Best of **Maplin**

PROJECTS

XC05F

BOOK 5
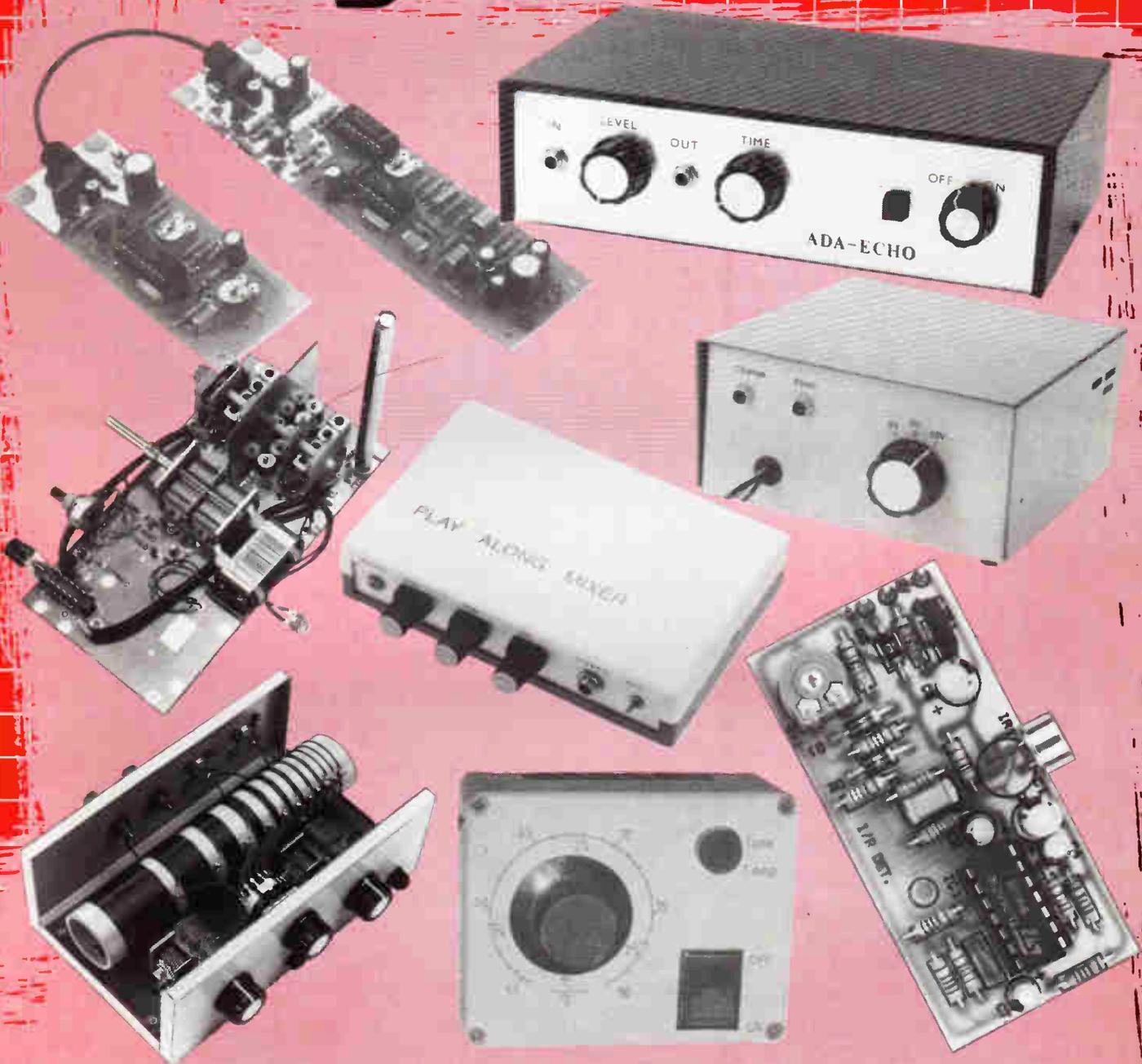
* Play Along Mixer
* Video Digitiser
* Hobbyists Temperature
  Controller

* Lead Acid Battery Charger
* Active Aerial & Tuning Unit
* Ada-Echo
* Stepper Motor Driver

* Fibre Optic Audio Link
* Infra-red Proximity
  Detector
* Fantastic Five

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BEST OF MAPLIN PROJECTS BOOK FIVE

PROJECTS

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PLAY ALONG MIXER

by Robert Penfold
- ★ **Easy To Build**
- ★ **Includes Pan Facility**
- ★ **Separate Level Controls**
- ★ **Play Along With Your Favourite Rockband**

An increasingly popular method of practicing one's musicianship with an electric or electronic instrument is to play along with a record, tape or whatever. This can be a very effective method of practice, as well as being great fun, and it can be achieved without the use of any special equipment. A hi-fi system can provide the programme material while a standard guitar amplifier and loudspeaker or a combo system is used to reproduce the output from the instrument. However, by processing the two signals in this totally separate way, the sound from your instrument remains rather detached from the programme material and much better results can be obtained by mixing the two signals and reproducing them through the same audio system.

The easiest way of doing this is to take the stereo output from the tape recorder or other programme source, and mix the signal from the instrument into it. The output of the mixer is then coupled to the hi-fi amplifier and reproduced through the stereo loudspeakers. With a suitable mixer it is then possible to position the instrument anywhere in the stereo sound stage. In fact, practically any mixer will suffice for this application, but most types actually provide far more inputs and other facilities than are really required and are consequently unnecessarily expensive when used in this application. They could also be relatively awkward to use. This simple mixer has been designed specifically for play along use, and it is very simple to operate. Separate level controls

for the stereo signal and the instrument are provided, together with a 'pan' control which enables the position of the instrument in the stereo field to be set where desired.

System Operation

The block diagram of Figure 1 shows the basic make-up of the unit. It really just consists of two mixers, one in each stereo

channel. Each mixer has two inputs, one for the stereo source and one for the instrument.

The position of a signal within the stereo image depends on its relative strength on the two stereo channels. By having the signal at exactly the same level in both channels it is placed in the centre of the stereo image. Making it slightly stronger in one channel than in the other offsets it in the sound stage to whichever side has the higher level. Although it is

generally thought that a high level of stereo separation is needed in order to reproduce a wide sound field, this is not in fact true. Having a signal about 6dB stronger in one channel than in the other (about twice as strong in terms of signal voltage) is sufficient to place the signal right at one side of the sound stage. The 'pan' control therefore has to permit the level at which the mono input signal is mixed into each stereo channel to be unbalanced by a few dBs either way, in order to permit the instrument to be moved over the entire sound stage.

A level control is provided at the stereo input, and this is a dual gang type which does not permit separate adjustment of each channel, and consequently does not facilitate channel balancing. However. channel balancing will presumably be possible at the stereo amplifier or at the signal source.

Summing Mode

The mixer circuits are based on the standard operational amplifier 'summing mode' type. This uses what is little more than an ordinary inverting mode operational amplifier circuit, as can be seen from the skeleton summing mode mixer circuit of Figure 2.

Rc and Rd form a potential divider which biases the non-inverting (+) input of the operational amplifier to half the supply potential. The circuit could be powered from dual balanced supplies with the non-inverting input biased to the central earth rail. but when operational

amplifiers are used in audio applications, it is often more convenient to use a single supply rail with potential dividers to provide biasing.

If we ignore Rb for the time being, Ra and Re form a negative feedback network and the operational amplifier is in the standard inverting amplifier configuration. An operational amplifier amplifies the voltage difference across its inputs, with the output going positive if the non-inverting input is at the higher voltage, or negative if the inverting input is the one at the greater potential. The innate voltage gain of an operational amplifier (the 'open loop' gain) is extremely high at low frequencies, being typically about 100,000 times. As a result of this the input voltages only need to be unbalanced by a very small amount in order to send the output fully positive or fully negative. Here the negative feedback through Re automatically balances the input voltages. If the inverting input is too high in voltage this sends the output negative, reducing the voltage fed to the inverting input due to the coupling through Re. Similarly, if the inverting input is too low in voltage, this sends the output more positive, which in turn takes the inverting input to a higher voltage due to the coupling through Re. Under quiescent conditions the output and both inputs are therefore at half the supply voltage.

Of course, coupling an input signal to input 1 will result in the balance of the operational amplifier being upset, but the feedback action will again compensate for this. As an example, assume that Ra and Re have the same value, and that the input is taken one volt above the bias level. This increases the voltage at the inverting input, which unbalances the input potentials and sends the output negative. It will go negative by one volt, at which point the potential divider action across Ra and Re gives the original potential at the inverting input. The circuit thus acts as a unity gain amplifier which inverts the signal. This inversion is of no consequence in an audio application as inverted and non-inverted signals sound the same.

Although the gain of the amplifier is only unity with Ra and Re at the same value, it can be boosted by making Re higher in value. The output then has to change by a greater amount than the input potential in order to

Figure 1. Block Diagram

Figure 2. 'Summing Mode' Mixer

maintain the balance. The voltage gain is in fact equal to Re/Ra. Note that this is the gain of the whole circuit, or 'closed loop' gain, which should not be confused with the open loop gain.

The fundamental way in which the circuit functions is the same when Rb and input 2 are taken into account, but the output must now change by an amount that will counteract the combined input voltages. For example, if both inputs are taken positive by 1 volt, the output must go negative by two volts in order to give a current flow through Re that will counterbalance the sum of the currents through Ra and Rb, and keep the input voltages balanced. The required mixing action is thus obtained. In this application only two inputs are required, but in theory it is possible to have as many inputs as you want, simply by adding extra input resistors. Apart from signal mixing, a mixer

Figure 3. Circuit

Figure 4. PCB Layout and Wiring

must also provide isolation between the two outputs so that one does not end up driving the other (which could result in distortion or even damage to one of the outputs). The input resistors would normally have a fairly high value which would prevent this, but almost total isolation is provided by the 'virtual earth' at the inverting input. Obviously, this point in the circuit is not connected to earth but, depending on the circuit design, the feedback action maintains it at earth potential or at some fixed offset from earth potential, and this blocks any signal flow from one input to the other.

Circuit Operation

The full circuit diagram of the mixer appears in Figure 3. The two mixer circuits bear an obvious resemblance to the basic configuration of Figure 2, and the main difference is the addition of DC blocking capacitors at the inputs and output of each one. Also, a common potential divider bias circuit is used for the two mixers, and this circuit includes decoupling capacitor C4. RV3 is the dual gang level control at the stereo input, and RV1 is the mono (instrument) gain control. The 'pan' control is RV2, and this acts

as part of the input resistance for the mono input of each channel. With RV2 at a central setting the input resistance for each channel is the same at 97k, giving roughly unity gain through the mixer. Offsetting RV2 gives a higher input resistance in one channel, with reduced gain, while there is reduced resistance and higher gain in the other channel. Each channel can be boosted by around 10dB relative to the other channel, which is sufficient to permit the instrument to be positioned anywhere in the stereo sound stage.

The device specified for IC1 is a Bifet type which uses Jfet transistors to achieve very low noise and distortion levels. An inexpensive bipolar dual operational amplifier such as the 1458C will also work quite well in the circuit though. The current consumption is only about 3.5 milliamps, and even a small (PP3 size) 9 volt battery will give many hours of operation.

Construction

Apart from the sockets and battery, all the components fit onto the printed circuit board. Details of the track pattern and component layout are provided in Figure 4. The only unusual aspect of
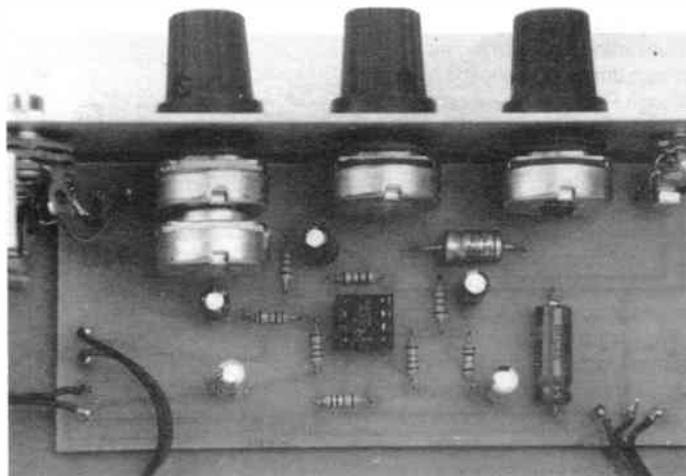
construction is the use of printed circuit mounting potentiometers, and obviously you must make sure you obtain the correct type. The printed circuit board is effectively mounted on the front panel of the case via these components. If preferred, ordinary potentiometers can be used, but these would have to be hard-wired to the printed circuit board. The board would then have to be bolted in place on the base panel of the case, and there are plenty of vacant areas on the board which could accommodate the mounting holes. When fitting the potentiometers, make sure that they are fully pushed down into place before making the soldered

connections, and use plenty of solder to ensure that physically strong joints are produced. Fit pins to the board at the points where connections to the battery, sockets, and on/off switch will be made.

On the prototype JK1 is a 3.5mm jack, while JK2 and JK3 are standard stereo jacks. These could be changed for other types that would be more convenient in your particular set-up, with the only proviso being that you must be sure that sufficient space is available for the proposed types of socket. A verocase having approximate outside dimensions of 180 by 120 by 39 millimetres is used as the housing for the

prototype. This is quite tough and gives a neat appearance, but care has to be taken with the layout as it has barely enough height to take the printed circuit assembly. The controls must be mounted a millimetre or two above the centre-line of the panel, and if the pins of the potentiometers protrude by a substantial amount on the underside of the board, it might be necessary to trim these down slightly. Some of the mounting pillars moulded into the case might tend to get in the way, but these can easily be drilled away using a bit of around 10 millimetres in diameter.

To complete the unit, the battery clip is connected and S1 plus the three sockets are wired to the printed circuit board. Ordinary connecting wire is adequate for the connections to the sockets and it is not essential to use screened cable here.

In Use

If the programme source is separate from the amplifier, in most cases the mixer will simply connect between the cassette deck, tuner, or other source, and the amplifier, using screened leads. The exception is where the unit is to be used with a record deck as the signal source. The output from a cartridge is not adequate to drive the mixer properly, and a suitable preamplifier would have to be added ahead of the mixer. In many cases the preamplifier in the receiver or amplifier can be used, with the mixer being connected between the 'preamp out' and 'power amp in' sockets, or perhaps being fitted into the tape monitor facility. This is something that varies from one hi-fi amplifier to another, and the method of connection must be varied to suit the particular equipment you are using. Reference to the amplifier's manual should help if you are uncertain about a suitable method of connection. If you have some form of integrated audio system such as a tuner/amplifier or a casseiver unit, there will probably be input/output sockets into which the mixer can be connected, or a tape monitor facility might again be the answer. It is only possible to use the mixer if there is some means of routing the output of the programme source through the mixer and into the power amplifier.
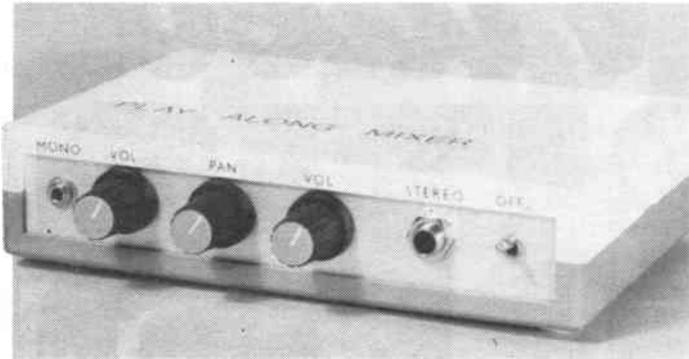
Results will probably be best with RV3 set at maximum, and RV1 set to mix in the instrument at the required level. RV3 can be backed off if there is any sign of overloading, or if the instrument cannot be brought up to a satisfactory level even with RV1 set at maximum. RV2 is, of course, set to place the instrument at the desired position within the stereo field.

If the instrument gives only a low output level it might be necessary to modify a few component values in order to boost the gain at the mono input and give an adequate signal level at the output. This simply entails raising R2, R5, R7 and R8 to about 1M in value. With something like a very low output guitar pick-up it would probably be better to drive the mixer via a preamplifier rather than try to modify the values to boost the gain at the mono input to a suitable level.

PLAY ALONG MIXER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1,6	47k	2	(M47K)
R2,5,7,8	100k	4	(M100K)
R3,4	10k	2	(M10K)
RV1	100k Pot Log	1	(FW25C)
RV2	100k Pot Lin	1	(FW05F)
RV3	100k Dual Pot Log	1	(FX12N)

CAPACITORS

C1	100μF 10V Axial	1	(FB48C)
C2	1μF 100V Axial	1	(FB12N)
C3,5	1μF 100V PC Elect	2	(FF01B)
C4	4μ7F 63V PC Elect	1	(FF03D)
C6,7	10μF 50V PC Elect	2	(FF04E)

SEMICONDUCTORS

IC1	LF353	1	(WQ31J)

MISCELLANEOUS

	DIL Socket 8-Pin	1	(BL17T)
	Pin 2145	1 Pkt	(FL24B)
S1	SPST Ultra-Min. Toggle	1	(FH97F)
JK1	Jack Socket 3·5mm	1	(HF82D)
JK2,3	Stereo Open Socket ¼in.	2	(HF93B)
	Low-Cost Collet Knob	3	(YG40T)
	Knob Cap Blue	3	(QY01B)
	Battery Clip PP3	1	(HF28F)
	Case Verobox 214	1	(LQ07H)
	Wire 7/0·2 10m Black	1 Pkt	(BL00A)
	PCB	1	(GD10L)
	Instruction Leaflet	1	(XT98G)
	Constructors' Guide	1	(XH79L)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
The above items are available as a kit, which offers a saving over buying the parts separately.
Order As LK93B (Play Along Mixer Kit).
Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

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Video DIGITISER

★ Resolution 312 x 255
★ 8-bit Luminance Resolution
★ Controller Board to detect Line & Synch Pulses Available

by Mark Brighton and Robert Kirsch

Video Digitiser is a device which converts a video picture, such as the output of a video camera or V.C.R. (still frame) into digital words representing the luminance or brightness of co-ordinates (X, Y) within the picture. Thus, by sampling and converting all co-ordinates in turn, a stream of digital words representing the video picture may be sent to a host microcomputer and displayed on a graphics screen, or stored on disk or tape.

The resolution of the final computer picture will depend on the graphic capability of the host computer, up to the limits of the Digitiser.

In this case, the maximum vertical resolution of the Digitiser is the same as the number of complete lines in a video frame, i.e. 312 (although twice this number should be available if the interlace frame is also stored).

The horiztonal resolution is 255 which is the possible number of sample points in one line scan, although some of these will be in non-valid picture area.

The resolution of the luminance samples is 8-bit for a standard video level, ≃ 1 volt of video. Most micro-computers will not be able to combine these resolutions in a graphic screen, and a compromise between (X, Y) resolution and luminance resolution will have to be made when programming.

Circuit Description

In Figure 1, the video content of the incoming signal is stripped off by TR1 to leave composite sync, which is further split into frame sync by TR2/TR3 and line sync by TR4/TR5. The line sync is externally wired to L.S.I. (Line Sync In) and controls the sample counter.

The sample counter (IC3,4) is preset by an incoming line sync pulse inverted by IC2b, a position byte having been set up on DP0-7 by an 8-bit output port from the host computer.

The line sync pulse also clocks flip-flop IC5 via OR gate IC6d, setting IC5 output high and enabling the oscillator IC1b via IC1c, which is used as a Schmitt Inverter.

This oscillator clocks the sample counter at a frequency determined by RV1/C4 (≃4MHz) and causes it to count down to zero and carry, disabling the oscillator by resetting IC5 via IC6d to prevent any further sample pulses during the present line.

The carry pulse is inverted by IC2c, and charges C9 which then discharges through R2, lengthening the pulse inverted by IC2a to operate the analogue switch IC8. This connects DC restored video from C25/D2 to the hold capacitor C8, which charges to the video voltage. The lengthened carry pulse is also inverted by IC2f whose output goes to the 'Start of Conversion' input on the analogue to digital converter IC10. When the pulse ends, the analogue switch opens and the 'Held' video voltage is applied to IC10 via IC9, a high input impedence op-amp connected as a voltage follower, i.e. unity gain.

The End Of Conversion (EOC) output from IC10 goes low enabling the clock oscillator IC1d via an emitter follower TR6 and IC1a which is connected as a Schmitt Inverter. After the ninth cycle of the oscillator, the EOC output of IC10 goes high, disabling IC1d and indicating end of conversion. This signal is sent to the host computer, indicating that the output of the A/D converter is valid. The host computer reads and stores the data on P(DA) via an 'X' bit input port, where 'X' is the required number of luminance bits.

IC7 is a voltage converter which produces a −5 Volt supply for IC9 and IC10.
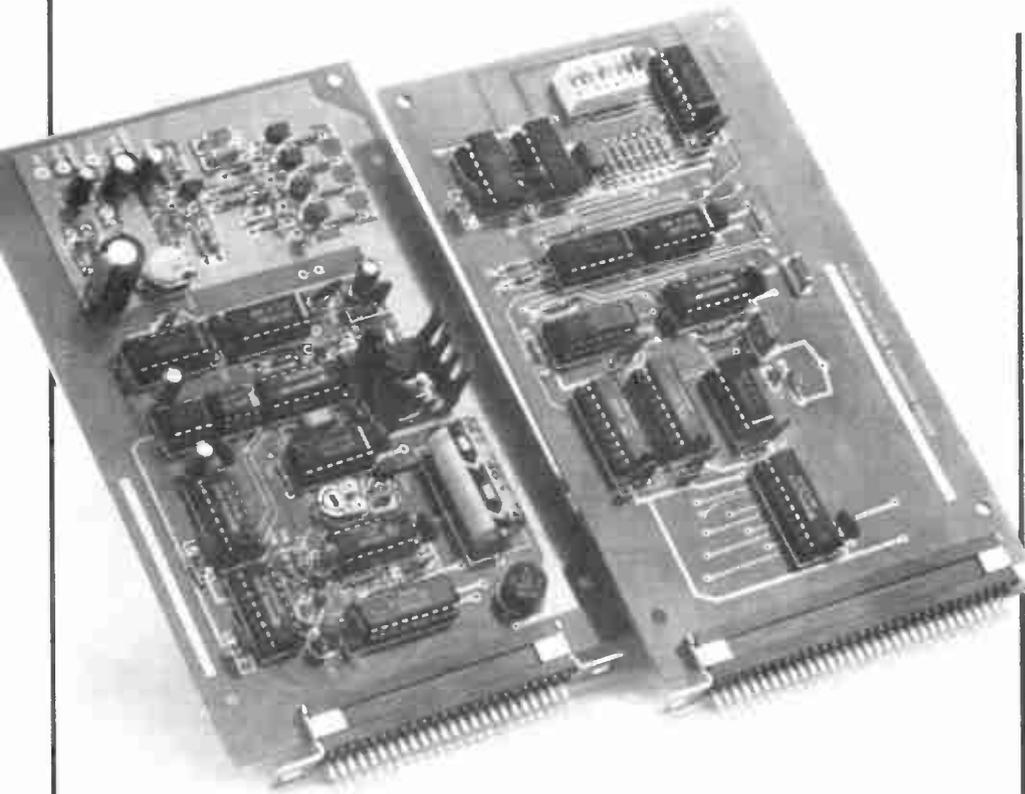
Construction

Referring to the Parts List and PCB layout diagram (Figure 2), insert and solder veropins 1 to 6 from the underside of the board (Side 1) and fit Link 1 if termination of the video signal is required. Insert and solder in position all resistors, capacitors and diodes, taking note of polarity.

Insert and solder all IC sockets, transistors, BR1 and mount REG1 using the insulating washer and heatsink supplied, first smearing mating surfaces with heat transfer compound (not supplied).

Double check your work for short circuits, components in wrong places, etc. Five minutes careful examination of your work now may save much time and expense later.

Plug IC7 into its socket, ensuring correct orientation.

