Price £9.95
UF73Q Amstrd Test 2716/M11. — Price £5.95
XH65V Amstrad Booklet. — Price £1.50 *NV*
YM15R Gen. Purpose Input Module (Mono). — Price £3.95
YM16S Gen. Purpose Input Module (Stereo). — Price £6.40
YM17T Tone Control Module (Mono). — Price £4.40
YM18U Tone Control Module (Stereo). — Price £7.75
YM19V Peak Overload Detector Module. — Price £3.20
YM20W Mixer Amp Assembled. — Price £6.50
YM21X Line Amp Assembled. — Price £5.50
YM22Y VU Meter Assembled. — Price £10.95
YM23A Headphone Monitor Assembled. — Price £8.95
YM25C Mic I/P Stereo Assem. — Price £9.95
YM26D Hi-Z Mic Mono Assem. — Price £5.95
YM57M Amstrad Contrllr Asm. — Price £59.95
YM58N Aerial Rod. — Price 80p
YM59P Sat Recvr PCB Assem. — Price £44.95

PROTECTION
YM52G The Fly. — Price £24.95
YM53H The Spider. — Price £34.95
YM54J Alarm Cash Box. — Price £44.95
YM55K Alarm Jewellery Box. — Price £54.95

SEMICONDUCTORS
RA99H 2N4393. — Price 98p
QY80B 8155 I/O Ports, 256 byte RAM and 14-bit programmable Timer IC. — Price £1.95

TEST GEAR
FA96E Min Probe Clip Set. — Price £2.95
YJ82D MF100 Freq Counter. — Price £89.95

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Publication dates are as follows:

XA20W Issue 20 8th August 1986 Price 75p *NV*
XA21X Issue 21 14th November 1986 Price TBA

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 66). 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.

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.

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 0.33mm.
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.

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.

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.

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.

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.

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

ADA ECHO ECHO ECHO

by Robert Penfold

Until quite recently digital delay lines were extremely expensive pieces of equipment which relatively few people could afford. Analogue delay lines of the charge coupled type offer an inexpensive alternative, but where long delays are required (a few hundred milliseconds or more) these are not very practical since a number of devices connected in series are required, and performance is compromised. The massive drop in the prices of memory chips over the last year or so has changed the situation dramatically, with some of the higher capacity types falling to only about one tenth of their previous cost.

Practical Digital Delay

This digital echo unit was designed to take advantage of these recent price reductions, and the unit is based on the 6264-3 memory chip. the 6264-3 is a CMOS static RAM having a capacity of 64k (organised as 8k of 8 bit bytes). Obviously, 8k is not a massive amount of memory, but it enables reasonable delay/bandwidth combinations to be provided. In analogue delay line terms it is equal to a 16384 stage device, bearing in mind that the 'bucket brigade' system used in such delay lines requires two stages per stored sample, whereas a digital type requires just one byte of memory per stored sample. It would, therefore, require thirty two of the popular TDA1022 512 stage delay lines to give a comparable level of performance to this unit!

The echo time is continuously variable from approximately 75ms to 450 milliseconds, giving a range of effects which vary from a short reverberation type sound to a medium-long echo. A feedback control enables the echo level and the echo decay time to be adjusted over a broad range. The unit is intended to operate with an input level of several hundred millivolts r.m.s, and it can therefore be driven directly from synthesisers and most guitar pick-ups. With low level sources, such as microphones and low output guitar pick-ups, a suitable preamplifier must be added at the input to the unit.

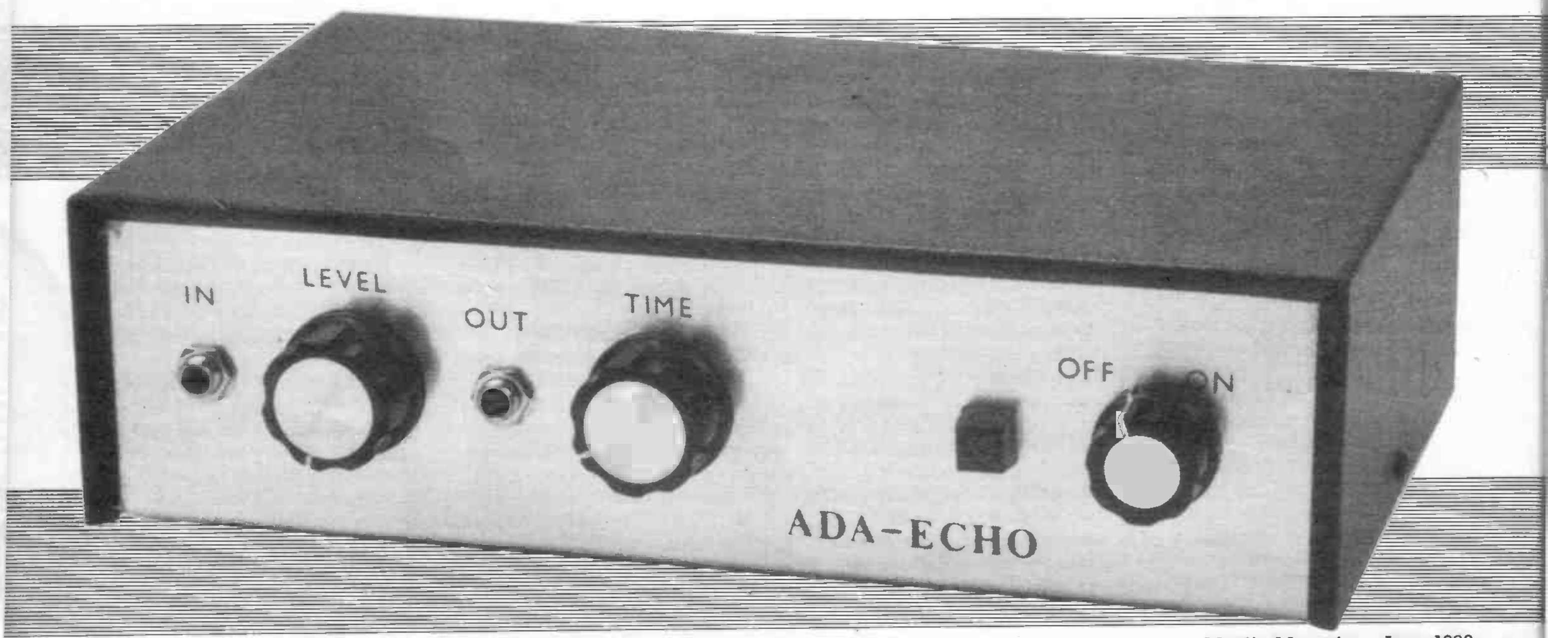
- ★ **Based on the 6264-3 CMOS Static RAM**
- ★ **Echo Variable from 75 to 450 Milliseconds**
- ★ **Can be Driven Directly from a Synthesiser**

Operating Principle

It is a common misconception that digital delay lines, like analogue types, operate on the 'bucket brigade' principle. This is not the case however, rather it can be best described as a simple form of recording and playback, where the 'recording medium' comprises the RAM chip, an operation quite different to the passing of sample voltages along a line of charge storage circuits. The method of operation is in many ways closer to that of a tape loop echo unit than a 'bucket brigade' type. The block diagram of Figure 1 helps to explain the way in which the unit functions.

Circuit Description

The input stage is a mixer, and its purpose is merely to combine the input signal with the delayed signal. Some of the mixer's output signal is used to drive the input of the delay circuit, and the first stage here is an active lowpass filter. With any form of sampling system, it is important that the sampling rate is at least twice the maximum



input frequency. In this case the minimum sampling frequency is at about 18kHz and the audio bandwidth accordingly has to be restricted to around 9kHz or less. Allowing strong signals at more than about 9kHz into the system would generate severe 'aliasing distortion,' and would give a very poor quality audio output. (See 'A/D/A Conversion Techniques', Maplin Magazine Vol. 5 Issue 18.) In this design the lowpass filter restricts the bandwidth of the delay line to about 8kHz. This is obviously far less than the full audio bandwidth, but it is still more than adequate for good results in this application. Note also that it is only the bandwidth of the *delayed* signal that is restricted; the straight-through signal is not subjected to any filtering.

The next stage is a compressor, and this is followed by the eight bit analogue to digital converter. An eight bit system has the advantage of enabling relatively inexpensive and easy to obtain components to be used in the design, but it has the disadvantage of not achieving much more than a rather low, innate level of performance. The signal to noise ratio is typically only about 46dB, and the total harmonic distortion is around 0.5% just below the clipping level. Performance is much worse than this would suggest though, as each time the input level is reduced by 6dB the distortion level doubles. This represents about 50% distortion at the −40dB level, which is an unacceptable level of performance.

The use of the compressor alleviates this to a large extent. The compressor has a 2 to 1 ratio characteristic, and when the input signal level is at −40dB, the signal fed to the analogue to digital converter is only at −20dB. This gives a much improved performance, with a distortion level of only about 5% with the input signal at −40dB. This is still far less than hi-fi standard, but it is quite acceptable for electronic music applications. Of course, severe compression of the signal is undesirable in the final output, and so it is corrected by a 1 to 2 expander at the output of the delay line. Overall, therefore, the delay line leaves the dynamic levels of the processed signal unaltered.

A useful by-product of the compression/expansion process is an effective doubling of the signal to noise ratio to about 90dB, and the compressor/expander circuit is in fact a standard compander type noise reduction system. However, in this application, it is the reduction in distortion rather than the reduction in noise which is of prime importance.

System Timing

A clock oscillator governs the sampling rate, and it is by varying the clock frequency that the delay time is varied. A timing control circuit ensures that the memory chip, the analogue to digital converter, and the digital to analogue converter are all synchronised together and operate in unison. The basic sequence of events is as follows. Firstly, the analogue to digital converter is presented with a 'start conversion' signal pulse. Then the memory chip is set to the read mode, and the output digital to analogue converter is activated. This latter converter has a built-in eight bit latch at the input, and it therefore holds its current output level until it is fed with a new sample.

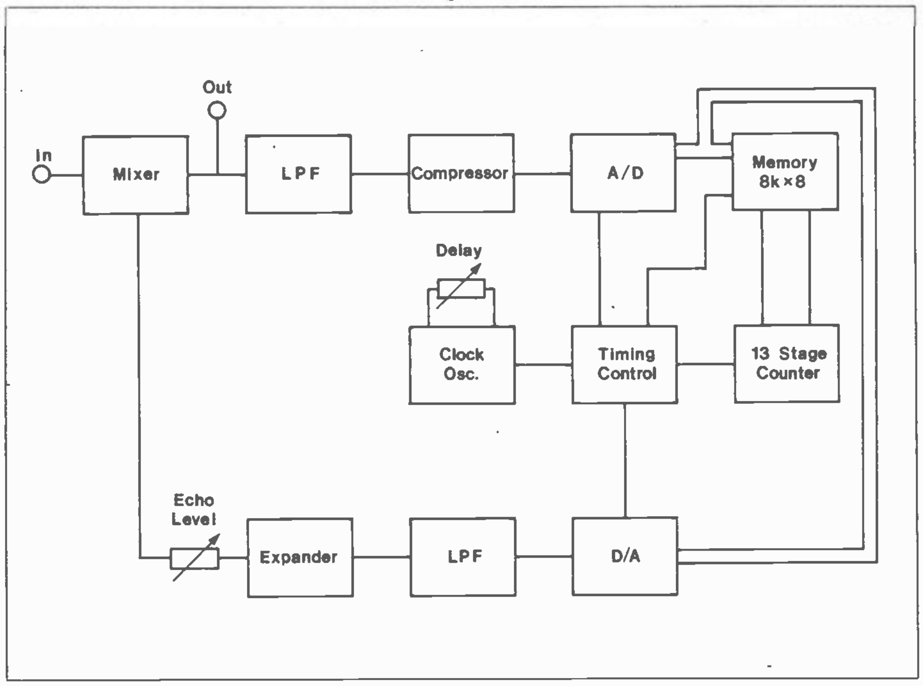


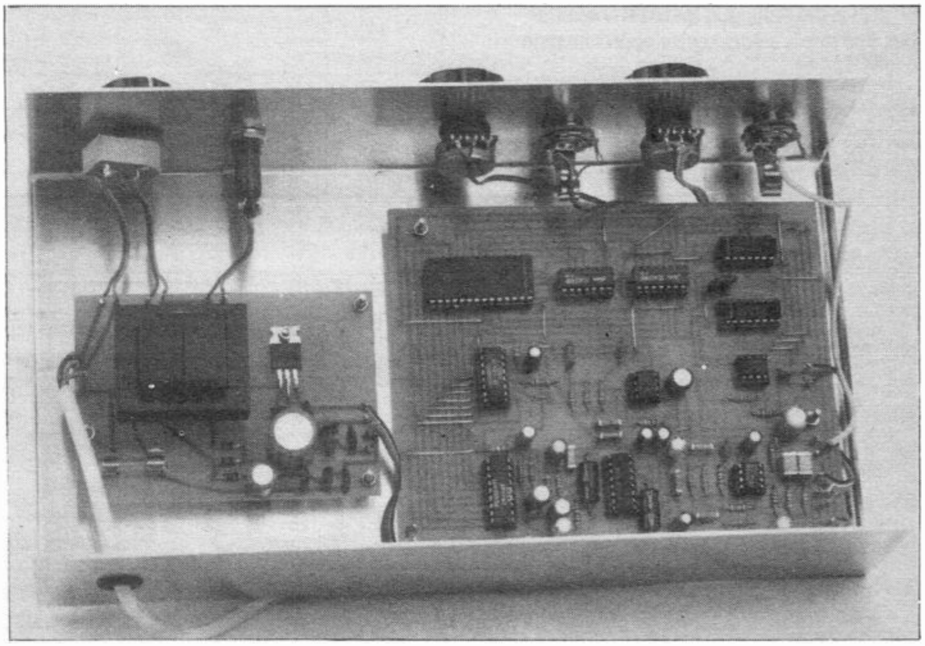
Figure 1. Digital Echo Block Schematic

The next step is for the memory chip to be set to the write mode, and for the input sample taken by the analogue to digital converter to be delivered to the current address, overwriting the existing sample value stored there. Then the 13-stage binary counter is fed with an input pulse, and as it is this counter which controls the sequencing of memory addresses, the memory circuit is moved on to the next address.

The whole process then repeats itself, with the old sample at the current memory address being delivered to the output digital to analogue converter, and then over-written by a new sample value, and the memory incremented. This process continues indefinitely, with the memory being continuously cycled through all 8192 addresses. The important point to note here is that each new sample does not reach the digital to analogue converter until the memory chip has been cycled through all 8192 addresses and back again to the address where the new value was stored. This gives the required delay, and the delay time is equal to 8192 divided by the clock frequency.

Recycling the Output

The output from the digital to analogue converter is a stepped waveform, by virtue of the conversion process, but a lowpass filter at its output smooths out the steps to some extent, giving an output waveform which closely resembles the input waveform. A controlled amount of the delayed signal is then mixed with the input signal. This results in the signal circulating around the system until it gradually dies away, giving a multiple echo effect.



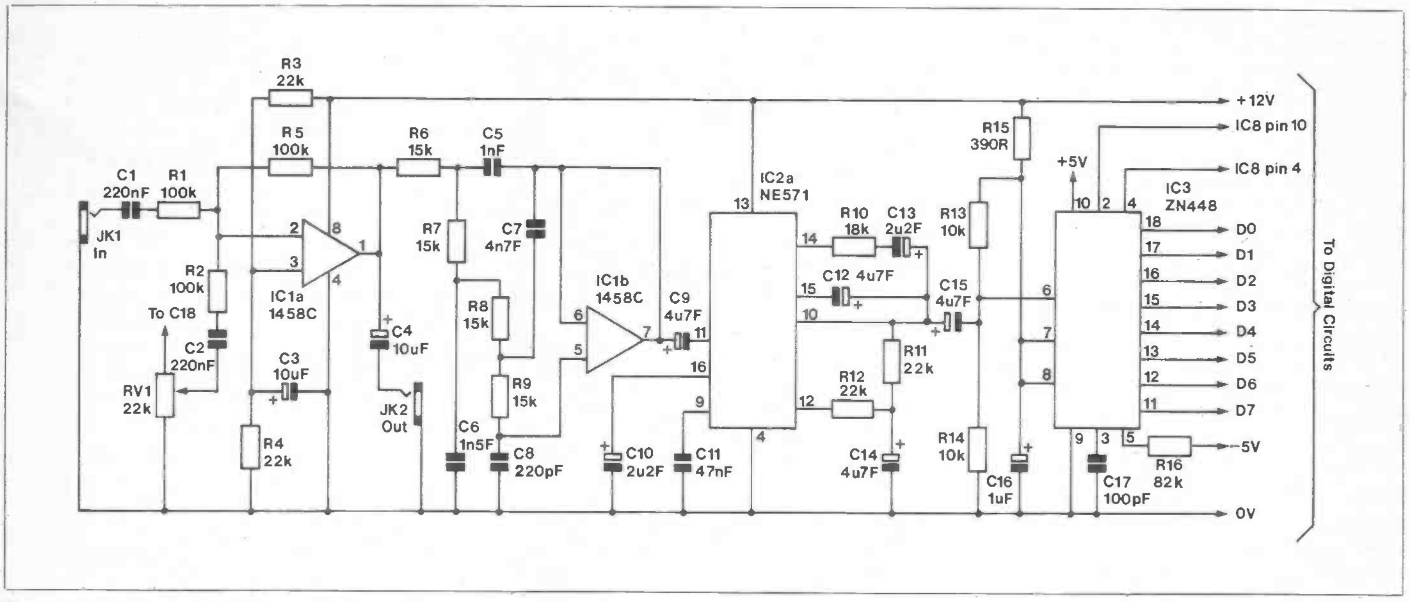


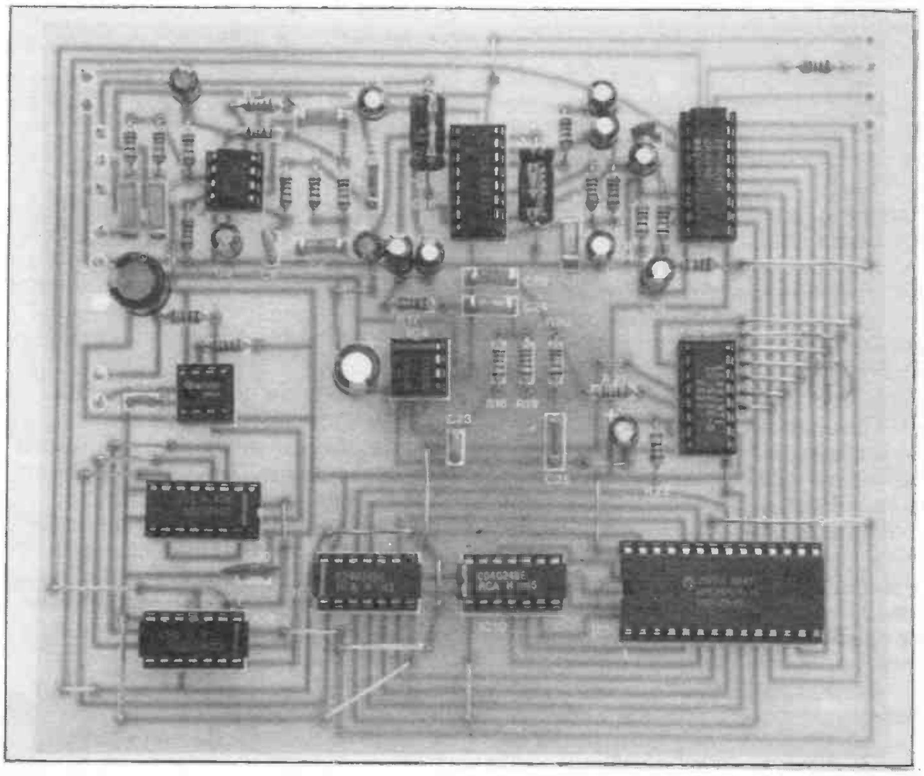
Figure 2. Analogue to Digital Converter Stage Circuit

With a low echo level the signal quickly decays to an insignificant level, but with a high level it can be made to take several seconds to die away to zero. In practice the amount of echo signal that can be used is limited by the noise and distortion that is added to the signal on each pass through the delay line. The maximum usable decay time is proportional to the delay time, since a short delay time results in the signal being circulated more frequently, and the noise and distortion therefore build up that much more rapidly.

Record Circuit

Figure 2 shows the circuit diagram of the input and analogue to digital converter stages. IC1a operates as the mixer stage, and this is a straightforward summing mode circuit. RV1 is the feedback level control. The lowpass filter is based on IC1b, and this is a conventional fourth order (24dB per octave) type having a cut-off frequency of just under 8kHz. The compressor uses one section of an NE571 (IC2a) which is specifically designed for use as a 2 to 1 compander.

IC3 is the analogue to digital converter chip, and this is a successive approximation



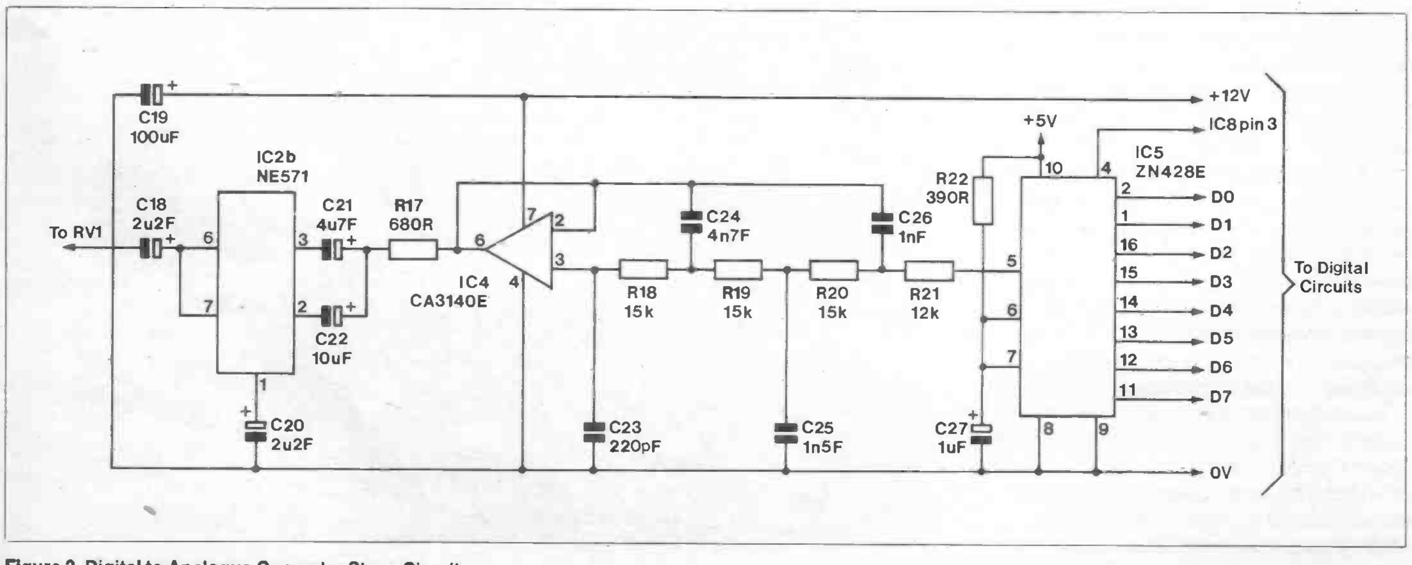


Figure 3. Digital to Analogue Converter Stage Circuit

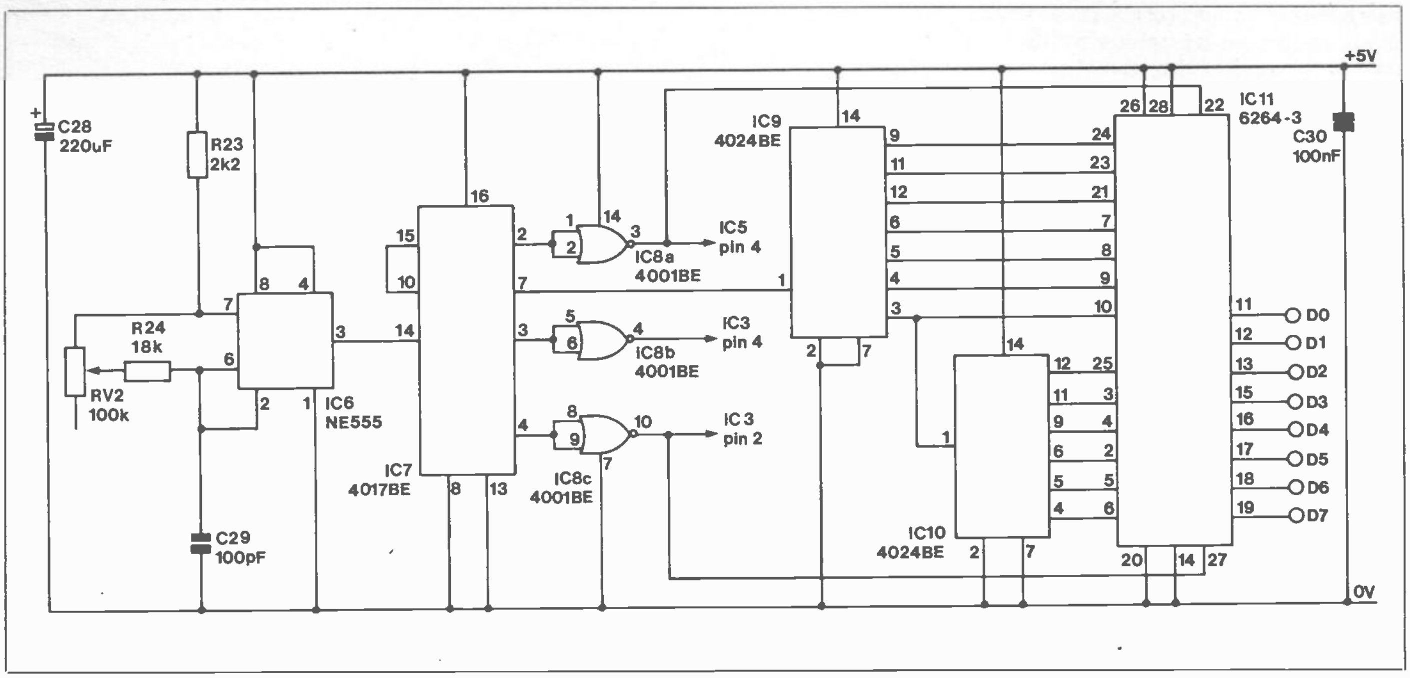


Figure 4. Clock, Control and Memory Stage Circuit

type. It has a built-in clock oscillator which has C17 as one of the timing components. The specified value for C17 sets the clock frequency at about 1MHz, which is the maximum figure at which the ZN448E is guaranteed to function properly. Nine clock cycles are required in order to complete each conversion, which corresponds to about 110,000 conversions per second at the maximum clock rate. This limits the minimum delay time to about 75ms, although shorter times could be obtained by using less than the full 8k of memory. However, for the present application, the 75 to 450ms delay range is perfectly adequate.