Testing

Minimum system I/O requirement is one 8-bit output port and one 8-bit input port. This allows for up to 5 bits of luminance information, which should be

IC	TYPE	+5V	0V
1	74132	14	7
2	74HC14	14	7
3,4	74HC161	16	8
5	4013	14	7
6	4071	14	7
7	7660	8	3
8	4066	14	7
9	LF351	7	4 (−5V)
10	ZN427	10	9
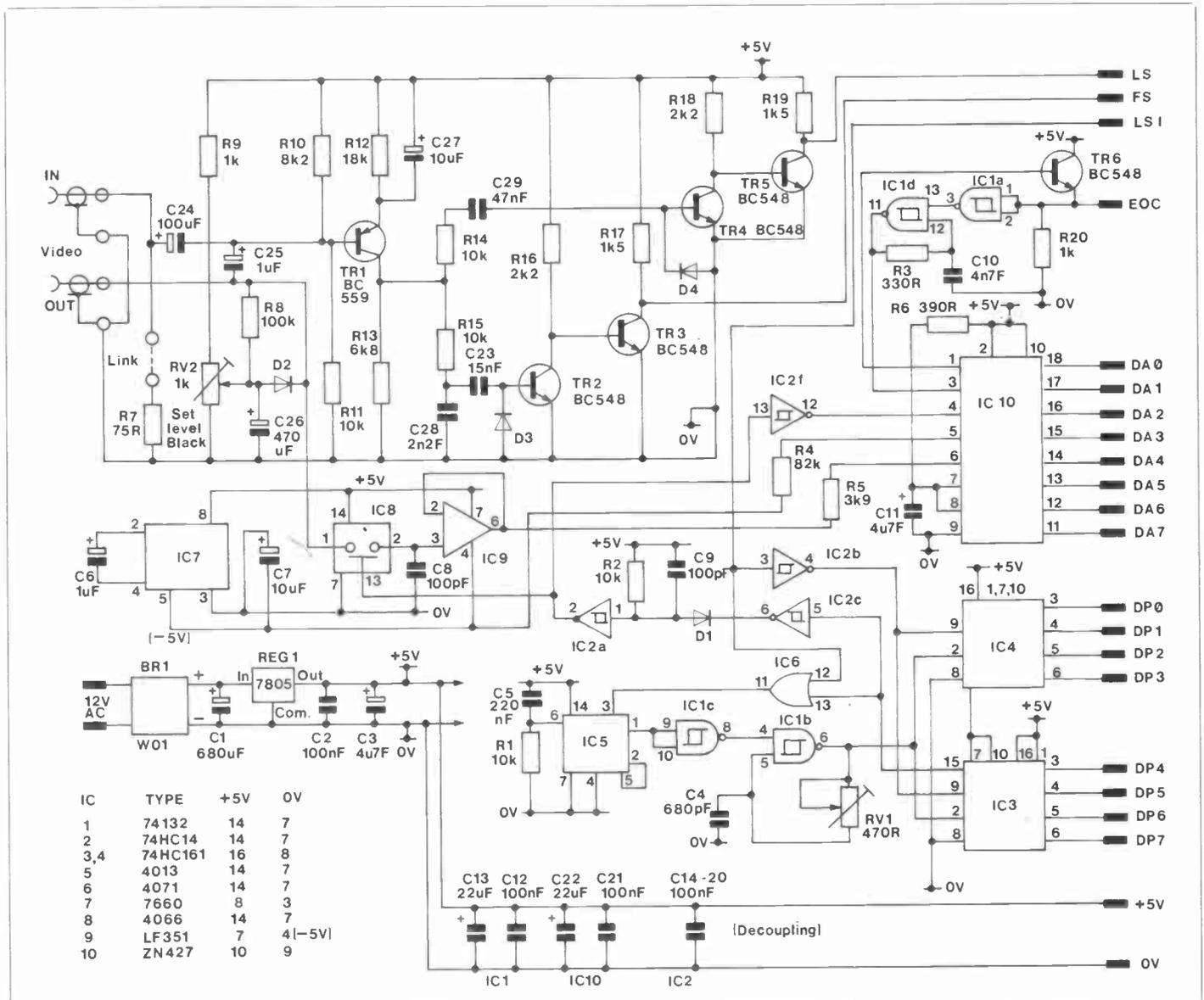
Figure 1. Digitiser Circuit
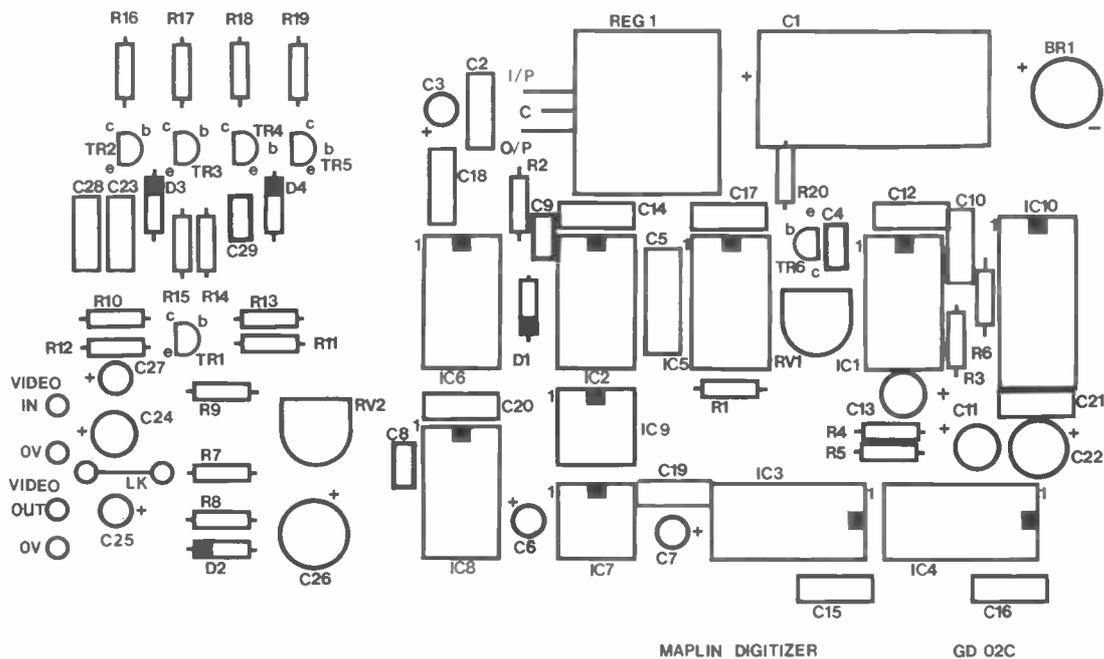
Figure 2. Digitiser PCB Layout

adequate for most microcomputer systems. For example wiring to host computer see Figure 3.

Without connecting the I/O lines to the host computer, apply power to the circuit and check for +5V and −5V supply rails. If either of these are not present, or read high, then switch off immediately and re-check your work.

If all is well however, switch off and insert the remaining IC's noting orientation. Connect a suitable source of video to the input of the Digitiser and the I/O lines to the host computer. Set the computer output port (PD in the example) to a valid position value, e.g. decimal 100. If an oscilloscope is available, check that TTL level Line Sync and Frame Sync pulses are present at LS and FS, respectively.

With LS connected to LSI and an

Oscilloscope to IC3 pin 2, 4MHz clock pulses should be present, gated at line rate (64μs). Set RV1 to about half travel and RV2 fully anticlockwise. Connect the scope to IC10 pin 4, where short pulses at line frequency should be present. Lastly, connect the scope to IC10 pin 3; the scope should display bursts of pulses at approximately 600kHz, gated at line rate. If an Oscilloscope is not available, a Logic Probe will give a fair indication that pulses are present at the above points.

Line and Frame Sync pulses may also be detected by software, as indeed they must be during operation of the Digitiser.

Programming and Use

Making use of this single board system is only possible using machine code software, since real time detection

of sync pulses is necessary to determine the vertical position of the sample point within the frame.

For those who are not keen on writing machine code, or wish to simplify the programming, a controller board has been designed to make use of the Digitiser as simple as possible, enabling a simple BASIC language program to operate the unit.

For those who are comfortable writing in machine language or assembly code, the program requirements are as follows:-

1. Set an 8-bit port for output (position port). Set an 8-bit port for input (luminance on low nibble and EOC, FS and LS on the three most significant bits. (LS should be the most significant bit for fast testing.) Reserve a block of memory for luminance information,
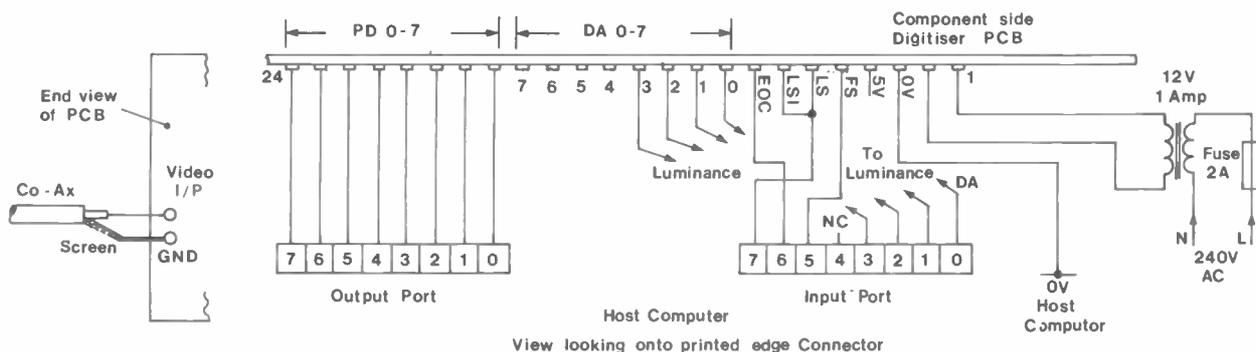
Figure 3. Board System Wiring

Figure 4. Controller Circuit

D1-4 1N4148

IC	Type	+5V	0V
1	40103	16	8
2,3	4013	14	7
4	4040	16	8
5	4081	14	7
6	74 HC 14	14	7
7	4071	14	7
8	4070	14	7
9	74 LS 244	20	10
10,11	2114	18	9

Decoupling Capacitors

IC1 -11
(C5 -15)
100nF

MAPLIN DIGITIZER EXPANSION GD 03D
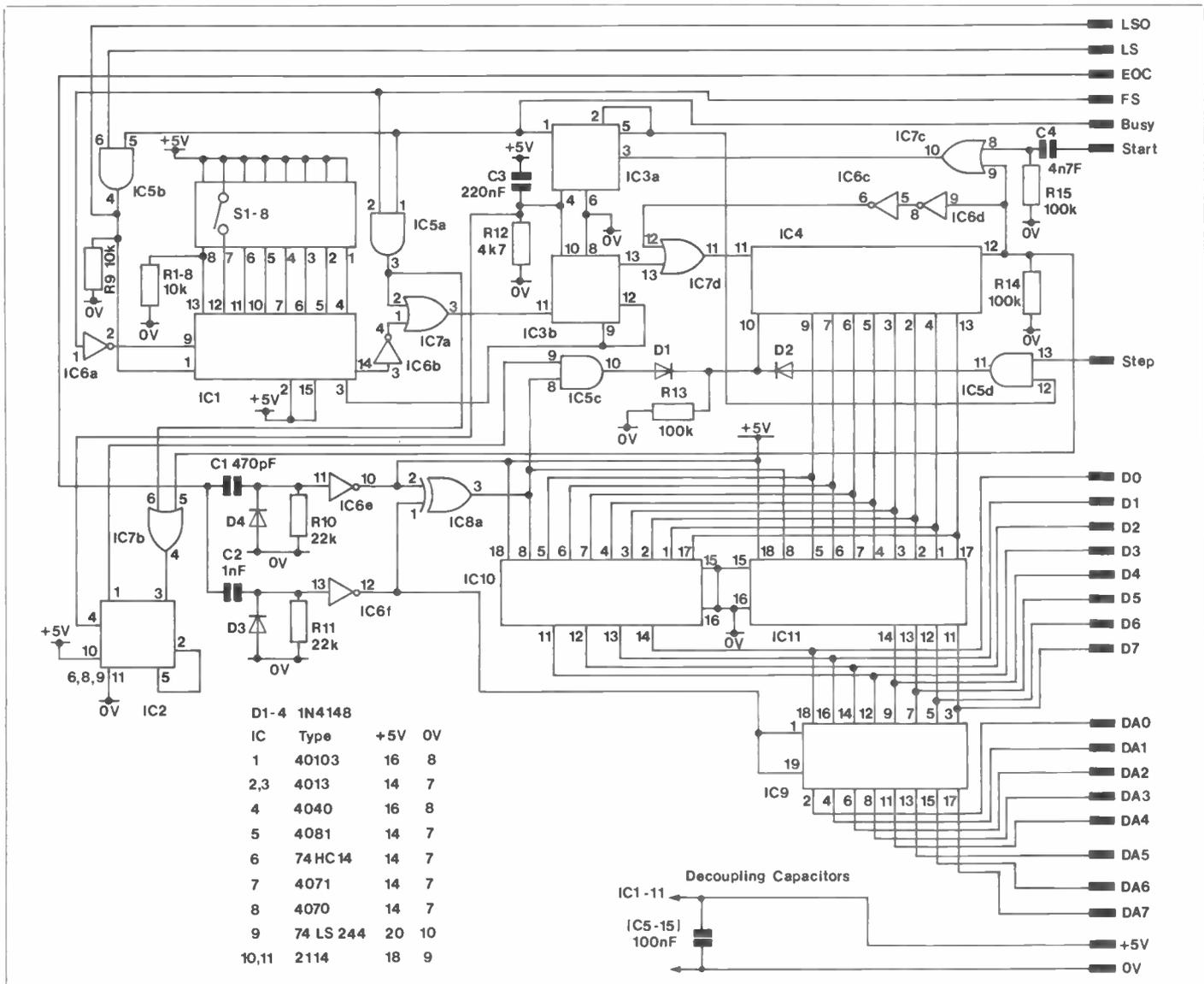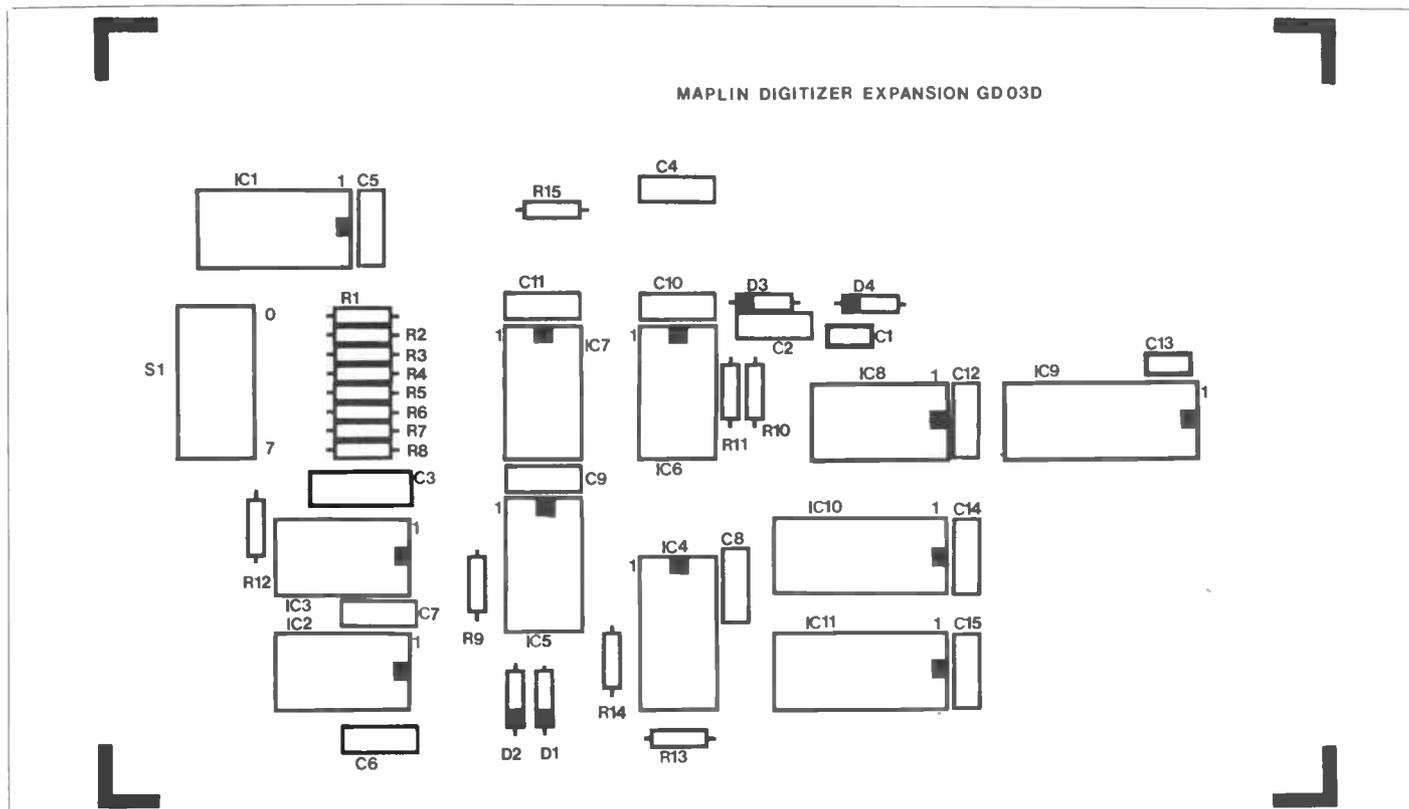
Figure 5. Controller PCB Layout

DA 0-7

Component side
Digitiser PCB

24   7 6 5 4 3 2 1 0   EOC LSI LS FS 5V 0V   1   12V 1 Amp

7 6 5 4 3 2 1 0
Output Port
(Host Computer)

Fuse 2A

N   L
240V AC

Component side
Controller PCB

32   Extension Board   1

Start Step Busy

3 2 1 0
Host Computer

5 6 7
Out Out In

I/O Port
Low Nibble
(Input)

I/O Port
High Nibble
(Bit 4 unused)

0V
Host
Computer

View looking onto printed edge Connectors
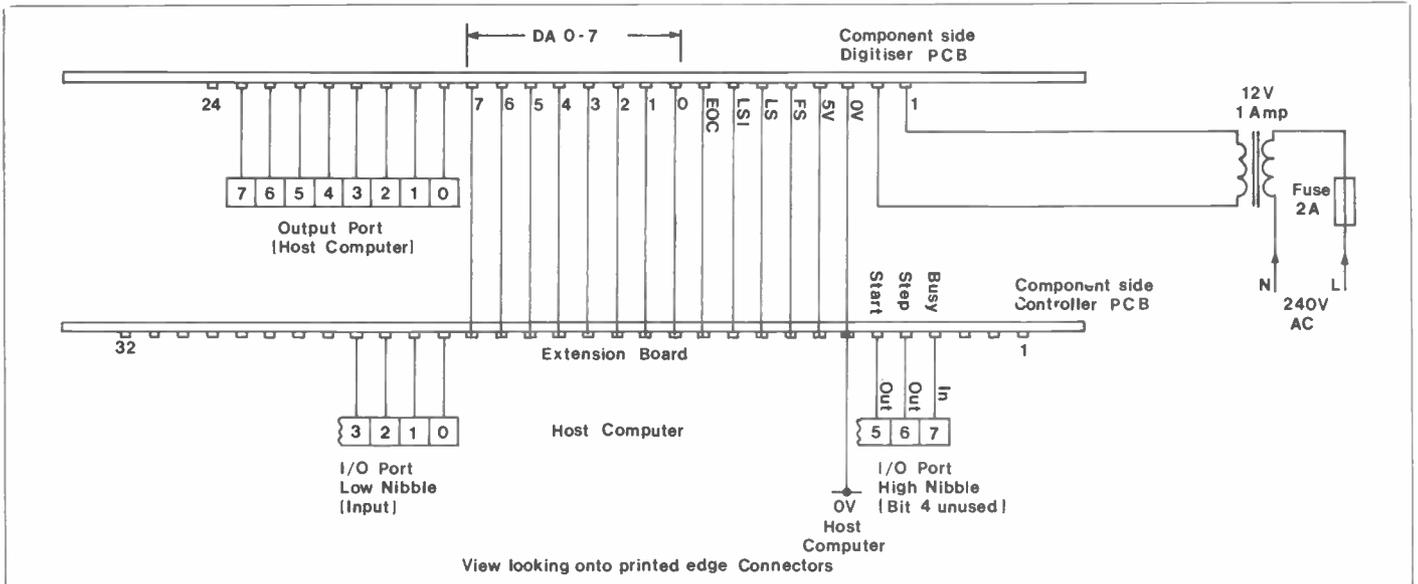
Figure 6. Two Board System Wiring

set up pointers to this block. Send initial position byte to position port (254 is extreme left, 0 is extreme right).

2. Wait for a Frame Sync pulse (test FS bit until high). Wait for end of Frame Sync (FS bit low).

3. By testing the LS bit in the same way, count the number of lines down the screen until the required line to start conversion occurs.

4. Reset the line counter to zero.

5. Wait for EOC bit to go low, then high.

6. Read luminance bits, store via pointer and increment pointer.

7. Compare current line scan number with maximum (312 or less, depending on requirement). If ≥ max then go to step 9.

8. Increment line counter. Wait for Line Synch. as before. Go to step 5.

9. Column stored. Compare current position byte with final position number. If ≥ max then go to step 11.

10. Increment position port. Go to step 2.

11. Frame stored. Process information to display on microcomputer.

In this way, the picture is built up in memory, column by column (one column for each frame, 20ms) in about 5 seconds (for a full width picture). Once a picture is being stored and displayed, contin-

VIDEO DIGITISER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1,2,11,14,15	10k	5	(M10K)
R3	330Ω	1	(M330R)
R4	82k	1	(M82K)
R5	3k9	1	(M3K9)
R6	390Ω	1	(M390R)
R7	75Ω	1	(M75R)
R8	100k	1	(M100K)
R9,20	1k	2	(M1K)
R12	18k	1	(M18K)
R13	6k8	1	(M6K8)
R16,18	2k2	2	(M2K2)
R17,19	1k5	2	(M1K5)
R10	8k2	1	(M8K2)
RV1	470Ω Hor. Enclosed Preset	1	(UF99H)
RV2	1k Hor. Enclosed Preset	1	(WR55K)

CAPACITORS

C1	470µF 63V Axial	1	(FB74R)
C2,12,14-21	100nF 16V Minidisc	10	(YR75S)
C3	4µ7F 63V PC Elect	1	(FF03D)
C4	680pF Ceramic	1	(WX66W)
C5	22nF Poly Layer	1	(WW45Y)
C6,25	1µF 100V PC Elect	2	(FF01B)
C7,27	10µF 50V PC Elect	2	(FF04E)
C8,9	100pF Ceramic	2	(WX56L)
C10	47nF Poly Layer	1	(WW26D)
C11	4µ7F 16V Tantalum	1	(WW64U)
C13,22	22µF 16V Tantalum	2	(WW72P)
C23	15nF Poly Layer	1	(WW31J)
C24	100µF 10V PC Elect	1	(FF10L)
C26	470µF 16V PC Elect	1	(FF15R)
C28	2n2F Poly Layer	1	(WW24B)
C29	47nF 16V Minidisc	1	(YR74R)

SEMICONDUCTORS

D1-4	1N4148	4	(QL80B)
TR1	BC559	1	(QQ18U)
TR2-6	BC548	5	(QB73Q)
BR1	W01	1	(QL38R)
REG1	µA7805UC	1	(QL31J)
IC1	74132	1	(WH03D)
IC2	74HC14	1	(UB10L)
IC3,4	74HC161	2	(UB41U)
IC5	4013BE	1	(QX23A)
IC6	4071BE	1	(QW43W)
IC7	7660	1	(YY75S)
IC8	4066BE	1	(QX23A)
IC9	LF351	1	(WQ30H)
IC10	ZN427E-8	1	(UF40T)

MISCELLANEOUS

|			
PCB		1	(GD02C)
Slotted Heatsink		1	(FL58N)
Kit (P) Plas		1	(WR23A)
DIL Socket 8-Pin		2	(BL17T)
DIL Socket 14-Pin		5	(BL18U)
DIL Socket 16-Pin		2	(BL19V)
DIL Socket 18-Pin		1	(HQ76H)
Edge Connector 124		1	(FL85G)
Edge Connector Foot Open		1	(YR58N)
Edge Connector Foot Closed		1	(FL91Y)
Bolt 6BA × ½in.		1 Pkt	(BF06G)
Nut 6BA		1 Pkt	(BF18U)
Transformer 12V 1A		1	(WB25C)
Instruction Leaflet		1	(XU00A)
Constructors' Guide		1	(XH79L)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
The above items are available as a kit, which offers a saving over buying the parts separately.
Order As LK95D (Video Digitiser Kit).
Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

uously, adjustment of RV1 will vary the aspect ratio to suit the graphics mode of the host computer.

The digitised pictures could be stored on an 'album' disk or used as backgrounds, for games for example. Some animation may be possible, if the host computer allows screen paging, by flipping between several stored images with slightly different subject positions.

However the stored images are used, this Digitiser provides a novel and interesting use for the home computer when the games begin to pall, and an answer to that recurrent question: 'What can you do with a computer?'

Controller

This is an optional extension of the Video Digitiser, which greatly simplifies the programming required to use it. Using the Controller, software detection of Frame and Line Sync pulses is no longer necessary, this being handled solely by hardware. In operation, a start pulse is sent to the controller board and the busy line is monitored until it goes low. This indicates that a column of data has been stored which is read by the host computer, using the step input to scan through the stored information. A new position byte is sent to the Digitiser and the process repeated until the whole picture has been stored.

Circuit Description

In Figure 4, upon receipt of a start pulse at CLK of IC3a via OR gate IC7c and C4/R15, a pulse length limiting network, the Q output of IC3a goes high, gating Line Sync pulses to LSO (Line Sync Out) which is connected to the sample pulse generating circuit on the Digitiser board. IC3a Q output also gates Frame Sync to IC3b via OR gate IC7a, causing IC3b Q output to go high upon receipt of the next Frame Sync pulse (start of picture). This holds line counter (IC4) reset via OR gate IC7d, while the $\overline{Q}$ output of IC3b enables counter IC1, a presettable counter that counts a number of 'wasted' lines before carrying, i.e. sets vertical start position of digitised picture. Note, this number should not be set (Dipswitch) higher than 55.

The carry pulse from IC1 is inverted and clocks IC3b, resetting it, via IC7a. IC1 is disabled by $\overline{Q}$ output of IC3b going high and IC4 enabled by Q going low. IC2 was clocked by Frame Sync via IC7,5 and its Q output gates CHIP SELECT pulses from IC8 through to clock input of IC4. These CHIP SELECT pulses are derived from the end of conversion output of the Digitiser board, as are WRITE ENABLE and ENABLE for the RAM and RAM Buffer, respectively.

WRITE ENABLE comes from pulse shaping circuit C1/R10 via IC6 and the longer ENABLE pulse from C2/R11 via IC6. $\overline{CS}$ and $\overline{E}$ are exclusively OR'ed by IC8 to produce $\overline{CS}$. Using this method to produce $\overline{CS}$ ensures that no conflict is possible on the Data Bus D0–D7 between the RAM and the Buffer (IC10/11 and IC9), since $\overline{CS}$ can only be low (active) when either:-

a) $\overline{WE}$ and $\overline{E}$ are both low. (Buffer has control of Bus) or,

b) $\overline{WE}$ and $\overline{E}$ are both high. (RAM has control of Bus).

Under the control of these signals, the data from the Digitiser is passed via buffer IC9 to RAM (IC10/11 for eight bit resolution) and the line counter (IC4) advanced to the next line address. This process continues for each line until IC4 carries, resetting itself via IC6/7 and resetting IC3a via IC7c. Line and Frame Sync pulses are no longer gated to the counters/flip-flops and the busy line goes low, indicating that a vertical column of screen data has been stored in the controller RAM, and is ready to be transferred to the host computer.

The 'step' input is now enabled by the $\overline{Q}$ output of IC3a and data may be transferred by reading the Data Bus and applying a step pulse, which clocks IC4, stepping it to the next line address, until all data has been read (≤256 lines depending on system requirement).