IC3 has an integral 2.55 volt precision reference source for its digital to analogue converter stage, and this has the discrete load resistor R15 and decoupling capacitor C16. The analogue input is biased from the reference source by R13 and R14. R16 is the 'tail' resistor for the high speed comparator stage at the input of IC3, and this must be fed from a −5 volt supply. Note that the analogue circuits are powered from a +12 volt supply, while the digital circuits operate from a +5 volt line. The circuit therefore requires three supply potentials.

Playback Circuit

The circuit diagram for the digital to analogue converter stages appears in Figure 3. The converter device is a ZN428E (IC5). Like the ZN448E, this has a built-in 2.55 volt reference source, and it is an ideal complementary converter for the ZN448E. The ZN428E is a conventional digital to analogue converter based on a precision voltage source driving an R–2R resistor network via eight electronic switches.

IC4 acts as the buffer stage in the lowpass filter, which is essentially the same as the one used in the record circuit. The filter is direct coupled to the output of IC5, and IC4 must be of a type which is capable of supplying output voltages right down to the 0 volt rail. Operational amplifiers such as the 741C and LF351 will not function properly in the place of IC4 in this circuit.

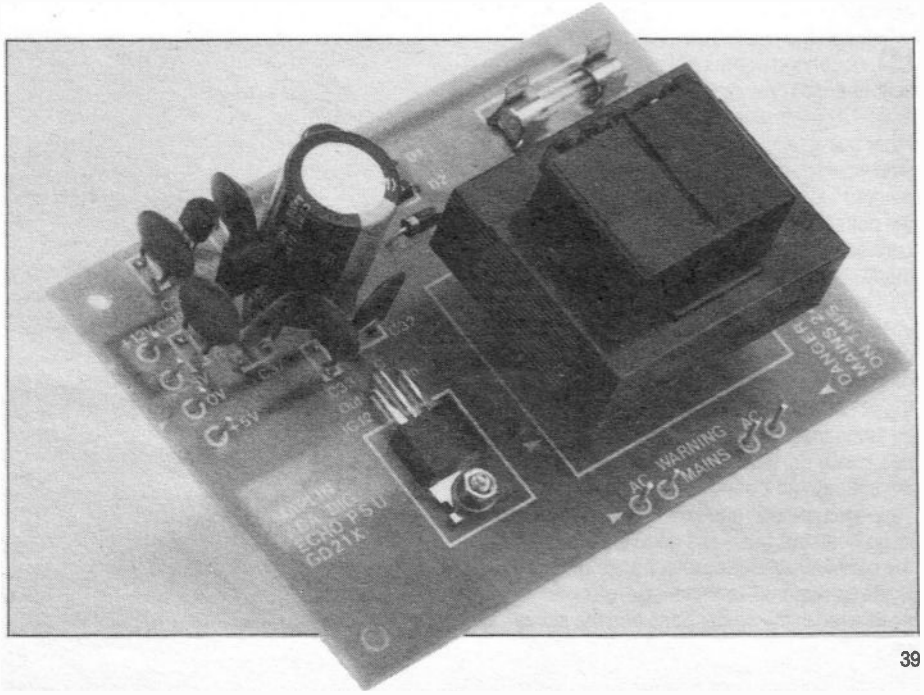
IC2b is the expander circuit, and it utilises the second section of the NE571. The two sections of the device are identical incidentally, and it is the discrete components which determine whether the device operates as a compressor or expander. This helps to give good complementary characteristics which ensure that there are no significant distortions to the dynamic levels overall.

Memory Circuit

The clock, control and memory circuit is shown in Figure 4. IC6 is a 555 timer device connected in the standard astable mode, and this acts as the clock oscillator. RV2 is the delay time control. IC6 has a higher operating frequency range than one might expect since the control circuit provides only one record/playback cycle per four clock cycles.

Control of the converters and memory chip is provided by IC7, which is a CMOS one of ten decoder. Outputs '0' to '9' of IC7 normally go high in sequence on successive clock pulses, and then the device cycles back to '0' on the next clock pulse, and this process repeats itself indefinitely. In this case though, output '4' is connected to the reset input and the count is consequently cut short with the device immediately resetting to '0' when output '4' goes high. Outputs '0' to '3' are used to control the four phases of each record/playback cycle.

Output '0' drives the 'start conversion' input of IC3, but as this input is active low, the output of IC7 has to be inverted. Next, output '1' activates the 'write' input of memory chip IC11 and the latches at the input of IC5, and again the positive pulse must be inverted as both inputs are active low types. On the third phase, output '2' goes high, but this signal is also inverted, giving a negative pulse to set IC11 to the read mode and activating the tri-



state buffers at the output of IC3. On the fourth phase, a clock pulse is supplied to the 13-stage binary counter which generates the address bus. The counter is comprised of two 7 stage devices connected in series (IC9 and IC10), with the final stage of IC10 being left unused.

Power Supply

The power supply circuit is shown in Figure 5, and this uses a 12 volt mains transformer and a push-pull rectifier to give an unstabilised supply of about +17 volts. IC12 and IC14 are monolithic voltage regulators which provide well smoothed and regulated outputs of +5V and +12V respectively from the unregulated supply. D1 provides a halfwave rectified negative supply, and IC13 then produces a stabilised −5 volt output from this.

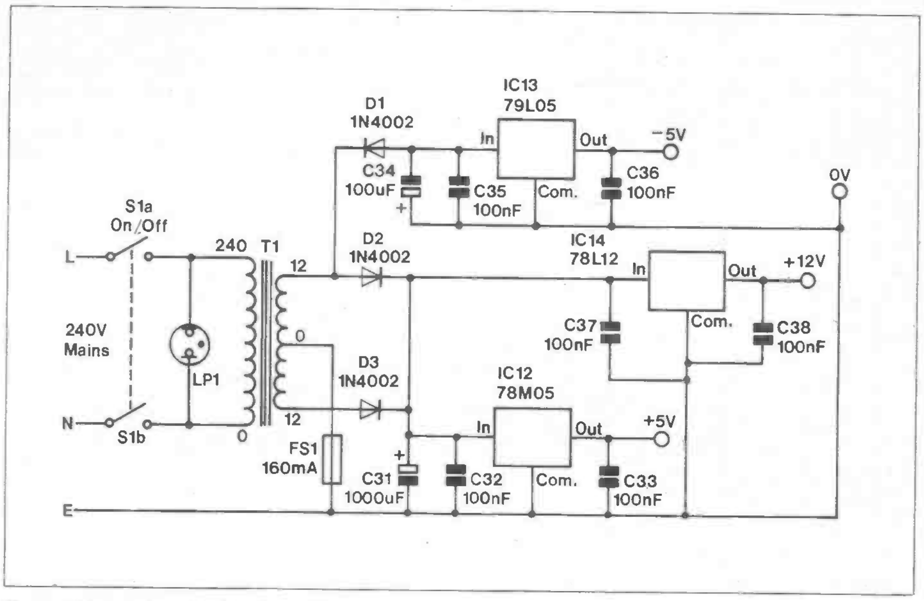


Figure 5. Power Supply Circuit

Construction

Nearly all of the components are accomodated on two printed circuit boards. There is one board for the main ADA Echo circuitry, and a separate p.c.b. for the power supply components only. Commence construction of the power supply board first. FS1 is mounted in a pair of printed circuit mounting clips, and mains transformer T1 is also a printed circuit mounting component. Make sure that these components are fully pushed down onto the board before soldering them in place, and use plenty of solder so that they are firmly held in position. Find and identify the six ceramic disc capacitors C32, C33, C35 to C38 with reference to the p.c.b. overlay and the parts list. Insert these into the postions as shown on the overlay, and bend over the leads underneath to retain them whilst soldering. After soldering, trim off all excess wires with side cutters.

Find and identify the 3 rectifiers D1–3. Insert these into position as shown on the legend after bending the leads first, but carefully so as not to break the plastic body. The stripe around one end of the package marks the cathode, and this *must* align with the white bar on the legend or serious damage could result. Solder and trim excess wire as above.

Insert the two PC electrolytics C31 and C34, observing correct polarity. These capacitors are usually marked with a black stripe and '–' sign adjacent to the negative lead, the other being the positive lead. Identify which lead is which and match these to the holes marked '+' on the legend. Fit eight veropins at the points circled on the legend where connections to off-board components will be made.

Insert IC13 and IC14 into the positions indicated by matching them to the 'D' shapes of the legend. Note the centre lead of each is offset to one side. Bend the leads over under the board and solder carefully, whilst checking by touch that these components do not get too hot. If they do, then allow to cool before continuing. IC12 does not have to dissipate very much power, and so it does not require a large heatsink, but is is a good idea to bolt it to the board. Do this now after bending the 3 leads as required so that they are correctly positioned in the solder pads and the screw holes line up, and then attach with the screw and nut supplied. Then solder the 3 leads now that IC12 is secure. Put the PSU board to one side.

Assembling the Main PCB

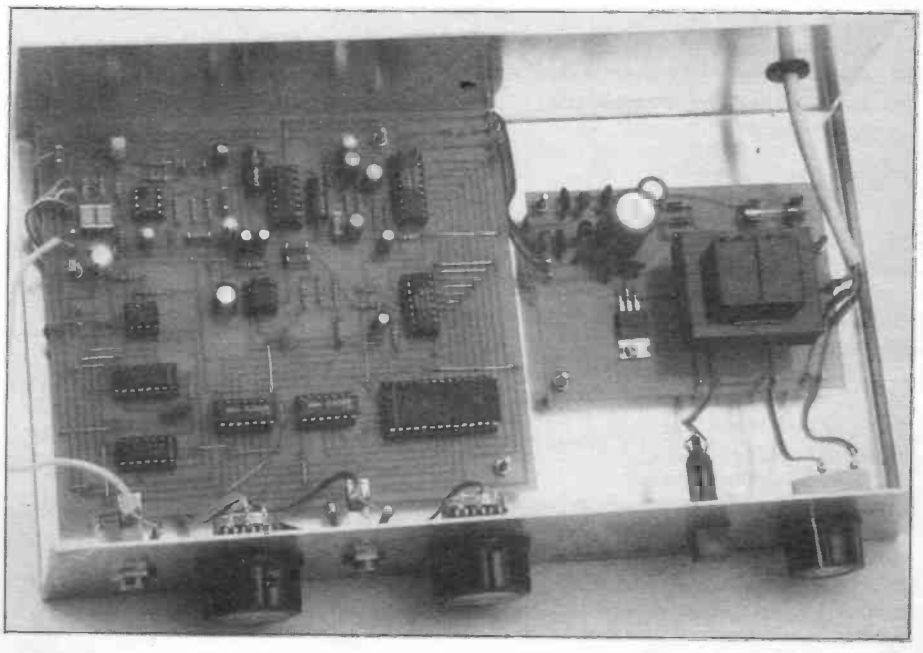
Find and identify all resistors with reference to the parts list and p.c.b. overlay. Make sure that the correct values are recognised with the aid of a resistor colour code chart if necessary. Commence installing all the resistors by inserting into the position indicated on the legend, bending the wires to right angles to facilitate insertion and then folding them over underneath prior to soldering. Trim off excess wire using side cutters.

Be careful not to omit any of the wire links shown as solid lines on the p.c.b. legend. These can be made from 22swg tinned copper wire, or the waste leads trimmed from resistors and capacitors should suffice if a reel of suitable wire is not to hand. Fit 13 veropins at the points circled on the legend, where connections to off-board components will be made.

Identify, mount and solder all non-electrolytic capacitors with reference to the parts list and the p.c.b. legend. Install them one at a time, double checking for the correct value. Next insert and solder all the PC electrolytics observing correct polarity as previously described.

Most of the integrated circuits on the main board are either CMOS types, fairly expensive, or both. It is therefore advisable to use the DIL integrated circuit holders, or sockets, provided in the kit for all eleven devices.

Additionally, IC4, IC7, IC8, IC9, IC10, and IC11 are the CMOS types and require the usual handling precautions; you must avoid a heavy build-up of static electric charge between yourself and the device or the work area. Work on a metal tray or aluminium foil, to thoroughly ensure that any static potentials around the work area are equalised. Hold the IC with thumb and forefinger at the ends, and touch the lead-out pins as little as possible. However, you may need to squeeze the pins slightly to ensure that the IC will push easily into its socket. In each case, identify pin 1 by



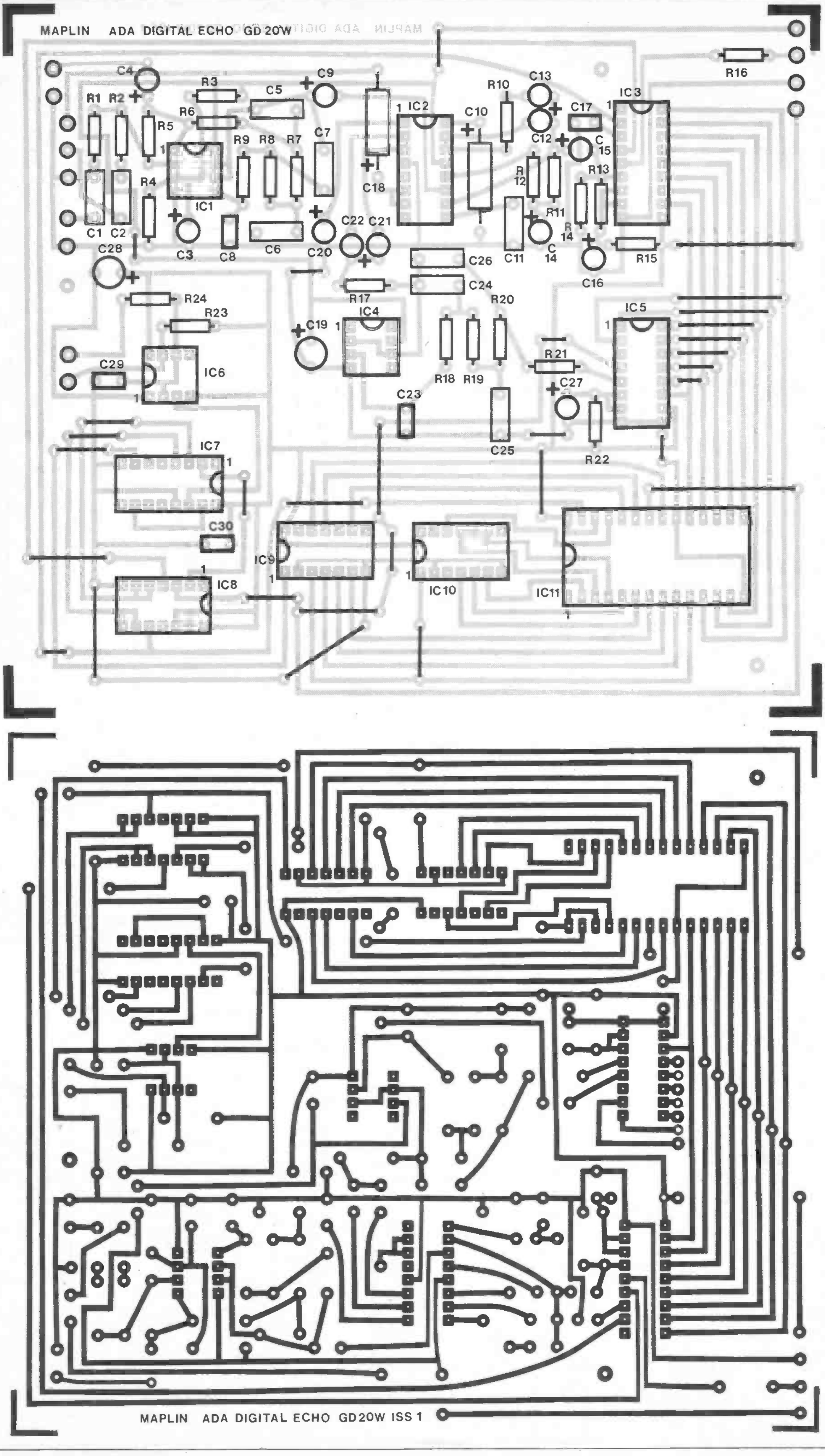


Figure 6. Main PCB Track and Overlay

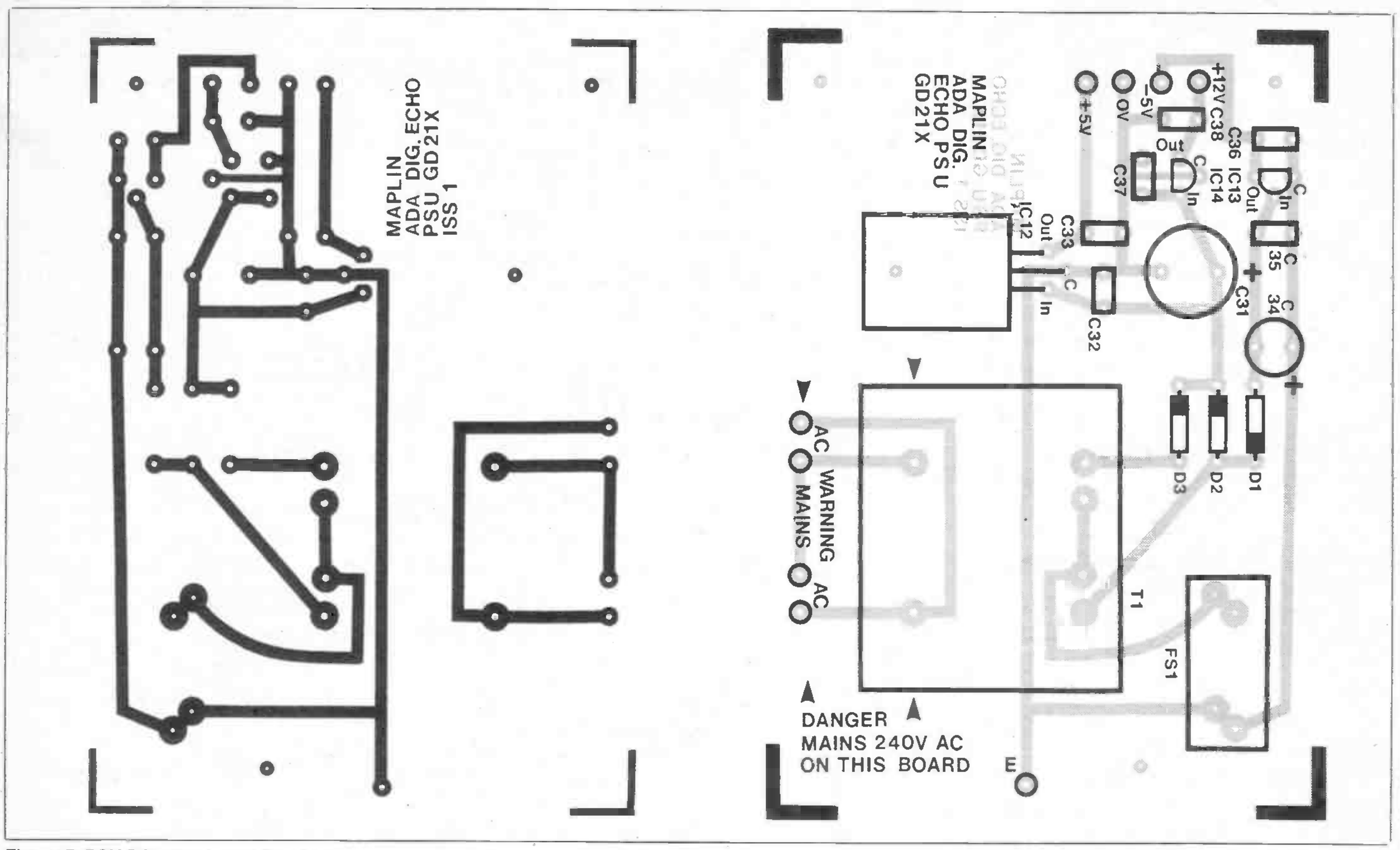


Figure 7. PSU PCB Track and Overlay

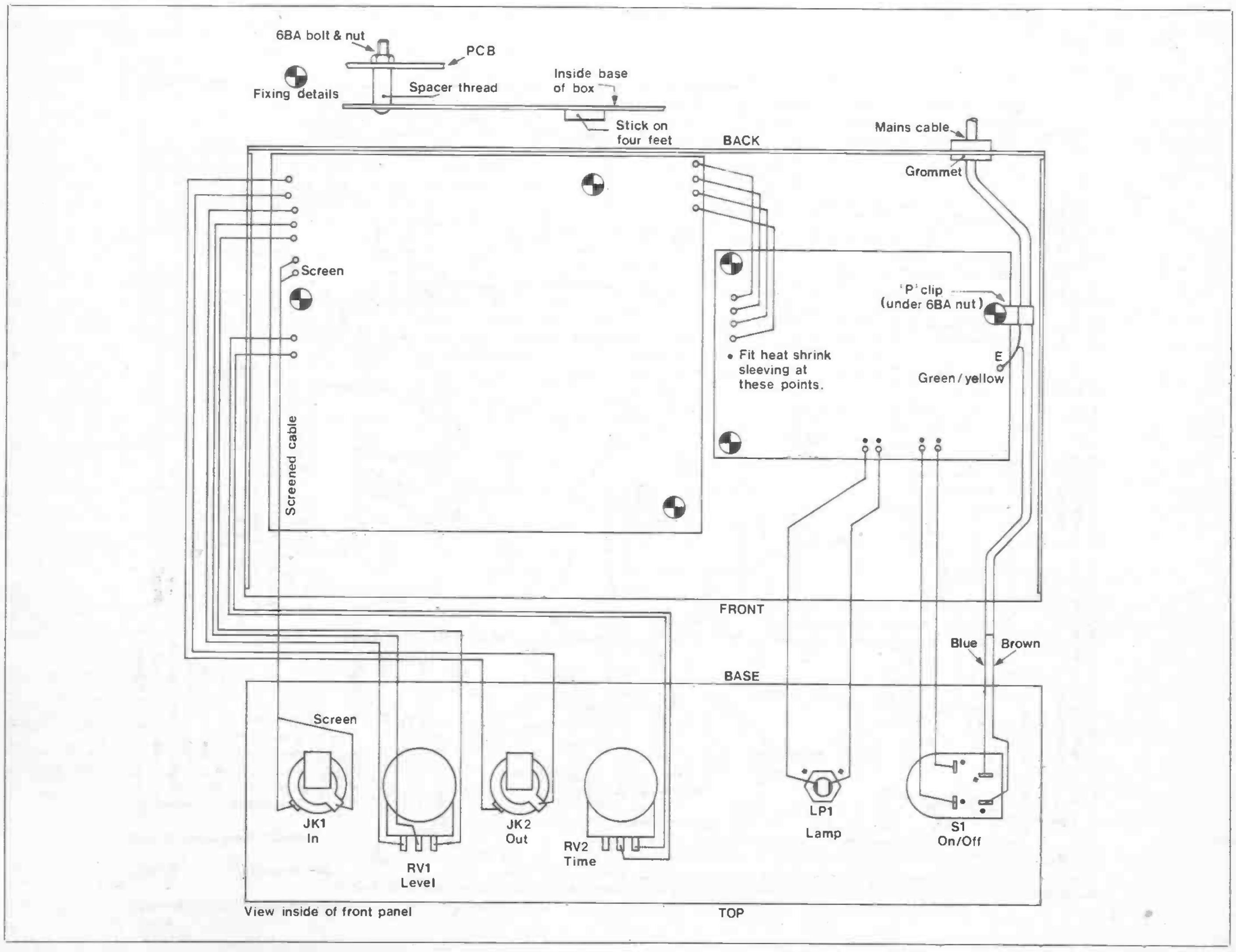


Figure 8. Wiring up the Project

the recessed dot or the notch at one end of the package. This must align with the white marker block shown on the legend, otherwise the device will be connected wrongly into the circuit and almost certainly destroyed, so be sure to fit them the right way around, and double check their orientation against Figure 6 when the board has been completed.

Installation

A metal instrument case having approximate outside dimensions of 279 x 159 x 76mm makes an inexpensive but practical and attractive housing for this project. Any similar case should be suitable, but the case should not be significantly smaller than the size specified above. The two printed circuit boards are bolted to the base panel of the case using 6BA fixings, including ½in. (12.7mm) threaded spacers to ensure that the connections on the undersides of the boards are kept well clear of the metal casing. The main board is positioned well towards the left hand side of the unit, and as far towards the rear as possible. This leaves plenty of space for the power supply board towards the right hand side of the unit.

Complete the unit by adding the small amount of point-to-point wiring, being especially careful to avoid errors when dealing with the power supply wiring. It is advisable to insulate all the connections that are at mains potential so that there is no risk of electric shocks being sustained due to accidental contact with these connections. Always use a ¼in. bore chassis grommet where the mains cable exits through the rear panel. Finish by wiring a mains plug to the mains lead.

Testing and Use

It is a good idea to wire up the power supply first and make sure that this is operating properly before wiring its outputs to the main Echo p.c.b. Do take care with mains wiring and ensure that no errors whatsoever exist, before even contemplating plugging in and switching on. The mains panel neon should light and then you can use a voltmeter to check for the three voltage outputs of +5V, −5V and +12V DC respectively. Also, chassis must be connected to mains earth – you can test for this by unplugging the unit and testing for continuity from the mains plug earth pin to chassis, using the lowest ohms range on the multimeter. If all is well, complete wiring to the main board.

Make quite sure that the outputs connect through to the main board correctly (the two boards have been designed so that no crossed wires are required here).

With RV1 and RV2 both set at a roughly middle setting, a short burst of noise will be produced from the output when the unit is first switched on, which should be followed by a very low background noise level. The burst of noise is simpy due to the random values present in the RAM at switch-on being outputed before they are over-written by the recording circuit.

The echo effect should be readily apparent on practically any type of input signal, and using RV2 it should be possible to vary the delay time over the approximate limits mentioned previously. With RV1 well backed off, the echo level should be quite low, and the echoes should rapidly fade away to an inaudible level. By advancing RV1 the echo level should be boosted, and the decay time should be substantially prolonged. If RV1 is advanced too far the echo signal will be maintained indefinitely, or it will actually increase in strength on each pass through the delay line. The unit is not normally used with such a high level of feedback, as it results in the signal building up to the point where overloading occurs and the output signal becomes just a mass of noise. However, there is an interesting technique whereby a short burst of input signal at a farily low level is supplied to the unit. Initially a high level of feedback is used in order to gradually build up the signal to a crescendo, after which the feedback level is decreased in order to make the signal die away again. This tehcnique works best with fairly long echo times.

The unit can take input levels of up to 2.55 volts peak to peak before the onset of clipping and serious distortion, and for optimum results the input signal should be at something approaching this level.

Continued on page 53.

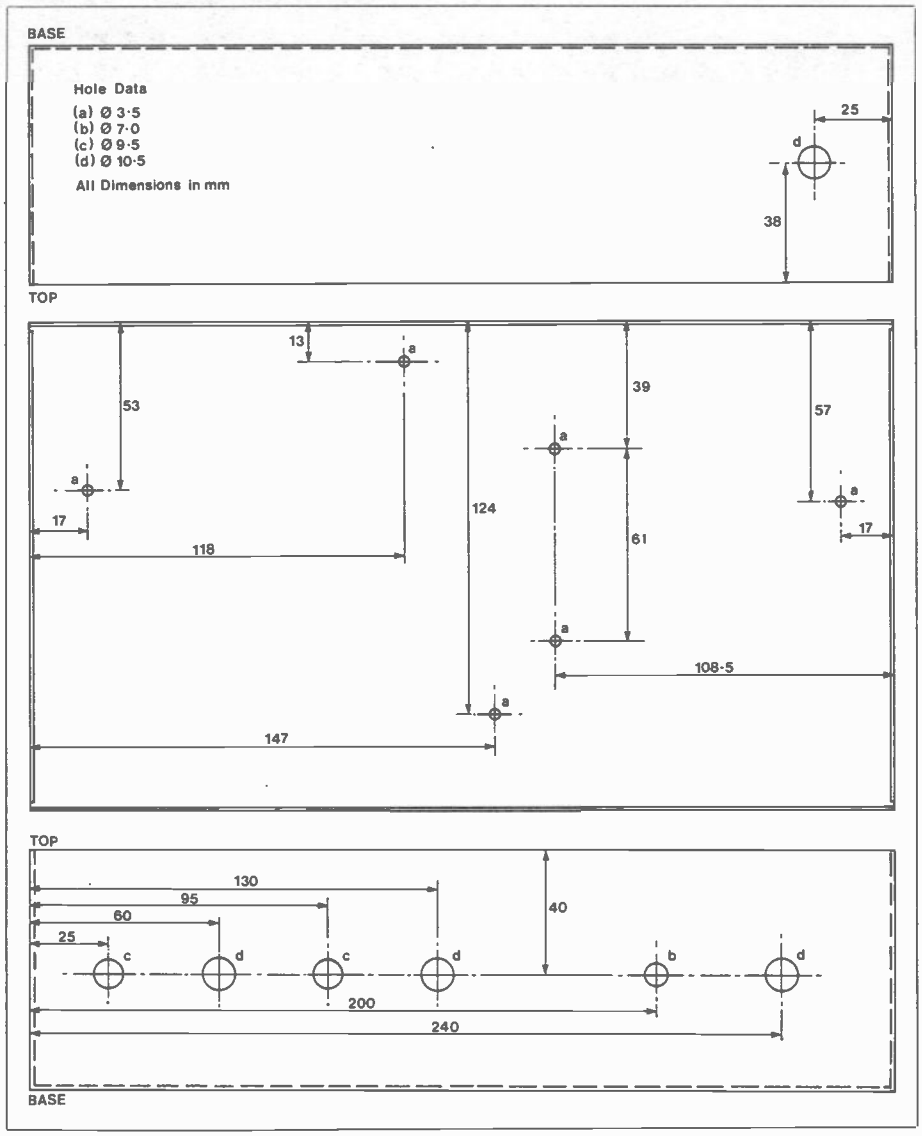
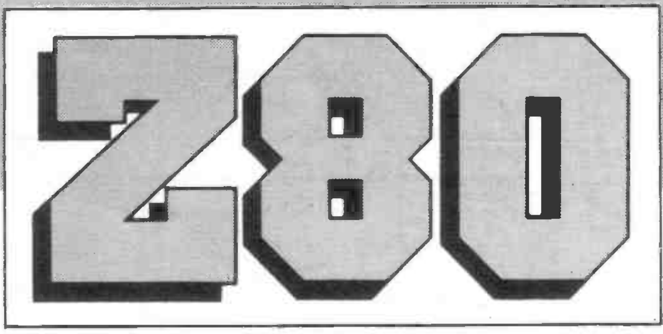


Figure 9. Box Drilling

MACHINE CODE PROGRAMMING WITH THE Z80



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

Exchanges

Much of the work carried out by a microprocessor is simply concerned with transferring data from one point to another. The load instructions, discussed in Part 2, were examples of data transfer instructions. In their case, they were used to transfer data between registers and memory (in either direction) or to transfer data from one register to another. Sometimes it is useful not merely to transfer data from one register into another (which is a mere copying process) but to be able to 'swap' the contents of registers, so that each ends up with the data that the other previously held. The instructions that effect this are known, logically enough, as the 'exchange' set.

It was stated in Part 1 that the Z80 has two register sets, known as the 'main' and 'alternate' register sets. The latter registers are distinguished by the prime '. Thus, the accumulator/flags register pair is known as AF in the main set and AF' in the alternate set. To exchange the contents of these pairs, the instruction EX AF,AF' would be used. Look this up in the table of exchanges in Part 1, and you will find the op-code 08. The instruction EXX (op-code D9) exchanges BC with BC', DE with DE' and HL with HL', thus swapping the contents of the other register pairs in one fell swoop. There is also an EX instruction that exchanges the contents of the DE pair with the HL pair and a further three EX instructions that exchange HL, IX or IY with the bottom two bytes on the stack. Since these latter three are merely carrying out exchanges with data 'already on the stack', they are not classed as PUSHES or PULLS and do not affect the value of the stack pointer. If some of this does not make a lot of sense just now, don't worry, for the moment it is only necessary to realise that there are instructions that allow data to be exchanged between corresponding register pairs of the two sets, and between register pairs within the main set.

The 8-bit Arithmetic and Logic Instructions

There are two addition instructions in the Z80 set, known as ADD and ADC. The first of these, ADD, is what you normally use if you just wish to add together two 8-bit numbers, without any complications. The second one, ADC, stands for 'add with carry', which means that, not only do the two numbers specified get added together, but the value of the 'carry flag' (in the F register) is also included in the addition. The obvious question is, when would you need to include the carry? The usual answer is, when you are adding together two 16-bit numbers. Since the Z80 is only an 8-bit processor, it has to deal with 16-bit numbers a byte (8 bits) at a time.

Therefore, the low bytes of the numbers are added first, the result is stored and *then* the two high bytes are added together. However, adding the two low bytes may have caused a carry out of bit 7 (the highest bit) of the accumulator; this automatically goes into the carry flag so that, when the two high bytes are added, if the 'add with carry' instruction is used, then the carry out from the low byte addition will be included, as it should be.

Obviously, it isn't necessary to include the carry in the low byte addition, since nothing went before to cause a carry. Indeed, to do so will result in serious errors because an extra '1' which should not be included will be added if the carry flag is set. Now look at this as it might appear in assembler format.

LD A, #BYTE 1 of P	Adds the low bytes of two
ADD A, #BYTE 1 of Q	numbers called P and Q.
LD (HL), A	Result stored at location addressed by HL.
LD A,#BYTE 2 of P	Adds the high bytes of the
ADC A, #BYTE 2 of Q	numbers P and Q.
INC HL	Contents of HL register pair increased by 1.
LD (HL), A	Result stored at next location addressed by HL.

Taking the program line by line, the first line puts the low byte of number P into the A register, and the second line adds the low byte of number Q to it; the result of this addition ends up in the A register and any carry that is generated will go into the carry flag.

In line three this result is stored in memory at a location 'pointed to' by the contents of HL. That is what is meant by the brackets around HL. For instance, if the number &5F00 was loaded into HL (by a previous instruction not shown), then when line three was executed, the A register contents would be stored at the location &5F00.

Now in line four the high byte of P is loaded into the A register (over-writing the original contents of this register) and in the next line the high byte of Q plus the contents of the carry flag are added to the A register, the result of this addition being deposited back at this register. It is now necessary to store this result and the logical place to put it is in the memory location next above the one where we put the low byte result. To do this we must make HL point to &5F01, which we do in line six by means of the INC (increment) instruction.

Thus, finally, in line seven, we can carry out a load that puts the high byte result into &5F01.

The following example of a 16-bit addition shows quite clearly how a carry can be generated after the low byte addition:

High Byte	Low Byte	
10010101	10110000	Number P
+00100100	11000011	Number Q

Look at the low byte addition first.

```
   10110000   (P Low)
 + 11000011   (Q Low)
  101110011     (sum of low bytes)
  ↑
'Carry out'
```

This addition has produced a 9-bit result, i.e. a carry has been generated, which must be passed onto the high byte addition. It is stored temporarily in the carry flag. The high byte addition looks like this:

```
  10010101    (P High)
 +00100100    (Q High)
 +        1   (Carry)
  10111010    (sum of high bytes)
```

If the ADD instruction had been used for both low and high byte additions the result would have been wrong, since the carry generated by the low byte addition would have been ignored.

The subtraction operations, SUB and SBC, are complementary to the ADD and ADC operations just described. They introduce nothing new and should cause no particular problems.

In general, the above arithmetic operations are performed between data in the A register (the accumulator of the Z80) and data in another register or a memory location. Access to data in memory locations is always indirect, using either the HL pair as a pointer or one of the index registers. Alternatively, the data may be 'immediate', i.e. the program specifies the number to be added to or subtracted from the A register contents, e.g. ADD A, #&0A adds the HEX number 0A (10 in denary) to the A register. This may seem straightforward enough, which it is, but it means that the data is 'embedded' in the program, whereas if it is stored in memory, the program can update itself as required, making for greater flexibility. A further point to note is that arithmetic operations condition the 'flags', thus indicating whether the result is positive or negative, or even zero, whether there has been a carry or perhaps an overflow.

The logic instructions AND, OR and XOR act, bit for bit, on two data bytes, one of which will be in the A register and the other will be either in another register or in memory, or will be an immediate data byte. The addressing modes are exactly the same as for the arithmetic operations.

A few words of explanation may not be out of place for those not too familiar with the niceties of Boolean logic. The AND, OR and XOR operators act on two (or more) variables to give a result that depends upon their logic values. In Boolean algebra these three operations are written as follows:

A AND B is written as A.B
A OR B is written as A + B
and A XOR B is written as $A \oplus B$

For two variables, A and B, there are four combinations of logic levels that they can take up, hence four possible results. These are best summarised in truth tables, as shown in Figure 1. Using these truth tables, it is quite easy to see the effect of each of the logical operations on sample data.

Assume that the A register has been loaded with 10011010, and that the specified operations will be carried out against a second byte, which can be assumed to be 10101101. Taking each operation in turn:

AND

A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

OR

A	B	F
0	0	0
0	1	1
1	0	1
1	1	1

XOR

A	B	F
0	0	0
0	1	1
1	0	1
1	1	0

Figure 1. Truth tables for the AND, OR and XOR functions.

```
     10011010  (byte 1 = &9A)
AND  10101101  (byte 2 = &AD)
     10001000  (result = &88)
```

Notice that there are only two '1s' in the result, since there are only two columns in which both bits are logical 1 (the result of an AND operation is 1 only when ALL variables are 1).

```
     10011010  (byte 1 = &9A)
OR   10101101  (byte 2 = &AD)
     10111111  (result = &BF)
```

In this case notice that there is only one '0' in the result, since there is only one column in which both bits are 0 (the result of an OR operation is always 1 as long as at least one bit is a logical 1).

```
     10011010  (byte 1 = &9A)
XOR  10101101  (byte 2 = &AD)
     00110111  (result = &37)
```

The result of an XOR operation is a 1 only when the two variables are of opposite logic value (two '1s' or two '0s' give a 0 result). This example is of limited interest, but a more interesting result can be obtained if the second data byte is all 1s, i.e. &FF.

```
     10011010  (byte 1 = &9A)
XOR  11111111  (byte 2 = &FF)
     01100101  (result = &65)
```

Looking at the result in binary, and comparing it with byte 1, we see that all the bits have been inverted or 'complemented'. In fact, the result is known as the 'one's complement' of byte 1. If a 1 was added to this, we should get the 'two's complement', used in complement arithmetic (see Back to Basics in Part 1). The AND and OR instructions, in particular, are very useful in input/output operations, which is where we shall, eventually, meet them again.

Also included in this group is an instruction that we shall use over and over again (in fact we used it in the bubble sort program of Part 2), and that is the compare instruction, CP. This allows the programmer to compare whatever is in the A register with a value that may be specified in a variety of ways. Direct comparison with immediate data is possible; or with the contents of another register; or with the contents of a memory location accessed by using the HL pair, or an index register as a pointer. The comparison is, in effect, a subtraction when executed, which merely conditions the flags without actually changing the data in the A register. It is often used to find whether a counter has reached a certain value.

Suppose we wish the program to go round a loop eight times, and then exit from it. The first thing to do is to set up a loop counter register, and load it with the number &00. Every time that the program goes around the loop, it encounters an instruction that *increments* the counter, that is, adds one to it. Each time that this is done we follow with the CP instruction, comparing it with &08 to see if we have yet gone around eight times.

Eventually we will have done so, and the CP instruction will recognise this fact and get the program out of the loop. The essential parts of the program to do this might look as follows:

```
LD A,  #&08     Load A register
                with no. of loops (8)
LD B,  #&00     Set up B as counter
                initial value 0

  Enter loop

INC    B        Increment counter
CP     B        Compare B with
                A register

Exit from loop
or go round again
```

When the counter holds less than eight, the comparison yields a positive result; when the counter reaches eight, the result of the comparison will be zero. All that is needed is an instruction that can distinguish between the positive and zero results, in order to decide whether to loop again or to exit. This instruction will work by inspecting the 'sign (S)' and 'zero (Z)' flags in the flags register. When the result is positive, both S and Z are reset (= 0); when the result is zero, S remains reset but Z becomes set. As mentioned before, this is the only effect of the CP instruction; it doesn't alter the contents of either A or B. Thus, if A contains &08 and B contains &03, CP will effectively produce &08 − &03 = &05, which although giving a positive result, is not actually retained.

Complementary to INC is the decrement instruction DEC, which reduces a number by 1. Both INC and DEC can be used on all the main registers, as well as on a memory location accessed by HL or one of the index registers.

The 16-bit Arithmetic and Logic Set

This set is smaller than the corresponding 8-bit set and acts on a limited number of registers. Taking the ADD instruction first, this can perform 16-bit addition between HL, IX or IY and any of the register pairs, BC, DE, etc., but *not* AF (Accumulator and Status Flags). ADC does the same but for the register pair HL only. The SBC instruction complements ADC in allowing subtraction between HL and the other register pairs (except AF).

Finally, the INC and DEC instructions act on the six register pairs already mentioned. Since register pairs are largely used as address pointers, these instructions are mainly concerned with the manipulation of addresses.

Block Transfer Group

The Z80 instruction set contains some very useful and powerful instructions for handling blocks of data, i.e. data stored in continuous areas of memory. The block transfer group has four such instructions that use Register Indirect addressing to transfer data from locations pointed to by HL (the source) to locations pointed to by DE (the destination).

After each byte is transferred, the contents of HL and DE are both either incremented or decremented. The register pair BC is used as a counter, which is decremented after each transfer. This means that if BC is first loaded with the number of bytes to be transferred, it will automatically keep track of the transfers.

The instructions LDI and LDIR differ only in one respect. LDI uses HL and DE to transfer a byte, as described, then increments both of these register pairs and decrements BC. It then waits until instructed before transferring another byte. BC must be tested separately to find out when all bytes have been transferred.

By contrast the R in LDIR stands for Repeat, so that the process of transferring data and incrementing and decrementing registers continues automatically until BC = 0. Thus, a single instruction transfers the whole block.

The other two instructions are LDD and LDDR. These differ from the previous two in that the third letter, D, stands for 'Decrement', so that, after transferring a byte of data, HL, DE and BC are decremented. What this means in practice is that the block is transferred in reverse order, i.e. highest byte in memory downwards.

Suppose the block is 20 bytes in length, and resides at the addresses &5C00 to &5C13 inclusive, and we wish to transfer it to the area of memory from &6E00 to &6E13. Using LDIR, the program would be:

```
LD HL, &5C00    Points to bottom
                address of
                old block.
LD DE, &6E00    Points to bottom
                address of
                new block.
LD BC, &14      Loads counter with
                number of bytes.
LDIR            Transfers block.
```

But, using LDRR, the program would be different as follows:

```
LD HL,  &5C13   Points to top
                address of
                old block.
LD HL,  &6E13   Points to top
                address of
                new block.
LD BC,  &14     Loads counter with
                number of bytes.
LDDR            Transfers block.
```

Since the transfer of a block of memory leaves the original memory block intact, this is not so much a transfer as a 'copy'. It is obviously a useful facility that allows chunks of memory to be moved around very rapidly. How large can these 'chunks' be? Well, since BC is a 16-bit counter, it can hold numbers up to &FFFF, which means that the memory blocks can virtually be up to 64k in size!

The Block Search Group

Four instructions, structured in a manner similar to the block transfer instructions, allow a block of memory to be searched to find a specified data byte. These instructions, taken in pairs, are first CPI and CPIR, which stand for 'block compare and increment', and 'block compare, increment and repeat' respectively. The comparison works in exactly the same way as the CP instruction described earlier and acts between data in the A register and data in a memory location pointed to by HL. The result isn't held in the A register, which is left unaffected, but flags are modified to reflect the result of the comparison. After the comparison, the CPI instruction increments HL and decrements BC (used as a byte counter as in the block searches); the program then waits for a new instruction. By comparison the CPIR instruction repeats the process for the next byte in the block, and the next and so on, until all bytes in the block have been compared.

The natural question to ask next is, how do you know when a comparison is true, or when you've reached the end of the block? The answer is that, in the 'repeat' modes, the program halts automatically if it finds a true comparison, or when it reaches the end of the block. In the non-repeating modes, when it waits after each comparison, the program must use instructions that test certain flags in order to identify a true comparison, or to know when the whole block has been searched.

These are the zero (Z) and Parity/Overflow (P/V) flags. If the comparison is true, the Z flag will be SET. If BC = 0, the P/V flag will be RESET.

Don't be put off by the name of the latter flag. It is, after all, just a flip-flop which can store a logic 1 or a logic 0. Provided that there is an instruction available to find out which value it holds, that is all that really need concern us at the moment. The instructions for testing flags will be dealt with next.

The other pair of instructions, CPD and CPDR, are now fairly obvious in meaning. Standing for 'block compare and decrement' and 'block compare, decrement and repeat' respectively, they differ only from their counterparts in that HL is 'decremented' after each comparison instead of incremented. In other words, the block is searched from the top down.

Jumps

Jumps are the means by which the program can be forced to leave its current sequence, and recommence execution elsewhere. Jumps can be 'conditional' (based on the status of a flag), or they can be 'unconditional' (jump occurs upon encountering the instruction). There are a useful variety of these instructions in the Z80, and they deserve close study.

I have already said that we need instructions that will allow us to test the state of a flag (and hence take appropriate action) and these are the conditional jumps, as you have probably realised already.

In the table of jumps, published in Part 1, we find the first of the jump instructions JP. This is a very versatile one, since it can be taken unconditionally, or subject to one of a very wide range of conditions being satisfied, depending upon the op-code used. The addressing mode used is Immediate Extended, which simply means that the two bytes following the op-code are the address to which the jump will be made.

So where in BASIC we would say 'GOTO 2000' (meaning go to line 2000 in the program), in assembler we could write JP &3600, which means 'jump to address &3600'. In practice this is achieved by the current value of the program counter being replaced by &3600, and program execution continuing from the new address. Incidentally, JP &3600 assembles as C3 00 36, which you can check from the table. Remember that addresses in machine code are *always written 'low byte first'.*

Now, from the same line in the table, take an example of a conditional jump. Suppose we wish to jump to location &4F1C when the A register contents are zero (following some operation in the A register). We could use the line:

```
JP Z,  &4F1C
```

This assembles as CA 1C 4F (check it!). So, to specify a conditional jump, a letter or letters follow JP to 'define the condition and then we look up the right op-code in the column under that letter or letters.

In the next line of the table we meet JR, a 'relative jump', which can be unconditional or conditional, subject to a restricted but useful range of conditions. Note the operand for JR, which is PC + e. This is shorthand for the program counter contents plus a 'signed displacement e'.

There is absolutely nothing to worry you in relative addressing, once you've grasped the basic principles. These are that, the address you're jumping to is formed by taking the current value of the program counter and adding a number to it (which may be positive or negative) that equals the number of steps forward or backward that you need to go in the program to reach the desired location.

The two difficulties that arise are remembering what the value of the program counter is at the moment that you add 'e', and knowing how to represent negative numbers.

If the latter is the case, then refer to 'Back to Basics' in Part 1. For example, if we want to go five steps forward, the operand for JR would be 05 (+5), but if five steps backward, the operand would be FB (−5).

The only pitfall is that, while the Z80 is looking at the value of 'e', the PC holds an address that is two steps ahead of the address for the JR instruction. This has been allowed for in the table by putting 'e−2' as the operand to be used instead of 'e'. To illustrate this, suppose that the jump needs to go 9 steps forward from JR, then the actual operand to use would be 07 (since 9−2 = 7), because we are already 'two' steps ahead of JR at this moment. Conversely, if we want to jump backwards in the program, we need to go two steps further back, for example −5 relative to the JR instruction gives an operand of −5−2 = −7, which is F9 in HEX.

Since relative jumps use only two bytes, they execute quickly and should be used whenever possible. Many examples will be found in later programs.

Finally, there are three unconditional jumps, JP, that use Register Indirect addressing. These cause jumps to addresses pointed to by the HL register pair, or by one of the index registers, IX or IY.

The remainder of the 'jump' instructions in this table will be discussed in Part 4, together with the remainder of the Z80 instruction set.

An ASCII File Search

Now let's do some programming, and this time the choice falls upon a program that will highlight two main points. It will help to illustrate some of the new instructions, particularly the block search, and also show how machine code can live with BASIC.

This has particular importance since, in a machine that has a resident high level language, such as BASIC on a home micro, machine code programs may be used as virtual utilities to enhance or speed up parts of a BASIC program. On such a machine, if you wanted to add or multiply, for example, the chances are you'd use BASIC; there'd normally be little point in writing a special program in machine code to do it, BASIC's arithmetic capabilities being what they are. But, if you wanted to manipulate data quickly or interact with a peripheral in 'real time', then there would be an advantage in using the speed of a machine code program. Data manipulation is something that a microprocessor probably spends more time doing than anything else.

The machine code routine would be CALLed by the BASIC program when required; after execution, control would return to BASIC. Figure 2 represents an example of this in the form of a Flow Chart.