Listing 1.

```
5 GRAPHICS 9
10 REM .*   SET UP PORTS    *
20 POKE 54019,56
30 POKE 54017,255
40 POKE 54019,60
50 POKE 54018,56
60 POKE 54016,112
70 POKE 54018,60
80 C=0
100 PA=54016:PB=54017
200 POKE PB,230
250 POKE PA,64:POKE PA,0
300 IF PEEK(PA)/128>=1 THEN GOTO 300
400 FOR X=0 TO 191:LUM=PEEK(PA)
410 GOSUB 2000:POKE PA,32
420 POKE PA,0:NEXT X
430 C=C+1:POKE PB,230-C
500 GOTO 250
2000 IF C=80 THEN GOTO 2000
2010 COLOR LUM:PLOT C,X:RETURN
```

DIGITISER CONTROLLER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film

R1-9	10k	9	(M10K)
R10,11	22k	2	(M22K)
R12	4k7	1	(M4K7)
R13,14,15	100k	3	(M100K)

CAPACITORS

C1	470pF Ceramic	1	(WX64U)
C2	1nF Poly Layer	1	(WW22Y)
C3	220nF Poly Layer	1	(WW45Y)
C4	4n7F Poly Layer	1	(WW26D)
C5-15	100nF 16V Minidisc	11	(YR75S)

SEMICONDUCTORS

D1-4	1N4148	4	(QL80B)
IC1	40103BE	1	(QW61R)
IC2,3	4013BE	2	(QX07H)
IC4	4040BE	1	(QW27E)
IC5	4081BE	1	(QW48C)
IC6	74HC14	1	(UB10L)
IC7	4071BE	1	(QW43W)
IC8	4070BE	1	(QX26D)
IC9	74LS244	1	(QQ56L)
IC10,11	2114 450ns	2	(QW12N)

MISCELLANEOUS

	PCB	1	(GD03D)
S1	DIL Switch SPST Octal	1	(XX27E)
	Edge Connector 132	1	(FL86T)
	Edge Connector Foot Open	1	(YR58N)
	Edge Connector Foot Closed	1	(FL91Y)
	DIL Socket 14-Pin	6	(BL18U)
	DIL Socket 16-Pin	3	(BL19V)
	DIL Socket 18-Pin	2	(HQ76H)
	DIL Socket 20-Pin	1	(HQ77J)
	Instruction Leaflet	1	(XU00A)
	Constuctors' Guide	1	(XH79L)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
The above items are available as a kit, which offers a saving over buying the parts separately.
Order As LK96E (Digitiser Controller Kit).

Construction

Locate and solder all resistors, capacitors and diodes, noting polarities. Fit and solder Dipswitch and all IC sockets, locating Dipswitch with the writing on its side facing the edge of the board, and the polarity notches of the IC sockets matching the square block marked on each IC legend. See Figure 5. Carefully insert all IC's in their respective positions, taking note of correct orientation. Wire the edge connector as shown in Figure 6, referring to your computer manual or instructions for your I/O port, where applicable. Keep all wiring between the boards and the computer as short as possible to avoid corruption of data. Take care to check all joints/connections for short circuits, dry joints, etc.

Testing

Plug both boards into their edge connectors and apply power. Check the

5V supply using a multimeter. IC3 pins 1 and 13, IC2 pin 1 should all be low (<1V), relative to 0V. All being well, switch off and connect the circuits to the host computer and video source as shown in Figure 6.

Programming

Listing 1 shows a BASIC language program to operate the Digitiser. The

addresses given relate to the port addresses of the Atari 400/800 computers. A BASIC program will take several minutes to complete the screen display, but has the advantage of being very quick and easy to write. For those who desire faster operation, a machine code program will be required. An example (Listing 2) is provided in 6502 assembly language, again for the Atari 400/800 computers, although no explanation of this program will be included here, this being beyond the scope of the present article.

Throughout this article, it has been assumed that the reader has a basic understanding of the construction of a video signal. For those who wish to gain some knowledge on the subject, the following book is recommended:

Newnes Guide to TV and Video Technology by Eugene Trundle (Order Code WS34M).

Listing 2.

```
10    *=$7000
20 PORTA=$D300
30 PORTB=$D301
40 PACTL=$D302
50 PBCTL=$D303
60 NMIEN=$D40E
70 IRQEN=$D20E
80 POKMSK=$0010
90 DMACTL=$D400
0100 SDMCTL=$022F
0110 SAVMC=$0058
0120 MASK=$06F9
0130 LINES=$06FA
0140 POSIT=$06FB
0150 SCNCOL=$06FC
0160 OFFSET=$00D4
0170 FINCOL=$06FE
0180        PLA
0190 INIT   LDA #$00
0200        STA LINES
0210        LDA #240
0220        STA POSIT
0230        LDA SAVMC
0240        STA SCNCOL
0250        LDA SAVMC+1
0260        STA SCNCOL+1
0270        CLC
0280        CLD
0290        TAX
0300        LDA SCNCOL
0310        ADC #40
0320        STA FINCOL
0330        BCC NOINT
0340        INX
0350 NOINT  STX FINCOL+1
0360        LDA#$38
0370        STA PBCTL
0380        STA PACTL
0390        LDA#96
0400        STA PORTA
0410        LDA#$FF
0420        STA PORTB
0430        LDA#$3C
0440        STA PBCTL
0450        STA PACTL
0460 START  LDA SCNCOL
0470        STA OFFSET
0480        LDA SCNCOL+1
0490        STA OFFSET+1
0500        LDA POSIT
```

```
0510        STA PORTB
0520 TOG    LDA#64
0530        STA PORTA
0540        JSR DELAY
0580        LDA#0
0590        STA PORTA
0600 HI     BIT PORTA
0610        BMI HI
0620 GETLUM LDX PORTA
0630        LDA POSIT
0640        LSR A
0645        LSR A
0650        BCC MULT
0660        TXA
0662        LDX#240
0664        STX MASK
0670        AND #$0F
0680        JMP STORE
0690 MULT   TXA
0692        LDX#15
0694        STX MASK
0700        ASL A
0710        ASL A
0720        ASL A
0730        ASL A
0740 STORE  LDY#$00
0750        ORA (OFFSET),Y
0760        STA (OFFSET),Y
0762        LDY#40
0764        LDA(OFFSET),Y
0765        AND MASK
0766        STA(OFFSET),Y
0770 NEWROW CLC
0780        CLD
0790        LDA OFFSET
0800        ADC #40
0810        STA OFFSET
0820        BCC LNCHK
0830        CLC
0840        INC OFFSET+1
0850 LNCHK  INC LINES
0860        LDA LINES
0870        CMP #191
0880        BCC STEP
0890        LDA #$00
0900        STA LINES
0910 ODD    LDA POSIT
0920        LSR A
0925        LSR A
0930        BCC PICFIN
0940        CLC
```

```
0950        LDA SCNCOL
0960        ADC #$01
0970        STA SCNCOL
0980        BCC PICFIN
0990        INC SCNCOL+1
1000 PICFIN DEC POSIT
1005        DEC POSIT
1010        LDA SCNCOL
1020        CMP FINCOL
1030        BCC NEWCOL
1040        LDA SCNCOL+1
1050        CMP FINCOL+1
1060        BCC NEWCOL
1070 FIN    RTS
1080 STEP   LDA#32
1090        STA PORTA
1100        JSR DELAY
1150        LDA#0
1160        STA PORTA
1170        JMP GETLUM
1180 NEWPIC LDA#$16
1190        STA POSIT
1200        LDA SAVMC+1
1210        STA SCNCOL+1
1220        LDA SAVMC
1230        CLC
1240        ADC #40
1250        STA SCNCOL
1260        BCC NEWCOL
1270        INC SCNCOL+1
1280 NEWCOL JMP START
1290 DIS    LDA #$00
1300        STA IRQEN
1310        STA POKMSK
1320        STA NMIEN
1330        STA DMACTL
1340        STA SDMCTL
1350        RTS
1360 ENA    LDA #$C0
1370        STA IRQEN
1380        STA POKMSK
1390        STA NMIEN
1400        LDA #34
1410        STA DMACTL
1420        STA SDMCTL
1430        RTS
1440 DELAY  LDX#30
1450 DOWN   DEX
1460        BNE DOWN
1470        RTS
```

Hobbyist's Temperature Controller

★ Temperature Range 13 to 27°C
★ Current Range upto 4 Amps
★ Wide Range of Applications

by D.E. Coe

Originally designed to control the temperature of a home-brew wine and beer fermentation cabinet, this unit provides a thermostat facility for a wide range of other activities; tropical fish aquaria, photographic processing and hot-house gardening to name but a few. In its described form, the unit covers an adjustable temperature range of 13–27°C (or 55–80°F) but modified ranges are easily accommodated.

The unit provides heating via an ordinary 60 watt mains light bulb or any other mains heating unit for which the turn-on surge current does not exceed 4 amps. Temperature sensing is performed with the LM334Z IC, the circuit of which is separated from the high voltage by the opto-isolator.

The LM334Z, realised in a 3-lead TO92 package, is designed primarily for use as a wide range adjustable current source. The current I_{SET} is determined according to Equation 1 where V_S is the device sense voltage and the adjusted resistor R_{SET} is between the V– and 'r' pins of the IC.

Equation 1

$$I_{SET} = \frac{V_S}{R_{SET}}$$

However, the linear temperature response of the sense voltage V_S makes it admirably suited for temperature sensing (Figure 1). The basic circuit, shown in Figure 2, gives an output potential change of 10mV/°C with the component values shown.

The Circuit

The circuit diagram is shown in Figure 3 and uses the CA3140E MOSFET input op-amp in a comparator configuration. The op-amp is used in a single rail arrangement at open loop gain and C1 improves HF stability. The voltage
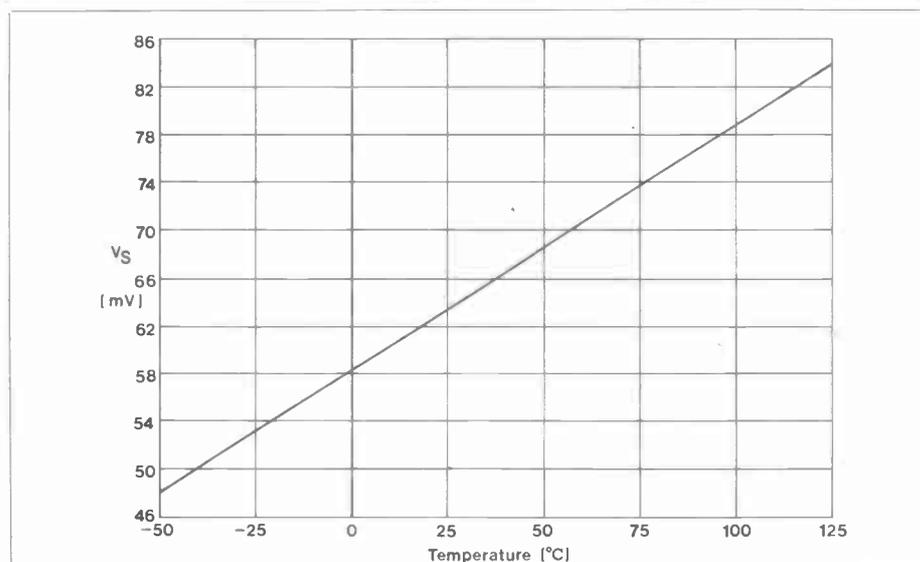

Figure 1. Temperature Response
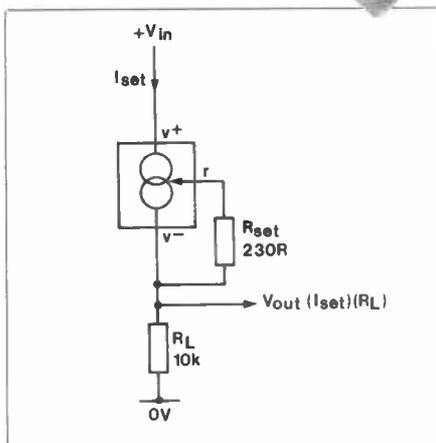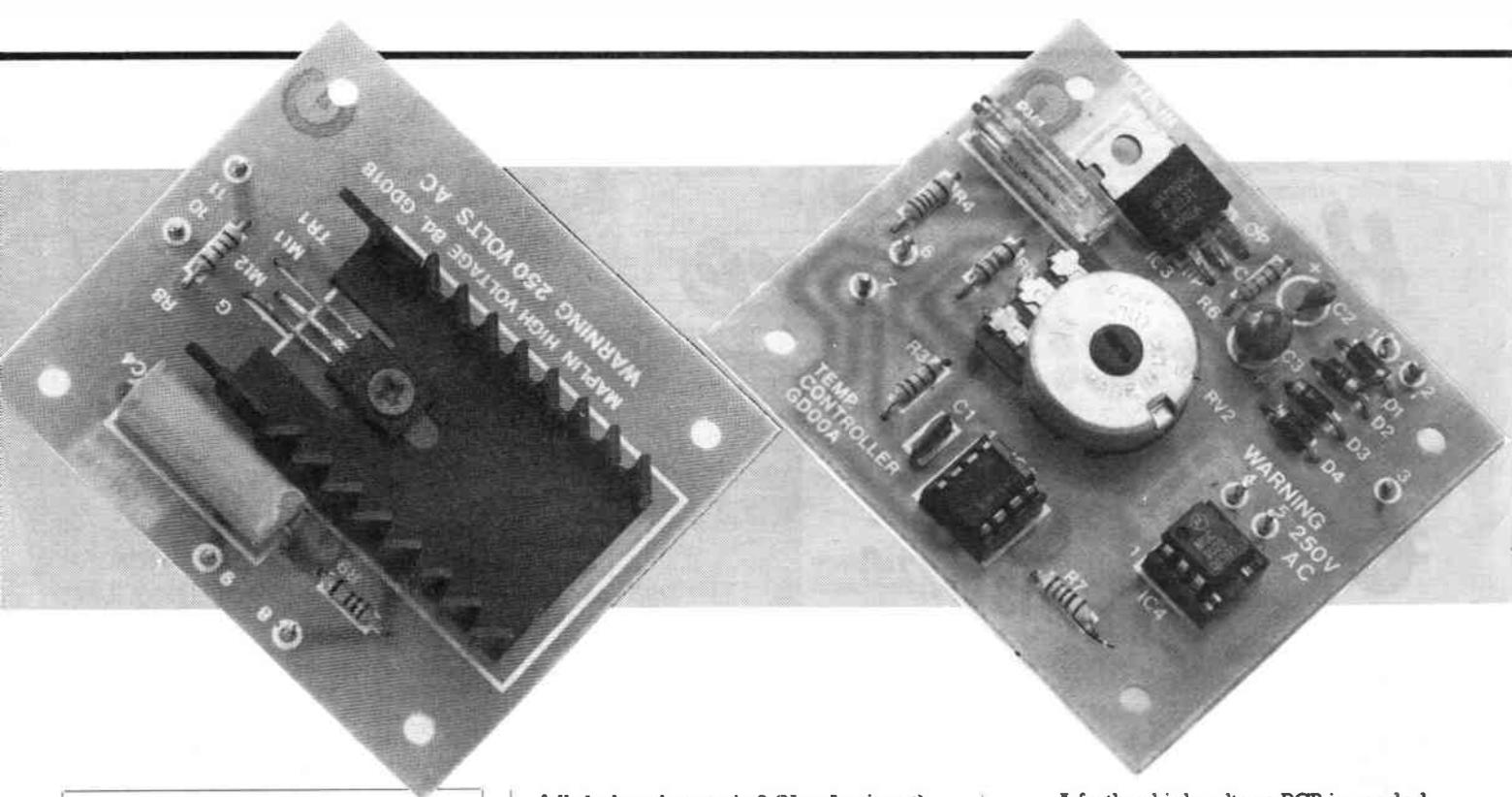
Figure 2. LM334Z Circuit

regulator IC3 provides both a regulated supply rail and acts as a reference voltage source for the op-amp Non-Inv input (pin 3) resistor chain.

As the sensor temperature falls, then so does the potential at pin 2 (Inv-input) of IC2 due to the change in sense voltage (V_S) of IC1. When the potential at pin 2 falls below that at pin 3 (Non-Inv input), set by RV2, the output which until then was close to the negative power rail will switch smartly to be close to the positive rail, thus turning on the LED of the opto-isolator.

Opto-isolation is provided via the opto-triac IC4, which is used to trigger the power triac TR1. By this means, the low voltage sensing circuitry is separated from the mains wiring. The capacitor-resistor combination of C4 and R9 form an interference suppression network to keep interference within acceptable limits.

Construction

As mains voltages are being handled scrupulous attention to all aspects of safety should be observed. An adequately earthed diecast box is suitable for housing the main circuitry. The printed circuit and overlay for the main PCB is shown in Figure 4. Construction is carried out with reference to the Parts List.

A further high voltage PCB is needed (Figure 5). It supports R8, the interference suppression components C4 and R9, and the power triac TR1 mounted on its heatsink.

Care should be taken to ensure correct polarity of diodes, electrolytic capacitors, integrated circuits and the opto-triac. Some useful pin-out diagrams are shown in Figure 6. Particular care should be taken when inserting the 6-pin DIL opto-triac package for both its orientation and correct pin positioning in the 8-pin DIL socket. The potentiometer RV2 should also be mounted correctly with the body on the component-side and spindle track-side of the circuit board (otherwise the temperature scale will be found to be reversed). A suitable scale for the potentiometer RV2 is shown in Figure 7.

Figure 8 shows the wiring diagram. The main circuit board and the high voltage PCB should be stacked with spacers ensuring that adequate clearances result all round between the high
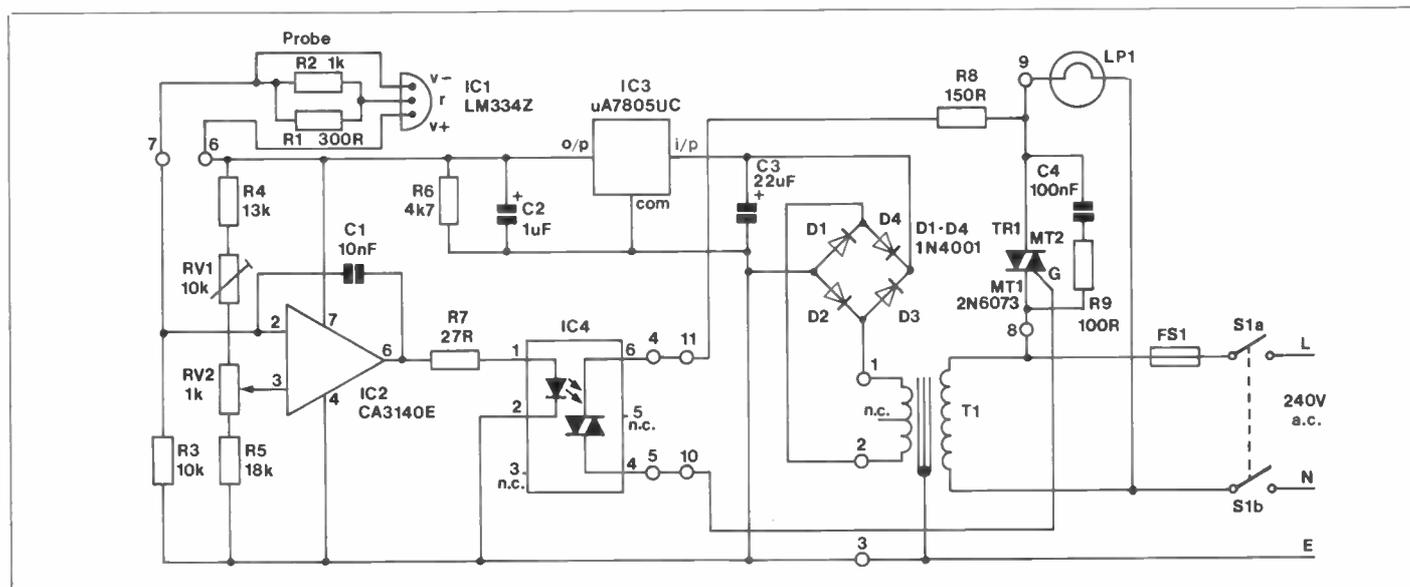
Figure 3. Temperature Controller Circuit
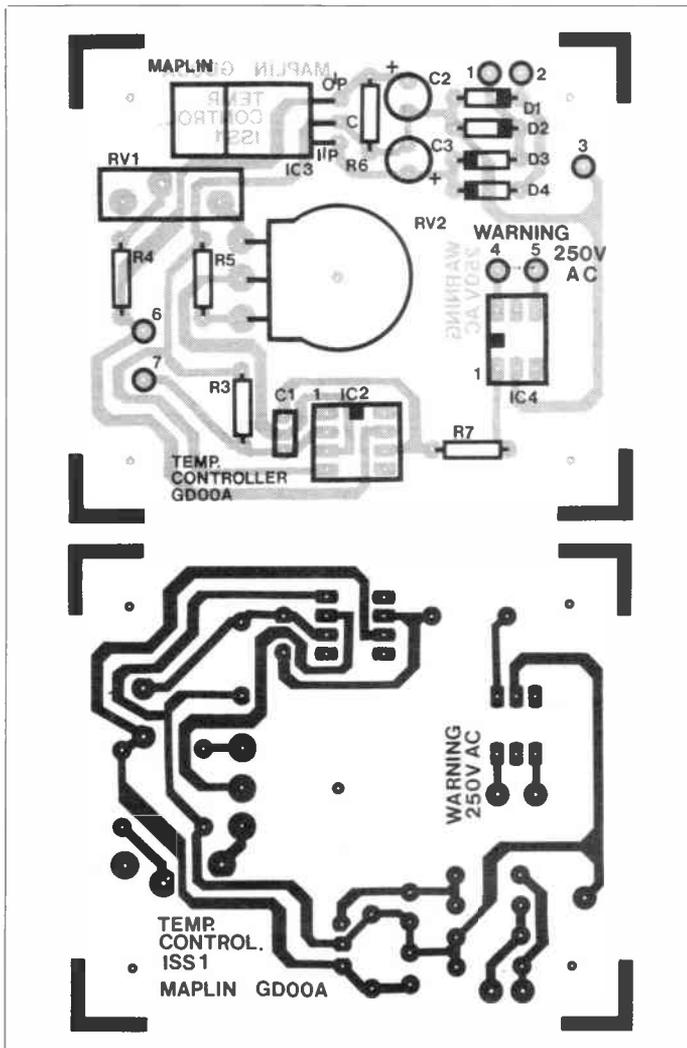
Figure 4. Controller PCB
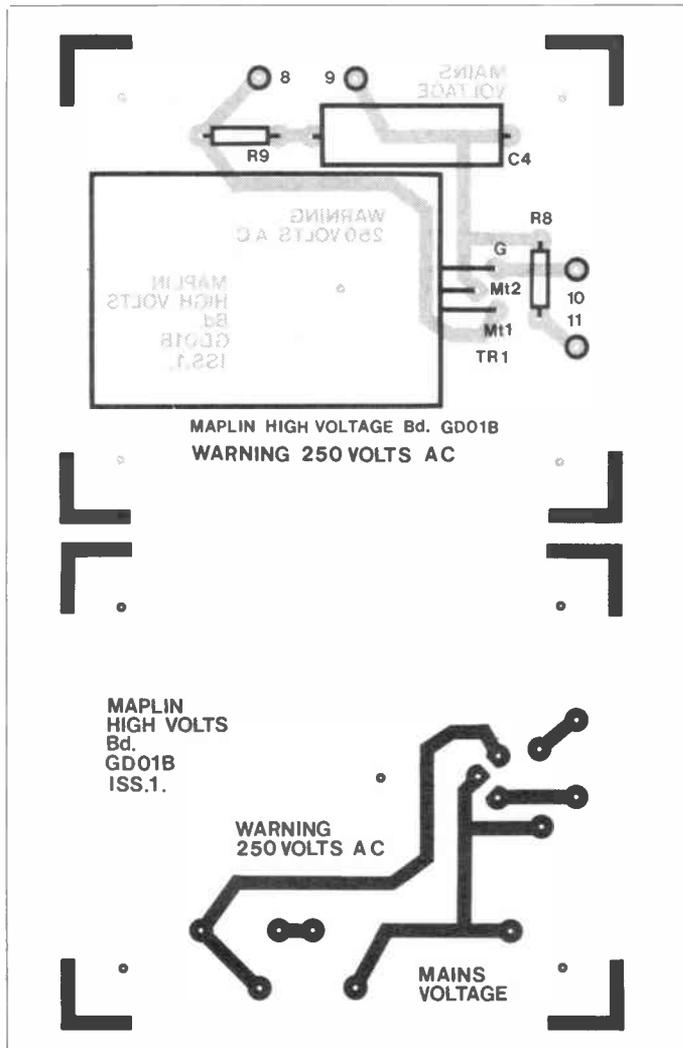
Figure 5. High Volts PCB

HOBBYISTS TEMPERATURE CONTROLLER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1	300Ω	1	(M300R)
R2	1k	1	(M1K)
R3	10k	1	(M10K)
R4	13k	1	(M13K)
R5	18k	1	(M18K)
R6	4k7	1	(M4K7)
R7	27Ω	1	(M27R)
R8	150Ω	1	(M150R)
R9	100Ω	1	(M100R)
RV1	10k 18-Turn Cermet	1	(WR49D)
RV2	1k Lin Pot	1	(FW00A)

CAPACITORS

C1	10nF Disc Ceramic	1	(BX00A)
C2	1µF 35V Tantalum	1	(WW60Q)
C3	22µF 25V Tantalum	1	(WW73Q)
C4	100nF IS Cap	1	(JR34M)

SEMICONDUCTORS

D1-4	1N4001	4	(QL73Q)
IC1	LM334	1	(WQ32K)
IC2	CA3140E	1	(QH29G)
IC3	µA7805UC	1	(QL31J)
TR1	2N6073	1	(QR51F)
IC4	Opto-Triac Isolator	1	(QQ10L)

MISCELLANEOUS

S1	Dual Rocker Neon Red	1	(YR70M)
T1	Sub-Min Transformer 6V	1	(WB00A)
FS1	Fuse 2A 20mm	1	(WR05F)
	Fuseholder 20mm	1	(RX96E)
	DIL Socket 8-Pin	2	(BL17T)
	Knob K14 D	1	(FK41C)
	Low Voltage PCB	1	(GD00A)

High Voltage PCB	1	(GD01B)
Strain Relief Grommet	2	(LR47B)
Stick-On Front Panel	1	(FA85G)
Vaned Heatsink TO202	1	(FG53H)
C/S Screw 6BA × ¼in.	1 Pkt	(LR56L)
Nut 6BA	2 Pkts	(BF18U)
Solder Tag 6BA	1 Pkt	(BF29G)
Threaded Spacer 6BA × ½in.	1 Pkt	(LR72P)
Brass Studding 6BA	1	(FW15R)
Pin 2145	1 Pkt	(FL24B)
Diecast Box DCM5007	1	(LH72P)
Spacer 6BA × ¼in.	1 Pkt	(FW34M)
Spacer 6BA × ½in.	1 Pkt	(FW35Q)
Heat Shrink Sleeving CP95	1m	(YR17T)
Heat Shrink Sleeving CP24	1m	(BF87U)
Kit (P) Plas	1	(WR23A)
Instruction Leaflet	1	(XU11M)
Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

White 3-Core Min Mains	As req.	(XR02C)
Twin Mains DS White	As req.	(XR00A)
Twin Zip Wire	As req.	(XR39N)
Potting Compound	1 Pkt	(FT17T)
Domestic Light Bulb 240V 60W	1	
Lamp Holder Inspection Type	1	

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately. Order As LK94C (Hobbyists Temp Controller Kit).

Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

15

Figure 6. Pinouts

IC1 LM334Z [pin view] — v+ r v−

IC2 CA3140E — offset / inv i/p / non-inv i/p / v− ; strobe / v+ / output / offset

IC3 uA7805UC — i/p com o/p

IC4 — anode / cathode ; triac / [substrate] / triac

TR1 2N6073 — MT1 G / MT2

[top views]

Figure 7. Temperature Scale

°C / °F FUSE OFF ON

and low voltage wiring. If no mica mounting set is used on the power triac TR1, don't forget that the securing bolt through the insulating board will be live with mains potential. High voltage connections should be covered with insulating sleeving.

The boards and other components may then be mounted on the inside of the box lid taking care to arrange adequate

clearance between the heatsink vanes and the bottom of the box (Fig. 9). The heatsink vanes can be bent if necessary and a sheet of plain matrix or plain fibre-glass board glued inside the box is an added precaution.

Holes should be provided in the box (Fig. 10) for sensor, mains and heater leads, the cables being clamped to avoid strain on the connections. Slots should be

cut in the box sides and covered with a grill to provide ventilation for the internal power triac heatsink. A further small hole is needed in the side of the box to allow for adjustment of the temperature calibration preset RV1.

The probe itself (Figure 11) should be constructed in a suitable piece of insulating tube (e.g. an old pen, test-tube) and sealed, preferably with a potting
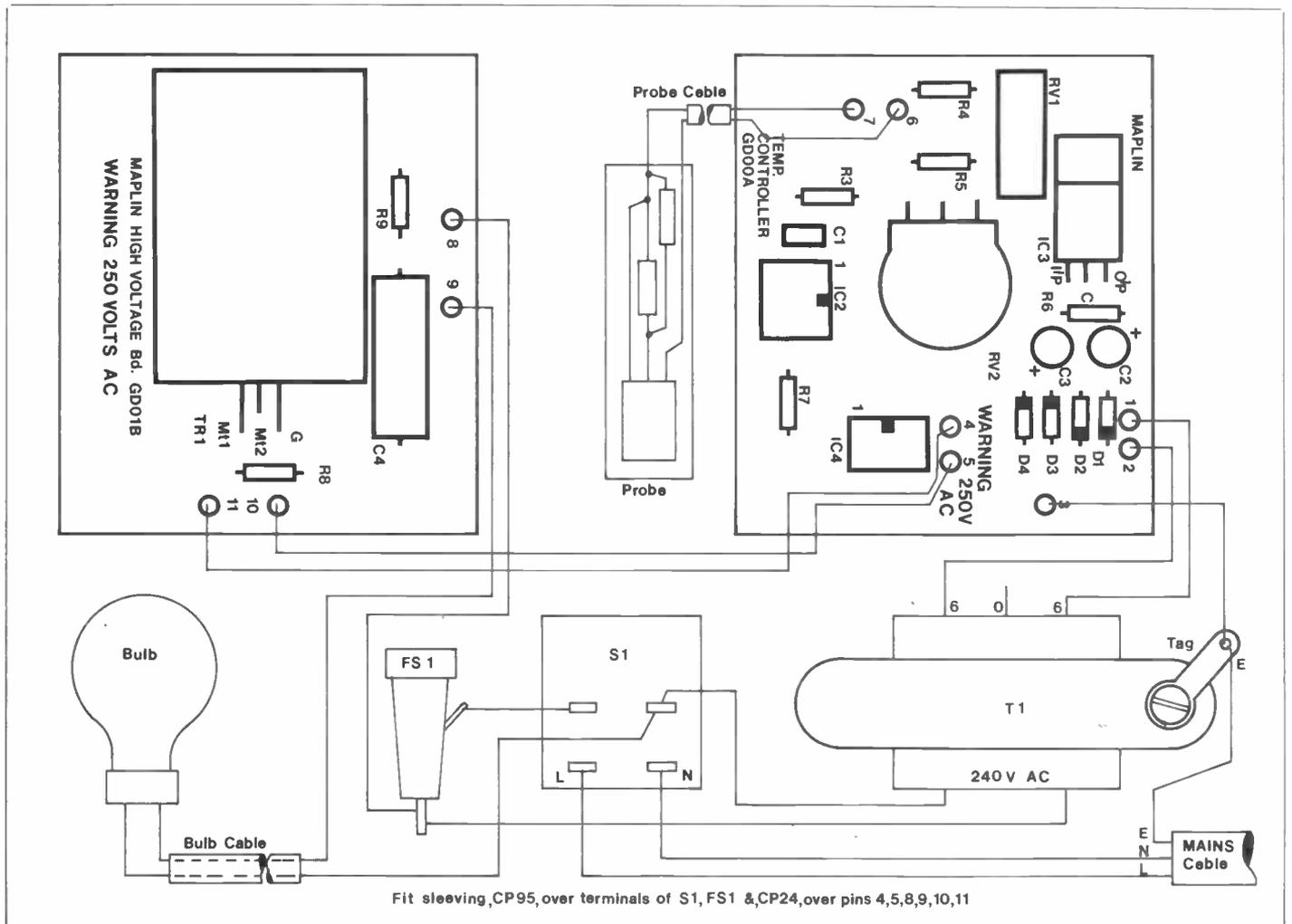
Fit sleeving, CP95, over terminals of S1, FS1 & CP24, over pins 4,5,8,9,10,11

Figure 8. Wiring

16
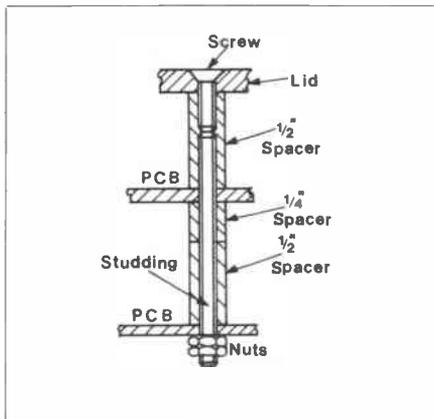
Figure 9. PCB Mounting

compound or Araldite. This not only provides strength and prevents ingress of moisture, especially when the probe is immersed in water, but also provides a certain amount of 'thermal inertia' to prevent the switch action from 'chattering' when close to the set temperature.

Now the wiring should be checked with special attention to all parts of the mains circuit. The box is closed up making sure that the circuit boards are correctly orientated with preset RV1 aligned with the adjustment hole in the case.

With applications using a mains light bulb for heating, adequate protection against accidental blows should be provided using a ventilated box or cage arrangement.

Setting Up

The unit should now be calibrated. Find a suitable temperature stable room e.g. an airing cupboard, of which the temperature is in the range covered by the unit. Set the knob of RV2 to the surrounding temperature as measured with a thermometer. Connect up the unit and turn on. Take an insulated adjustment tool and vary preset RV1 until the heater/lamp just switches. The unit is now aligned and ready for use.

Applications

For the originally intended application to home brewing, the most convenient set up consists of a cabinet of some kind in which sufficient fermentation vessels can be placed to meet requirements. In most brewing work, a steady temperature in the range 15–25°C (or 60–75°F) is preferred. The cabinet itself can take many forms but the author prefers a chest arrangement which is inobtrusive in the spare bedroom where it usually resides. Double walled construction with fireproof insulation between, seems to work well. The control unit should be fixed outside of the heated chamber/area for access and adequate cooling of the electronics. The sensor should be fixed to the inside of the cabinet, not too near the top or near the heater lamp; otherwise false readings could result.

A very similar arrangement is useful in a greenhouse propagator where temperatures around 20°C (68°F) are needed to give an early start to plants in
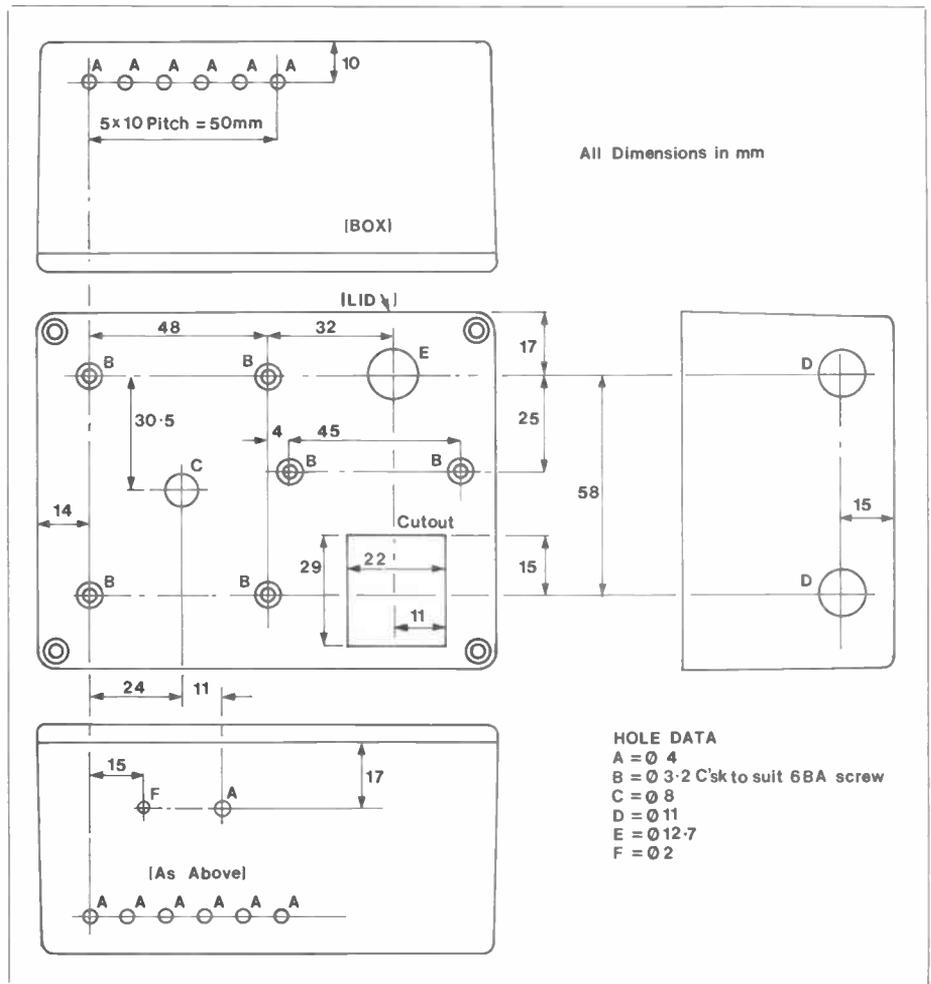

Figure 10. Box Drilling
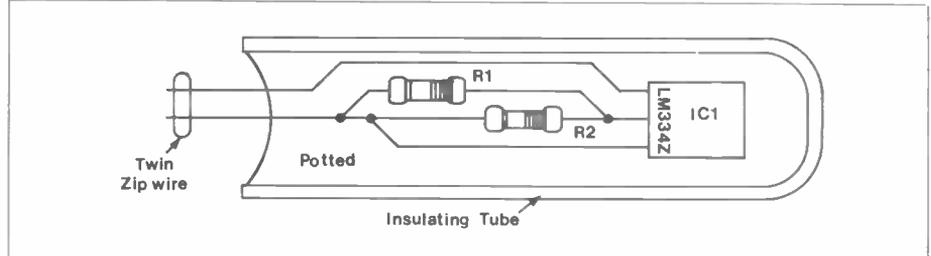
Figure 11. The Probe

spring and to maintain the more exotic hot house plants through the winter. For this application, particular care must be taken to make the mains heater waterproof as there will be a lot of water and condensation about. A sealed bulkhead lampholder is suitable here. Also, careful placing of the control box is needed e.g. mounted on a nearby wall, to avoid accidental splashing.

The unit can also be used for heating liquids. For tropical fish aquaria, the heater bulb is replaced by a proper aquarium heater made for the purpose. The heater turn-on surge current should not exceed 4 amps when using the power triac recommended. Temperatures around 23°C (75°F) are usual for this application, slightly lower temperatures being tolerated by the hardier types e.g. Angelfish, while some other types may prefer the temperature adjusted a little higher e.g. the Labyrinth Fish. To be able to adjust the temperature easily will be especially appreciated by those intending to breed tropical fish, convenient adjustment not being possible with the

cheaper fixed temperature thermostats commonly used.

The same arrangement is also well suited to photographic processing requirements. For this, all the chemicals needed for a particular operation may be equilibrated to the same temperature of choice by standing their bottles in a bowl or water bath (called a 'tempering box') in which the aquarium heater and temperature sensor are immersed.

If for any application the temperature range is inadequate, it may be altered by changing the values of R4 and R5. Adding so much to one resistor and subtracting the same amount from the other will bodily shift the temperature range covered while keeping the span of degrees covered by the control RV2 the same. The scale, as shown in Figure 7 will, of course, have to be redrawn.

More powerful heaters can be used if the heater bulb is replaced by a mains relay, which opens up such possibilities as central heating control. Whatever the application the required temperature is set by one simple dial adjustment.

17

Lead-Acid Battery Charger Lead-Acid Battery Charger Lead-Acid Battery Cha

by Mark Brighton

Properly charging sealed lead-acid batteries is very important for long trouble free battery service. The circuit shown in Figure 1 is capable of quickly and safely charging lead-acid batteries, and features temperature compensation in addition to two charging levels (with automatic switchover).

Circuit Description

Temperature compensation in a charger is important to prevent over-charging, especially if the battery is subjected to wide temperature variations. A temperature coefficient of −5mV/°C/cell at the output of the charger is provided by IC1, a current mode temperature sensor which is either located near the battery, or if high charging currents are involved, it could be attached directly to the battery.

The two-step charging feature provides a higher initial charging voltage

> ★ **4V, 6V & 12V Settings**
> ★ **Two Step Charging**
> ★ **Simple Construction**
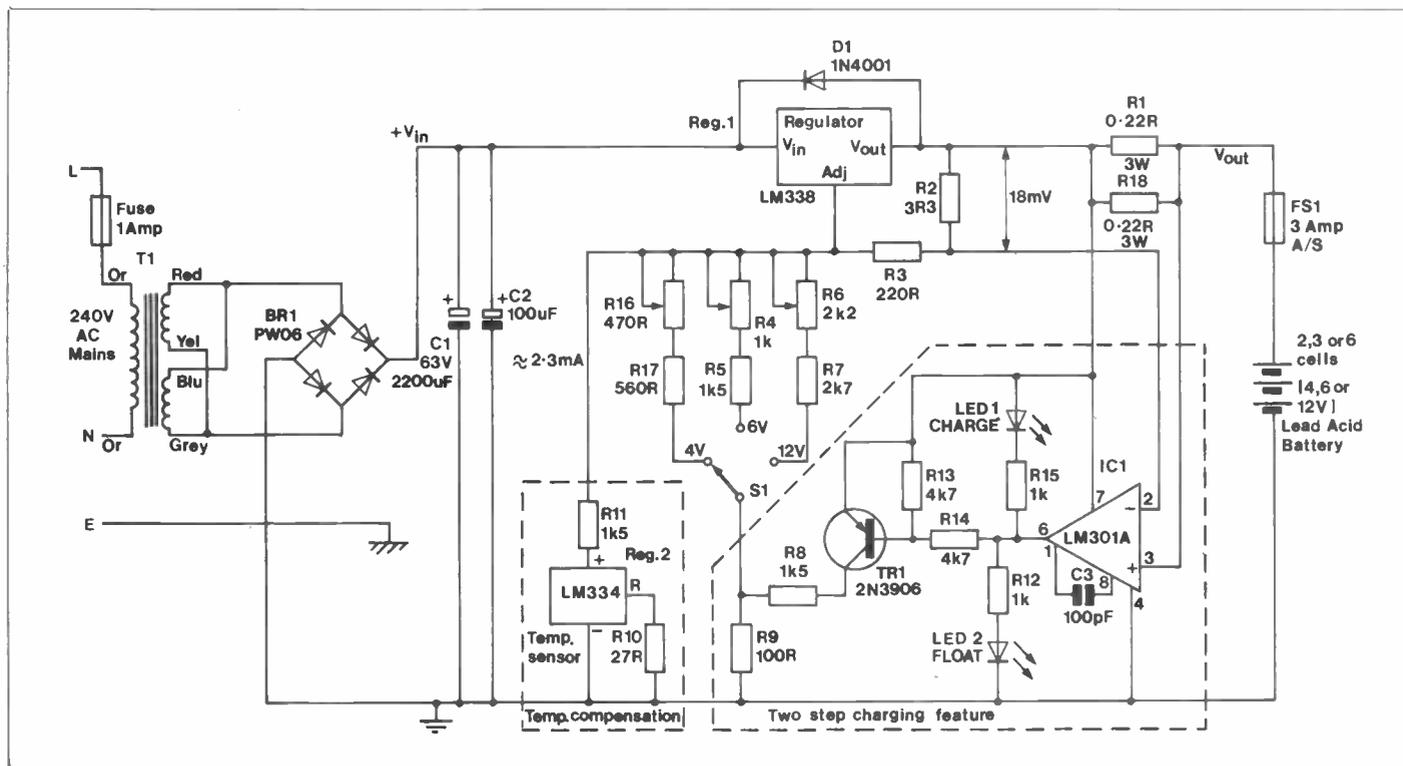
Figure 1. Circuit Diagram
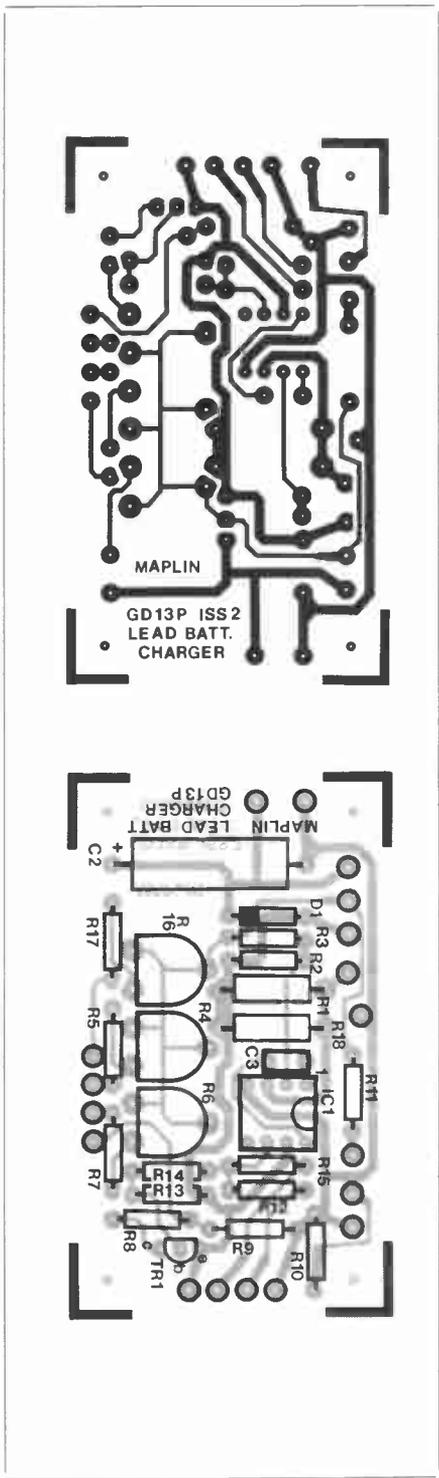
Figure 2. PCB Layout and Legend
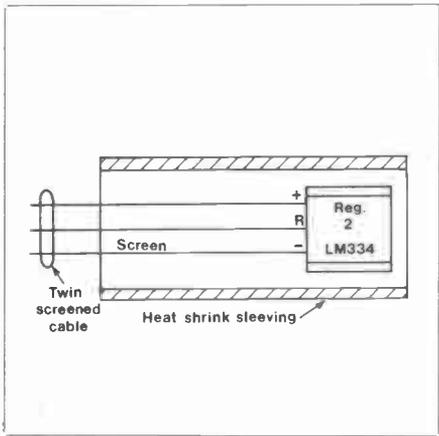
Figure 3b. Fitting REG 2
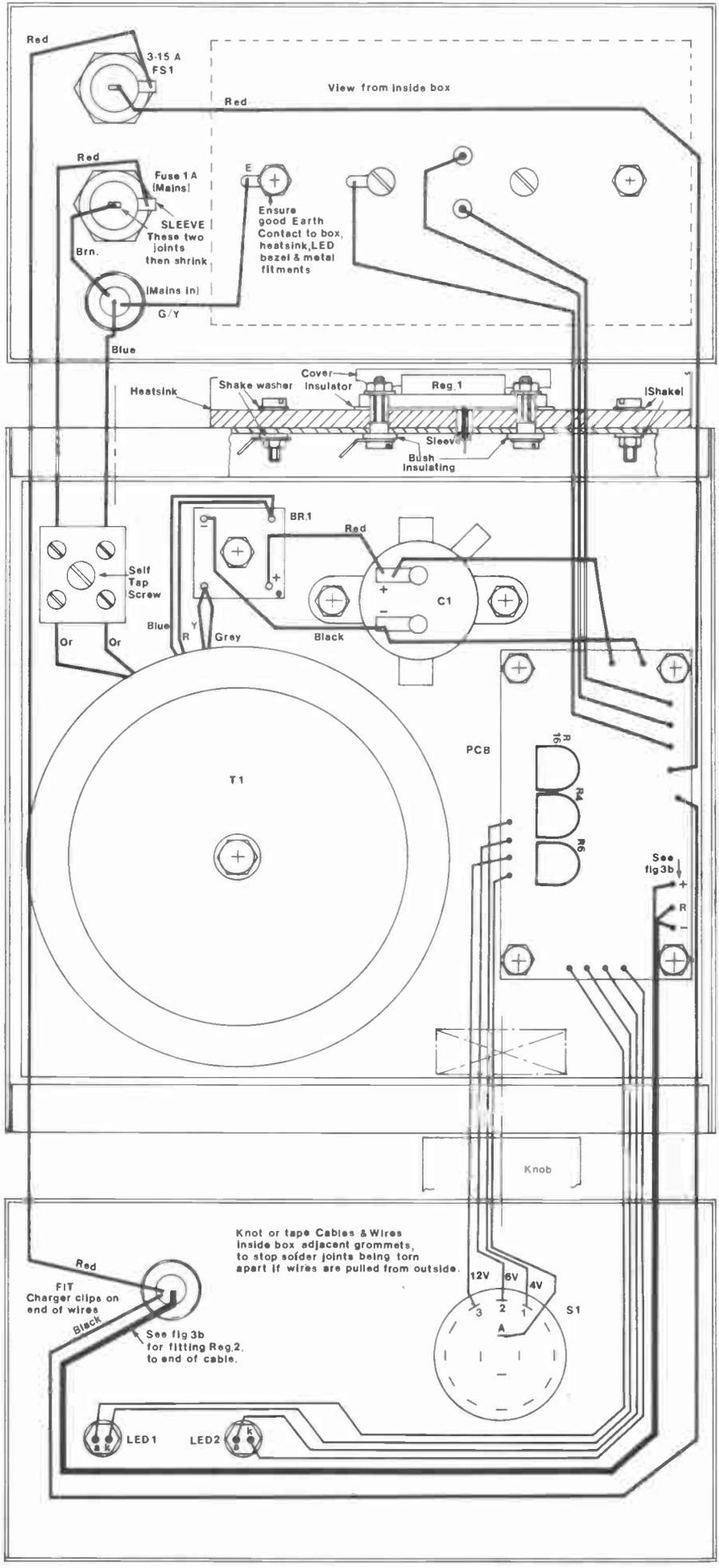
Figure 3a. Wiring Diagram

Figure 4. Box Drilling Details

All six holes in heatsink & box.