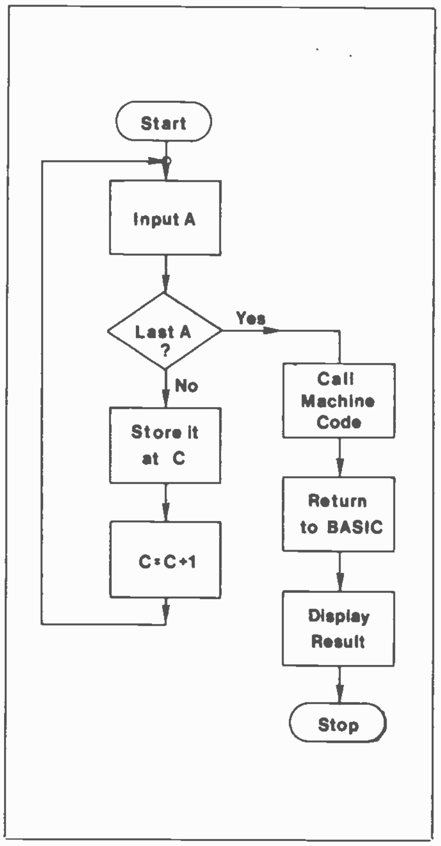


Figure 2. Flowchart for BASIC program.

Numeric		Capitals		Lower Case		Special	
30	0	41	A	61	a	20	space
31	1	42	B	62	b	21	!
32	2	43	C	63	c	22	"
33	3	44	D	64	d	23	#
34	4	45	E	65	e	24	$
35	5	46	F	66	f	25	%
36	6	47	G	67	g	26	&
37	7	48	H	68	h	27	'
38	8	49	I	69	i	28	(
39	9	4A	J	6A	j	29	)
		4B	K	6B	k	2A	*
		4C	L	6C	l	2B	+
		4D	M	6D	m	2C	,
		4E	N	6E	n	2D	-
		4F	O	6F	o	2E	.
		50	P	70	p	2F	/
		51	Q	71	q	3A	:
		52	R	72	r	3B	;
		53	S	73	s	3C	<
		54	T	74	t	3D	=
		55	U	75	u	3E	>
		56	V	76	v	3F	?
		57	W	77	w	40	@
		58	X	78	x	5B	[
		59	Y	79	y	5C	\
		5A	Z	7A	z	5D	]

Table 1. The ASCII set for keyboard characters (excludes controls).

The example illustrated in Figure 2 is an 'ASCII file search', in which characters are entered from the keyboard. These may be the normal alpha-numerics, or punctuation marks found in written text. The keyboard handling and storage to memory are handled by BASIC, and machine code is called to count the number of words in the text file. This is the ASCII file search. Finally, when the search has been completed, program control returns to BASIC. For those not too familiar with ASCII, a word or two are in order.

ASCII (American Standard Code for Information Interchange) is a method in which any of the keyboard characters, plus a variety of control functions (carriage return/line feed, etc.) is encoded as a single-byte number, usually expressed in HEX. Table 1 shows the ASCII set for all alpha-numeric characters (capitals and lower case) and punctuation marks, but excludes the control codes. To illustrate how it is used, consider the following message of fifty characters, and its equivalent ASCII file in hexadecimal:

'This is an ASCII file search in Z80 machine code'

27 54 68 69 73 20 69 73 20 61 6E 20 41 53 43 49 49 20 66 69 6C 65 20 73 65 61 72 63 68 20 69 6E 20 5A 38 30 20 6D 61 63 68 69 6E 65 20 63 6F 64 65 27

The relation between this file and Table 1 should be fairly obvious, but let's look at the first few characters anyway. The opening quote mark is code 27, capital T is code 54, lower case h is code 68, lower case i is code 69, lower case s is code 73 (making 'This), all of which is followed by code 20, which is the invisible character, the space; and so on for the rest of the characters in the file. The file as you see it here is as you would see it in memory, a string of ASCII characters stored in consecutive memory locations. Further on you will find a print out from memory, showing the result of the file search.

If the object of the program is to count the number of words in the file, what type of search will achieve this? The answer is, of course, to search for a space, since that marks a boundary between one word and the next. But, in the same way that ten telegraph poles have only nine spaces between them, this will be true for words. Consequently, when the search is finished and the number of spaces counted, this total must be incremented by 1 to get the number of words.

The program shown in Table 2 was assembled using Arnor's MAXAM Z80 assembler, run on an Amstrad CPC464. The use of an assembler makes life such a lot easier, as it bypasses the need to look up op-codes in tables, work out jump lengths, etc. However, don't feel inhibited if you haven't one. Hand

```
00002  A20C  21 70 A2            LD    HL,&A270     ;Start of ASCII file
00003  A20F  01 32 00            LD    BC,&32       ;No. of bytes in file
00004  A212  3E 20               LD    A,&20        ;ASCII code for 'space'
00005  A214  16 00               LD    D,&00        ;Initial value of D
00006  A216  ED B1      AGAIN    CPIR               ;Start block search
00007  A218  CA 20 A2            JP    Z,COUNT1     ;Jump if space found
00008  A21B  E2 24 A2            JP    PO,COUNT2    ;Jump if search finished
00009  A21E  18 F6               JR    AGAIN        ;Otherwise loop again
00010  A220  14         COUNT1   INC   D            ;Record word is found
00011  A221  C3 16 A2            JP    AGAIN        ;Loop again
00012  A224  14         COUNT2   INC   D            ;Last word found
00013  A225  21 2F A2            LD    HL,&A22F     ;HL is result pointer
00014  A228  72                  LD    (HL),D       ;Store result
00015  A229  C9                  RET
```

Table 2. Print out after assembling the program.

assembly will teach you a lot about the instruction set, addressing modes and generally how the processor works. Consequently, it's not a bad apprenticeship to use hand assembly methods at first, and use an assembler later as skills develop. Some programs are quite short so it doesn't take too long to assemble them. Now look at the flowchart of Figure 3, and see how it is implemented by machine code.

Taking the program line by line, the first line sets up the pointer for where the data is to be found; thus, the first address of the block is &A270, pointed to by HL. The second line specifies the number of bytes in the block, which is 50 or &32 in HEX. Next the ASCII code for the character to be searched for (the space) is specified, this being &20. Finally, in these first instructions, which initialise the registers, the initial value of D is set to zero (&00), since the word count is zero at the start. CPIR starts the block search, incrementing HL and decrementing BC as it does so. It will not stop until one of two things happens. Either the 'searched for' character is found, in which case it jumps to label COUNT1 to record the fact, or BC reaches zero, meaning we have reached the end of the block. After finding a space and jumping to COUNT1, D is incremented and we jump back to label AGAIN to continue the search. This goes on until we reach the end of the block, by which time BC holds zero and

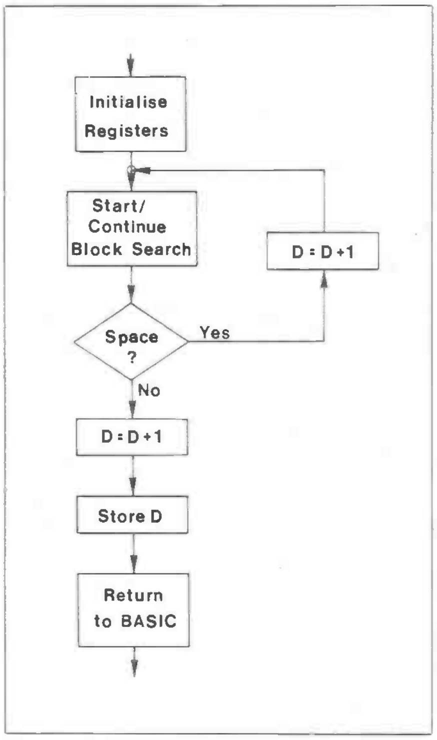


Figure 3. Flowchart for machine-code program.

D holds the number of words in the block, less one. At this point the program exits via the jump to COUNT2, which increments D for the last time, making the total correct. After this the address for the result (&A22F) is loaded into HL as a pointer and, in the last line, the result is loaded from D into the store address.

It is worth noting that of the branches, three use JP and one uses JR. Two of the JP's are conditional; Jump on Zero (space found) and Jump on Parity Odd (end of block). The other JP is unconditional and takes us back to AGAIN. To illustrate how this could also be achieved using a relative jump, line 00009 shows JR with an operand of F6. This is equivalent to −10 in decimal. Now check this. To do so remember we start two steps ahead of JR, i.e. at the first instruction on line 00010, and end up at the label AGAIN, which is at the start of line 00006. Using the machine code bytes between these points, count the number of steps. They are:

14 > F6 > 18 > A2 > 24 > E2 > A2 > 20 > CA > B1 > ED

This makes a total of ten steps backwards altogether. Well, that's the whole program – not that large is it? Yet, what it performs is a very powerful function, and it does it quickly. To demonstrate that it does work, I have included in Table 3 a print out from the Amstrad's memory, which shows the ASCII file in memory locations &A270-&A2A2, and the result stored in location &A22F. Is the result correct? Count the number of words in the ASCII file, compare with the contents of location &A22F and I think you'll agree it's right.

```
A20C  21 70 A2 01 32 00 3E 20  16 00 ED B1 CA 20 A2 E2  !p".2.> ..m1J "b
A21C  24 A2 18 F6 14 C3 16 A2  14 21 2F A2 72 C9 00 00  $".v.C.".!/"rI..
A22C  00 00 00 0A 00 00 00 00  00 00 00 00 00 00 00 00  ................
A23C  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  ................
A24C  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  ................
A25C  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  ................
A26C  00 00 00 00 27 54 68 69  73 20 69 73 20 61 6E 20  ....'This is an
A27C  41 53 43 49 49 20 66 69  6C 65 20 73 65 61 72 63  ASCII file searc
A28C  68 20 69 6E 20 5A 38 30  20 6D 61 63 68 69 6E 65  h in Z80 machine
A29C  20 63 6F 64 65 27 00 00  00 0A 00 00 00 00 00 00   code'..........
```

Table 3. Print out of memory after program run. Program resides in &A20C to &A229 inc.; ASCII file is in &A270 to &A2A2 inc.; the result is in &A22F.

'MIXING IT'

by Dave Goodman

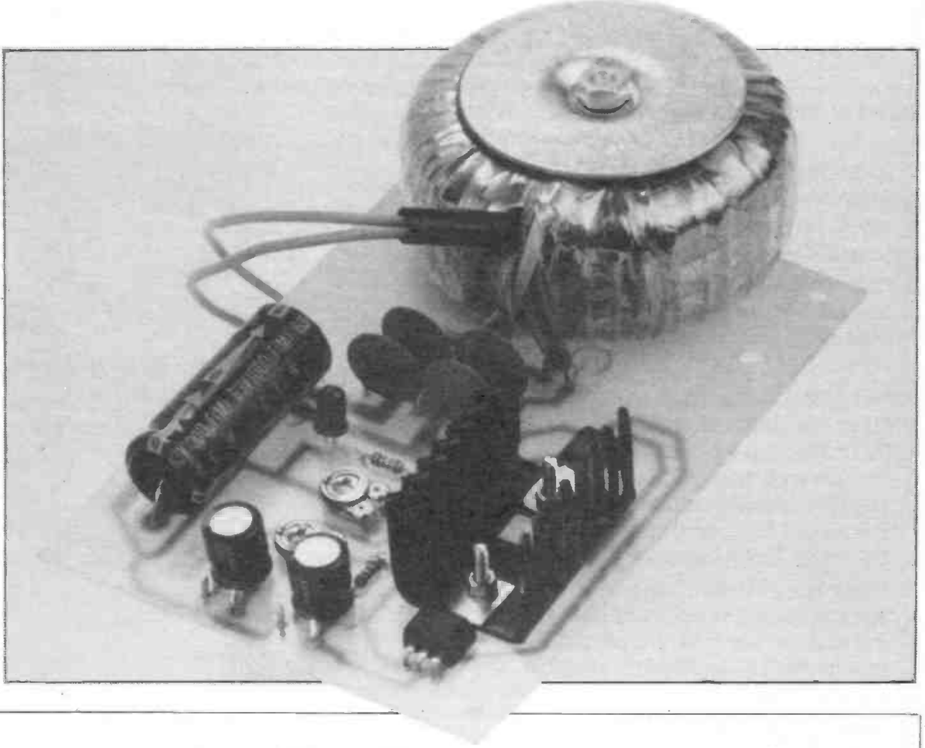
Part 3

Using Maplin High Quality Mixer Modules

The Maplin range of HQ mixer pre-amplifier modules serve as useful building blocks in audio circuits requiring high quality signal processing. In Parts 1 and 2 of this series, several modules were detailed, along with general specifications and use. To recap on this, here is a list of available modules:

In Part 1 (Vol.5, No.17).

1. General Purpose Input Module Mono.
2. General Purpose Input Module Stereo. For use with either pre-amplified signal sources or musical instruments such as guitars, organs and synthesisers. Supply requirements: 30V DC @ 25mA.
3. Tone Control Module Mono.
4. Tone Control Module Stereo. Active bass and treble controls. Supply requirements: 30V DC @ 1mA(M), 2mA(S).



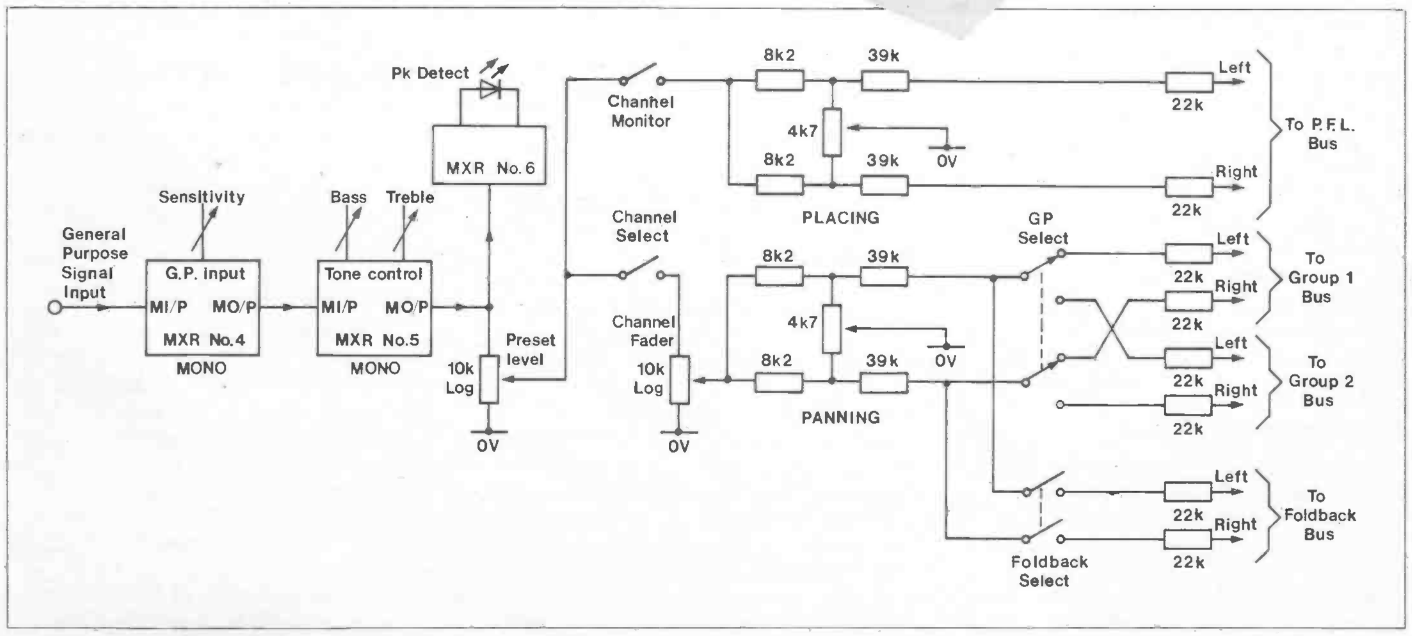


Figure 36. Typical Mono System

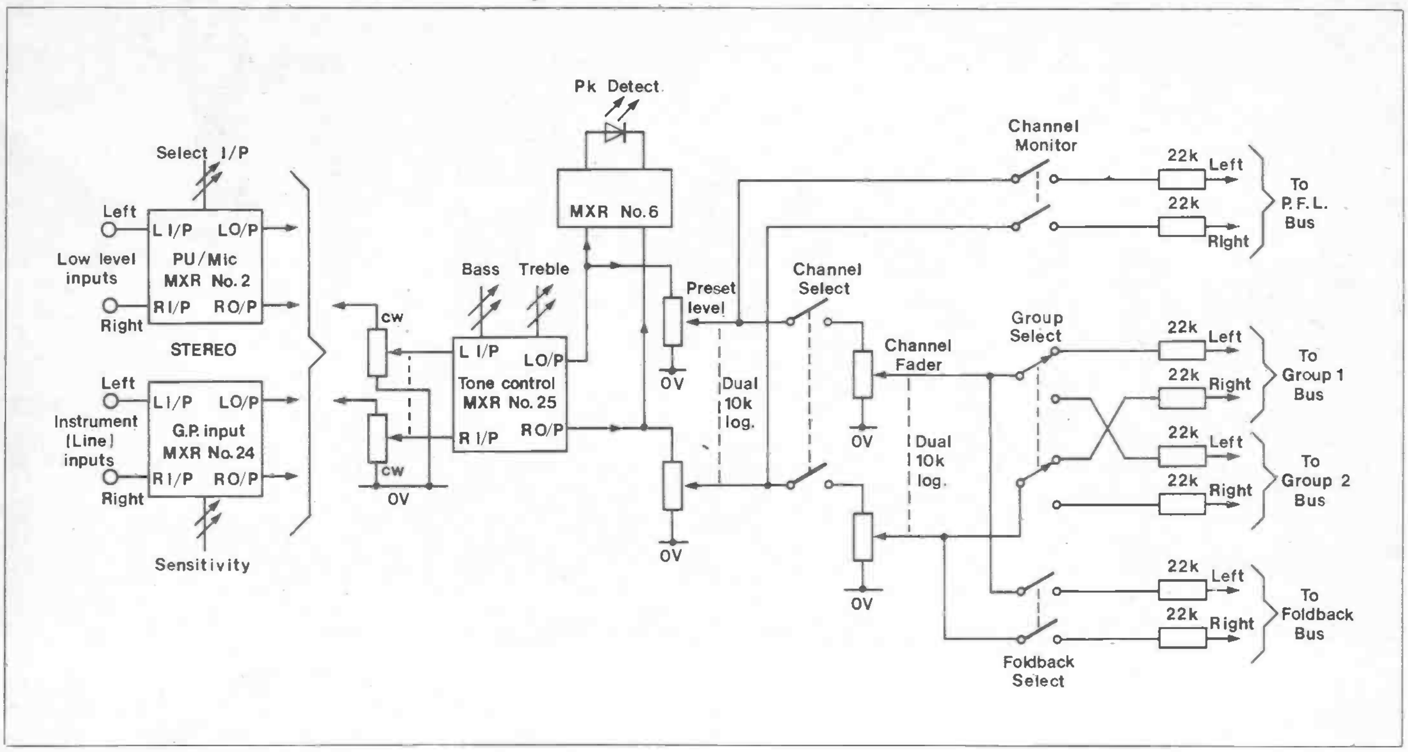


Figure 37. Typical Stereo System

5. Peak Overload Detector Module. Mono/stereo input LED driver. Supply requirements: 30V DC @ 12mA (Inc. LED).
6. Filter Module (Mono Only). Switchable low pass filter with variable slope control. Supply requirements: 30V DC @ 5mA.

In Part 2 (Vol.5, No.18).

7. PU or MIC Input Module Mono.
8. PU or MIC Input Module Stereo. For use with magnetic cartridges, High-Z microphones and ceramic cartridges. Supply requirements: 30V DC @ 6mA(M), 12mA(S).
9. Mixer Amp Module Stereo. For combining several different signal sources together. Supply requirements: 30V DC @ 14mA.
10. Line Amp Module (Mono Only). High level buffer stage driver. Supply requirements: 30V DC @ 14mA.
11. VU/Monitor Amp Stereo. For driving headphones or twin VU meter movements. Available in two different versions, Supply requirements: 30V DC @ 40mA max.

When deciding on power supplies, determine the total current requirement from all modules to be used. A twin PSU module is available with two separate regulated supply rails. Each rail is rated up to 0.3A and variable from 1.5V to 30V DC.

Interconnection

There are countless ways in which any combination of these modules are likely to be used in practice, dependant upon individual requirements and specifications. To help the constructor get a general idea of mixer arrangements, Figures 36 to 38 show the different modules in a theoretical large scale mixing system. The diagrams are *not* complete projects and are shown as examples only. Figure 36 could be a typical 'Mono' channel for pre-amplified or instrument inputs, with tone controls and preset volume control. The channel can be monitored over the Pre-Fade Level bus, and a 'Placing' control determines left or right channel levels.

The main group busses are really sub-mixing channels allowing multi-channel mixing and selection as in Figure 38. The foldback bus is used for monitoring input channels and would then drive Stage or Local amplifiers and speakers for monitoring purposes. Figure 37 shows a typical 'Stereo' channel with Pick-Up, Microphone or General Purpose inputs. Again, the PFL, Group and Foldback busses are selectable and any number of such channels could be connected to the various busses using 22k resistors.

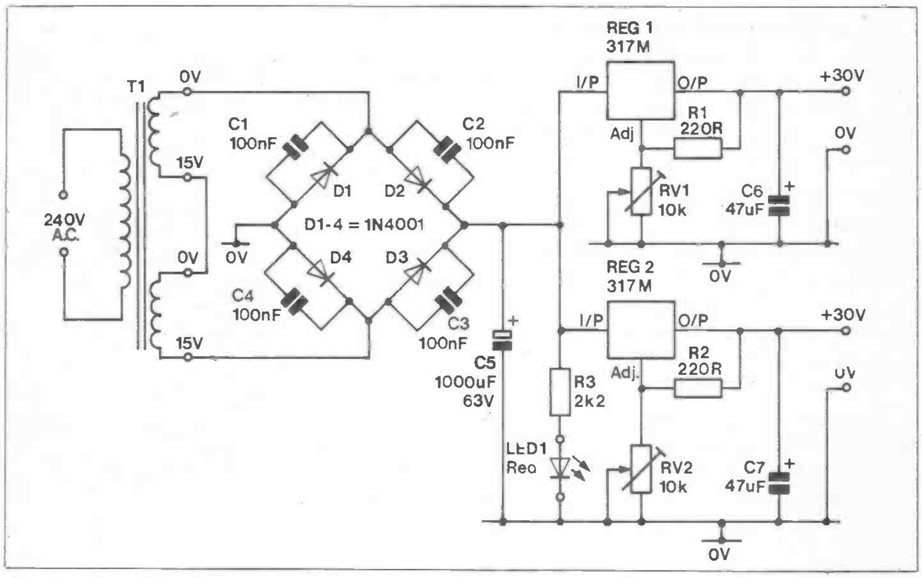


Figure 39. PSU Circuit

Mixer PSU Module

Figure 39 shows a twin, variable power supply capable of providing up to 300mA from each of the two outputs or up to 500mA from one output only. Both regulator outputs can be varied for 1.5V to 30V DC.

Construction and Use

Locate and fit bridge diodes D1 to D4, and ceramics C1 to C4. Insert the 220Ω resistors R1 and R2 and LED supply resistor R3. Mount presets RV1, RV2 and fit LED 1 with the longer lead (Anode) in hole a, and short lead (Cathode) in k. The cathode may also be identified by a flat on the skirt around the LED body.