Heatsink outline

Rear panel
Base
Top
Box
Chassis

All Dimensions in mm

Holes
a ⌀ 2·5
b ⌀ 3·2
c ⌀ 4·D
d ⌀ 5·2
e ⌀ 8·0
f ⌀ 10·0
g ⌀ 12·7

Front panel
Top
Base
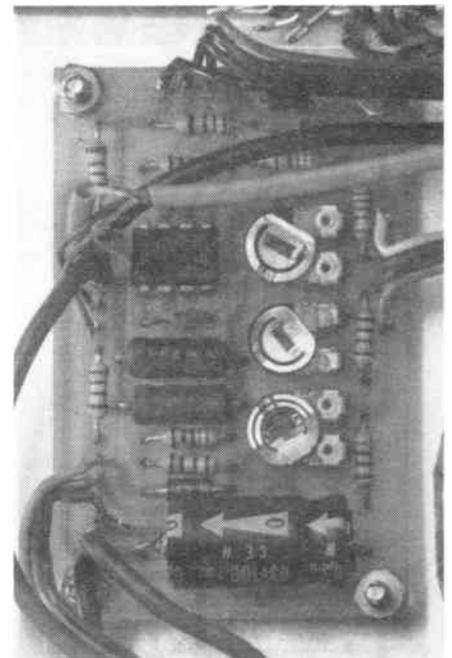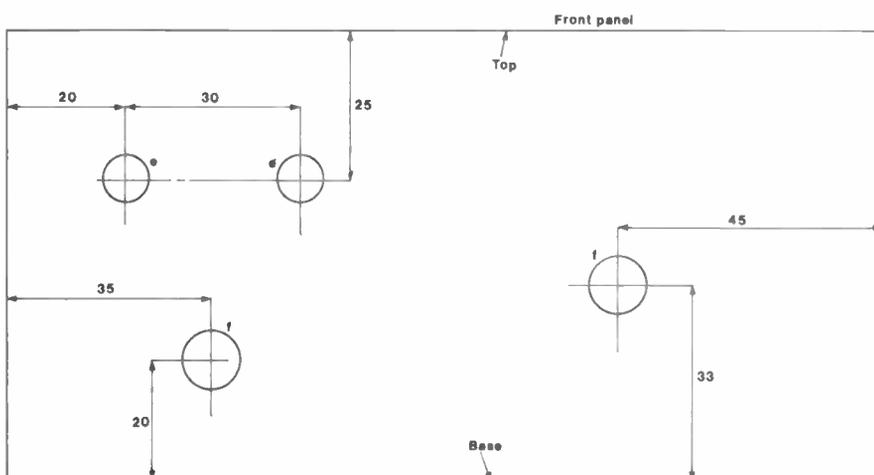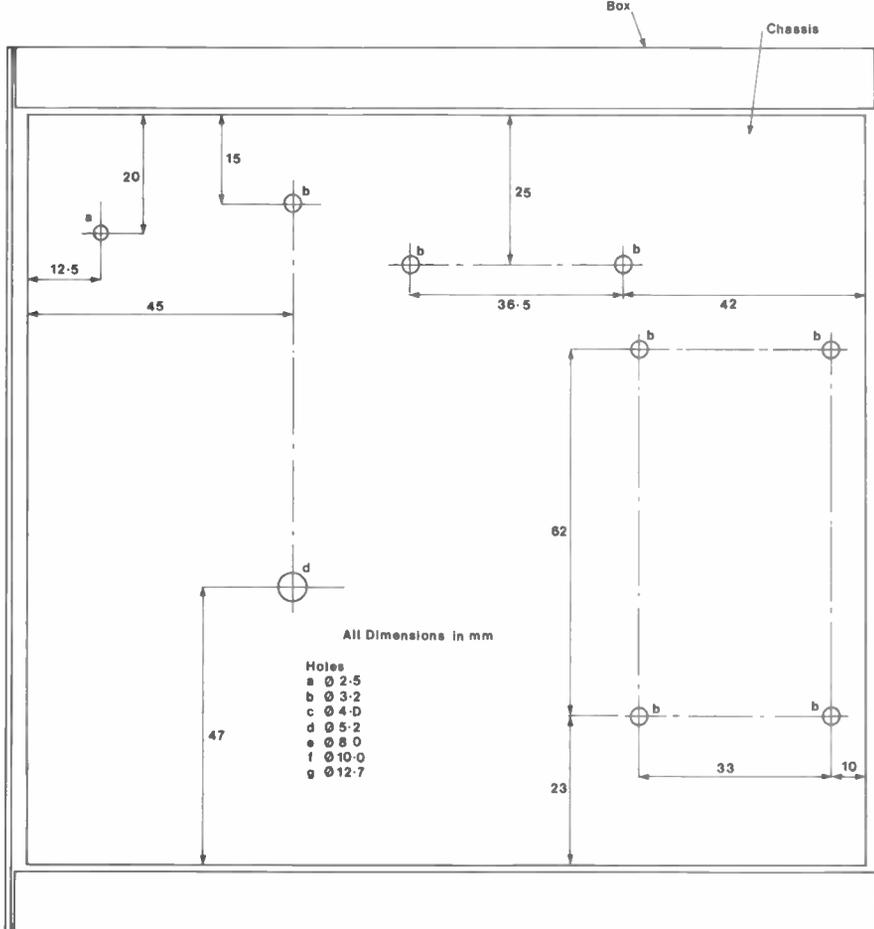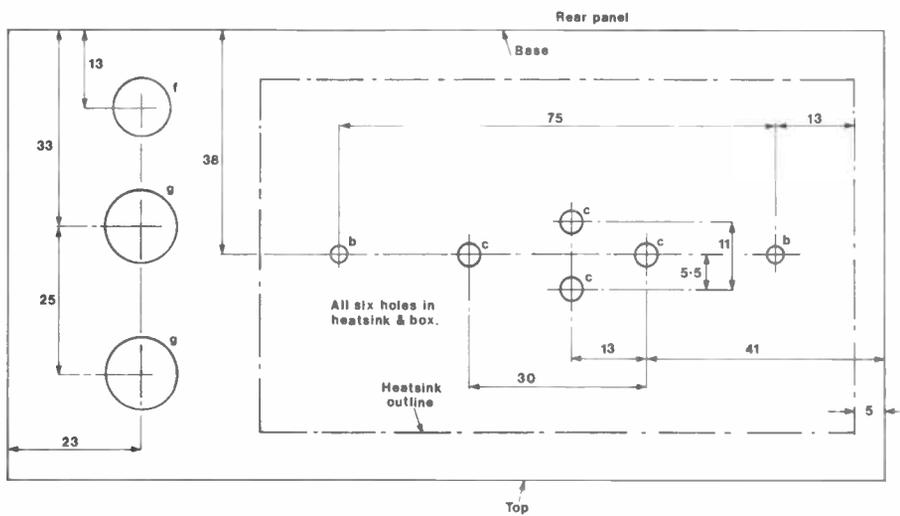
(2.5 Volts/cell @ 25°C) to rapidly bring a discharged battery up to near full charge. The amount of charging current is determined by the amount of charge remaining in the battery and the current limit of the regulator, REG 1. As the battery approaches a fully charged condition, the current begins to decrease. When it drops below a predetermined level ($\simeq$ 180mA) the charger's output voltage drops to a float condition voltage of 2.35 Volts/cell @ 25°C, which maintains the battery in a fully charged condition. This float voltage prevents the battery from becoming overcharged, which can seriously shorten its life.

R1/R18 and R2 determine the current level when the charger switches from a charge mode to a float mode, while R8 and R9 set the amount of voltage change. The LED's indicate which mode the charger is in (charge or float). The amount of temperature compensation is controlled by the value of resistor R10.

A unique feature of this charger is that it provides the correct temperature coefficient and the correct amount of charge-mode voltage boost for each cell, regardless of the number of cells being charged.

Construction

Insert all veropins from the track side of the board (shown in Figure 2), and push them home firmly with a soldering iron. Solder the pins into place. Now insert all resistors and capacitors, noting the polarity of C1, and solder the component leads in place. Insert and solder the IC socket, ensuring that the end notch is at the same end as the white bar on the legend; then TR1, referring to the legend for correct orientation. Plug IC2 into the DIL socket with the notch on the IC aligned with the cutout on the socket, and/or pin 1 (marked with a dot) adjacent to the '1' on the legend. Bolt REG

l onto the heatsink, using the mounting kit provided. Referring to Figure 3, wire-up the pcb to S1, LED 1 and 2, IC1, and REG 1 respectively, and also the transformer/rectifier etc. Figure 4 shows drilling details of a suggested case.

Testing and Use

The accuracy of a digital voltmeter is really required here in order to carry out the following procedure. Apply power to the circuit and connect the digital volt-meter across the output leads. Set S1 to 4V, and adjust R16 for a 4.5V output. Set S1 to 6V, and adjust R4 for a 7.05V output. Set S1 to 12V, and adjust R6 for a 14.1V output. Now connect the output leads to a partially discharged lead-acid battery, first selecting the appropriate voltage setting at S1, and via a multimeter set to read current up to a minimum f.s.d. of 5A. Check the direction of current flow, (if the battery is discharging, you have a problem: re-check your wiring, etc). *Under NO circumstances should the current exceed 5A.*

The red 'charge' LED should be on and should remain on until the charge current falls below ≃ 180mA, at which point the green 'float' LED should light, indicating that the charge cycle has finished and the charger is in trickle charge mode.

Lastly, if the temperature sensor is held between finger and thumb, the charge current should start to drop, indicating that the temperature compensation is functioning correctly.

NOTE: When using the charger, you should ensure that correct polarity of the battery connections is always observed and that prolonged short circuit of the output leads is avoided. It is also worth bearing in mind that if the mains supply is removed from the charger whilst it is connected to a battery, the battery will commence to slowly discharge through the charger, so always disconnect the battery before switching off at the mains.
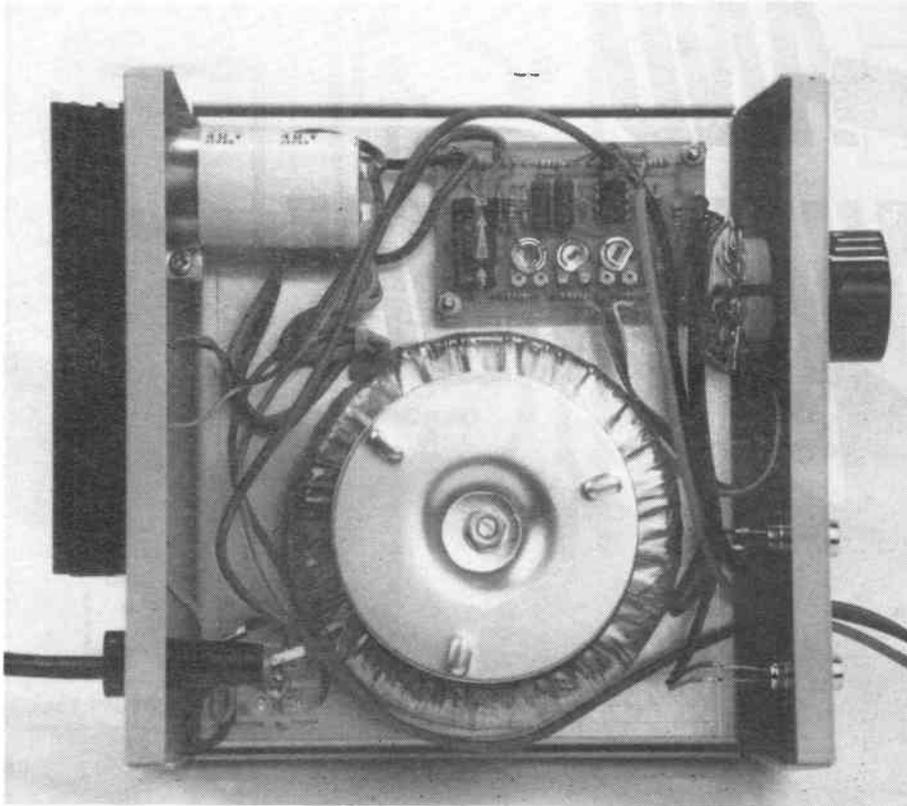
LEAD ACID BATTERY CHARGER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1,18	0·22Ω 3W 5% Wirewound	2	*Kit only*
R2	3Ω3	1	(M3R3)
R3	220Ω	1	(M220R)
R4	1k Hor. Enclosed Preset	1	(UH00A)
R6	2k2 Hor. Enclosed Preset	1	(UH01B)
R7	2k7	1	(M2K7)
R8,5,11	1k5	3	(M1K5)
R9	100Ω	1	(M100R)
R10	27Ω	1	(M27R)
R13,14	4k7	2	(M4K7)
R12,15	1k	2	(M1K)
R16	470Ω Hor. Enclosed Preset	1	(UF99H)
R17	560Ω	1	(M560R)

CAPACITORS

C1	2200µF 63V Can Electrolytic	1	(FF22Y)
C2	100µF 63V Axial	1	(FB51F)
C3	100pF Ceramic	1	(WX56L)

SEMICONDUCTORS

TR1	2N3906	1	(QR42V)
IC1	LM301A	1	(QH36P)
REG1	LM338K	1	(RA88V)
REG2	LM334	1	(WQ32K)
BR1	PW06	1	(WQ58N)
D1	1N4001	1	(QL73Q)
LED1	Chrome LED Large Red	1	(YY60Q)
LED2	Chrome LED Large Green	1	(QY47B)

MISCELLANEOUS

T1	Transformer Toroidal 80VA 18V	1	(YK17T)
	Safuseholder 20	2	(RX96E)
FS1	Anti-Surge Fuse 20mm 3·15A	1	(RA11M)
FS2	Fuse 20mm 1A	1	(WR03D)
	Heatsink 4Y	1	(FL41U)

|			
	Kit TO3	1	(WR24B)
	TO3 Cover	1	(FL56L)
	Thick Grommet 6·4mm	1 Pkt	(JX62S)
	Terminal Block 5A	1 Strip	(HF01B)
S1	Rotary Switch SW3B	1	(FF76H)
	Knob K7C	1	(YX03D)
	Blue Case 231	1	(XY44X)
	PCB	1	(GD13P)
	Spacer 6BA × ⅛in.	1 Pkt	(FW33L)
	Bolt 6BA × ½in.	2 Pkts	(BF06G)
	Nut 6BA	2 Pkts	(BF18U)
	Solder Tag 6BA	1 Pkt	(BF29G)
	Shakeproof Washer 6BA	1 Pkt	(BF26D)
	Washer 6BA	1 Pkt	(BF22Y)
	Self-Tapping Screw No.6 × ½in.	1 Pkt	(BF67X)
	Extra-Flex Black	2m	(XR40T)
	Extra-Flex Red	2m	(XR44X)
	Heat Shrink Sleeving CP48	1m	(BF89W)
	Ribbon Cable 10-Way	1m	(XR06G)
	Lapped Twin Screened Cable	2m	(XR20W)
	Min. Mains Black	2m	(XR01B)
	Charger Clip	2	(HF26D)
	Pin 2145	1 Pkt	(FL24B)
	Stick-On Front Panel	1	(FS00A)
	DIL Socket 8-Pin	1	(BL17T)
	Instruction Leaflet	1	(XU12N)
	Constructors' Guide	1	(XH79L)

WorldRadioHistory

ACTIVE AERIAL AND TUNING UNIT

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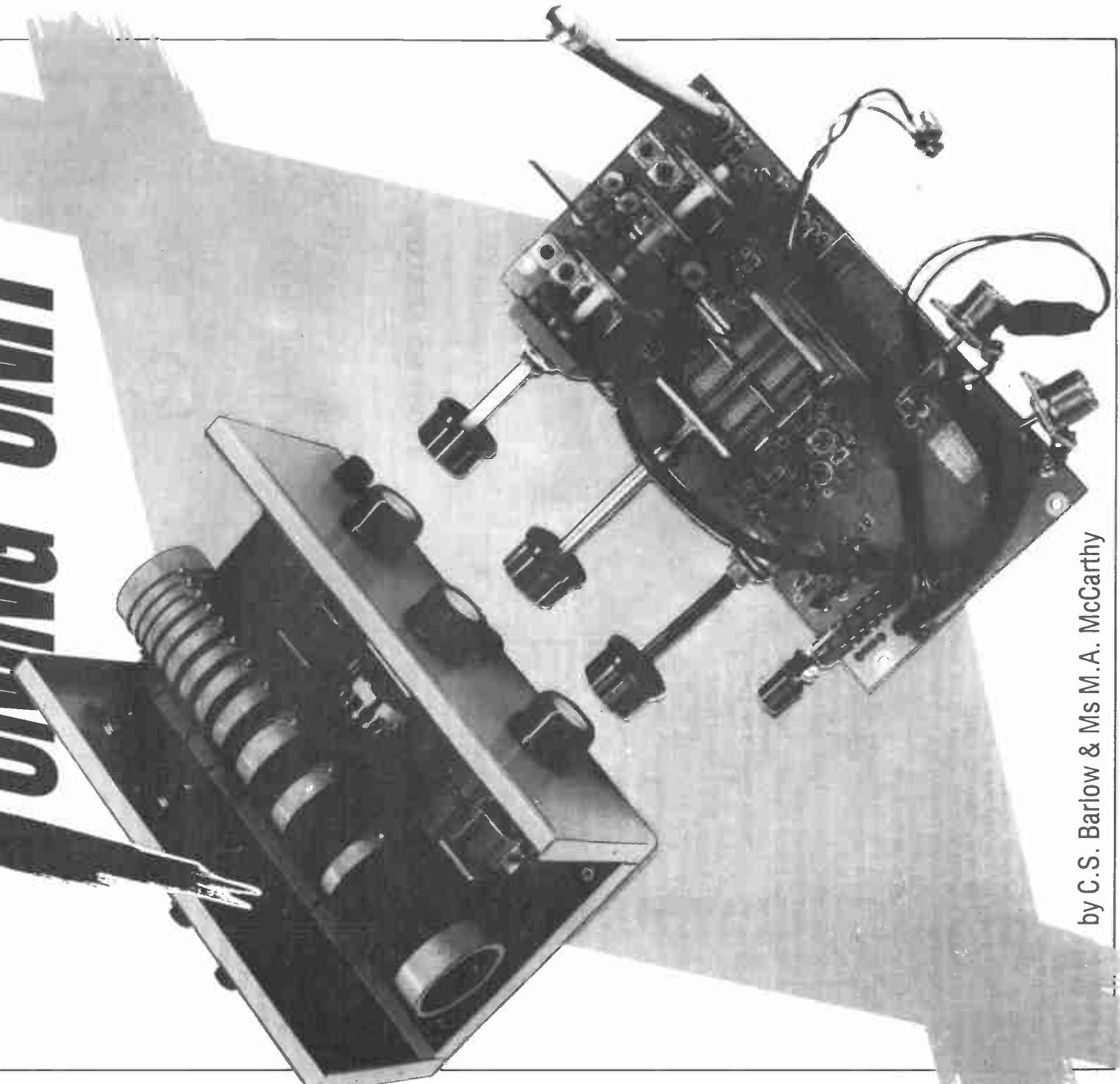
Two Devices

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 short wave 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.

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

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

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

AERIAL TUNING UNIT
GD19V MAPLIN

L1

S1

S3

VC 2

VC1

S2

A.T.U.
GD19V ISS.2.
MAPLIN
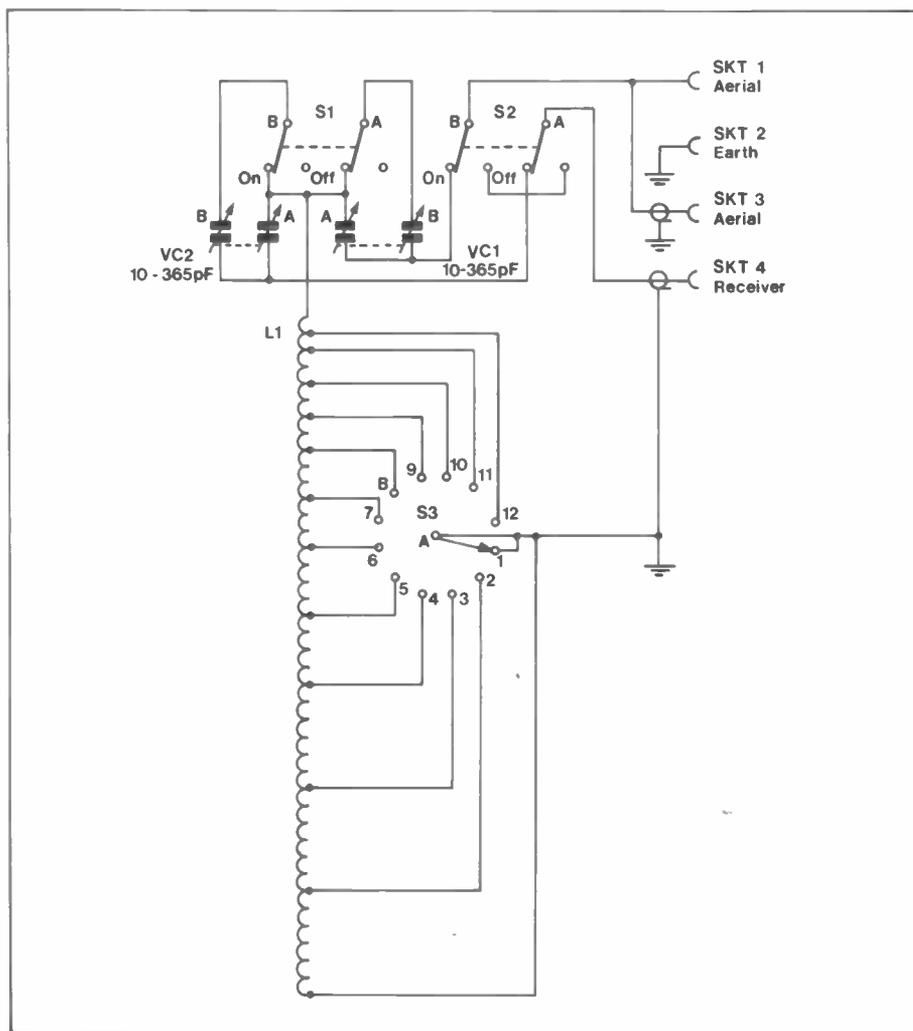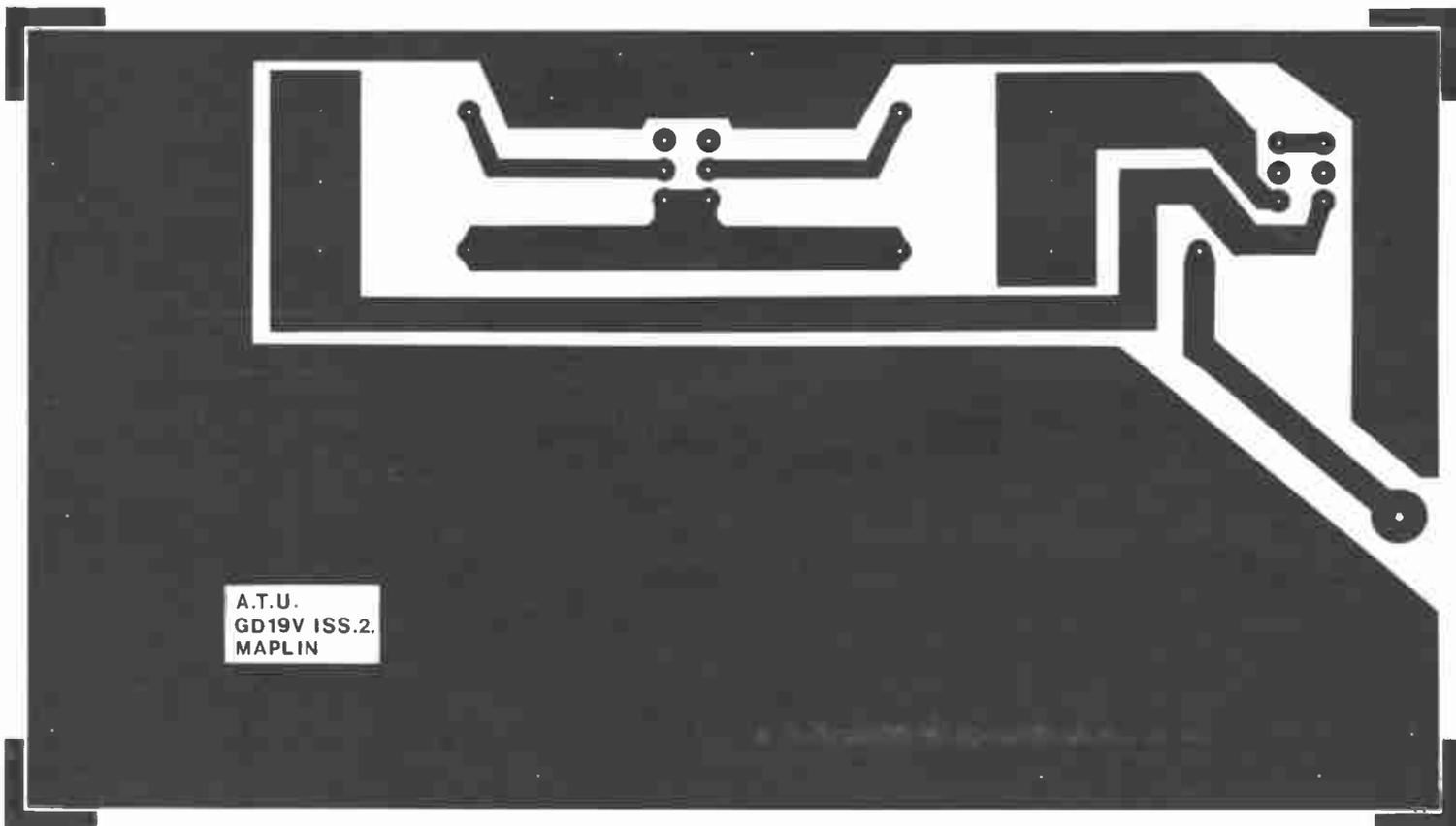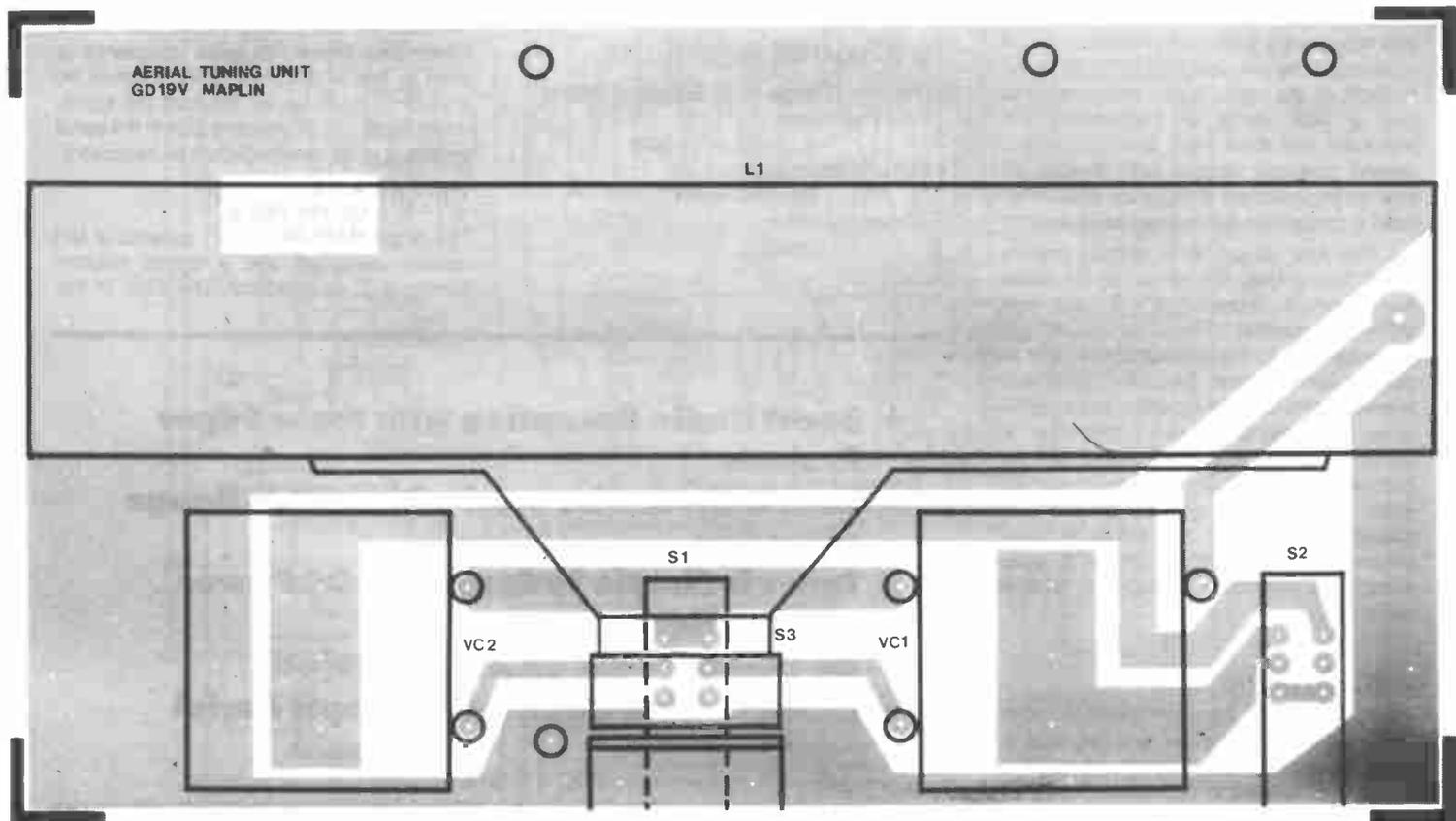
Figure 2. Tuner PCB
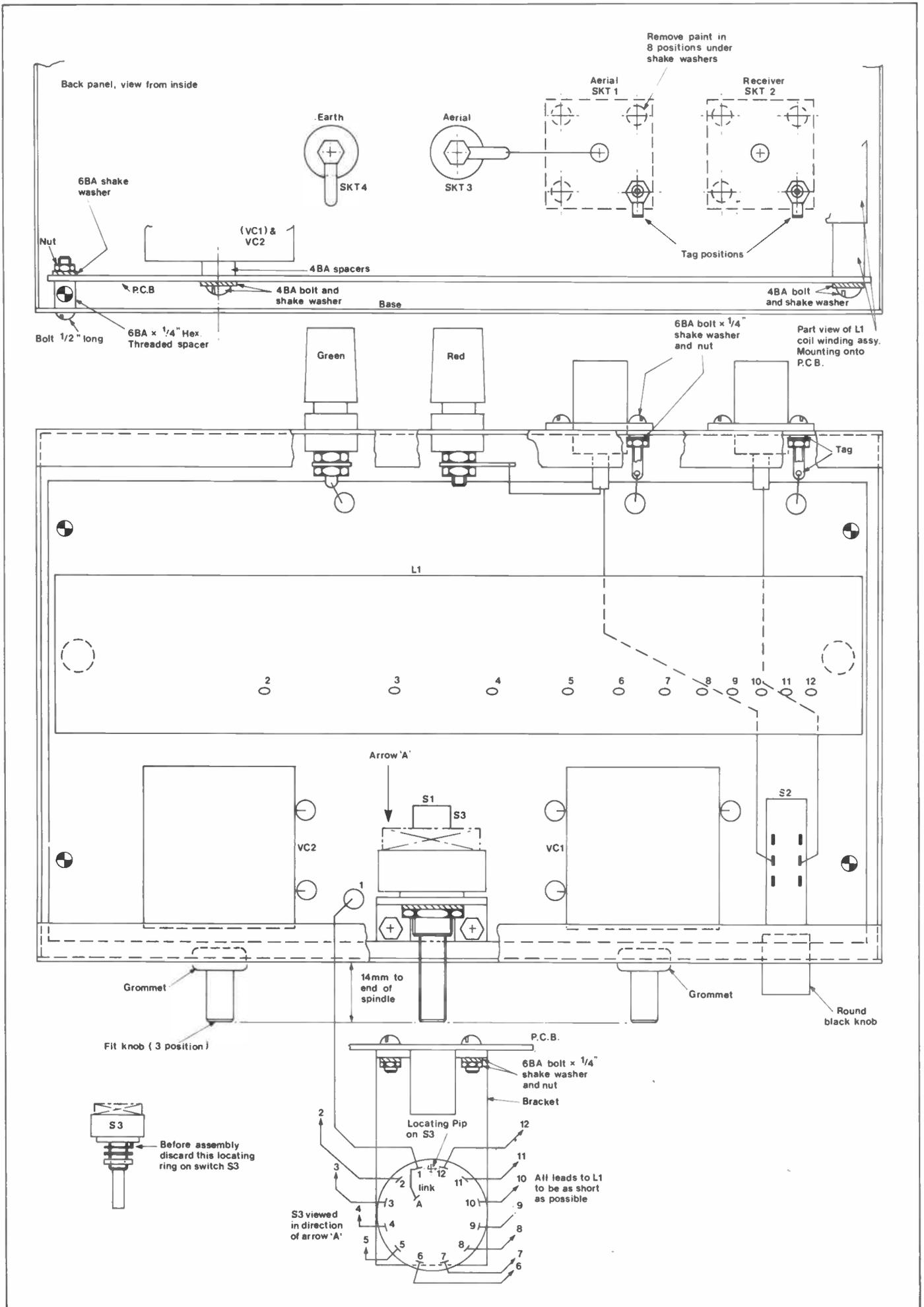
Figure 3. Wiring the Tuner

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 × 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 dependent 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 drilling
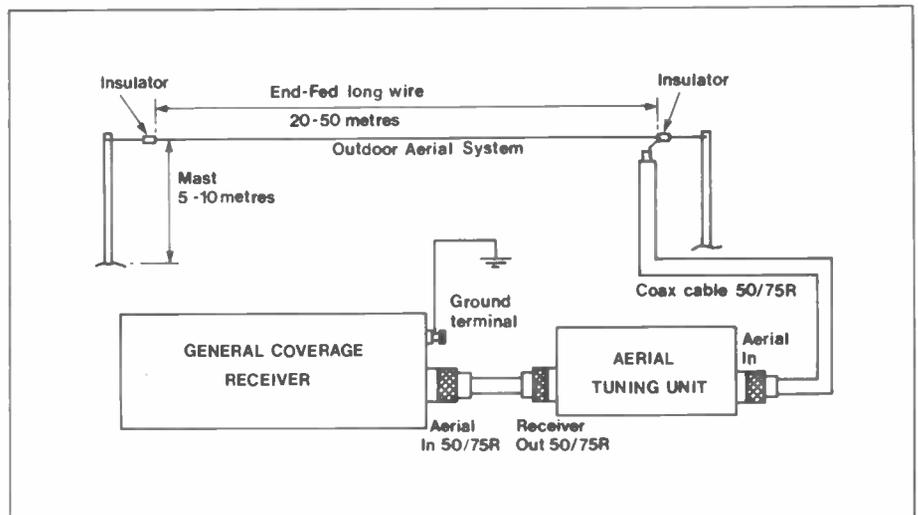
Figure 4. System Set-up
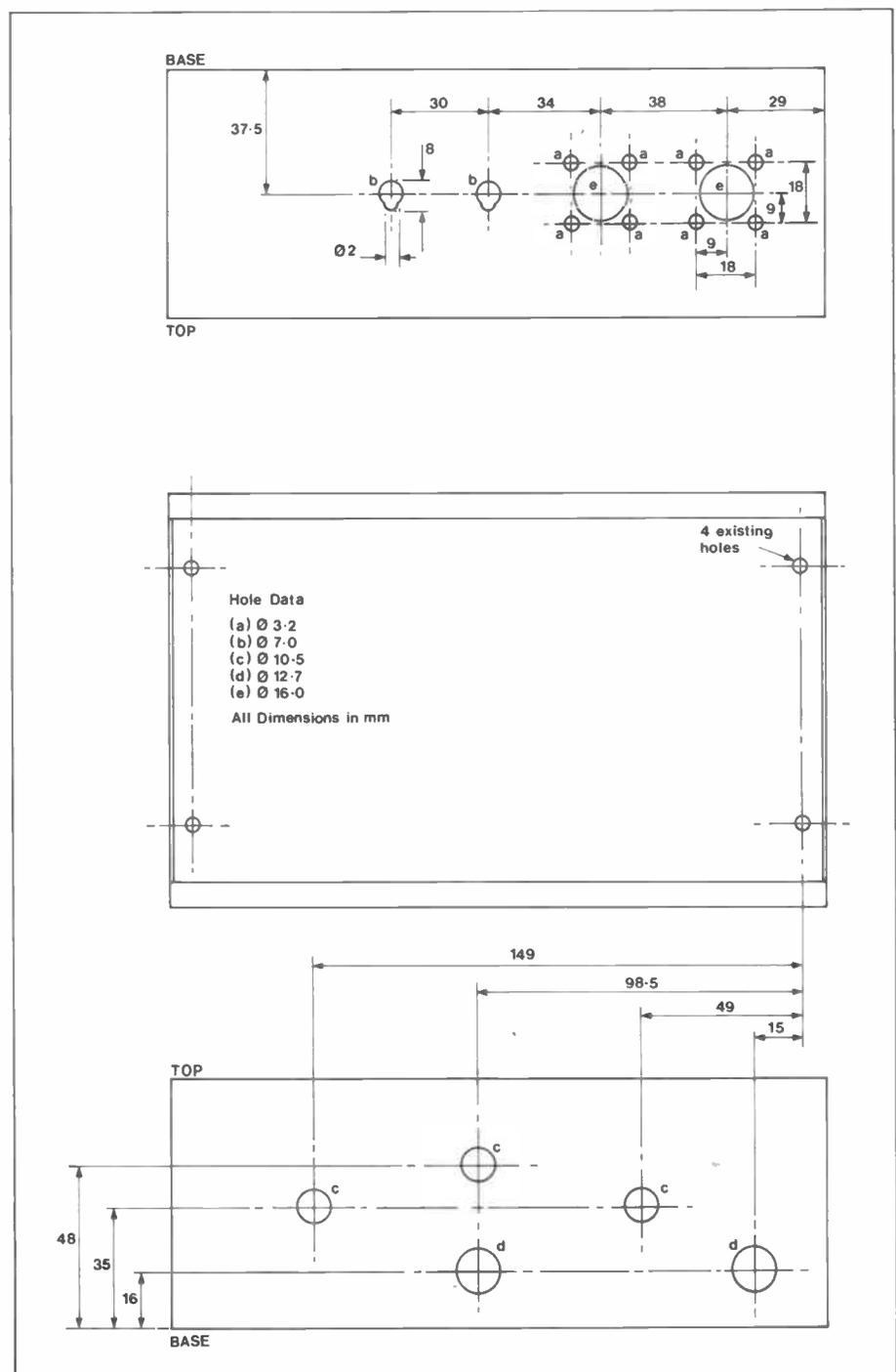
Figure 5. Tuner Case Drilling

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 ¼in., 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 onto 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.
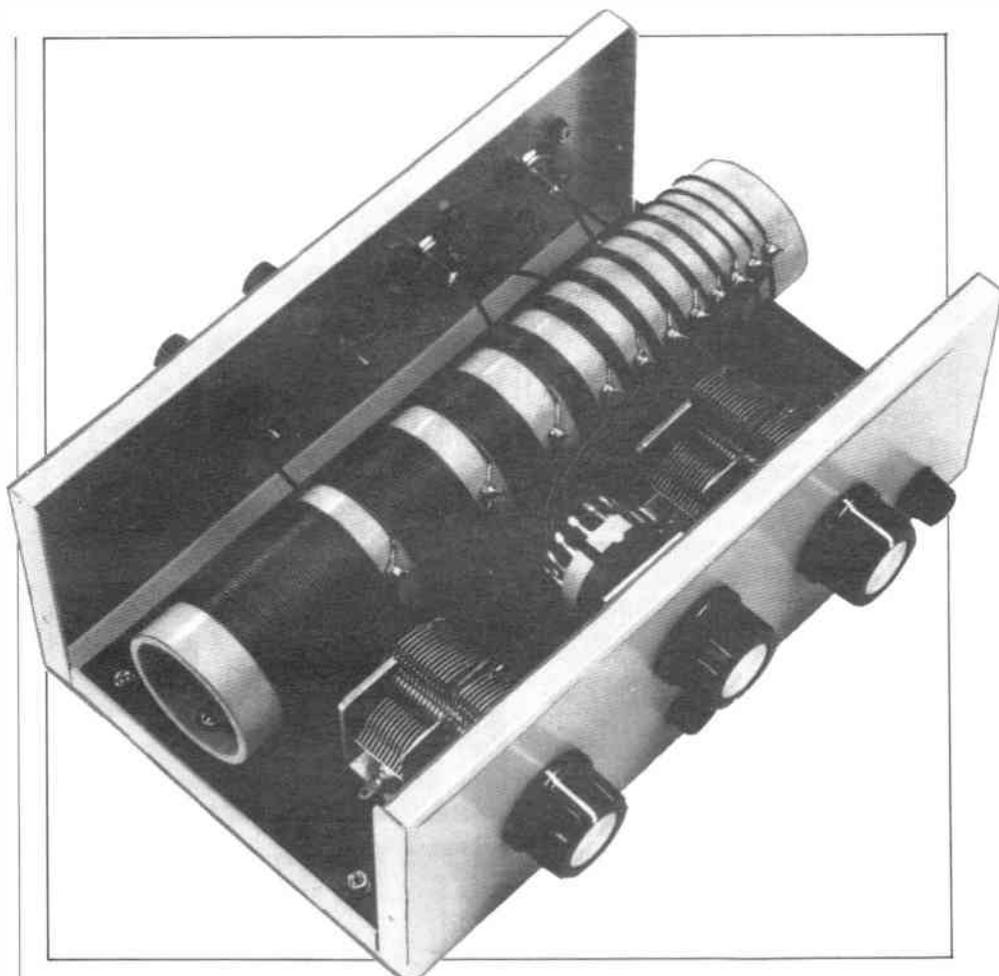
Typical record

RECEIVER	AERIAL	FREQUENCY	INDUCTANCE L	RECEIVER C	AERIAL C	C × 2
TRIO - TS940S	Long wire	14·2 MHz	9	4	7	Out
YAESU - FRG 880C	Dipole	3·7 MHz	3	8	4	Out
ICOM - R71	Long wire	700 kHz	1	6	10	In

Figure 6. Typical Record Chart

All dimensions in mm.
Holes a,b and c = Ø 1·3 (13)
Holes d = Ø 4·2 (2)
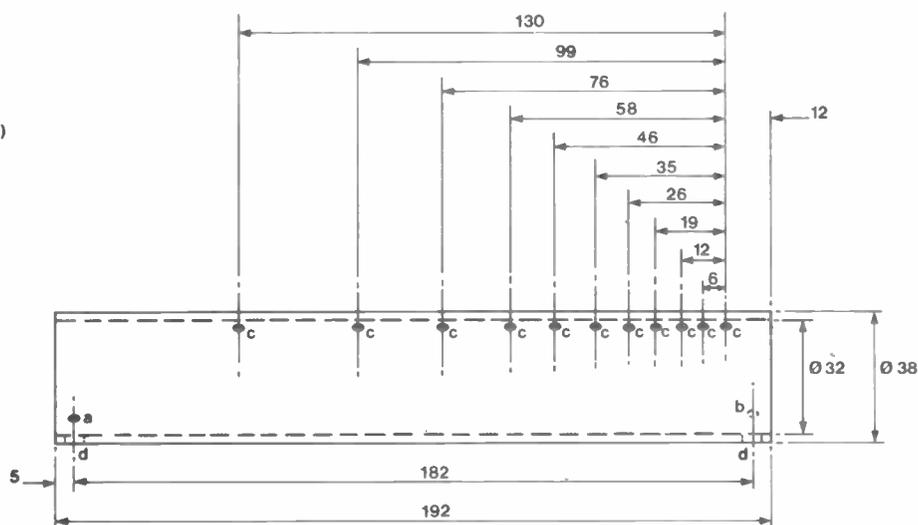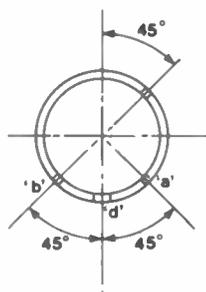
Figure 7. Coil Tube Drilling
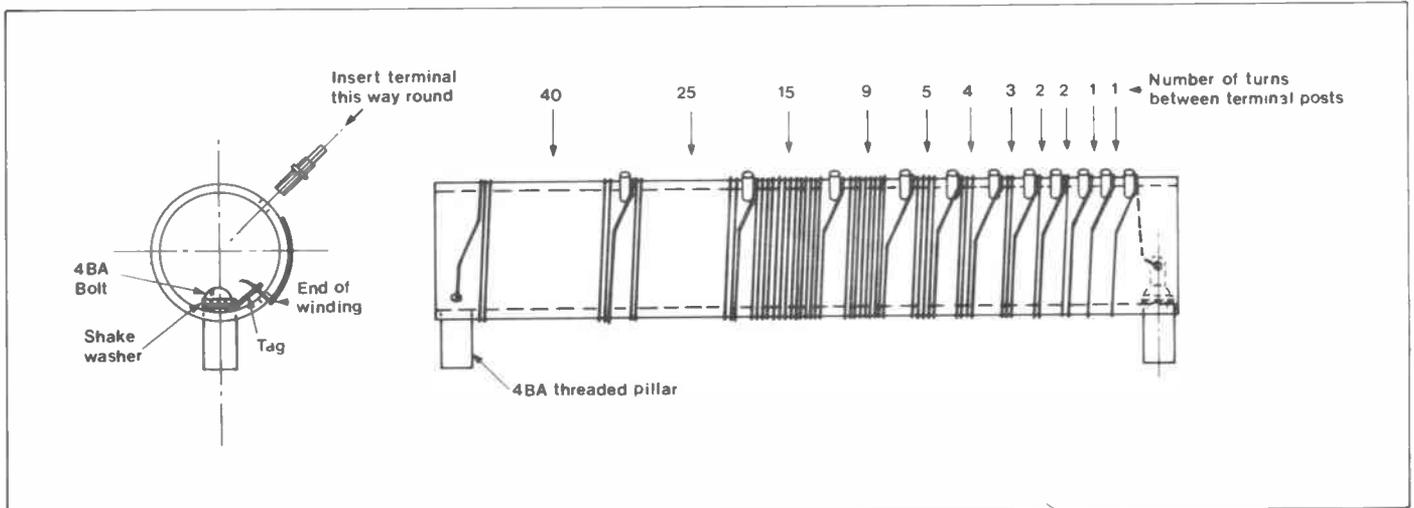
Figure 8. Coil Winding

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, ½in. bolts and spacers underneath, plus four 6BA shakeproof 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 into 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
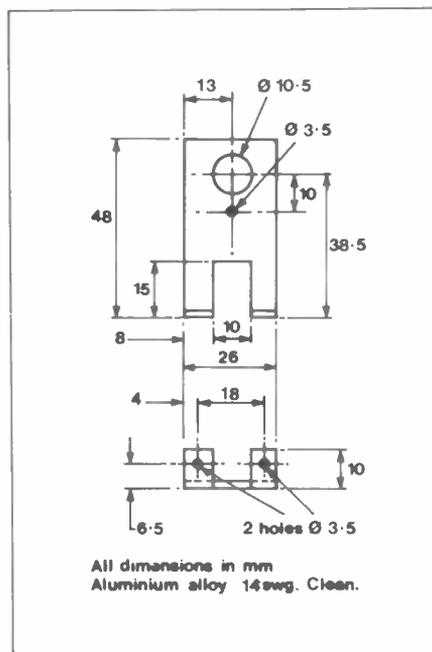

Figure 9. Tuner Bracket

the AGC, then the peak in signal will be more audible.

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 × 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 × 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 10W 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,	(0dB to +10dB SW3)
High (Integral Telescopic Aerial)	= 50kΩ
Input Impedance, Low (External Aerial)	= 50Ω
Output Impedance	= 50Ω
Power Supply, Internal PP3 Battery or External DC	= +7 to +15V
Low Voltage Indicator Threshold	< +7V

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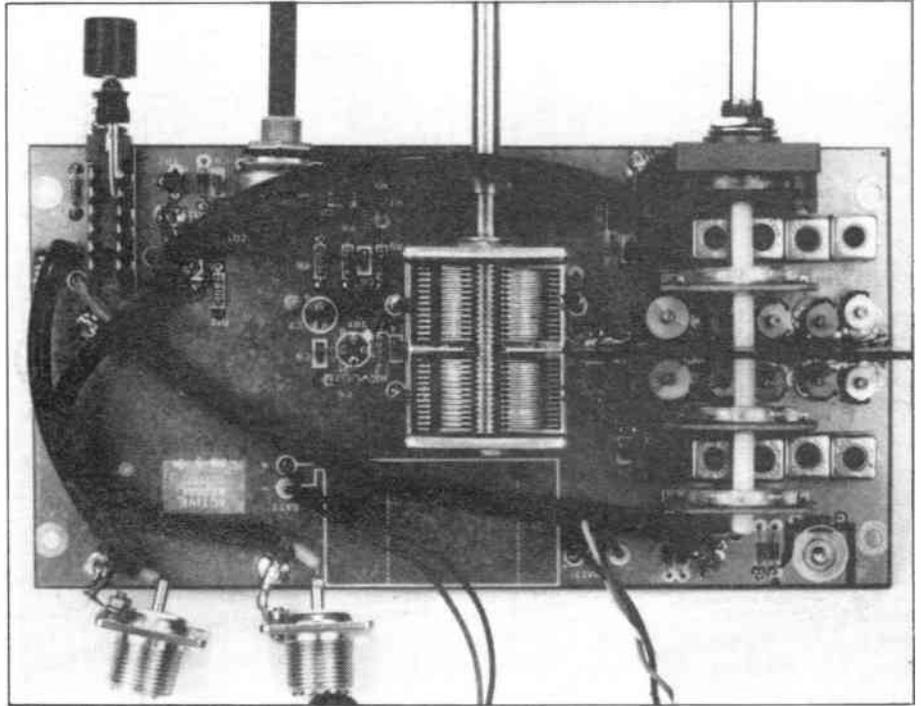
The power source for the active aerial is an internal PP3 battery or, an external DC power supply of between +7V and +15V can be used. This means the active aerial can be used virtually anywhere, i.e. at home, in the car or on a boat.

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
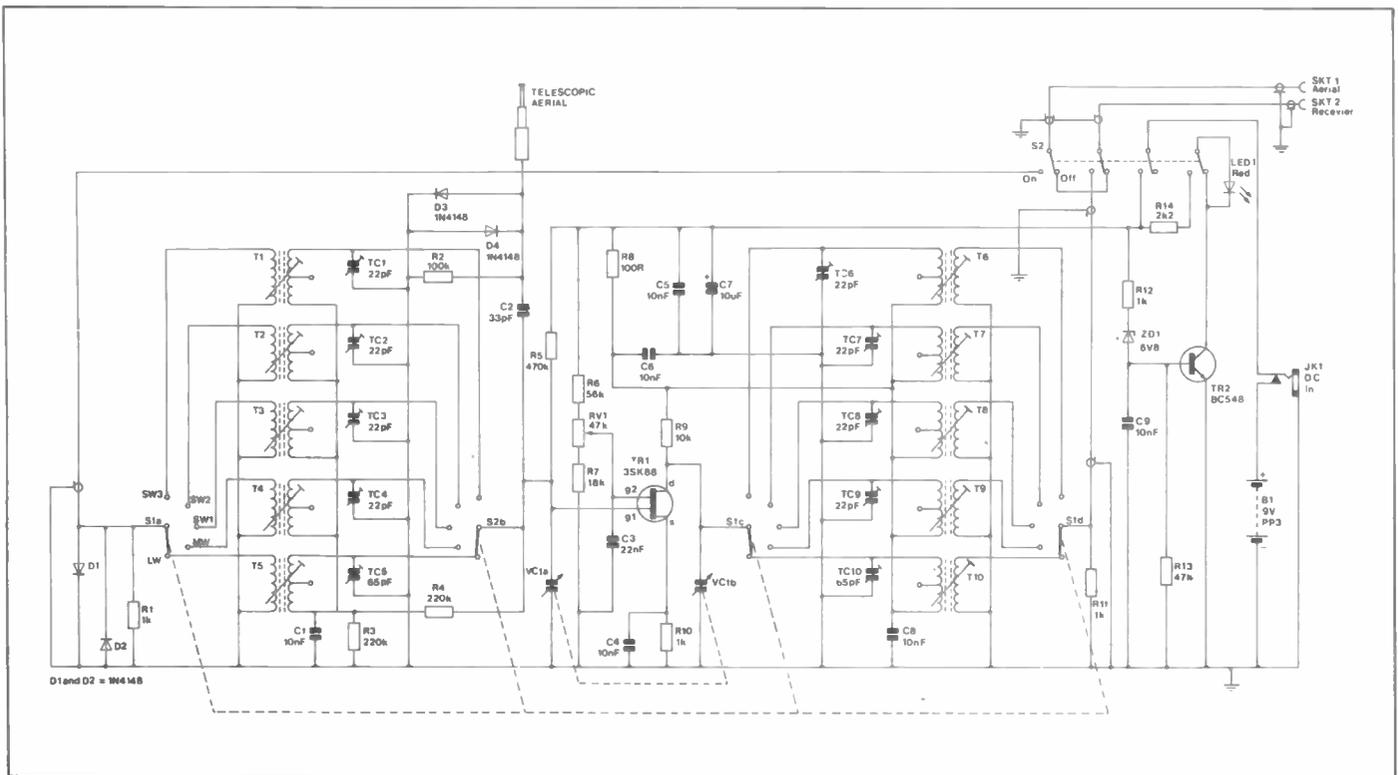