Insert PC electrolytics C6, C7 and axial C5 noting lead polarity. The negative lead is marked with a minus (−) sign on the body. Insert two 6BA x ¼in. bolts through the pcb from the track

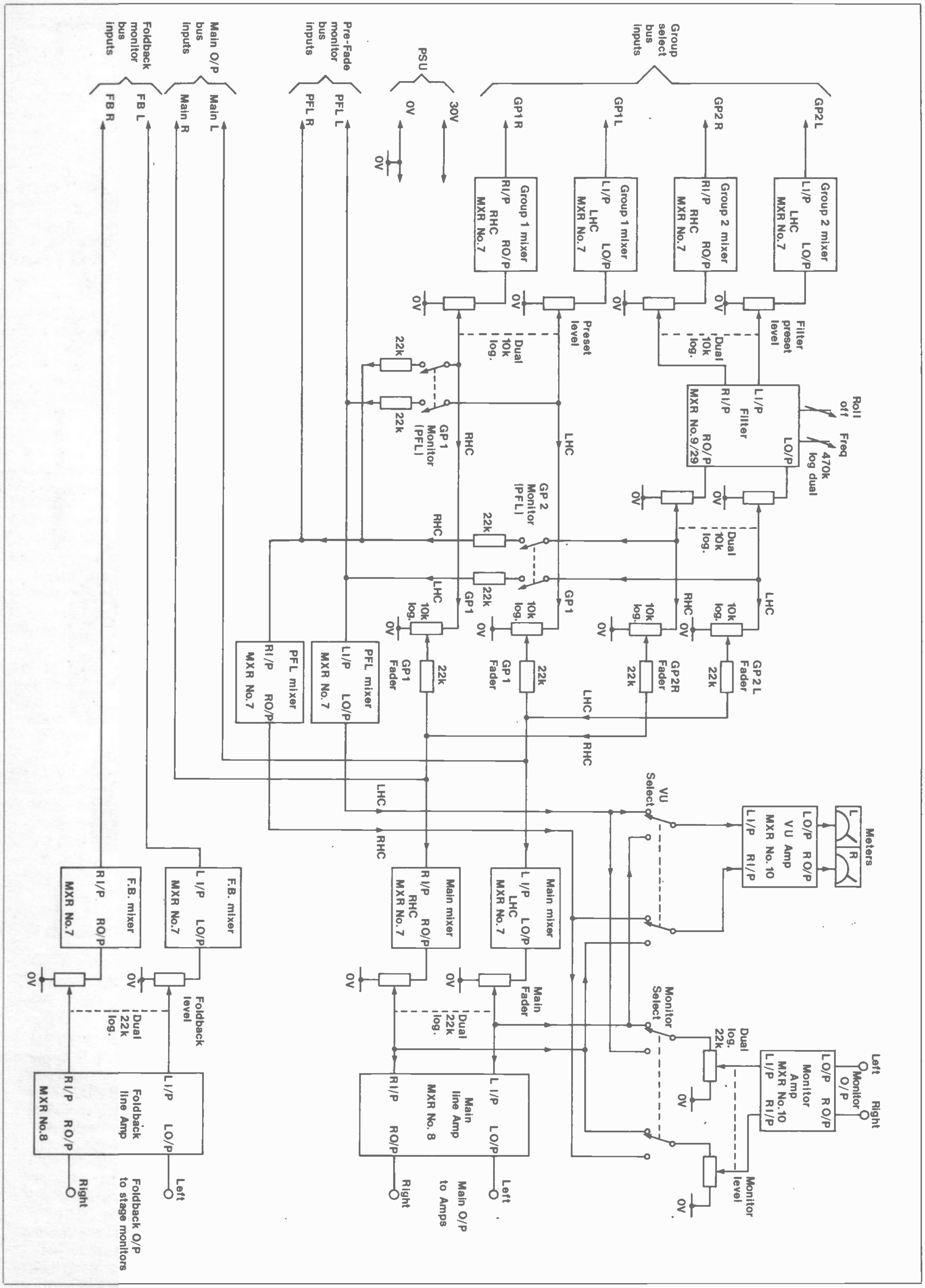


Figure 38. Multi-channel Mixing

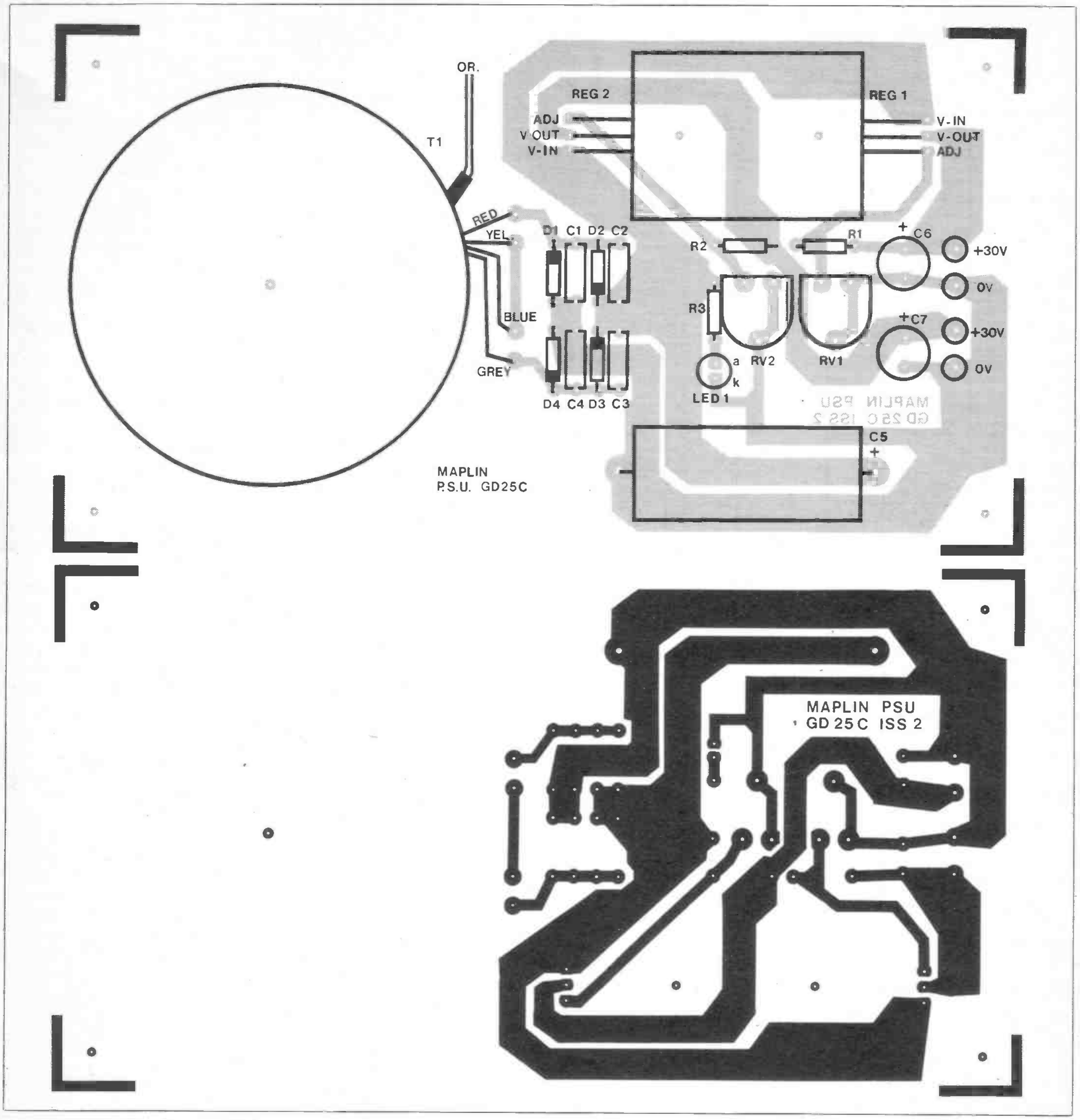


Figure 40. PSU Layout and Legend

side, and place a powerfin heatsink over them. Next fit REG1 and REG2 mounting tabs over both bolts and heatsink, with the body identification markings (LM317) facing upwards, away from the pcb.

Insert the three regulator terminal leads into their respective holes, after bending to 90° to the same pattern, and bolt in place with 6BA washers and nuts. Only after doing this should you solder the six leads on the track side of the pcb.

Insert a 4mm toroidal mounting bolt through the pcb from the track side. Slide a 50mm rubber pad over this bolt, on the component side and position the toroidal transformer over both bolt and pad. Fit a second rubber pad on top of T1 and also the recessed, metal washer.

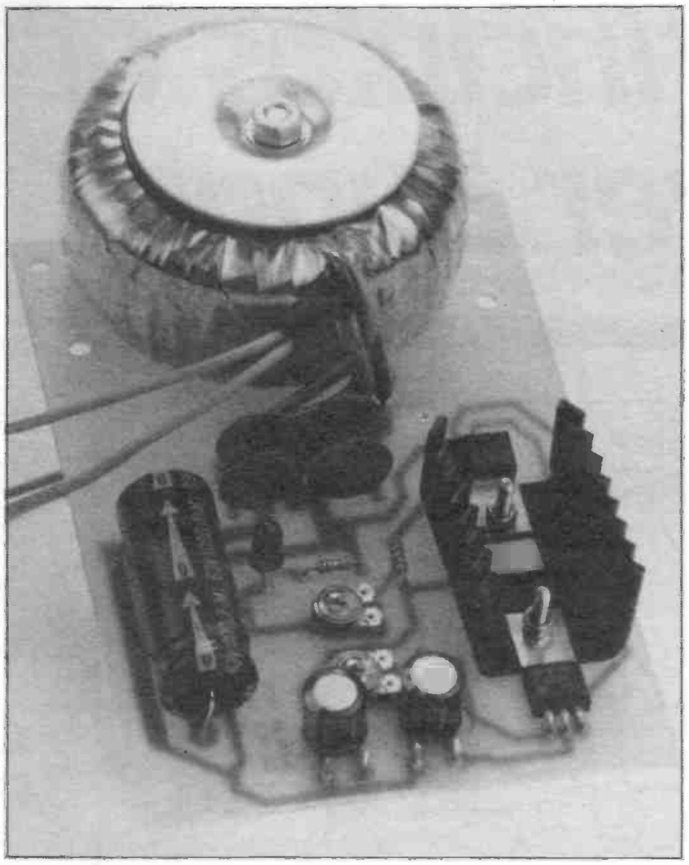
Finally, tighten the whole assembly in place with the small washer and nut supplied. Do not overtighten as the pcb will distort and may crack tracks and components. All four colour coded secondary wires from T1 should be inserted into the board, following the legend. Any deviation from the legend colour coding could well result in a damaged transformer! The final pair of orange primary leads are for connecting to 240V AC mains only. Solder all components and leads carefully, and cut off all excess wire ends. Insert four vero pins in each supply output, 0V and +V positions, and solder them to the track. Figure 40 shows the PSU pcb layout and legend.

Testing

Connect a voltmeter to the +V pin nearest to REG1 and any 0V pin. Apply 240V mains to T1 primary (orange) leads and adjust RV1 to read +30V DC on the meter. The wiper positioning should be approximately half way on the preset.

Remove the voltmeter and re-connect to the second supply pins 0V and +V. Adjust RV2 for +30V DC as before.

With the PSU module in use, ensure adequate air flow around the REG1/2 heatsink bracket to prevent overheating problems. The bracket runs quite hot under full load conditions so keep it away from any object liable to melt or burn, especially mains cables!



MIXER PSU PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,2	220Ω	2	(M220R)
R3	2k2	1	(M2K2)
RV1,2	10k Hor Sub-min Preset	2	(WR58N)
CAPACITORS			
C1-4	100nF Disk Ceramic	4	(BX03D)
C5	1000µF 63V Axial Electrolytic	1	(FB84F)
C6,7	47µF 63V PC Electrolytic	2	(FF09K)
SEMICONDUCTORS			
D1-4	1N4001	4	(QL73Q)
LED1	LED Red	1	(WL27E)
REG1,2	LM317M	2	(RA86T)
MISCELLANEOUS			
T1	Toroidal Transformer 30VA 15V	1	(YK11M)
	Mixer PSU PCB	1	(GD25C)
	Vaned Heatsink Penta	1	(FG54J)
	Bolt 6BA x ¼in.	1 Pkt	(BF05F)
	Nut 6BA	1 Pkt	(BF18U)
	Washer 6BA	1 Pkt	(BF22Y)
	Veropin 2145	1 Pkt	(FL24B)

A complete kit of all parts is available for this project:
Order As LK90X (Mixer PSU Kit) Price £16.95
The following item in the above kit is also available separately but is not shown in the 1986 catalogue:
Mixer PSU PCB **Order As GD25C Price £3.95**
A ready-built Module is also available:
Order As YM24B (Mixer PSU Assembled) Price £19.95

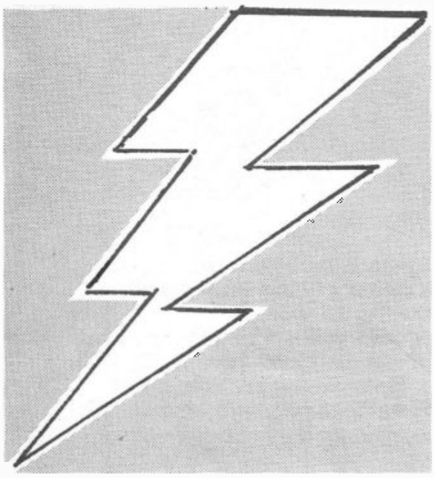
ADA ECHO *Continued from page 43.*

ADA-ECHO PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,2,5	100k	3	(M100K)
R3,4,11,12	22k	4	(M22K)
R6-9,18-20	15k	7	(M15K)
R10,24	18k	2	(M18K)
R13,14	10k	2	(M10K)
R15,22	390Ω	2	(M390R)
R16	82k	1	(M82K)
R17	680Ω	1	(M680R)
R21	12k	1	(M12K)
R23	2k2	1	(M2K2)
RV1	22k Pot log	1	(FW23A)
RV2	100k Pot lin	1	(FW05F)
CAPACITORS			
C1,2	220nF Poly layer	2	(WW45Y)
C3,4,22	10µF 50V PC Electrolytic	3	(FF04E)
C5,26	1nF Poly layer	2	(WW22Y)
C6,25	1n5F Poly layer	2	(WW23A)
C7,24	4n7F Poly layer	2	(WW26D)
C8,23	220pF ceramic	2	(WX60Q)
C9,12,14,15,21	4µ7F 63V PC Electrolytic	5	(FF03D)
C10,18	2µ2F 100V Axial Electrolytic	2	(FB15R)
C11	47nF Poly layer	1	(WW37S)
C13,20	2µ2F 100V PC Electrolytic	2	(FF02C)
C16,27	1µF 100V PC Electrolytic	2	(FF01B)
C17,29	100pF ceramic	2	(WX56L)
C19,34	100µF 25V PC Electrolytic	2	(FF11M)
C28	220µF 16V PC Electrolytic	1	(FF13P)
C30,32,33,35-38	100nF Minidisc	7	(YR75S)
C31	1000µF 35V PC Electrolytic	1	(FF18U)
SEMICONDUCTORS			
D1-3	1N4002	3	(QL74R)
IC1	1458C	1	(QH46A)
IC2	NE571	1	(YY87U)
IC3	ZN448E	1	(UF43W)
IC4	CA3140E	1	(QH29G)
IC5	ZN428E	1	(UF41U)
IC6	NE555	1	(QH66W)
IC7	4017BE	1	(QX09K)
IC8	4001BE	1	(QX01B)
IC9,10	4024BE	2	(QX13P)
IC11	6264-3	1	(UF34M)
IC12	µA78M05UC	1	(QL28F)
IC13	µA79L05AWC	1	(WQ85G)
IC14	µA78L12AWC	1	(WQ77J)
MISCELLANEOUS			
S1	Rotary mains switch	1	(FH57M)
JK1,2	Jack skt open	2	(HF91Y)
T1	PCB Transformer Tr0-12x2 0.25A	1	(YJ54J)
LP1	Min. neon red	1	(BK52G)
FS1	Fuse A/S 160mA 20mm	1	(RA05F)
	Fuse clips	2	(WH49D)
	A/D/A Digital Echo PCB	1	(GD20W)
	A/D/A Dig. Echo PSU	1	(GD21X)
	Veropin 2145	1 Pkt	(FL24B)
	DIL socket 8-pin	3	(BL17T)
	DIL socket 14-pin	3	(BL18U)
	DIL socket 16-pin	3	(BL19V)
	DIL socket 18-pin	1	(HQ76H)
	DIL socket 28-pin	1	(BL21X)
	Cable 'P' clip 3/16in.	1	(LR44X)
	Sleeving H/Shrink CP24	1 mtre	(BF87U)
	Screened cable single white	1 mtre	(XR14Q)
	Cable Min. mains white	1 mtre	(XR02C)
	Ribbon cable 10-way	1 mtre	(XR06G)
	Knob K7B	1	(YX02C)
	Knob K7C	2	(YX03D)
	Grommet small	1	(FW59P)
	Bolt 6BA x 1in.	1 Pkt	(BF07H)
	Nut 6BA	1 Pkt	(BF18U)
	Threaded spacer 6BA	1 Pkt	(LR72P)
	Case WB5 vinyl	1	(LH40T)
	Cabinet feet	1 Pkt	(FW19V)

A complete kit of all parts is available for this project:
Order As LM04E (A/D/A Digital Delay Kit) Price £54.95
The following items in the above kit list are also available separately, but are not shown in the 1986 catalogue:
A/D/A Digital Echo PCB **Order As GD20W Price £5.95**
A/D/A Dig. Echo PSU PCB **Order As GD21X Price £2.50**

The Basic Principles of an AC Power Supply



by R. Richards

The three main methods used for generating electric power by the Central Electricity Generating Board in the UK are as follows:
a) By coal and oil burning boilers which generate steam at a very high pressure to drive turbine generators.
b) By utilising the potential of large volumes of water stored behind dams. As the water is released, it flows through the hydro-electric plant, where it turns the turbine generators.
c) Since the explosion of the atomic bomb, scientists have discovered ways of converting this enormous energy into other uses, by utilising the nuclear reactors to produce heat, to generate steam, to drive the turbine generators.

Single Phase Alternators

A generator used to produce AC voltage is known as an alternator, so we will now look at the simple principles of an alternator. Michael Faraday discovered that by moving a conductor at a right angle through a magnetic field, a voltage is induced in one direction, and when the conductor was moved in the opposite direction, the current flow was also reversed.

Let us now consider a loop of wire rotating in a magnetic field, between the north and south poles of two permanent magnets, as shown in Figure 1. The first half cycle starts at zero, and the induced voltage rises to peak value in a positive direction, and returns to zero. The second half cycle starts at zero and falls to a peak value in a *negative* direction and then rises to zero. Notice that one cycle corresponds to one complete revolution of the loop, and this completes one cycle of alternating current, which is transferred to the external circuit via the slip rings and brushes as illustrated in Figure 1.

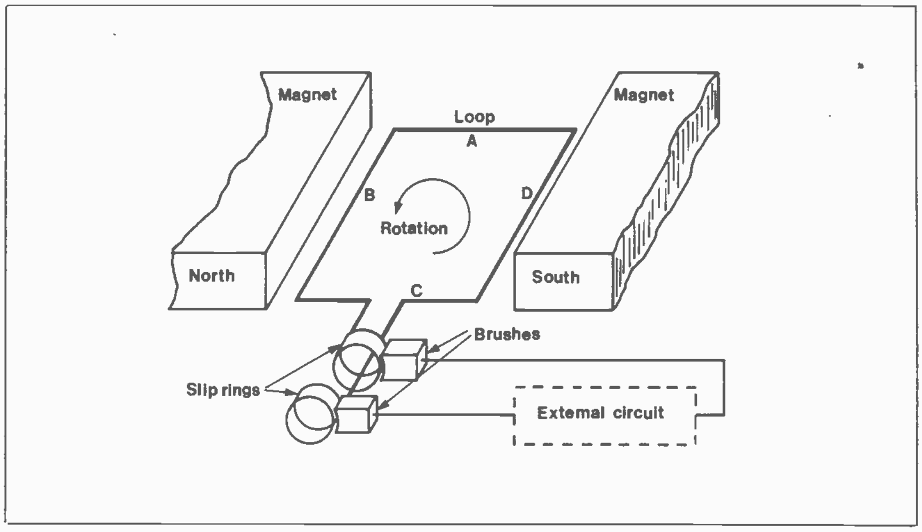


Figure 1. The Rotation of a Loop between two Magnetic Poles.

This explains the principles of a generator and for simplicity, shows two magnetic poles and a single loop of conductor (where, in practice, there are many poles and a large number of conductors). As the loop is driven by the turbine through the positions shown, there is a perpetual change of current owing to the change of angle at which the lines of force are 'cut', i.e. where the conductor moves parallel to the magnetic lines of force the output is zero, and where it moves at 90° to the lines of force it is at a maximum.

The Output Waveform

Figure 2 illustrates the voltage output, and the curve represents the magnitude of the voltage and the polarity for one complete cycle. This is known as the output waveform, which is sinusoidal

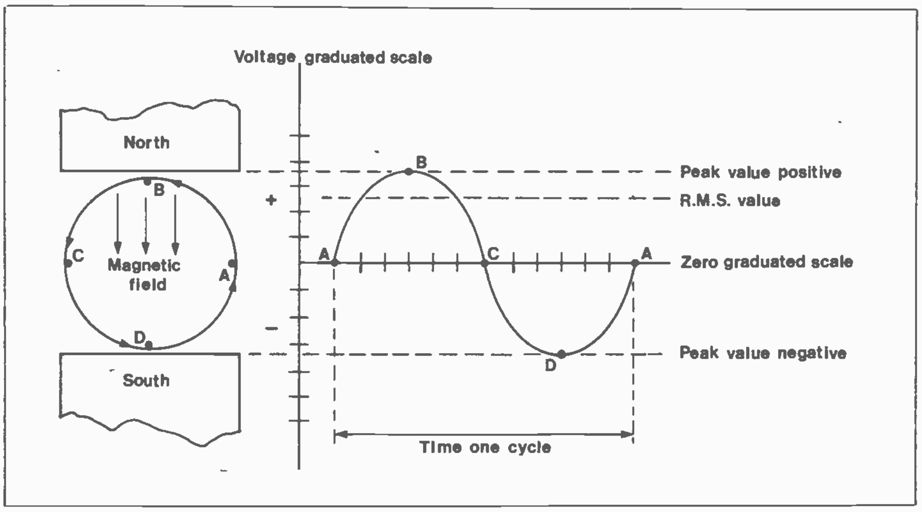


Figure 2. Single Phase Waveform.

in shape, and such a waveshape is common to all AC sources of this type. The zero line is shown at points A/C/A, and the distance from points A to A represent the time for one complete cycle.

Point B represents the peak value in the positive direction, and point D the peak value in the negative direction. The dotted line represents the r.m.s. value, which is equivalent to the DC value.

For example, in the case of the waveform for a 240 volt 50 Hertz AC supply, i.e. 50 Hertz meaning 50 complete cycles per second, the 240 volts value would represent the r.m.s. value. The peak value can be found by multiplying the r.m.s. value by 1.414, which equals 339 volts approximately. Alternatively, the r.m.s. value can be found by multiplying the peak value by 0.707, e.g. 339 x 0.707 = 240 volts.

The r.m.s. value is the root-mean-square and is sometimes referred to as the effective value. In short, it means that a 240 volt AC current would have the same heating effect for an electric fire as that of a 240 volt DC current. The above explains the basic principles of generating a single phase power supply, and it is worth noting that the above formulæ apply to any sinusoidal waveform.

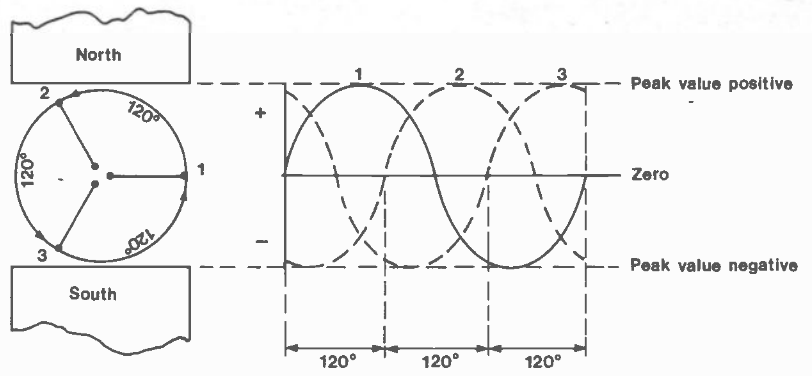


Figure 3. Three Phase Waveform.

Three Phase Alternators

We will now look at the basic principles of the three phase power supply. The three phase system is similar to the single phase system, but instead of having one conductor loop revolving in the magnetic field, there are three, spaced at angles of 120 degrees, or one third of a cycle, and each loop producing a voltage equal to the single phase. By virtue of this arrangement the three phase system is an example of what is known as a 'Polyphase System'.

Star or Delta

If one end of each phase is joined to a common neutral point, and the other ends become the line wires, then it is a 'Star Connected' polyphase system having three phases and a common 'Neutral'. The advantage of this is that 240 volts can be obtained by using any one of the three phases to neutral, and 415 volts can be obtained by using any two phases only. This provides for a system that can supply power at a voltage of 240 volts for the domestic supply, and 415 volts to operate machinery, street lighting, etc.

Alternatively, all the windings could be connected together in series to form a closed circuit – which can be drawn as a triangular shape – the line wires being joined to the junction of the phases, there being no neutral, and this is called a 'Delta or Mesh Connected' system. In this case the maximum voltage available is equal to the output of any one phase. Such industrial machinery as might use the Delta system will have AC electric motors with three phase armatures constructed in a virtually identical manner to the source generator.

The waveform for a three phase system is fully illustrated in Figure 3, which shows the three conductor loops rotating in the magnetic field, and the resulting waveform for each revolving loop.

It may not be fully obvious why the apparent extra complexity of the three phase system should be preferred over the simpler, two wire single phase. The fact is that although in both types the output power is based on the r.m.s. voltage/current value, which as we have seen is averaged from the two half cycle extremes of zero to peak voltage; in the case of single phase, there are only two half cycles occurring repetitively in a regular sinusoidal pattern. Hence, there are regular periods where the output power from single phase is very small, and indeed is momentarily equal to no output (zero), each time the output waveform passes through the zero crossing point. It is possible for a single phase, synchronous AC motor to stall under load if the armature speed is drastically reduced during the zero crossing period, where at this point the braking force of the load overcomes the negligible driving force available to the motor.

As can be seen in Figure 3, the manner in which the three output waveforms overlap means that the total supply current at no instant falls to zero. Indeed, almost all of the r.m.s. value is constantly available, and so a three phase motor can combine output power with excellent speed accuracy. The only possible drawback might be in ensuring that the motor revolves in the required direction on start-up, which may require switching and/or delay circuits of a somewhat involved nature.

A good demonstration of the superiority of the three phase principle is in its application to the modern motor car alternator, where some 80% of the total output capability may be available at engine speeds not much greater than idling speed. This ensures adequate electrical power is available for lighting and battery charging whatever the r.p.m. of the engine.

Transformers

Alternating current was chosen for national distribution by the Electricity Generating Authorities because of the simplicity of being able to step up to a higher voltage, or step down to a lower voltage by means of a transformer.

Michael Faraday discovered that when two coils were placed close together, or wound on top of one another and an alternating current applied to one coil, an alternating e.m.f. was induced in the other. He also noticed that the magnitude of the induced e.m.f. was proportional to the ratio of the number of turns in each coil.

The coil to which the alternating current is applied is known as the 'input' or 'primary' winding, and the coil in which the e.m.f. is induced is called the 'output' or 'secondary' winding. Figure 4 shows how the magnetic field is produced when an alternating current is applied to the 'primary' winding, and how the polarity of the magnetic field is changed for each complete cycle. Position A shows the magnetic field at zero. Position B shows the 'primary' winding with the north pole at the top, and at position C the magnetic field is back at zero, but at position D the polarity of the coil has been reversed, with the north pole at the bottom. From the foregoing, it will be noted that the polarity of the 'primary' winding is reversed every half cycle, and it is the reversing magnetic field that induces an e.m.f. into the secondary winding.

Transformer Construction

To ensure efficient magnetic linkage between the two coils, they are assembled on a laminated iron core. The object of the laminations is to reduce iron losses and ensure that the maximum magnetic field is common to both coils. A common method of lamination is as follows: The laminations are made from thin sheet iron, sometimes called 'electrical steel', stamped out in 'T' and 'U' shaped pieces; 'E' and 'I' patterns are also used. The first layer of 'T' and 'U' shaped plates are fitted with the 'T' piece on the top and the 'U' piece on the bottom. On the second layer, the 'T' piece is fitted on the bottom and the 'U' piece on the top, i.e. the odd numbered layers with the 'T' piece at the top, and the even numbered layers with the 'T' piece at the bottom. Each layer is insulated from each other by paper, enamel, or a layer of oxide.

This method of construction allows the transformer to be built with the primary and secondary windings on the centre leg of the laminated iron core, with all the plates clamped firmly together with four corner bolts, see Figure 5. The laminated iron core confines the magnetic field to the primary and secondary windings, making the transformer more efficient. The insulating coating on each lamination also prevents residual eddy currents from flowing in the core by virtue of the fact that the core is otherwise naturally conductive; these currents would be induced from the primary winding and would consume power and generate extra heat. A well designed transformer can have an efficiency of as much as 99 per cent.

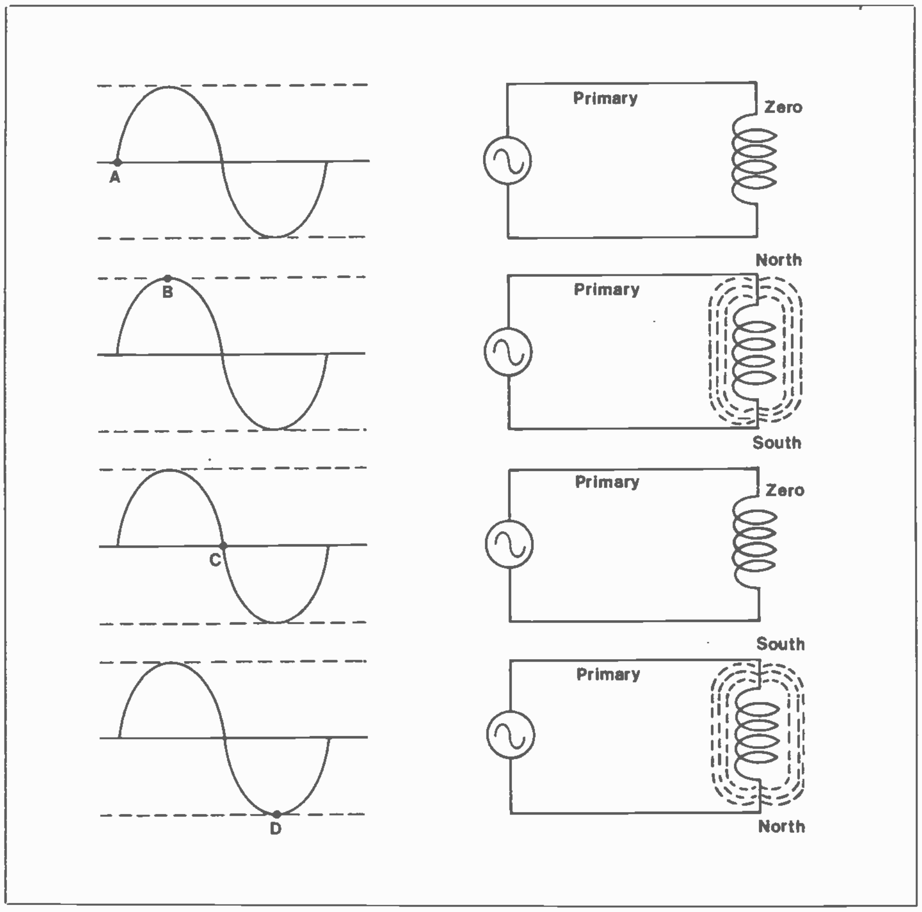


Figure 4. The Magnetic Field for one complete cycle.

Calculating Ratios

The relationship between the induced e.m.f. and the number of turns in each coil may be expressed as follows. The number of turns in the primary winding, divided by the number of turns in the secondary winding, is equal to the e.m.f. of the primary winding divided by the e.m.f. of the secondary winding. A formula is:

$$\frac{Np}{Ns} = \frac{Ep}{Es}$$

From this equation, it will be noted that if any of the three values are known, the fourth value can be calculated as follows:

$$Np = \frac{Ns \times Ep}{Es} \text{ or}$$

$$Ns = \frac{Np \times Es}{Ep} \text{ or}$$

$$Ep = \frac{Np \times Es}{Ns} \text{ or}$$

$$Es = \frac{Ns \times Ep}{Np}$$

For example, the primary of a transformer has 3600 turns, and is fed with a 240 volt AC supply, how many secondary turns are required to deliver 150 volts? Answer:

Np = 3600, Ep = 240, Es = 150

Therefore:

$$Ns = \frac{150 \times 3600}{240} = 2250 \text{ turns.}$$

It must not be overlooked that when a transformer is used to 'step up' the voltage, there is always a reduction of current in the secondary winding. Similarly, where a 'step down' in voltage is required, the secondary current is increased, and therefore the ratio of the output current is inversely proportional to the induced e.m.f., and may be expressed in a formula as:

$$\frac{Ep}{Es} = \frac{Is}{Ip}$$

By cross multiplying and dividing, the current flowing in the primary or the secondary windings can be calculated as follows:

Current in primary winding:

$$Ip = \frac{Es \times Is}{Ep}$$

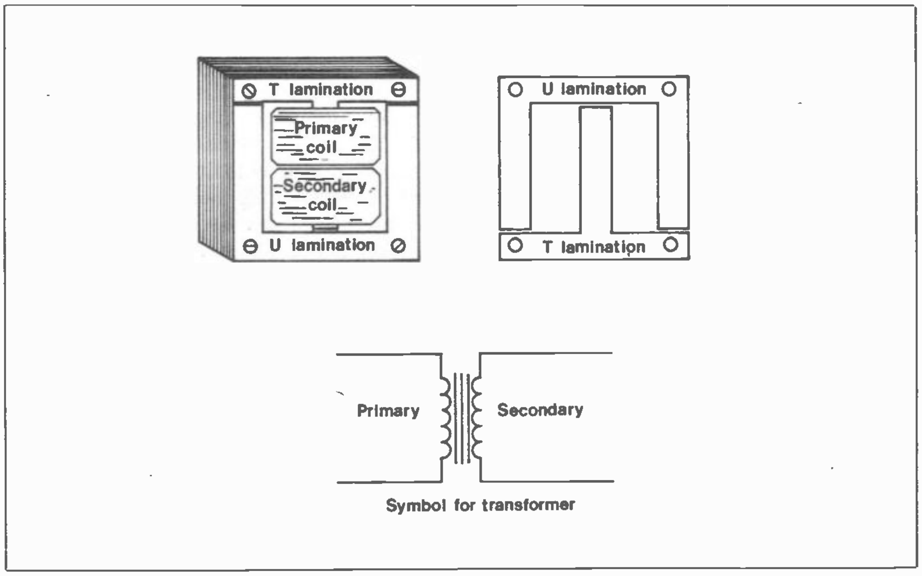


Figure 5. Transformer Laminations and Symbol.

Current in secondary winding:

$$Is = \frac{Ep \times Ip}{Es}$$

Also the current is inversely proportional to the number of turns, and can be expressed in a formula as:

$$\frac{Np}{Ns} = \frac{Is}{Ip}$$

Which follows that if any three values are known, the fourth can be calculated by cross multiplying and dividing in the same way as we have for the e.m.f. ratio.

The power ratio cannot be altered, therefore the power input is always equal to the power output, and as the power is calculated by multiplying volts by amperes, then E x I in the input will equal E x I in the output, in units of watts.

Transformer Efficiency

The ratio Watts Output divided by Watts Input gives the efficiency of the transformer, and if this ratio is multiplied by 100, the results can be stated as a percentage.

There are always some losses in the system, and these should be taken into consideration when performing the above calculations. For example it may be prudent to slightly overrate the secondary output current required in the calculation in order to compensate for these losses. Even so, some of the larger size transformers will deliver 99 per cent of the input power.

In Figure 4, we saw how the magnetic field was induced into the secondary winding. The strength of this magnetic field is the product of the current in amperes together with the number of turns in the primary. This is known as the 'MMF', and is expressed in units of ampere turns, so in designing a transformer, it is the rule of thumb to allow a minimum of five turns per volt.

For example, if a transformer input was 240 volts and the output 150 volts, the minimum number of turns in the primary winding would be 240 x 5, or equal to 1200 turns, while the minimum for the secondary winding would be 150 x 5 to equal 750 turns. From the foregoing, it will be appreciated that an increase in the number of turns per volt will increase the strength of the magnetic field, thus increasing the efficiency of the transformer.

Distribution

In actual practice, the type of high tension transformer used is immersed in oil and self cooling. The oil convects the heat from the core and windings, thus dissipating it to the surrounding air by means of cooling tubes and fins. Such a transformer is capable of dealing with outputs up to 3000 KVA.

Power companies use transformers to increase the voltage for transmission of high tension power over long country lines. The power is generated, at say, 33KV and transformed up to 132KV, for transmission over the grid network to the various power stations. By increasing the voltage, the current is reduced, and as the power loss in the line is proportional to the square of the current, it is obvious that the power loss in the line will be reduced. For example, if the output of a generator is 330KVA, i.e. 33KV at 10 amperes, and is connected to an external line having a resistance of 100 Ω, the power loss in the line would be 10 x 10 x 100 which equals 10,000 watts. If the 33KV was transformed up to 132KV, the current would be reduced to 2.5A, therefore the power loss in the 100Ω line would be 2.5 x 2.5 x 100 which equals 625 watts. Therefore, the loss in the 33KV line is 16 times greater than that of the 132KV line.

Besides making it simple to conserve power during transmission, the transformer is used to step-up or step-down the voltage as required by the consumer. A common example for domestic use is where power is generated at 33KV, and is then transformed up to 132KV for transmission over the Grid System to the various transformer and sub-stations, whereupon it is transformed down to reach our homes at 240 volts.

The British Grid System is designed in such a way that it is possible for any one station either to supply power to others, or to receive power from them when there is a deficit.

Figure 6 shows the transformers and the voltage, current and power in each section, and how it is transformed from 132KV down to 240 volts. This diagram can also be used to try out the formulas given previously, but it must be borne in mind that these are basic principles, and no allowance is made for minor losses in the magnetic circuit; in actual practice the output power is slightly less than the input.

For simplicity, Figure 6 illustrates a single phase system, but in reality this would normally be a three phase system. A list of abbreviations used in this article is shown in Table 1.

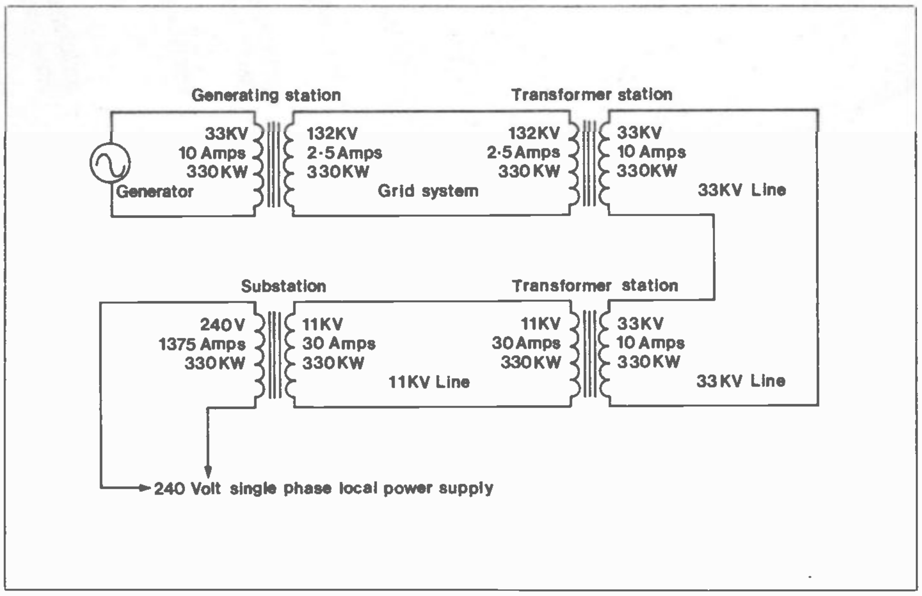


Figure 6. Power Supply from Generator to Local Supply.

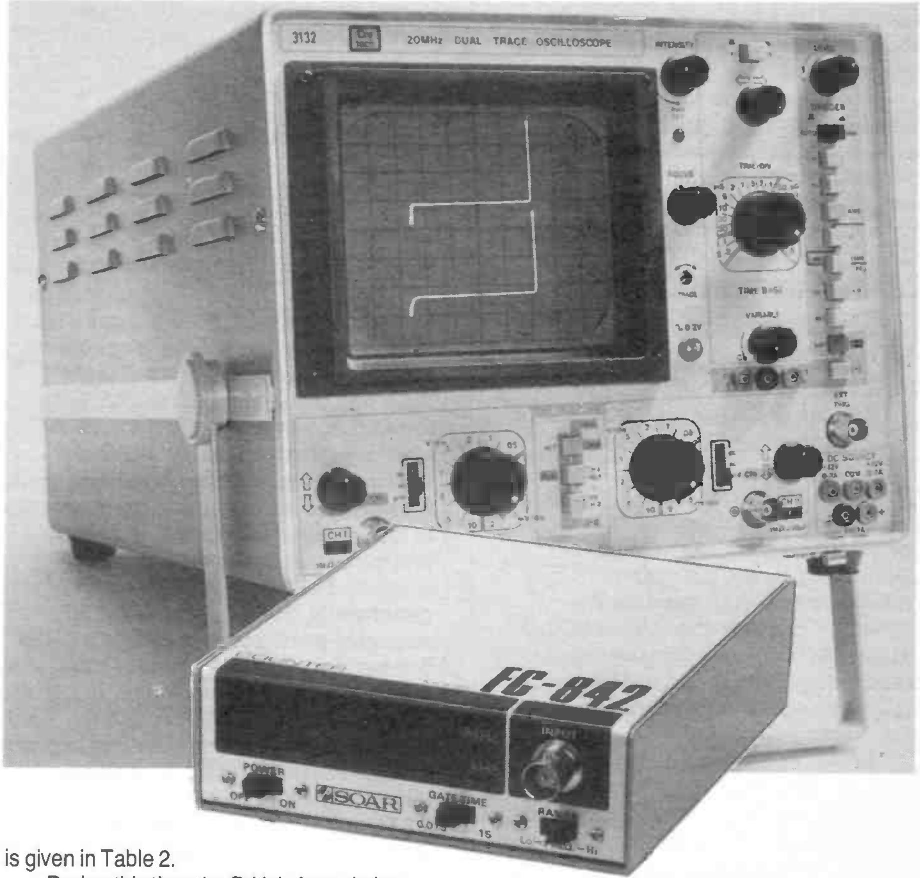
ABBREVIATIONS

Np	Number of turns in primary winding.
Ep	e.m.f. volts in primary winding.
Ip	Current drawn from primary winding.
Ns	Number of turns in secondary winding.
Es	Induced e.m.f. in secondary winding.
Is	Induced current drawn from secondary winding.
E	e.m.f. volts.
I	Current (Amperes).
R	Resistance (Ohms).
KV	Kilovolts (One thousand volts).
KW	Kilowatts (One thousand watts).
KVA	One thousand volt-amperes.
MMF	Magnetomotive force.

Table 1. Abbreviations.

TEST GEAR AND MEASUREMENTS

by Danny Stewart
Part 1



Man has two passions, classifying the things around him and measuring the things around him. Although failing to put himself in order, he has the urge to put everything else around him in order. Even if there is the slightest room for improvement, he will not rest. But, like athletic records, the room for improvement sometimes gets smaller and smaller.

Units and Standards

Two types of units are used in scientific measurements: fundamental and derived.

Distance and time are examples of fundamental units. Areas and volumes are examples of derived units, since these are derived from the fundamental unit of distance (length). However, even derived units may have unique names. For instance, the dimensions of Force are kg m/s, and a unit of force is called a Newton (N).

Imperial Units

The Romans left us the foot and the pound, which are not as easy to work with as the decimal system. Conversion between the Imperial and Metric systems is not difficult since the inch has been equated to 25.4mm exactly, and the pound to 0.45359237kg.

The unit of force is the poundal, and the unit of work is the foot-poundal. Table 1 gives the metric equivalents of some Imperial units.

Metric Units

In 1790 the French Government instructed the French Academy of Science to suggest a sytem of units that would replace systems in use at that time.

The French Academy decided to base their measurements on natural phenomena, and chose their unit of mass as being 1 cubic centimetre of distilled water at atmospheric pressure (760mm of Mercury), and at 4°C. This they called one gram.

The unit of time, the second, remained the same as before. The second was defined a 1/86,400 of the mean solar day.

The unit of length was the metre. This was calculated as being one-tenmillionth of the distance from the equator to the pole, and along the meridian which passes through Paris.

It really wouldn't have mattered if they had chosen someone's big toe as the unit of length. What does matter, and what makes calculations so easy, is the decimal system. The names of the multiples and submultiples is given in Table 2.

During this time the British Association for the Advancement of Science put forward the CGS (centimetre-gram-second) system. This is useful to physicists since the MKS (metre-kilogram-second) system has units which are too large for scientific purposes.

The original proposals of the French Academy were introduced in France in 1795, and were approved by seventeen countries at the Metre Convention of 1875. Britain and the USA did not adopt the MKS system but recognised its usefulness in international dealings.

It was left to the inventiveness of an Italian engineer, Giorgi, to suggest that the MKS system should include electrical units, and in 1935 the Ampere was accepted into the MKSA system.

In 1960, these units were accepted by international agreement as SI units (Systeme International d'Unites). The names and symbols of some of these units are given in

	IMPERIAL UNIT	METRIC EQUIVALENT
Length	Inch	25.4mm
Mass	pound	0.45359237kg
Temperature	degree F	5 (T−32)/9 degree C
Power	horsepower	745.7 watt
Work	foot-poundal	0.0421401 Joule
Velocity	foot per second	0.3048m/s
Force	poundal	0.138255 Newton

Table 1. Metric Equivalents of Imperial Measures

		Symbol
Tera	10^{12}	T
Giga	10^{9}	G
Mega	10^{6}	M
Kilo	10^{3}	K
Hecto	10^{2}	h
Deca	10	da
Deci	10^{-1}	d
Centi	10^{-2}	c
Milli	10^{-3}	m
Micro	10^{-6}	u
Nano	10^{-9}	n
Pico	10^{-12}	p
Femto	10^{-15}	f
Atto	10^{-18}	a

Table 2. Decimal Multiples

Table 3. Since these units are becoming more widely acceptable, other units are likely to die out eventually.

Measurement Standards

There are four levels of standards. At the highest level is the International standard, followed by the Primary and Secondary standards, and lastly the Working standards.

International standards are kept at the International Bureau of Weights and Measures near Paris, and these are the standards agreed upon internationally. From time to time, these measurements are checked by the best technology of the day.

Primary standards are kept by National laboratories in different parts of the world. The oldest is Physikalisch – Technische Reichsanstalt in Germany. The UK has the National Physical Laboratory (NPL), and the USA has the National Bureau of Standards in Washington. Primary standards are used to calibrate secondary standards. The primary standards are also compared with one another to give an average figure.

Secondary standards are used by industrial laboratories who are responsible for calibrating that standard and working standards are used to calibrate laboratory instruments.

Standard for Frequency and Time

The mean solar second (1/86,400 of the mean solar day) is not accurate enough since the rotation of the earth is not uniform.

The caesium clock was established in 1955, and has an accuracy of better than 1μs per day, and the International Committee of Weights and Measures has declared the emission of caesium as 9, 192, 631, 770Hz.

This emission occurs when the electrons orbitting around an atom fall from a higher energy level to a lower energy level; see Figure 1. The emission is given by the equation:

$$hf = E_1 - E_2$$

Where h = Planck's constant
f = frequency
E_1 & E_2 = energy levels

And since a time period is the reciprocal of frequency, the two are inextricably linked by the equation $T = 1/f$.

Standards for Luminous Intensity and Temperature

The standard of luminous intensity is defined as a Planckian radiator (black body) at the temperature at which platinum solidifies (2,042°K). One-sixtieth of the intensity per square centimetre of this full radiator is called a candela.

The above is a primary standard, and tungsten filament lamps are used as secondary standards. These lamps are operated such that the power distribution in the visible region is the same as that of the primary standard, and this power distribution is achieved by maintaining the correct temperature.

A platinum thermometer is used as a primary standard thermometer, and absolute temperatures are quoted in degrees Kelvin. The triple point of water is the temperature at which ice, liquid water and steam are at equilibrium, i.e. at 273.16°K.

	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	Second	s
Current	ampere	A
Temperature	degree Kelvin	°K
Velocity	metre per second	m/s
Force	Newton	N
Work	Joule	J
Power	Watt	W
Quantity of electricity	Coulomb	Q
Potential difference	Volt	V
Resistance	ohm	Ω
Capacitance	Farad	F
Inductance	Henry	H
Magnetic field strength	ampere/metre	A/m
Magnetic flux density	tesla	T
Magnetic flux	Weber	Wb
Frequency	Hertz	Hz

Table 3. SI Units Fundamental and Derived

Standards for Length and Mass

The metre was represented as the distance between two lines on a platinum-iridium bar kept at the International Bureau of Weights and Measures near Paris. After 1960, the metre was more accurately defined in terms of the wavelength of the discharge from a Krypton-86 lamp. This radiation is orange-red in colour, and is accurate to 1 in 10^6 which is an order of magnitude better than the platinum-iridium bar. The metre is then equal to 1,650,763.73 times the wavelength of this radiation.

Working standards use steel blocks with flat parallel faces of accuracy in the range 0.5 to 0.25 micron (one micron = 1/10^6 metre).

The term mass is used instead of weight, since the weight of a body varies depending on its distance from the earth, whereas mass remains constant. For instance, a 170lb astronaut on earth may weigh only 2 ounces in space.

The international kilogram is kept at the International Bureau of Weights and Measures near Paris. This is accurate to within 1 in 10^8, whereas Laboratory standards are accurate to only 1 in 10^6 and working standards may be accurate to only 5 in 10^6.

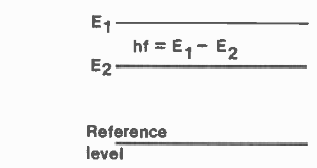


Figure 1. Electron Energy Levels

Standards for Voltage, Current and Resistance

The Weston cell is used as a voltage standard. This cell comes in two forms, saturated and unsaturated. The unsaturated form is more stable at room temperature, but the saturated type produces the voltage more faithfully, hence the saturated type is used as the primary standard.

Figure 2 shows the construction of a saturated Weston cell, where cadmium sulphate crystals cover the electrodes at all temperatures. In the unsaturated variety, saturation occurs only at 4°C. There is a negative electrode of cadmium amalgam with 10% cadmium, and a positive electrode of mercury. The electrolyte is cadmium sulphate. The drift of the saturated cell is -40μV for every degree C increase.

The saturated Weston cell at 20°C is 1.0185V and is kept in an oil bath to keep the temperature constant. The internal resistance of Weston cells is 500-800Ω, therefore the current drawn must not exceed 100μA, or the internal voltage drop becomes significant.

Unsaturated cells are more rugged and therefore used as secondary or working standards.

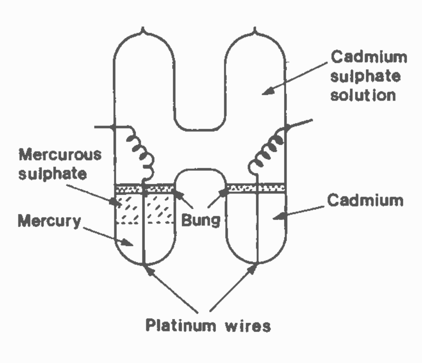


Figure 2. Saturated Weston Cell

The International unit of current, the Ampere, was defined as that current flowing in two parallel conductors placed 1 metre apart in a vacuum, and producing a force between conductors of 2 x 10^{-7} Newton per metre of length.

As may be imagined, a working example of this was difficult to reproduce in any laboratory, and the definition of the International Ampere was changed to that current which would deposit silver from a silver-nitrate solution at a rate of 1.118mg/s.

Once again, it was difficult to measure the rate of deposition, and the International Bureau returned to force measurements in 1948. This time it was defined as the force between two coils, and the current producing this force is called the Absolute Ampere.

The primary standard of resistance is one ohm, made from an alloy like manganin which has a low temperature coefficient, i.e. the resistance does not vary a lot with a change in temperature. Manganin also has high resistivity, e.g. the resistance of manganin per metre is much greater than a metre of say, copper. This means that only a short length is required to make up a standard one ohm. The standard is sealed in a double walled glass jar (see Figure 3), to keep the moisture and temperature constant.