Figure 10. Aerial Circuit
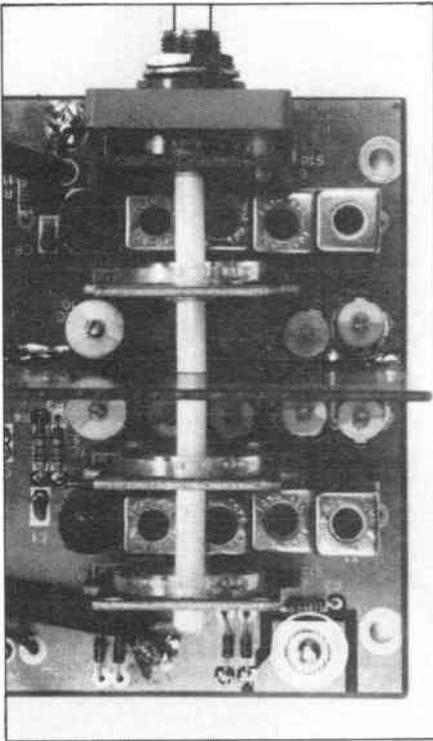
input to the amplifier and a further five on the output. The bands are as follows: LW, MW, SW1, SW2, and SW3. As can be seen from the circuit diagram, the input and output of each coil must be switched. This is achieved by the multi-segment rotary switch S1. S1a connects the external aerial to the low 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 +7V applied to the cathode of ZD1. As soon as the voltage drops below +7V 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
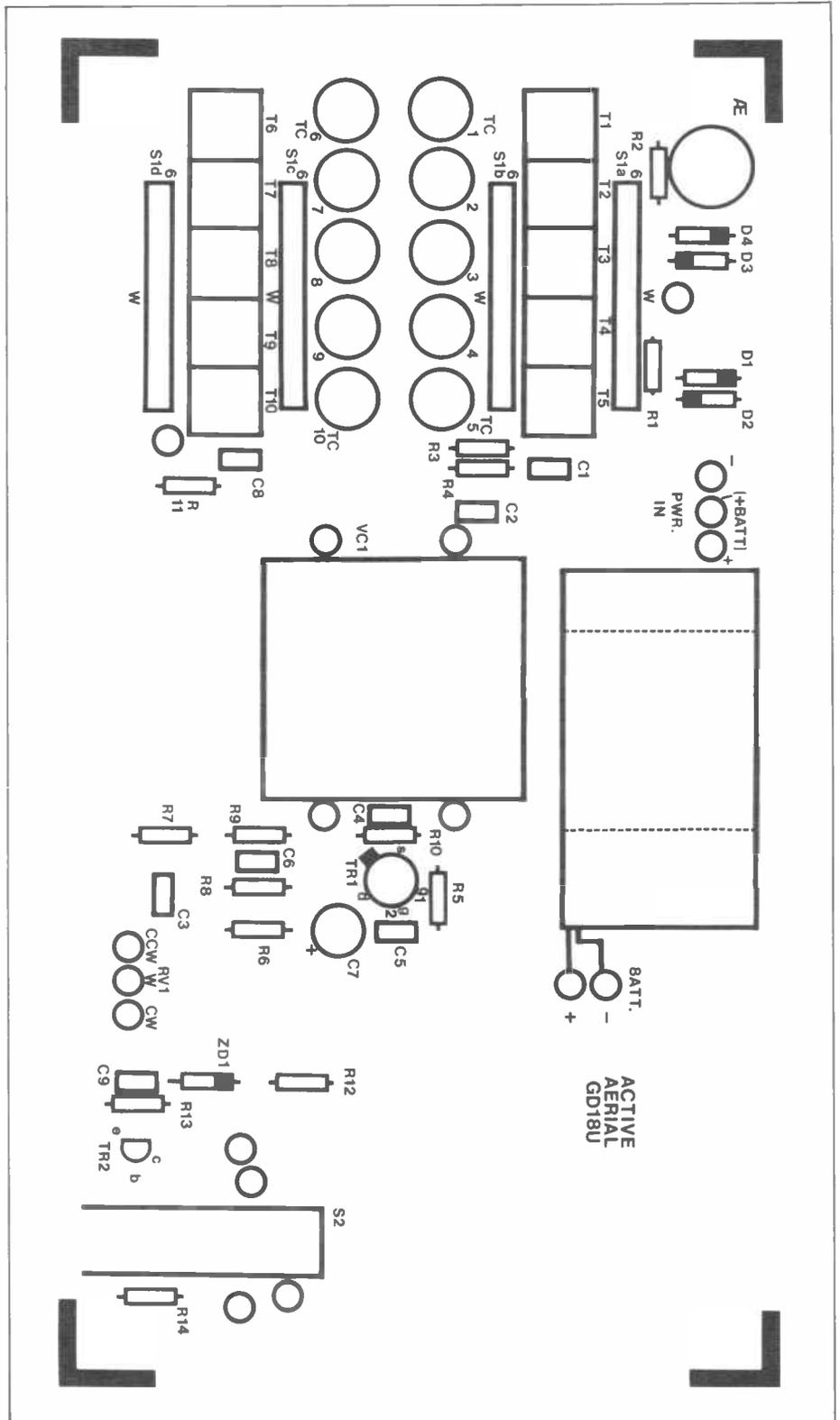

Figure 11. Aerial PCB Overlay

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 16. 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 +9V 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 PCB 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 example, S1a, b, c, d, and T1 to T10.

Back panel view from inside

Receiver SKT 2

Remove paint in 8 positions under shake washers

SKT 1 Aerial

Telescopic Aerial

Large grommet through hole in lid

DC Input

JK1

6BA shake washer

Nut

M3 screw

Nut

Shake washer

VC1

Tag positions

4BA spacers (2 positions)

PCB

Base

4BA bolt and shake washer

6BA × 1/4" Hex threaded spacer

Bolt 1/2" long

6BA bolt, shake washer and nut

Aerial fixing

Tag

Battery

Braid

Braid

S1(a)

T1

T5

Clip

S1(b)

TC1

TC5

Screen

VC1

TC6

Letter "F" this side

TC10

S1(c)

S2

T6

T10

S1(d)

k a

RV1

LED and clip

Secure front switch wafer to P.C.B. using the 2 screws supplied

Stop ring

Shake washer

14 mm to end of spindles

Flat on LED body

Round black knob

Nut

Slot

Wiper

2 3 4 5 6 7 8 9 10 11

Fit tab of Stop ring in position 5, tighten up nut.

Tin braid before soldering to P.C.B.

Prepare ends of coax before assembly

Wafers (a)(b)(c)

When fitting spindle coupling, turn front switch (d) fully anti-clockwise. Position wafers a,b and c as shown above and slide spindle through from back. Ensure that the screen between wafers b and c is assembled.

Figure 12. Aerial Wiring

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 how-ever, 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 capacitors. 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, ¼in. 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 25W, 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
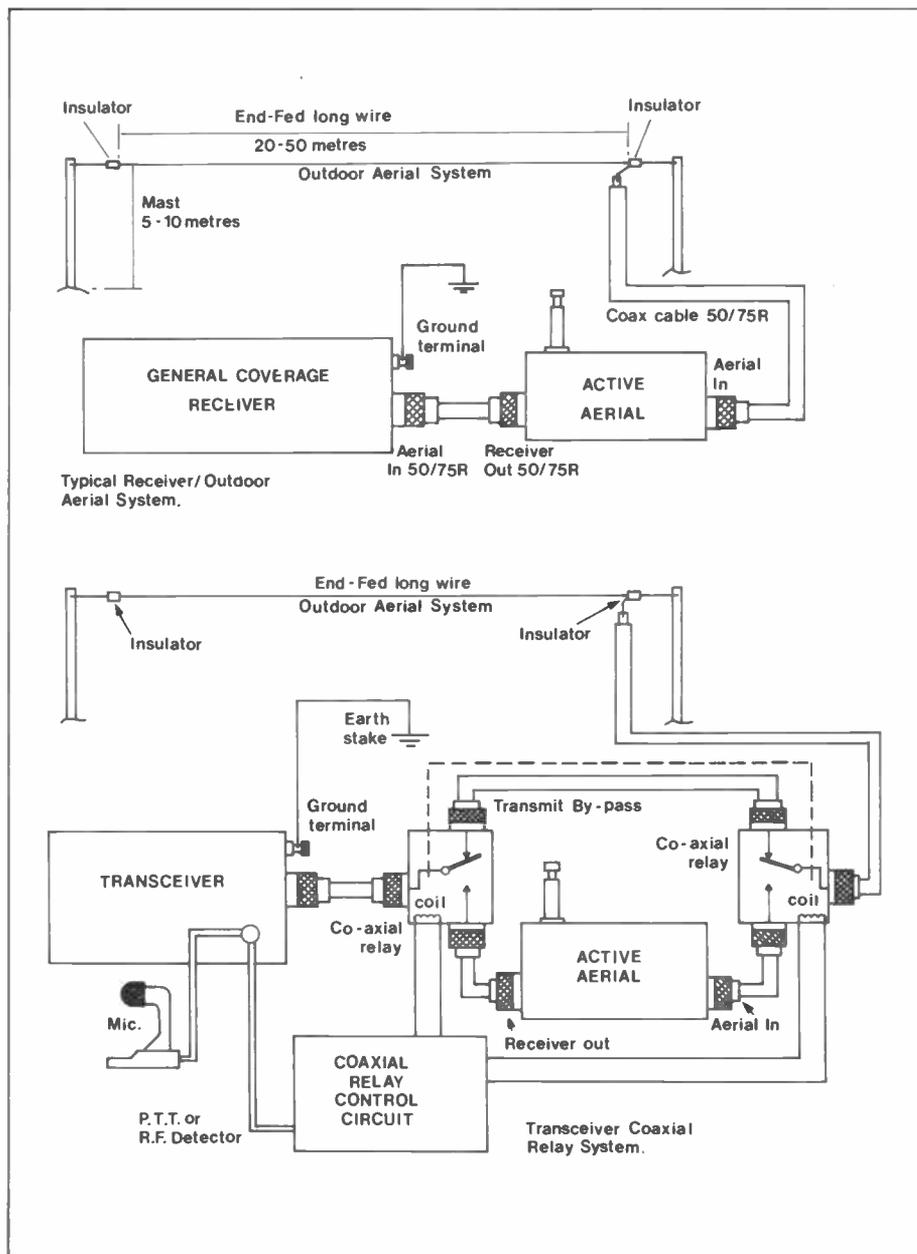

Figure 13. System Set-ups
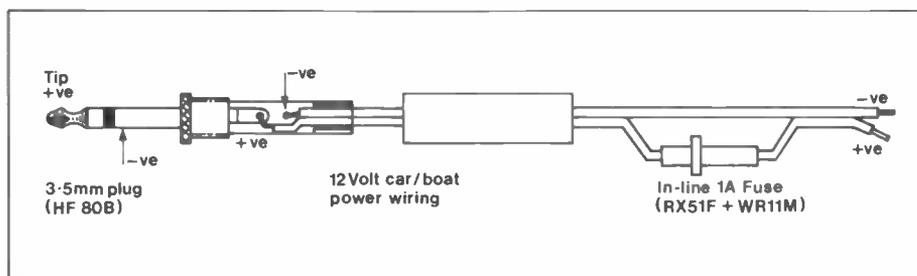
Figure 14. Power Plug

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.

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 offcuts of wire from the resistor
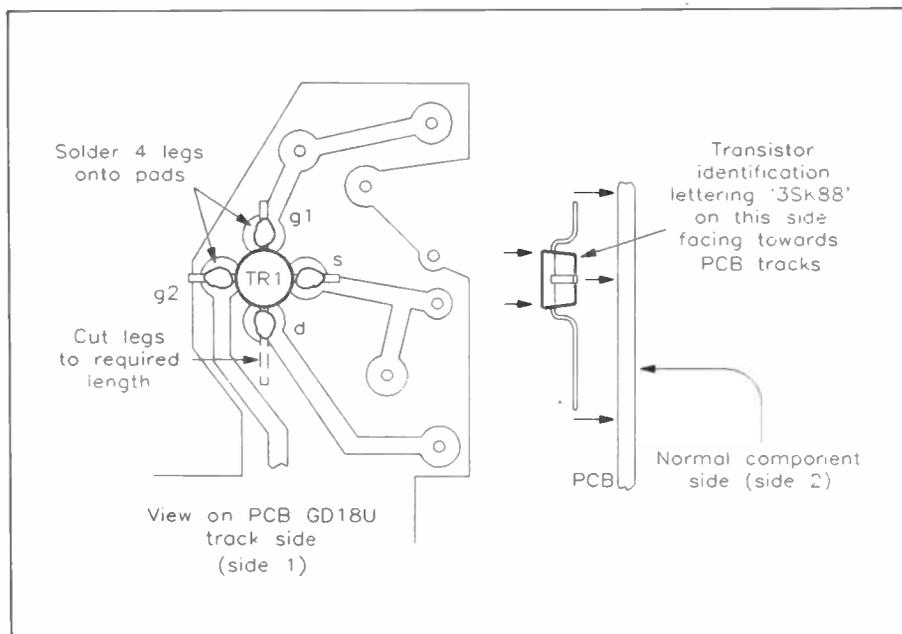
Figure 15. Fitting TR1.

leads for wiring in the four tags on the variable capacitor to the corresponding holes in the PCB.

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 onto the *underside* of the PCB at the position shown in Figure 15, 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 18. This will ensure a good earth connection to the chassis, which is very important at radio frequencies. Follow the drilling instructions in Figure 18 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 aforementioned shaft is cut to 36mm in length *overall*. The PCB assembly is held in place with four 6BA ½in. bolts and spacers underneath, plus four 6BA shakeproof 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 onto the front of the case using the nut and shakeproof 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 onto 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 9V 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 16.

If your circuit readings are close to those given in the chart then you can begin the RF

STEP	BAND SWITCH	ACTIVE AERIAL AND RADIO TUNING	ADJUST FOR PEAK SIGNAL READING	
			INPUT	OUTPUT
1	LW	150 kHz	T5	T10
2	LW	500 kHz	TC5	TC10
REPEAT	STEPS	1 and 2		
3	MW	500 kHz	T4	T9
4	MW	1·5 MHz	TC4	TC9
REPEAT	STEPS	3 and 4		
5	SW 1	1·5 MHz	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 17. Alignment Chart

TR 1	GAIN MINIMUM	GAIN MAXIMUM
G1	+2·8V	+2·8V
G2	+1·4V	+4·7V
D	+8·7V	+8·8V
S	+1·14V	+2·8V
CURRENT DRAIN	5·8mA	7·5mA

Figure 16. Voltage Chart

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


Figure 18. Aerial Case Drilling

the LW and MW coils T4, T5, T9 and T10, the 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 in-built 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 17.

Until the unit is properly aligned on each band you cannot 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
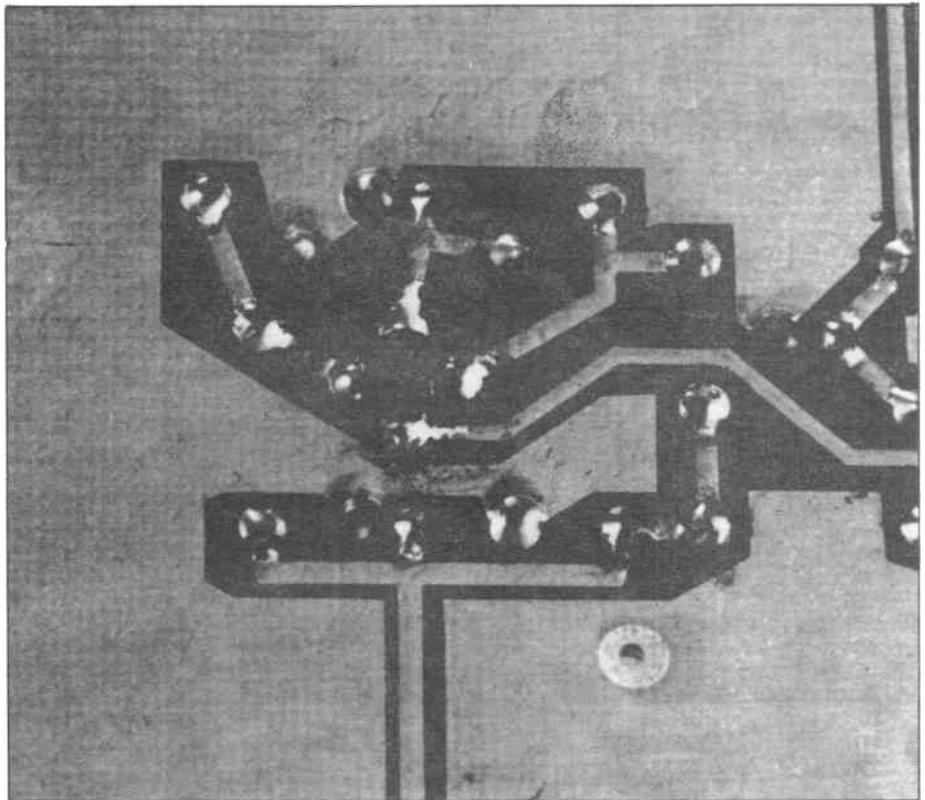
Location of TR1.

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 +12V 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 +12V 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. This device has since been developed and an article was published in issue 21 of this magazine (XA21X). 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!

ACTIVE AERIAL PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1,10,11,12	1k	4	(M1K)
R2	100k	1	(M100K)
R3,4	220k	2	(M220K)
R5	470k	1	(M470K)
R6	56k	1	(M56K)
R7	18k	1	(M18K)
R8	100Ω	1	(M100R)
R9	10k	1	(M10K)
R13	47k	1	(M47K)
R14	2k2	1	(M2K2)
RV1	47k Potentiometer Linear	1	(FW04E)

CAPACITORS

C1,4,5,6,8,9	10nF Ceramic	6	(WX77J)
C2	33pF Ceramic	1	(WX50E)
C3	22nF Ceramic	1	(WX78K)
C7	10μF 16V Tantalum	1	(WW68Y)
VC1	10-365pF Variable	1	(FF40T)
TC1,2,3,4,6,7,8,9	22pF Trimmer	8	(WL70M)
TC5,10	65pF Trimmer	2	(WL72P)

SEMICONDUCTORS

D1,2,3,4	1N4148	4	(QL80B)
ZD1	BZY88C6V8	1	(QH10L)
TR1	3SK88	1	(UH63T)
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)
Isobolt M3 × 12mm		1 Pkt	(BF52G)
Isonut M3		1 Pkt	(BF58N)
PCB		1	(GD18U)
Coax Cable Low C		1m	(XR19V)
Bolt 6BA × ½in.		1 Pkt	(BF06G)
Nut 6BA		2 Pkts	(BF18U)
Shakeproof Washer 6BA		2 Pkts	(BF26D)
Solder Tags 6BA		1 Pkt	(BF29G)
Bolt 4BA × ¼in.		1 Pkt	(BF02C)
Spacer 4BA × ⅛in.		1 Pkt	(FW30H)
Hook-up Wire 7/·02mm		1 Pkt	(BL00A)
Plastic Wafer Shaft		1	(FA98G)
Screen Plate		1	(GD26D)
Bolt 6BA × ¼in.		1 Pkt	(BF05F)
Shakeproof Washer 4BA		1 Pkt	(BF25C)
Tapped Spacer 6BA × ¼in.		1 Pkt	(FD10L)
Instruction Leaflet		1	(XT43W)
Constructors' Guide		1	(XH79L)

OPTIONAL (Not in Kit)

Case Blue 222		1	(XY45Y)
Front Panel		1	(FA99H)
Ultra Power PP3		1	(JY60Q)
AC Adaptor Regulated		1	(YB23A)
Re-usable Cable Tie		1	(RK59P)

> The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or Current Maplin Catalogue for details.
> **The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately. Order as LM05F (Active Aerial Kit).**
> Please Note: Where 'package' quantities are stated in the Parts List (e.g. packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

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	(HF05F)
SKT3,4	Socket SO239	2	(BW85G)
	Round Button Black	2	(FL31J)
	Knob K7B	3	(YX02C)
	PCB	1	(GD19V)
	Plate (Rotary Switch Mtg)	1	(FD07H)
	Veropin 2140	1 Pkt	(FL20W)
	Bolt 6BA × ¼in.	1 Pkt	(BF05F)
	Bolt 6BA × ½in.	1 Pkt	(BF06G)
	Nut 6BA	2 Pkts	(BF18U)
	Shakeproof Washer 6BA	2 Pkts	(BF26D)
	Solder Tag 6BA	1 Pkt	(BF29G)
	Solder Tag 4BA	1 Pkt	(BF28F)
	Shakeproof Washer 4BA	1 Pkt	(BF25C)
	Bolt 4BA × ¼in.	1 Pkt	(BF02C)

Spacer 4BA × ⅛in.		1 Pkt	(FW30H)
Threaded Spacer 6BA × ½in.		1 Pkt	(LR71N)
Spacer 6BA × ¼in.		1 Pkt	(FD10L)
Thick Grommet 6·4mm		1 Pkt	(JX62S)
Bell Wire White		1 Pack	(BL94C)
Wire EC 22swg		2 Reels	(BL27E)
Tube drilled		1	(YM61R)

OPTIONAL (Not in Kit)

Case Blue 222		1	(XY45Y)
Front Panel		1	(FD11M)

> The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
> **The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately. Order as LM06G (Aerial Tuner Kit):**
> Please Note: Where 'package' quantities are stated in the Parts List (e.g. packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

ADA

ECHO ECHO ECHO

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,

★ **Based on the 6264-3 CMOS Static RAM**

★ **Echo Variable from 75 to 450 Milliseconds**

★ **Can be Driven Directly from a Synthesiser**

by Robert Penfold

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.

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

ADA-ECHO

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.
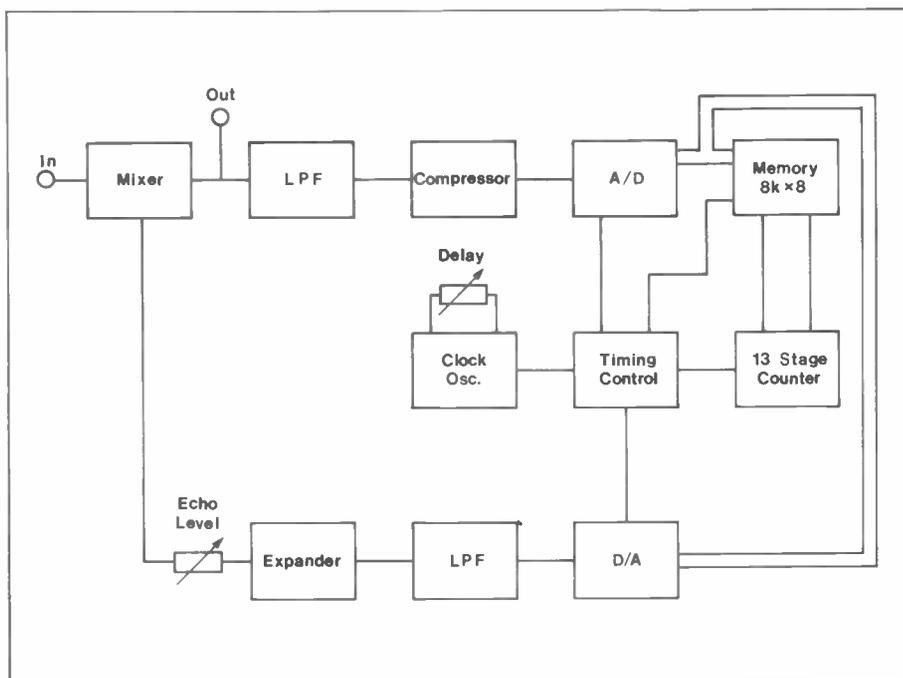

Figure 1. Digital Echo Block Schematic

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 overwritten 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.
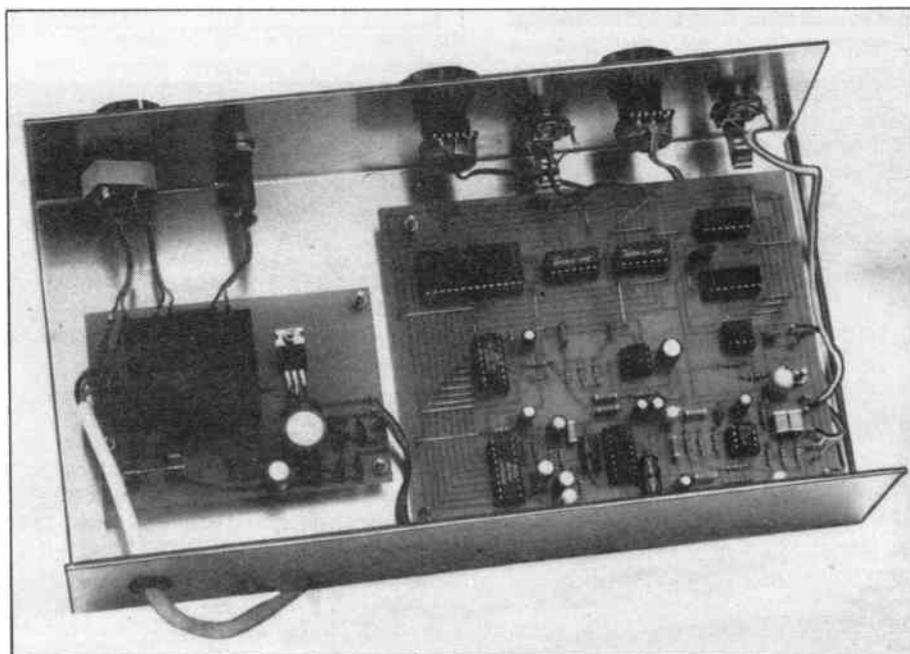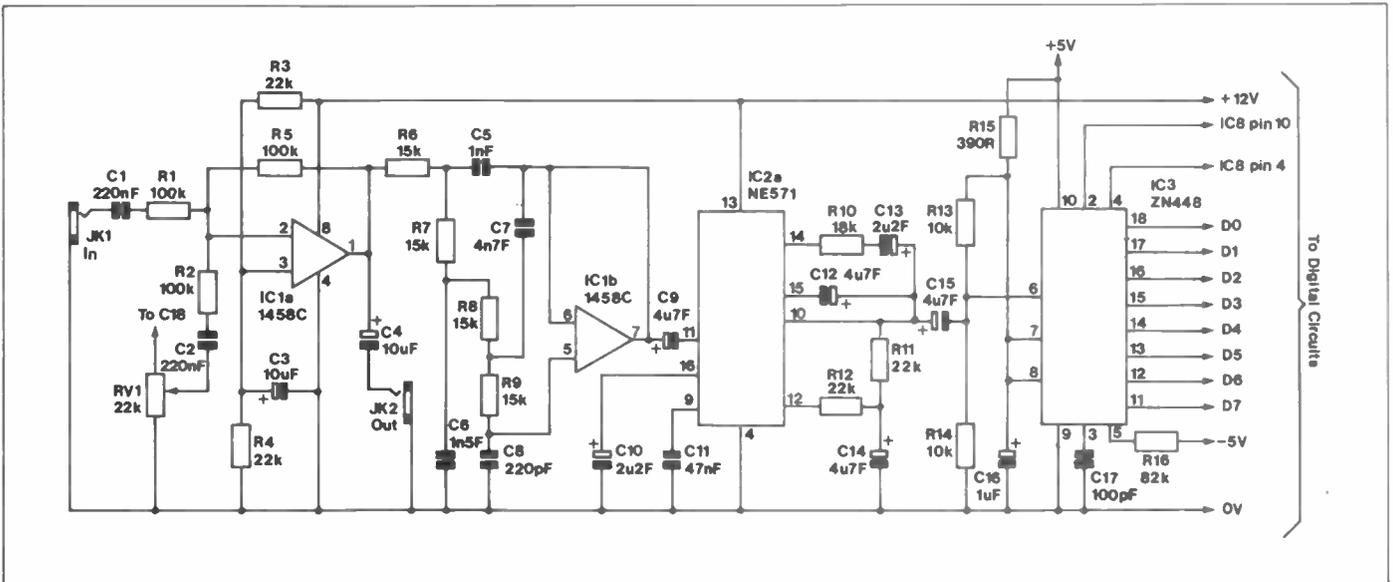
Figure 2. Analogue-to-Digital Converter Stage Circuit