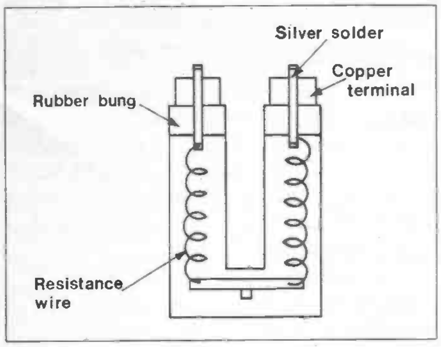


Figure 3. Standard Resistor

Secondary standards are placed in a bath of oil to keep the temperature constant, and the variation in resistance is given by:

$R = R_{25} + m(T-25) + n(T-25)^2$

m, n are temperature coefficients
T is the ambient temperature
R_{25} is the resistance at 25°C

Secondary standards are also made from manganin or Evanohm, and mounted between polyester film to support the wire. The connections are soldered with silver.

Standard Capacitors and Inductors

Standard capacitors are made of metal plates with air as the dielectric. Working standards also use air dielectric capacitors for small values of capacitance. Large values of capacitance employ solid dielectrics like silver-mica which are fairly stable.

Inductors are available from 100μH to 10H, and mutual inductance standards from 0 to 200mH.

Magnetic Flux Standard

The Hibbert method (see Figure 4), for measuring magnetic flux, is a simple and useful one. A container made of soft iron contains a permanent magnet, and a hollow brass cylinder has windings of insulated copper. A catch releases the cylinder which drops through the air gap, cutting the flux and inducing current in the windings.

The flux is cut at a constant rate, since the gravitational force pulling the brass cylinder is constant. The current in the windings is therefore proportional to the flux in the gap.

Transducers

A transducer is a device which converts energy from one form to another. Examples that readily spring to mind are the loudspeaker and microphone. The loudspeaker converts electrical energy into sound energy, and a microphone does the opposite.

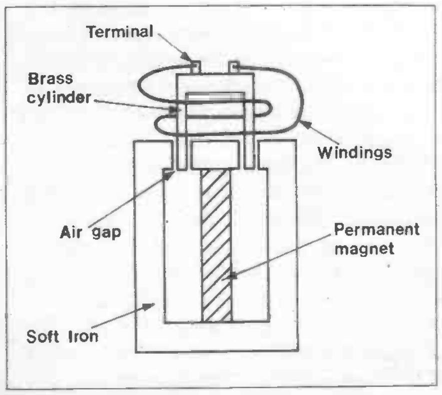


Figure 4. Hibbert Standard for Magnetic Flux

Very often measurements and instrumentation require that a non-electrical quantity be measured and converted to an electrical quantity, so that it may be displayed on a meter. For instance, engine revolutions (a mechanical quantity), need to be displayed on a meter on a motor car's dashboard.

The forms of energy that may need measurement are:

Heat, light, sound, mechanical, electrical and chemical.

Transducers used to measure these, fall broadly into two classes:

Active and passive.

The active ones produce a current or voltage which can be used to drive a meter directly. The passive ones rely on changing resistance or inductance or capacitance, and require an external source of power for measuring the change in these components. Some examples of active transducers are:

a. Piezoelectric crystals which produce a voltage when flexed mechanically, for example as used in record player pick-up cartridges.
b. Thermocouples to measure temperature. When a junction of two dissimilar metals is heated, an e.m.f. is produced.
c. Photovoltaic cells are used in light meters. Light falling on a semiconductor junction results in a potential difference, which operates an indicator.

Some examples of passive transducers are:

a. Pressure and displacement can be measured by altering the position of a core in an inductor. This changes the inductance, which must be measured in order to compare it with a reference point, i.e. core fully in or fully out.
b. Pressure and displacement can also be measured by varying the distance between the plates of a capacitor, or by changing the dielectric, e.g. a rising liquid. The liquid of higher dielectric constant displaces the air between the capacitor plates.
c. Temperature can be measured by altering the resistance of a wire. For this purpose, a metal with a large temperature coefficient, e.g. platinum needs to be used. These large changes are then readily measured. The above are resistance thermometers and made from pure metals, whereas thermistors are metal oxides with negative temperature coefficients and therefore used for temperature compensation in electrical circuits.

We shall take a broad look at how transducers can be used as photosensitive devices, temperature devices, and in displacement and strain measurements.

Photosensitive Devices

These can be either tubes, or valves, or solid state devices. The valves may be either vacuum or gas filled, the latter being used as a sound on film detector in cine-projectors, and the former for higher frequency applications.

Multiplier tubes are useful for detecting

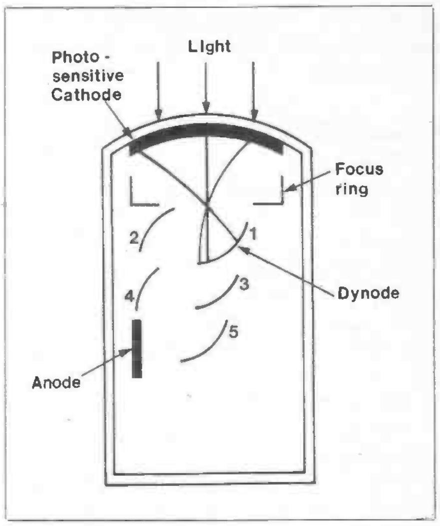


Figure 5. Photomultiplier Tube

low intensity light, which is then amplified up to 10^6 times by the multiplier, see Figure 5. The intermediate reflectors between the cathode and anode are called dynodes and up to six electrons are emitted for every electron hitting a dynode.

Semiconductor devices may be photovoltaic or photoconductive, i.e. they either produce a voltage or a current when light falls on them.

Apart from lightmeters, photovoltaic cells can be used as solar cells. The structure is a 0.5 micron layer of n-type semiconductor diffused into a single crystal of p-type material about 2cm square.

Photoconductive cells are made from silicon and germanium. The cadmium sulphide cell in particular has a response that matches the human eye and is therefore, used in the control of camera shutters and switching of street lamps. The voltage-current characteristic of a photosensitive diode with and without illumination is shown in Figure 6.

In general, photosensitive devices are more sensitive than the human eye. Their range is also greater and extends into the ultraviolet and infra-red.

Temperature Devices

Thermal resistors or thermistors are made from the oxides of copper, iron, nickel, cobalt, manganese and uranium. They are made into discs and beads. The discs are from 2.5mm to 2.5cm in diameter, and the beads from 0.1mm to 1.3mm.

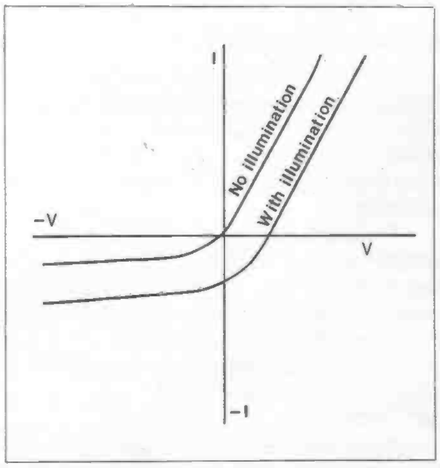


Figure 6. Photodiode Characteristic

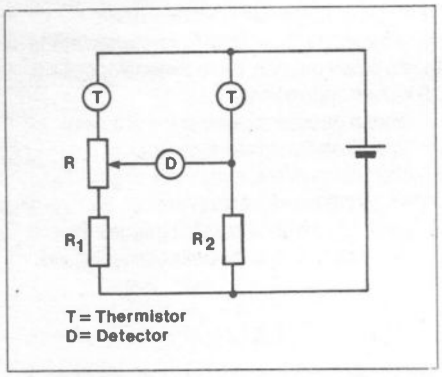


Figure 7. Thermistor Application in Air Flow Measurement

The resistance of these devices varies from about 1 ohm to 75M ohm, in a variety of resistance ranges depending on requirements. Most have a negative temperature coefficient, that is with the resistance dropping about 6 percent for every 1°C rise in temperature. The temperature range is excellent from +300°C down to −100°C.

Bridges are often used to detect small changes in resistance, and Figure 7 shows how two thermistors can be used to measure the flow of air; both are heated by the current flowing in them to a moderate degree. If one thermistor is sealed in a brass cavity to provide a stable temperature environment, and acts as the reference, then the other can be mounted in a tube to measure the rate of air flow. With no air flowing the bridge is balanced, but when air flows through the tube, the thermistor cools and the resistance increases.

This unbalances the bridge, and a new balance point needs to be found. If the bridge detector is a meter, it can be calibrated directly in terms of rate of flow. The thermistor-bridge combination is sensitive enough for detecting flow rates as low as 0.001 cubic centimetres per minute. An interesting application follows from the above. A carbon dioxide analyser for setting up motor car carburettors can be designed. As before, the thermistor in the brass block is the reference. Now carbon dioxide has a lower thermal conductivity than air, and so the other thermistor gets hot and therefore lower in resistance. The bridge needs to be re-balanced, and once again the meter détector can be calibrated for varying proportions of carbon dioxide in air.

The physicist Thomas Seebeck discovered that if a junction of two dissimilar metals is heated, a current will flow which is proportional to the temperature. This is called the Seebeck effect, and is the principle of all thermocouples. Figure 8 shows how a meter can be connected in a thermocouple circuit. Since the meter may be several yards away

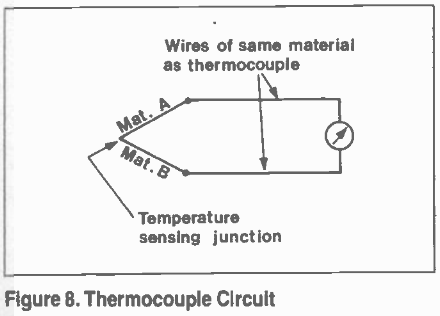


Figure 8. Thermocouple Circuit

from the thermocouple, accuracy is maintained if the leads to the meter are of the same materials as the thermocouple itself.

Typical thermocouple materials are iron-constantan with a temperature range up to 2200°F, and platinum – Platinum/rhodium up to about 300°F.

Resistance thermometers, in combination with bridges, are popular in the range −180°C to +630°C because of their high accuracy.

Pure metals like copper, platinum and nickel are also used. Figure 9 shows the change in resistance of these with temp-

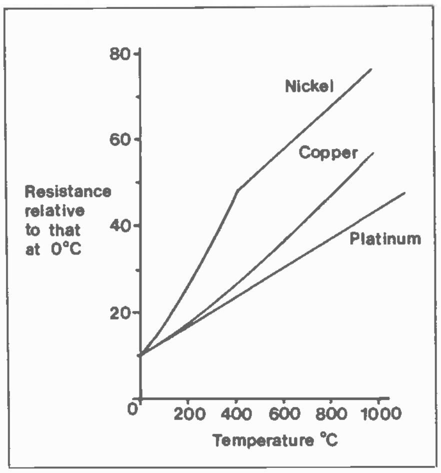


Figure 9. Resistance/Temperature Response

erature. The resistance R at any temperature t, can be calculated from:

$$R = Ro\,(1 + a\frac{dy}{dx}t).$$

Where Ro is the temperature at 0°C

$\frac{dy}{dx}$ is the gradient

'a' is the temperature coefficient of resistance.

Both nickel and copper are cheaper than platinum, but since the response of nickel is

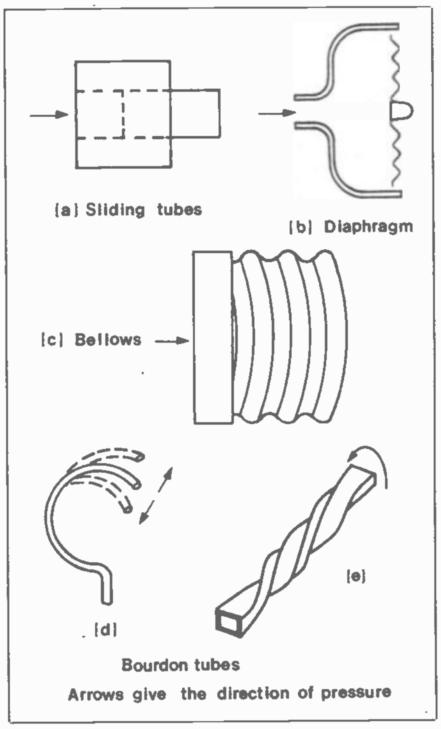


Figure 10. Force Summers

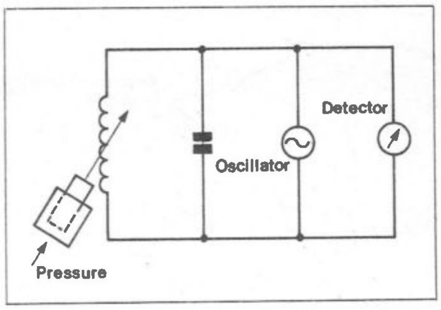


Figure 11. Physical Displacement changes the Frequency

not linear, it is useful only up to 150°F. Copper is good between −325°F and +250°F. Although platinum is useful between −300°F and +1500°F, its response time is slow, typically 15 seconds.

Often these thermometers are used to measure temperatures of liquids, and gases under high pressure, for example in pumping stations, steam engines and pipelines. In some of these applications, the pressure could exceed 45lb/sq. inch and therefore, these thermometers are mounted inside protective wells.

The well is made by drilling a solid bar of steel and the temperature is sensed through a coupling head.

Displacement Measurements

Any displacement needs to be converted to a change in resistance, capacitance or inductance so that it can be measured. These transducers are sometimes called force summing devices.

Some examples of force summing devices are shown in Figure 10. Displacement can be indicated by pushing one tube through another Figure 10a, flexing a diaphragm Figure 10b, or bellows Figure 10c. Bourdon tubes Figure 10d and 10e are not obvious choices but are, nevertheless quite effective.

Let us see how some of these could be used in circuits. The tube of Figure 10a could for instance displace the core of an inductor. Instead of measuring inductance, we could measure frequency (Figure 11) and therefore, a change in frequency.

The same circuit of Figure 11 could be used, but this time using a fixed inductor and a variable capacitor, Figure 12.

Figure 13 shows how a Bourdon tube can be used to change the reluctance of a magnet. The applied force tends to untwist the tube, bringing the armature closer to the magnet. Once again, the magnet's coil could be used in an oscillator circuit.

Potentiometers can also be used to measure displacement. Potentiometers can be of either the slide wire type or carbon deposited. The displacement changes the setting of the potentiometer which alters the

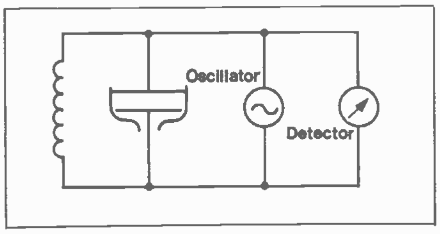


Figure 12. Capacitance Transducer

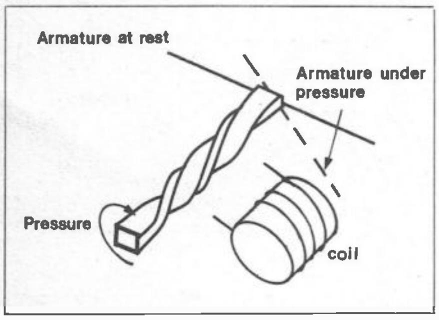


Figure 13. Bourdon Tube in Circuit

resistance. This change in resistance then alters the setting of a meter which is already in the circuit. The disadvantage is that potentiometers wear out quickly and get noisy with use.

Piezo-electric crystals (Rochelle salt, barium titanite and quartz) produce an e.m.f. when stressed. Therefore, these can be used to measure small displacements. The principal disadvantage being that they cannot measure static conditions, i.e. there is no e.m.f. when force is absent. The main advantage, on the other hand, is that they produce their own e.m.f., they can measure small changes and are useful if the stresses are continuously varying.

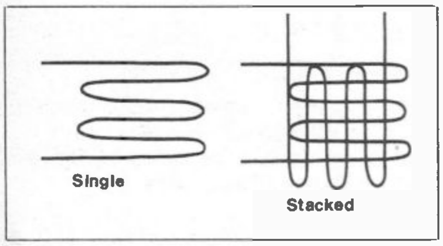


Figure 14. Wire Strain Gauges

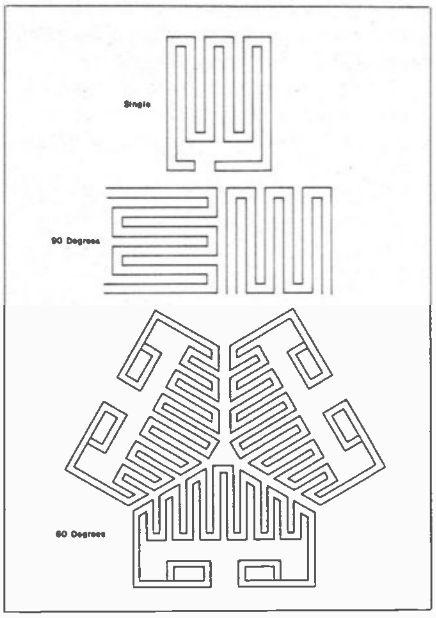


Figure 15. Foil Strain Gauges

Strain Gauges

The general requirement for strain gauges is for a linear characteristic, i.e. if a wire is stretched, the change in resistance must be proportional to the stretching over the useful range. Another requirement must be for the adhesive to hold the strain gauge to the sensor under varying temperature and humidity conditions.

Some of the materials used are Constantan (60% copper, 40% nickel), Platinum-tungsten and Dynaloy (nichel-iron). Stabiloy and Nichrome are also used. Both are combinations of nickel and chrome of varying percentage.

Most of these can operate in temperatures of 300°C to 1000°C, and when made up into strain gauges, have dimensions of 1 x 0.5 inches approximately.

Strain gauges may be in the shape of wire or foil, and can measure strain in one direction or in several directions. Figure 14 shows wire gauges singly and stacked. Similarly, Figure 15 shows foil gauges for measuring a single force or forces at 90° and 60°.

General Notes on Transducers

Transducers need to be sturdy, since they often operate in difficult conditions of temperature, moisture and mechanical stress. They may also need to operate in chemically hostile environments, or under pressure as in pipelines.

Transducers need to be linear or logarithmic or follow some known law so that their outputs can be interpreted and displayed by electrical circuits. As a result, transducers may be deliberately operated on the required part of their characteristic. But because of the hostile conditions in which transducers operate, they may exhibit failure when their characteristics depart from the expected.

Finally, this article has explored how a non-electrical quantity can be measured electrically. It must be noted that some transducers are reversible, i.e. if a voltage is applied they may exhibit movement etc.

In other instances, the arrangements may be slightly different. For example, a microphone serves the opposite purpose to a loudspeaker, yet speaking into a loudspeaker would not produce a significant voltage for transmission.

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VARIOUS FOR SALE

MULTIMETER ETU 101 1000Ω/V. In mint condition, still with original carton and battery only occasionally used. £3.50 + P&P. Mr K. Lord, 82 Rosefold Road, Sundon Park, Luton, Beds. LU3 3HH.

TWO LITESOLD SOLDER POTS 60W and 100W £12 each. Connoisseur BD1 Turntable Deck with arm, cartridge and stylus £20. Transformer suitable for amplifier etc. Offers. Please telephone 01-568 5014.

SMITHS FUEL COMPUTER Brand new, still in box. Unwanted gift. £25 ono. Tel: (0533) 897268.

POLAROID ULTRASONIC Ranging System. Designer's Kit detecting presence and distance of objects 0.9 to 35 feet. The distance between transmission is converted to a LED display. £45. Tel: (0484) 25589.

IBM ELECTRIC GOLFBALL Teleprinter suitable for Maplin Project. Serviced and tested. £50. Tel: Reading 692481.

TELEQUIPMENT DUAL TRACE OSCILLOSCOPE D33 working, £65. Solartron Dual Trace Oscilloscope, no tube (electronics working), £5. Several electrostatic CRT's, 25p to £1 each. Tel: Farnborough (Kent) 55966.

HEATHKIT SHELF-TOP DIGITAL CLOCK with full Westminster chimes (GC-1197 GCA-1195-1). Brand new, fully assembled, never used. Now costs £280 but will accept £225 ono. Tel: Southend 711181.

COMPUTERS

ATARI 400 48K COMPUTER plus 410 program recorder, lightpen, joystick, assembler cartridge and manual, many books, manuals and memory map plus some software. Absolute bargain £100 o.n.o. Tel: 0536 200038.

ATOM COMPUTER with extra EPROMS, £29. ASCII Keyboard with numeric pad, in 'tangerine' metal enclosure, £19. Microtan-65, tanex, mini-motherboard & HEX keypad, £25. 3-octave Keyboard with contacts, £15. Vincent Fojut, 39 Arderne Road, Timperley, Altrincham, WA15 6HN. Tel: 061-969 2710 after 6pm.

WANTED Issue Three ZX81. Must be working. Also 16k Rampack. Reasonable prices paid. Contact: Mr N. Bingham, 108 Drumgooland Road, Ballyward, Castlewellan, Co. Down. BT31 9QX.

If you would like to place an advertisement in this section, here's your chance to tell Maplin's 200,000 customers what you want to buy or sell, or tell them about your club's activities – absolutely free of charge. We will publish as many advertisements as we have space for. To give a fair share of the limited space, we will print 30 words free of charge. Thereafter the charge is 10p per word. Please note that only private individuals will be permitted to advertise. Commercial or trade advertising is strictly prohibited in the Maplin Magazine.

Please print all advertisements in bold capital letters. Box numbers are available at £1.50 each. Please send replies to Box Numbers to the address below. Please send your advertisement with any payment necessary to: Classifieds, Maplin Mag., P.O. Box 3, Rayleigh, Essex SS6 8LR.

For the next issue your advertisement must be in our hands by 30th June 1986.

CLUBS

INTERESTED in Supernatural Electronics Applications? You better get APM, the newsletter for young Amateur Parapsychologists everywhere. 20p plus SAE to Simon Green, 19 Chequers Park, Wye, Ashford, Kent. TN25 5BB.

MUSICAL FOR SALE

MAPLIN 5600S SYNTHESISER for sale half complete with case. First offer £200 or more will secure. Tel: (0803) 665388 after 5pm.

MAPLIN PIANO built/working needs attention to increase touch sensitivity. £150 o.n.o. Mr. I. Spearman, No. 18 Queensway, Shelley, Ongar, Essex or phone Ian on 0277 362197/364485.

KEYBOARDS 3, 4 & 5 OCTAVE £5 per octave. MES 55 Auto-Organ, £20 ono. Apple Software, Incredible Jack, Integrated Word-processor, Database and Calculator. £35 ono. Tel: Durham (0385) 854734.

QUERY! Pensioner having repeated trouble with noisy Swell Pedal in Maplin Organ. Has anyone fitted volume control from January 82 EMM Magazine with success? Mr E. Matthews, 63 The Oval, Otley, West Yorkshire, LS21 2EE.

WERSI HELIOS W2S ORGAN superb condition, offers around £1,750. Also Helios in custom-built Cabinet based on W2T design, offers around £1,250. Tel: Abingdon (0235) 831391.

SIEL ELECTRIC ORGAN 2 x 27 keyboards, 13-pedal, 5 voices, vibrato, rhythm section, auto-chord. Little used, as new £180. Tel: Giltrow, Preston 747585.

MAPLIN 5600S SYNTHESISER plus custom-built Stand. Synth built to a professional standard, hardly used. Genuine reason for sale. £650 ono. Robert Snelling, Tel: Watford (0923) 36486.

WANTED

TEST EQUIPMENT: Oscilloscope; Digital Multimeter; Signal Generator; Capacitance Meter; RF, AF oscillator; Power Supply; CRT tester; Logic Probe; Flashing Beacon; Programmable Timer External Horn. Kirit, 1 Fisby Road, Leicester.

CIRCUIT DIAGRAMS or plans for an FM/VHF Transmitter, range approx. 5-10 miles. All help is welcome. Send to: R. Lewis, 16 South Hill Grove, Harrow, Middlesex, HA1 3PR.

'ELECTRONICS - THE MAPLIN MAGAZINE' Issue Nos. 3, 10, 11, 16, 17. I will pay 75p each plus postage. Contact: Tim Scott, 4 Studley Close, Romanby, Northallerton, DL7 8HZ. Tel: (0609) 6766.

'ELECTRONICS - THE MAPLIN MAGAZINE' Nos. 1 to 4. Offers to: M.G. Harper, 3 Windsor Drive, Cleadon, Nr. Sunderland, Tyne & Wear, SR6 7SY.

DO YOU HAVE any items of 'Green' RACAL Tactical Equipment? Collector requires TRA931, TRA967, MA988, TA940, TA944, MA937, MA949, TA970, antennas, mounting frames, connectors, spares, manuals, brochures. Purchase or exchange. Write to: W.H.Y.? Racallector, 120 Birmingham Road, Redditch, Worcs. B97 6EP.

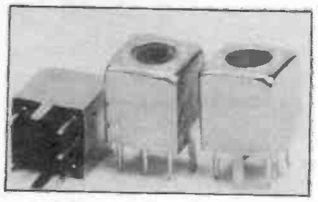
INSTRUCTION MANUAL for Digital Multimeter Module PCIM 176 REV. G. Write to: Osei - Asiedu, Waldhausweg 15, Zi. 711002, 6600 Saarbrucken; W. Germany.

'ELEKTOR' MAGAZINE May 1982, issue 85. Will pay up to £3. Write to: Graham Daley, 97 Barras Avenue West, Blyth, Northumberland, NE24 3LR.

NEW PRODUCTS

RF/Antenna and Oscillator Coils

Five RF/Antenna or oscillator coils are now available. All coils are fitted in screening cans to the standard miniature size of 10mm square x 12mm high. Pins are spaced on 7mm base. Ferrite tuning core is included. The five types cover the AM to SW bands and are shown in the table.



Order As

CAN1A350EK (FD00A)	*Price 88p*
RWR331208 (FD01B)	*Price 55p*
KANK3333R (FD02C)	*Price 55p*
KANK3334R (FD03D)	*Price 55p*
KANK3335R (FD04E)	*Price 55p*

Type	Function	Colour	Q	Inductance
CAN1A350EK	LW RF/antenna coil	Red	100	3.5mH
RWR331208	MW RF/oscillator	Red	70	330μH
KANK3333R	SW1 RF/antenna	Violet	60	45μH
KANK3334R	SW2 RF/antenna	Yellow	85	5.5μH
KANK3335R	SW3 RF/antenna	Pink	80	1.2μH

Large Size Positive Photoresist Aerosol Spray

A larger size 200g aerosol can of Positive Photoresist for coating copper clad board, to complement the 75g aerosol currently in the catalogue (YJ98G). To use, first use a fine grade emery cloth or polishing block to remove dust, dirt, grease, fingermarks and oxide from the copper surface. Rinse well and dry thoroughly. The coating must be applied in subdued light. Shake the can, place the board horizontally in a dust-free area, then

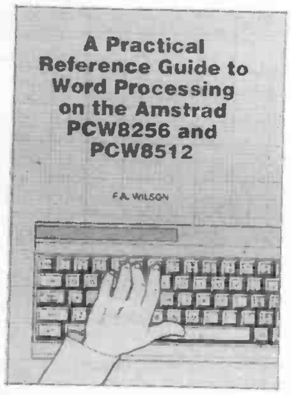
holding the can at a 30° to 45° angle, from a distance of 20 to 30cm spray with smooth strokes in a zig-zag pattern. Leave in low light for 5 minutes until touch-dry. Move to a dark well-ventilated area and leave for 24 hours (or heat to 80°C for 15 minutes, but do *not* use an open flame or incandescent element). The board may now be used in the normal way, with our UV Light Box.

Order As YM62S
200g Photoresist Aerosol Price £3.98

A Practical Reference Guide to Word Processing on the Amstrad PCW8256 & PCW8512

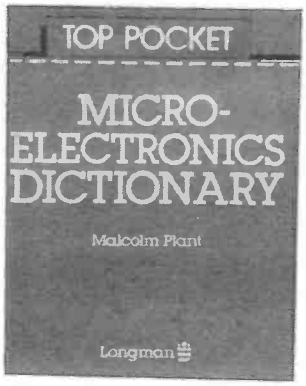
by F.A. Wilson

With the PCW8256 and 8512 Amstrad have now brought word processing within the reach of everyone. These machines are capable of manipulating letters and words in practically every conceivable way, and what can be achieved with them is probably limited only by the user's ingenuity.



It may come as no surprise to find that each machine is provided with *two* instruction manuals, the bulk of which is likely to put off the most enthusiastic new-comer. Hunting through the manuals for the information required could be a daunting task and even then it may not be fully understood.
This indispensible book has been especially written to complement these manuals, offering much practical advice and explanation, and includes easy to follow step-by-step charts to guide the inexperienced through many complex procedures. The book includes a comprehensive reference section for the manuals, and has itself been entirely prepared by the author to produce camera-ready copy for the final printed pages, using a PCW8256.

Order As WP42V
Wrd Proc on PCW8256-8512
Price £5.95 NV



Micro-Electronics Dictionary

by Malcolm Plant

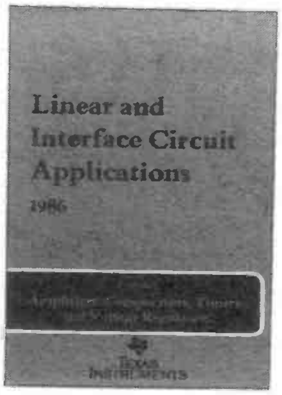
A pocket sized A to Z dictionary of terms used in electronic engineering, microelectronics, space research, medicine, telecommunications, computer science and hardware, electronic components and consumer products. Begins with an introduction describing the manufacture of silicon chips for transistors and IC's.
1985. 114 x 90mm, 218 pages.

Order As WP46A
Micro Elec Dictionary
Price £1.50 NV

Linear and Interface Circuit Applications Vol. 1

Texas Instruments

Although naturally biased towards the circuit applications of IC devices made by Texas, this book nevertheless would prove to be an extremely useful and educational reference book, design manual or library of circuit building blocks. Eight sections cover a wide range of IC devices and their applications from op-amp theory to frequency synthesisers and staircase generators. All specific parameters and specifications are covered in depth under various headings, supported by copious circuit/block diagrams qualified by not too complex mathematics where relevant.
The various main headings are: Op-amps and Comparators – theory, performance characteristics, op-amp amplifiers, comparators, active filters, audio amplifiers, oscillators, choosing an op-amp type. Video Amplifiers. Voltage Regulators – applications, layout and input supply design, fixed, variable, shunt, battery charger, general purpose and specialised. Switch Mode Power Supplies – converters, step-up, step-down, push-pull, half/full wave, generating the



switching waveform, designing, protection circuitry and safety considerations for power supplies. Integrated Circuit Timers – the 555 timers, internal functions, operating modes, application circuits, programmable timer/counter, cascaded timers.
1986. 210 x 148mm, 304 pages, illustrated.

Order As WP45Y
Lin Cct Applctns
Price £8.00 NV

More Advanced Electronic Music Projects

by R.A. Penfold

Complementing 'Electronic Music Projects' by the same author, this book carries on from where the former left off providing a selection of somewhat

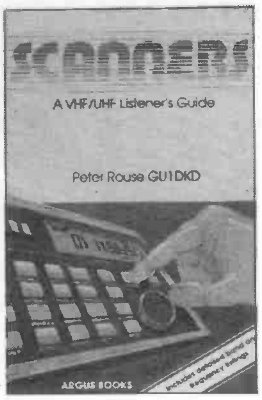
more advanced projects in a similar vein. These include popular effects units such as a Flanger, Phaser, Mini-Chorus and Ring modulator circuits. Also described are some useful percussion synthesisers providing a comprehensive range of effects including drum, cymbal and gong sounds. Each project is presented individually with an introduction, circuit description with diagrams, and all necessary constructional and setting-up details. Pcb layouts and other special construction details have not been included however, as these very much depend on the final application according to the individual wishes of the constructor. Therefore this book is not recomended for the absolute beginner, but anyone who has had some experience in building up electronic projects and have worked with veroboard should not have difficulty in tackling most of the projects in this book.
1986. 178 x 112mm, 82 pages, illustrated.

Order As WP44X
More Adv Elec Music Proj
Price £2.95 NV

Scanners - a VHF/UHF Listeners's Guide

by Peter Rouse GU1DKD

The first complete British guide to VHF/UHF listening, this book explains in simple terms how the VHF and UHF



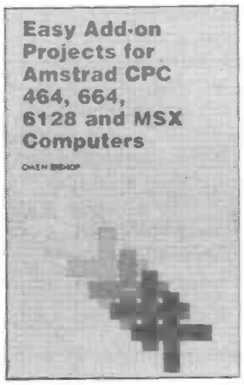
bands are allocated to different users. Subjects covered include the equipment, accessories and aerials, and explains basic radio theory, modes, and simplex and duplex transmission, installation and use.
A most useful feature is the inclusion of full British wave-band charts from 26MHz to 1300MHz, including aviation, marine, amateur, emergency services, satellites (amateur, military, communication, navigation, weather, including the COSMOS and NASA Space Shuttle frequencies), cordless telephones, cellular radio, beacons, pagers, message handling, private mobile radio (PMR), radio microphones, telemetry, industrial, scientific and medical etc. Also explained is how to interpret what is being said when 'RT procedure' is being used. A review of equipment currently available in the UK with a list of importers and suppliers is also provided.
1986. 234 x 154mm, 180 pages, illustrated.

Order As WP47B
Scanners *Price £7.95 NV*

Easy Add-On Projects for Amstrad CPC 464, 664, 6128 and MSX Computers

by Owen Bishop

Seventeen projects which can be used with the Amstrad CPC 464, 664, 6128 or MSX computers. The projects include a Picture Digitiser, Five-Key Pad, Model Controllers, Bleeper, Lamp Flasher, Magnetic Catch, Lap Sensor, Photo-Flash, Games Control, Data Selector and six more projects that make up a Weather Station.
All of the projects are fairly simple and



inexpensive to build, and a complicated Address Decoder does not need to be made first since the computer is accessed via its joystick or printer ports.
1986. 178 x 112mm, 154 pages, illustrated.

Order As WP43W
Add-on Proj for CPC464, 664, 6128 & MSX *Price £2.95 NV*

MAPLIN'S TOP TWENTY KITS

THIS MONTH	LAST MONTH	DESCRIPTION OF KIT	ORDER CODE	KIT PRICE	DETAILS IN PROJECT BOOK
1.	(1)	Live Wire Detector	LK63T	£3.50	14 (XA14Q)
2.	(3)	100W Mosfet Amplifier	LW51F	£17.95	Best of E&MM
3.	(2)	Partylite	LW93B	£9.95	Best of E&MM
4.	(6)	Ultrasonic Intruder Detector	LW83E	£11.95	4 (XA04E)
5.	(5)	U/Sonic Car Alarm	LK75S	£17.95	15 (XA15R)
6.	(4)	Car Burglar Alarm	LW78K	£7.95	4 (XA04E)
7.	(7)	8W Amplifier	LW36P	£5.95	Catalogue
8.	(–)	Car Battery Monitor	LK42V	£7.50	Best of E&MM
9.	(9)	PWM Motor Driver	LK54J	£9.95	12 (XA12N)
10.	(10)	15W Amplifier	YQ43W	£6.50	Catalogue
11.	(–)	Stepper Motor and Driver	LK76H	£15.95	18 (XA18U)
12.	(11)	Logic Probe	LK13P	£14.95	8 (XA08J)
13.	(8)	Computadrum	LK52G	£11.95	12 (XA12N)
14.	(15)	Burglar Alarm	LW57M	£59.95	2 (XA02C)
15.	(16)	Harmony Generator	LW91Y	£17.95	Best of E&MM
16.	(12)	Light Pen	LK51F	£8.95	12 (XA12N)
17.	(–)	Noise Gate	LK43W	£10.95	Best of E&MM
18.	(–)	Infra-red Movement Detector	LK33L	£34.95	9 (XA09K)
19.	(–)	50W Amplifier	LW35Q	£17.95	Catalogue
20.	(19)	DXer's Audio Processor	LK05F	£9.95	7 (XA07H)

Over 150 other kits also available. All kits supplied with instructions.
The descriptions above are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate Project Book mentioned in the list above – see inside back cover for details.

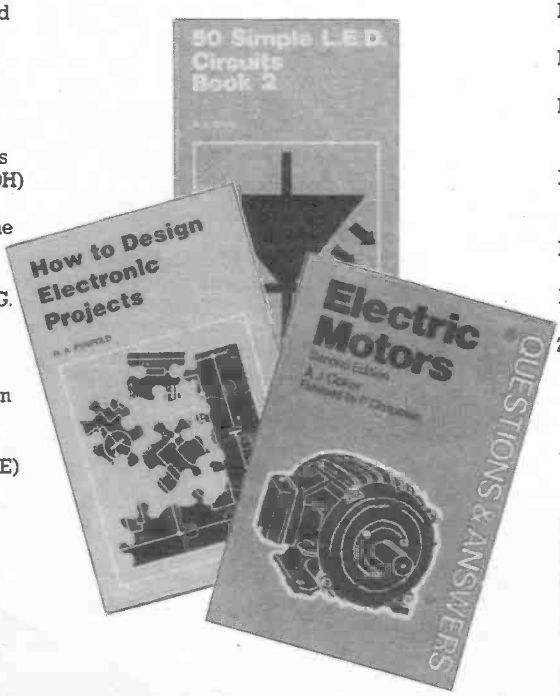
CORRIGENDA

Vol. 5 No. 17
Golfball Printer: On page 26 at the end of the first paragraph, it states "A similar arrangement for CR, C5 and C7." This should read C2, C5 and C7.

Vol.5 No. 18
Fantastic Five: In the Parts List for the Clap Switch, DIL socket 14-pin (BL18U) should be: DIL socket 16-pin (BL19V).

TOP TWENTY BOOKS

1. (1) Loudspeaker Enclosure Design and Construction. (WM82D) Cat. P52.
2. (3) Power Supply Projects, by R.A. Penfold. (XW52G) Cat. P49.
3. (2) Remote Control Projects, by Owen Bishop. (XW39N) Cat. P50.
4. (4) International Transistor Equivalents Guide, by Adrian Michaels. (WG30H) Cat. P45.
5. (16) An Introduction to Programming the Atari 600/800XL, by R.A. and J.W. Penfold. (WM80B) Cat. P63.
6. (11) Radio Control for Beginners, by F.G. Rayer. (XW66W) Cat. P50.
7. (5) Mastering Electronics, by John Watson. (WM60Q) Cat. P48.
8. (7) How to Design and Make Your Own PCB's, by R.A. Penfold. (WK63T) Cat. P48.
9. (6) IC555 Projects, by E.A. Parr. (LY04E) Cat. P51.
10. (19) How to Use Op-amps, by E.A.Parr. (WA29G) Cat. P47.
11. (12) Electronic Music Projects, by R.A. Penfold. (XW40T) Cat. P53.
12 (–) 50 Simple LED Circuits Book 2, by R.N. Soar. (WG43W) Cat. P52.
13. (13) Counter Driver & Numeral Display Projects, by F.G. Rayer. (XW34M) Cat. P52.



14. (–) Electronic Security Devices, by R.A. Penfold. (RL43W) Cat. P50.
15. (10) Audio Amplifier Construction, by R. A. Penfold. (WM31J) Cat. P52.
16. (15) How to Get Your Electronic Projects Working, by R.A. Penfold. (WA53H) Cat. P48.
17. (20) Electronic Household Projects, by R.A. Penfold. (XW44X) Cat. P49.
18. (–) How to Design Electronic Projects, by R.A. Penfold. (WM67X) Cat. P48.
19. (9) A Z80 Workshop Manual, by E.A. Parr. (WA54J) Cat. P59.
20 (–) Questions and Answers on Electric Motors, by A.J. Coker and P. Chapman. (RR02C) Cat. P43.

These are our top twenty best selling books based on mail order and shop sales during January, February and March 1986. Our own magazines and publications are not included. The Maplin order code of each book is shown together with page numbers for our 1986 catalogue. We stock over 500 different titles, covering a wide range of electronics and computing topics.

DID YOU MISS THESE ISSUES?

Project Book 1 Universal Timer. Programmable mains controller. **Combo-Amplifier.** 120W MOSFET power amp. **Temperature Gauge.** 10°C - 100°C, LED readout. **Pass The Bomb!** Pass-The-Parcel with a difference. **Six easy-to-build Projects on Vero-board.** Car batt. monitor; Colour snap game; CMOS Logic Probe; Peak Level meter; Games timer; Multi-colour pendant.
Order As XA01B (Maplin Project Book No. 1)
Price 75p *NV*.

Project Book 2 Digital Multi-Train Controller. Controls up to 14 model trains. **Home Security System.** Six in-dependant channels. **Digital MPG Meter.** With large LED display, a must for more economical motoring.
Order As XA02C (Maplin Project Book No. 2)
Price 75p *NV*.

Project Book 3 ZX81 Keyboard. 43 keys, plugs directly into ZX81 with no soldering. **Stereo 25W MOSFET Amp.** 25W r.m.s per channel; Disc, Tape, Tuner & Aux. **Radar Intruder detector.** 20 metres range, may be used with our security system. **Remote Control for Train Controller.** Remote control by infra-red, radio or wire.
Order As XA03D (Maplin Project Book No. 3)
Price 75p *NV*.

Project Book 4 Telephone Exchange. Up to 32 extensions on 2-wire lines. **Remote Control for Amplifier.** Volume, balance and tone controlled via infra-red link. **Frequency Counter.** 8 digit DFM, 10Hz - 600MHz range. **Ultrasonic Intruder Detector.** Areas up to 400 square feet can be covered.
Order As XA04E (Maplin Project Book No. 4)
Price 75p *NV*.

Project Book 5 Modem. 300 baud transmission speed over normal telephone lines. **Inverter.** 240V AC 60W from 12V car battery. **ZX81 Sound Generator.** 3 tone generators fully controlled from BASIC. **Central Heating Controller.** Optimised performance with this advanced system. **External Horn Timer.** Exterior intruder alarm. **Panic Button.** Add on to our Home Security System. **Model Train Projects.** Add on to our Multi-Train Controller. **Interfacing Micro processors.** How to use parallel I/O ports, with circuits.
Order As XA05F (Maplin Project Book No. 5)
Price 75p *NV*.

Project Book 6 VIC20 & ZX81 Talkbacks. Speech synthesis projects. **Scratch Filter.** Tunable active circuit 'reclaims' scratched records. **Bridging Module.** Converts two 75W MOSFET amps to one 400W full bridge amplifier. **Moisture Meter.** Finds damp in walls and floors. **ZX81 TV Sound and Normal/Inverse Video.** TV sound and inverse video direct. **Four Simple Veroboard Projects.** Portable Stereo Amp; Sine Generator; Headphone Enhancer and Stylus Organ.
Order As XA06G (Maplin Project Book No. 6)
Price 75p *NV*.

Project Book 7 CMOS Crystal Calibrator. For amateur radio receiver calibration. **DX'er's Audio Processor.** Improved sound from Communications Receivers. **Enlarger Timer.** An accurate timer for the darkroom. **Sweep Oscillator.** Displays AF frequency response on an oscilloscope screen. **VIC20 and ZX81 Interfaces.** RS232 compatable.
Order As XA07H (Maplin Project Book No. 7)
Price 75p *NV*.

Project Book 8 Spectrum Modem/RS232 Interface. 2400 baud self contained operating system. **Synchime.** Simulates bells, gongs and other chiming sounds. **Dragon 32 RS232/Modem Interface.** Plugs into ROM expansion port. **Codelock.** Programmable electronic lock. **CMOS Logic Probe.** Digital display shows logic states. **Minilab Power Supply.** Versatile unit for the test bench. **Dragon 32 I/O Ports.** Two 8-bit ports. **Doorbell for The Deaf.** Flashing lamp attracts attention.
Order As XA08J (Maplin Project Book No. 8)
Price 75p *NV*.

Electronics Issue 9 Spectrum Keyboard. 47 full travel keys. **VIC Extendiboard.** Three expansion ports, one switchable. **Oric Talkback.** Speech synthesiser for the Oric 1. **Infra-Red Movement Detector.** 30 metres range outdoors. **TDA7000 FM Radio.** Complete FM receiver on a chip. **ZX81 High Resolution Graphics.** 256 x 192 fine pixel display. **Ten Projects!** Personal Stereo Dynamic Noise Limiter; Logic Pulser; ZX81 1K Extendi-RAM; TTL/RS232 Converter; Pseudo Stereo AM Radio; and more.
Order As XA09K (Maplin Magazine Volume 3 Issue 9) Price 70p *NV*.

Project Book 10 Spectrum Easyload. Helps cassette loading with the Spectrum. **80m Receiver.** Simple SSB direct conversion receiver. **Fluorescent Tube Driver.** 8W 12V for camping and caravanning. **Auto-Waa.** Automatic waa-waa effects unit. **Digi-Tel Expansion.** Expands Maplin Telephone Exchange to 32 extensions. **Oric 1 Modem Interface.** Adapts the Oric 1 to the Maplin Modem. **Dragon 32 Extendiport.** Makes the Dragon's cartridge socket more accessible.
Order As XA10L (Maplin Project Book No. 10)
Price 75p *NV*.

Project Book 11 Mapmix. Six channel audio mixer. **Xenon Tube Driver.** Xenon flash tube module with strobe. **Enlarger Exposure Meter.** Simple inexpensive tool for the darkroom. **8 Channel Fluid Detector.** Check control fluid level in up to 8 containers. **Servo & Driver Module.** Servo mechanism with driver module kit. **Mk II Noise Reduction Unit.** Improves signal/noise ratio of tape recordings. **Cautious Ni-Cad Charger.** Controlled charging of ni-cad cells. **Motherboard for The BBC Micro.** Gives easy access to ports.
Order As XA11M (Maplin Project Book No. 11)
Price 75p *NV*.

Project Book 12 RTTY Unit. The TU1000 receives/transmits Radio Teletype; connects to computer via RS232. **Computadrum.** Use your computer as a drum synthesiser. **Light Pen.** Draw onto the TV screen or select menu options. **PWM Motor Drive.** Reversible model motor driver for 6V and 12V.
Order As XA12N (Maplin Project Book No. 12)
Price 75p *NV*.

Project Book 13 Explosive Gas Alarm. Flammable gas detector. **Flash Meter.** Get your exposure right when using your flash gun. **Musical Announcer.** A doorbell with a difference. **Mains Controller.** An add-on for the 8-Channel Fluid detector.
Order As XA13P (Maplin Project Book No. 13)
Price 75p *NV*.

Project Book 14 Live Wire Detector. Invaluable aid for the handyman. **Trundle.** The line follower robot as featured on Channel 4. **4-Channel PWM Controller.** Digital control of motors and servos. **Display Driver Module.** How to use our LED bargraph display ICs. **Control-A-Train.** Full inertia control of model trains. **Spectrum I/O Controller.** Buffered 2-way 8-bit data bus and 8 control lines.
Order As XA14Q (Maplin Project Book No. 14)
Price 75p *NV*.

Project Book 15 Z80 CPU Module. Expandable CPU based controller. **Sharp MZ-80K Serial Interface.** Get into communications with this project. **Ultrasonic Car Alarm.** Stop car thieves. **Active Crossover.** Includes matched output power amplifiers. **Guitar Equaliser.** Specifically for six string electric guitatrs. **Fabulous Five.** A selection of interesting circuits.
Order As XA15R (Maplin Project Book No. 15)
Price 75p *NV*.

Electronics Issue 16 Floodlight Controller. Both power supply and mains switching unit for the Infra-red Intruder Detector Kit. **Spectrum Parallel/Serial Interface.** Provides 8-bit I/P and O/P parallel or serial transfer with programmable UART. **Mains Tx/Rx Data Communications System.** Sends or receives data via the mains wiring. **16-Channel Logic IC Tester.** Simultaneously displays logic states for any logic IC of up to 16 pin-outs on your oscilloscope.
Order As XA16S (Maplin Magazine Volume 4 Issue 16) Price 75p *NV*.

Electronics Issue 17 Video Digitiser. Interface a TV camera to your computer. **Mixing It.** A comprehensive range of audio amplifier modules. **Hobbyist's Temperature Controller.** General purpose electronic mains power thermostat. **ASCII Keyboard.** Professional computer keyboard with standard ASCII output. **Play Along Mixer.** Play along to your favourite records and tapes on your own instrument.
Order As XA17T (Maplin Magazine Volume 5 Issue 17) Price 75p *NV*.

Electronics Issue 18 Weather Satellite Receiver. Display regional weather systems on your TV or monitor. **Mixing It Part 2.** Mono/stereo Hi–Z mic input, mixer and line amplifiers; VU/headphone driver. **Stepper Motor Driver.** How to build and start using the Stepper Motor Kit featured in the Catalogue. **Amstrad Expansion System.** The Maplin Amstrad External ROM Card System for the CPC 464, CPC 664 and 6128. **Sealed Lead Acid Battery Charger.** Special high stability output with automatic trickle charge mode for sealed lead acid batteries. **Fantastic Five.** Veroboard projects comprising HF tremolo unit, crystal checker, clap switch, low–Z ohmmeter, snooze timer.
Order As XA18U (Maplin Magazine Volume 5 Issue 18) Price 75p *NV*.

Win The Maplin Voyagers Bounty

The Treasure

The Choice is Yours

To enter this *Free* Competition, just visit one of the Maplin shops during May or June 1986, enter the adventureland of electronics, and you may find yourself some treasure.

The Maplin Voyager is seen above returning with her bounty; all you need to do is answer a few simple questions and you could be choosing your reward.

First prize is your choice from:

- 22" Remote Control Colour Television
- Hi-Fi Midi System
- Video Recorder
- Compact Disk Player System.

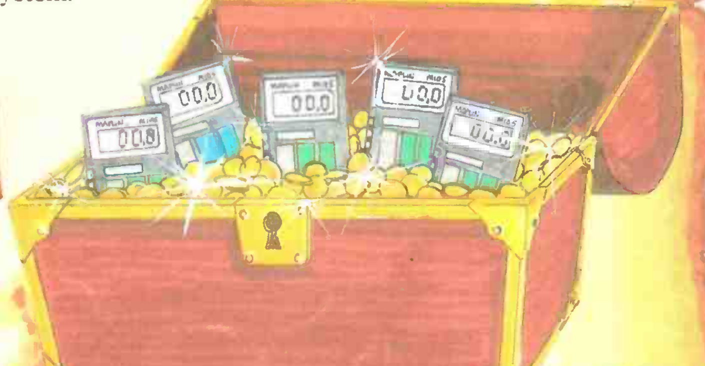
Second Prize is your choice from:

- Portable Television
- Portable Music System

Claim Your Stake in The Bounty

X Marks The Shop

× Birmingham: Lynton Square, Perry Barr, Tel: 021-356 7292.
× London: 159-161 King Street, Hammersmith, W6. Tel: 01-748 0926.
× Manchester: 8 Oxford Road, Tel: 061-236 0281.
× Southampton: 46-48 Bevois Valley Road, Tel: 0703 225831.
× Southend: 282-284 London Rd, Westcliff-on-Sea, Essex. Tel: 0702-554000.



Five Runners-up will each receive one of the the latest Digital Multimeters from the Maplin Precision Gold range.