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
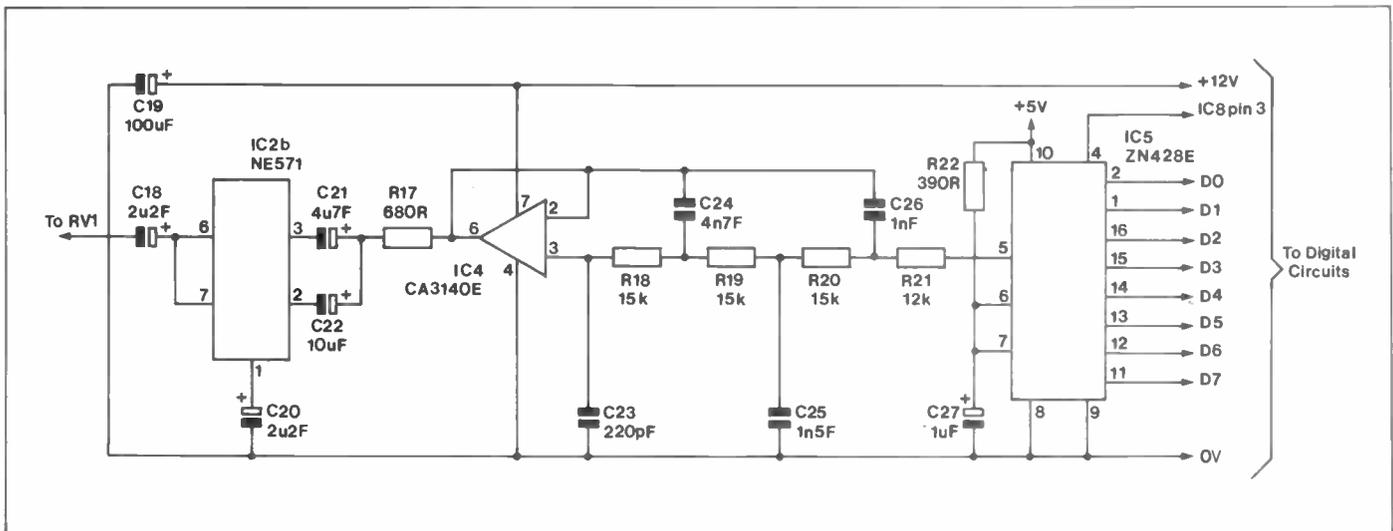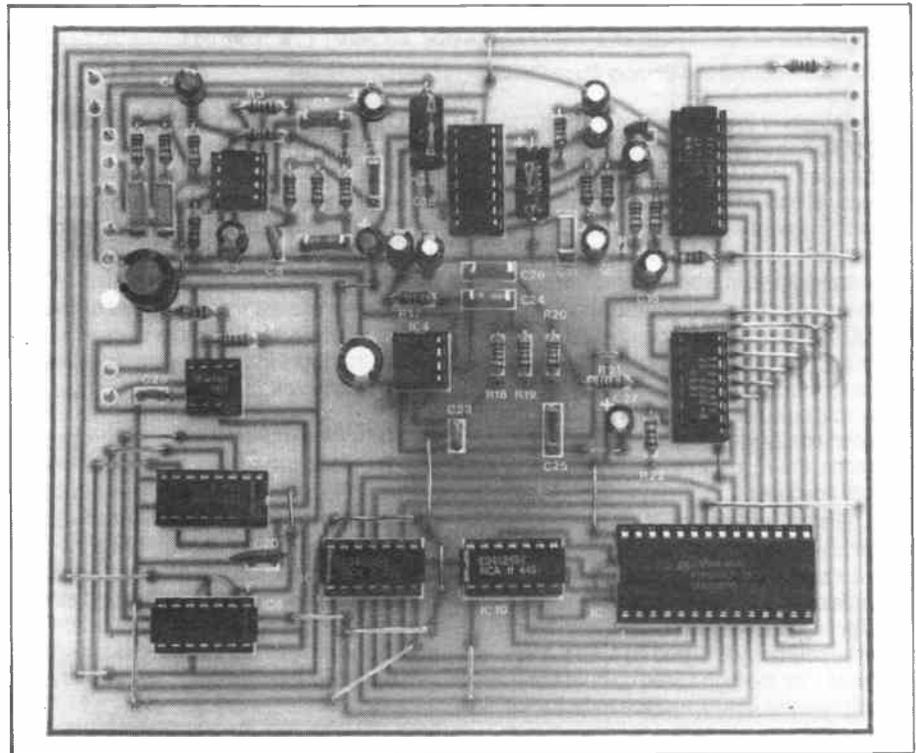
Figure 3. Digital-to-Analogue Converter Stage Circuit
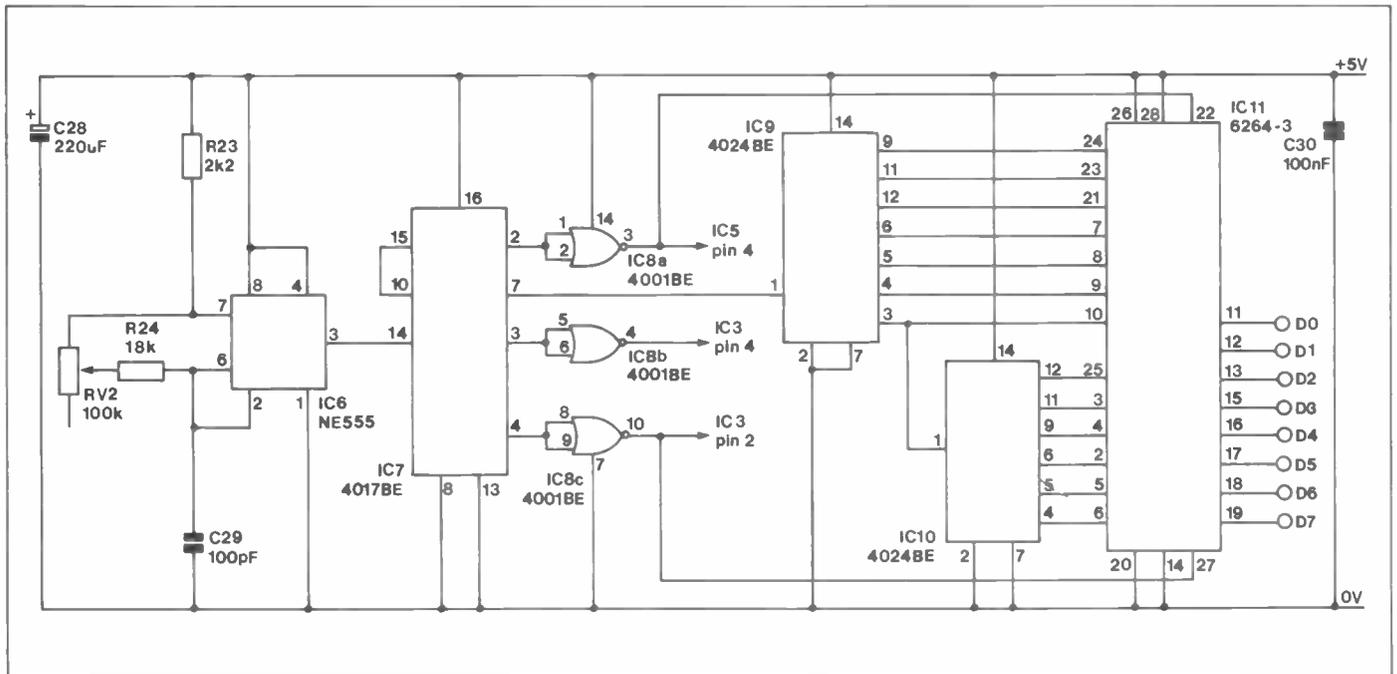
Figure 4. Clock, Control and Memory Stage Circuit

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 2·55V 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 −5V supply. Note that the analogue circuits are powered from a +12V supply, while the digital circuits operate from a +5V 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 2·55V 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 0V 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

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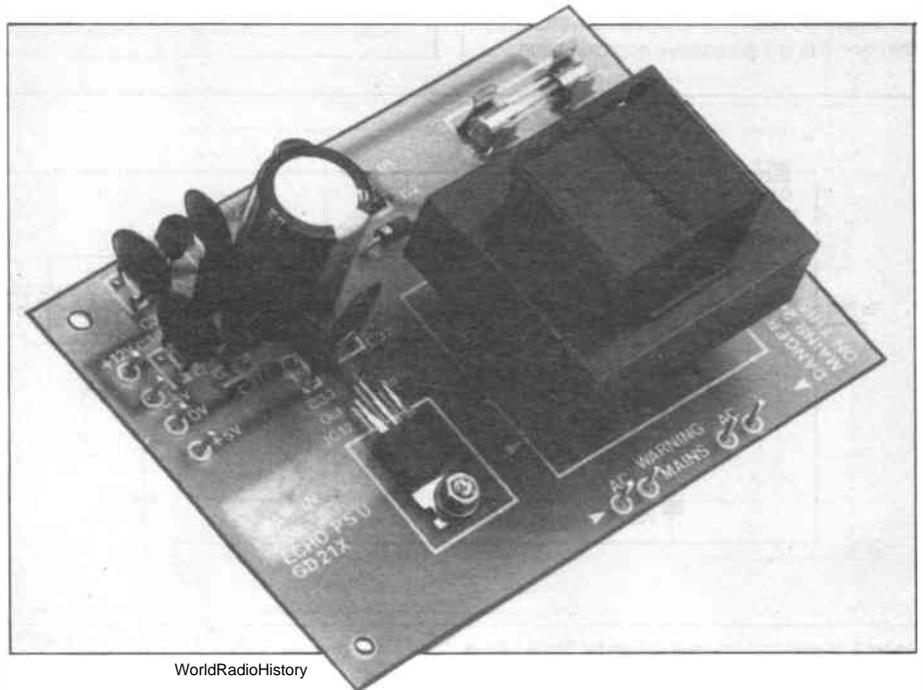
tristate buffers at the output of IC3. On the fourth phase, a clock pulse is supplied to the 13-stage binary counter which generates the address bus. The counter is comprised of two 7-stage devices connected in series (IC9 and IC10), with the final stage of IC10 being left unused.

Power Supply

The power supply circuit is shown in Figure 5, and this uses a 12V mains transformer and a push-pull rectifier to give an unstabilised supply of about +17V. 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 −5V output from this.

Construction

Nearly all of the components are accommodated on two printed circuit boards. There is one board for the main ADA Echo circuitry, and a separate PCB 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 PCB overlay and the parts list. Insert these into the positions 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
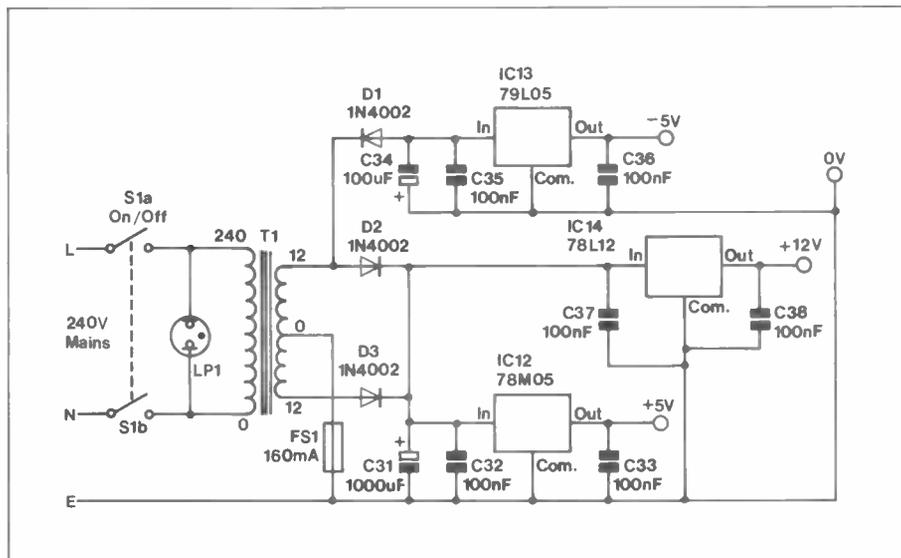

Figure 5. Power Supply Circuit

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 PCB 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 PCB 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 PCB 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

MAPLIN ADA DIGITAL ECHO GD 20W

MAPLIN ADA DIGITAL ECHO GD 20W ISS 1
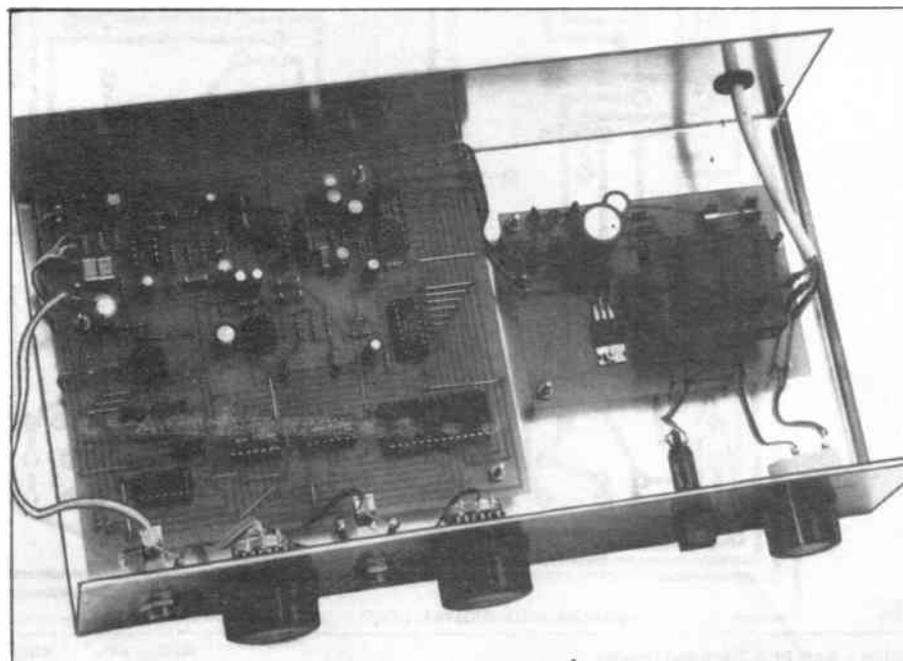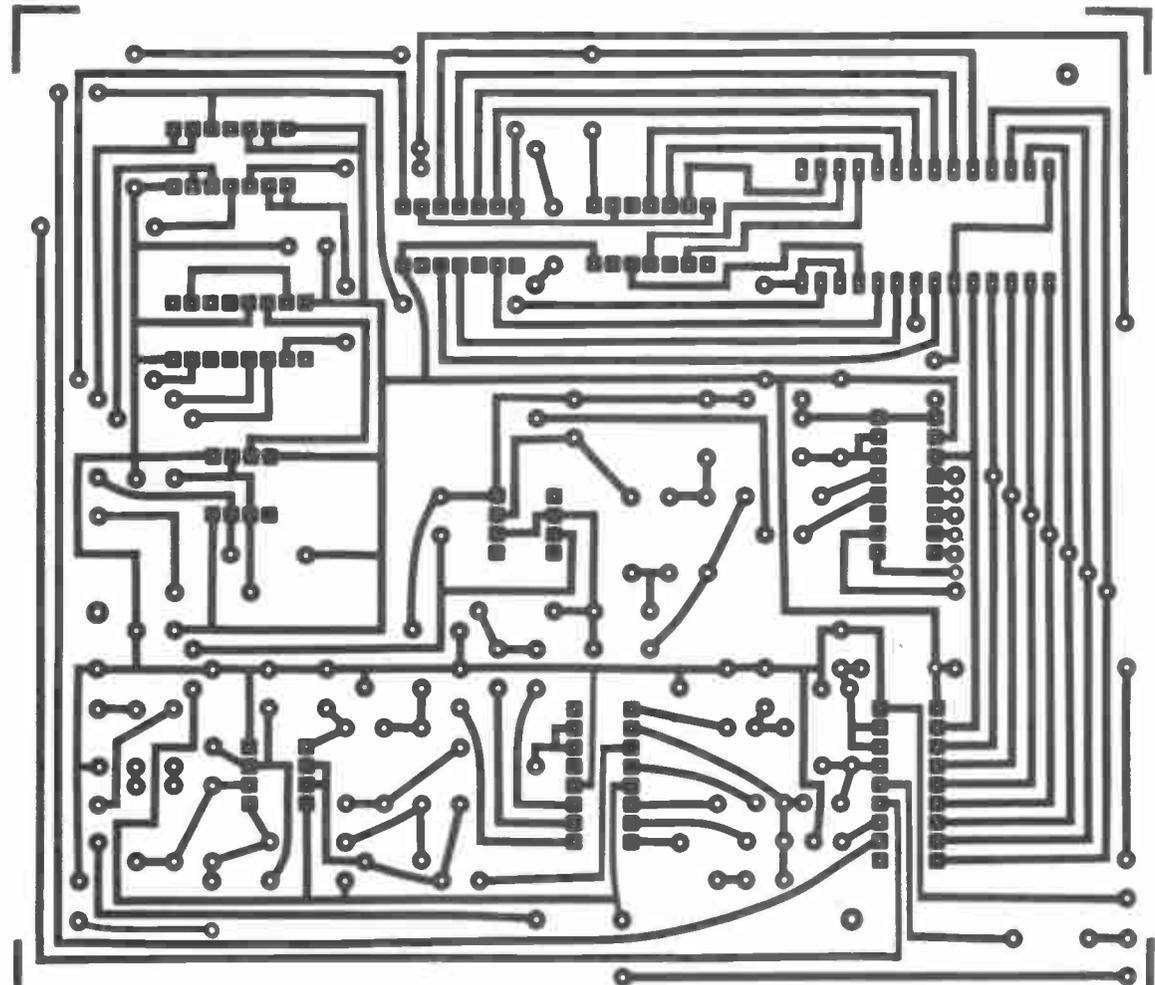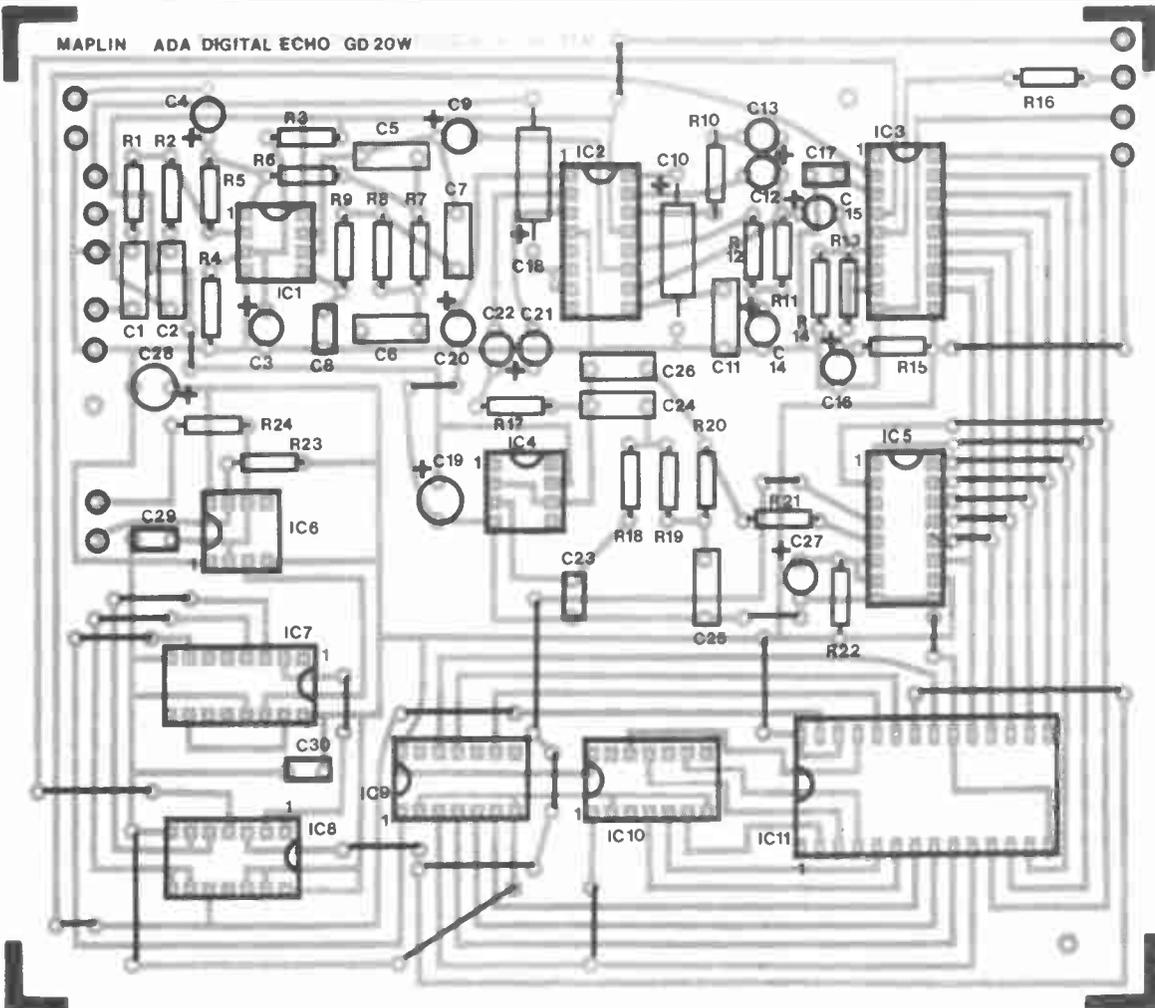
Figure 6. Main PCB Track and Overlay   WorldRadioHistory

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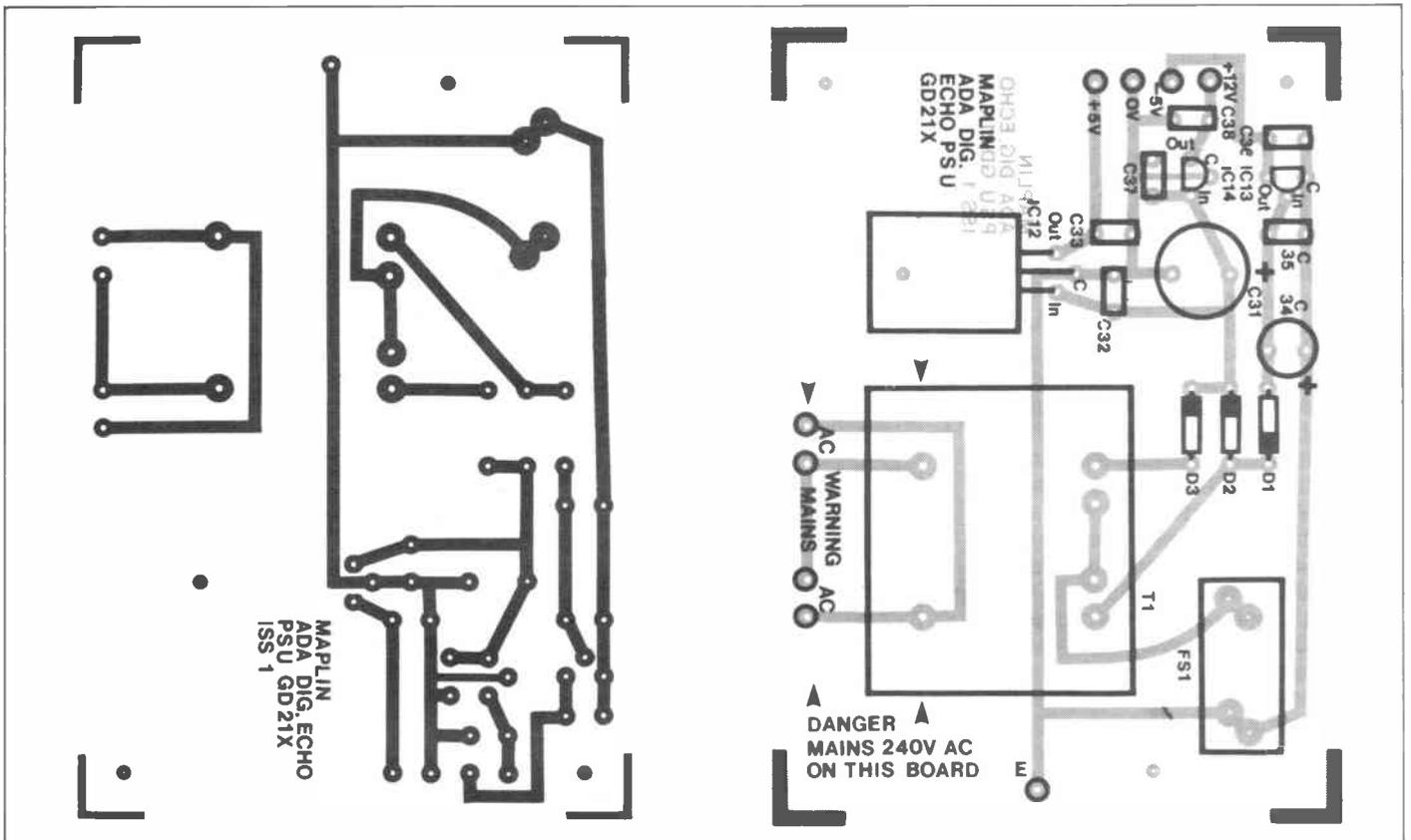
Figure 7. PSU PCB Track and Overlay
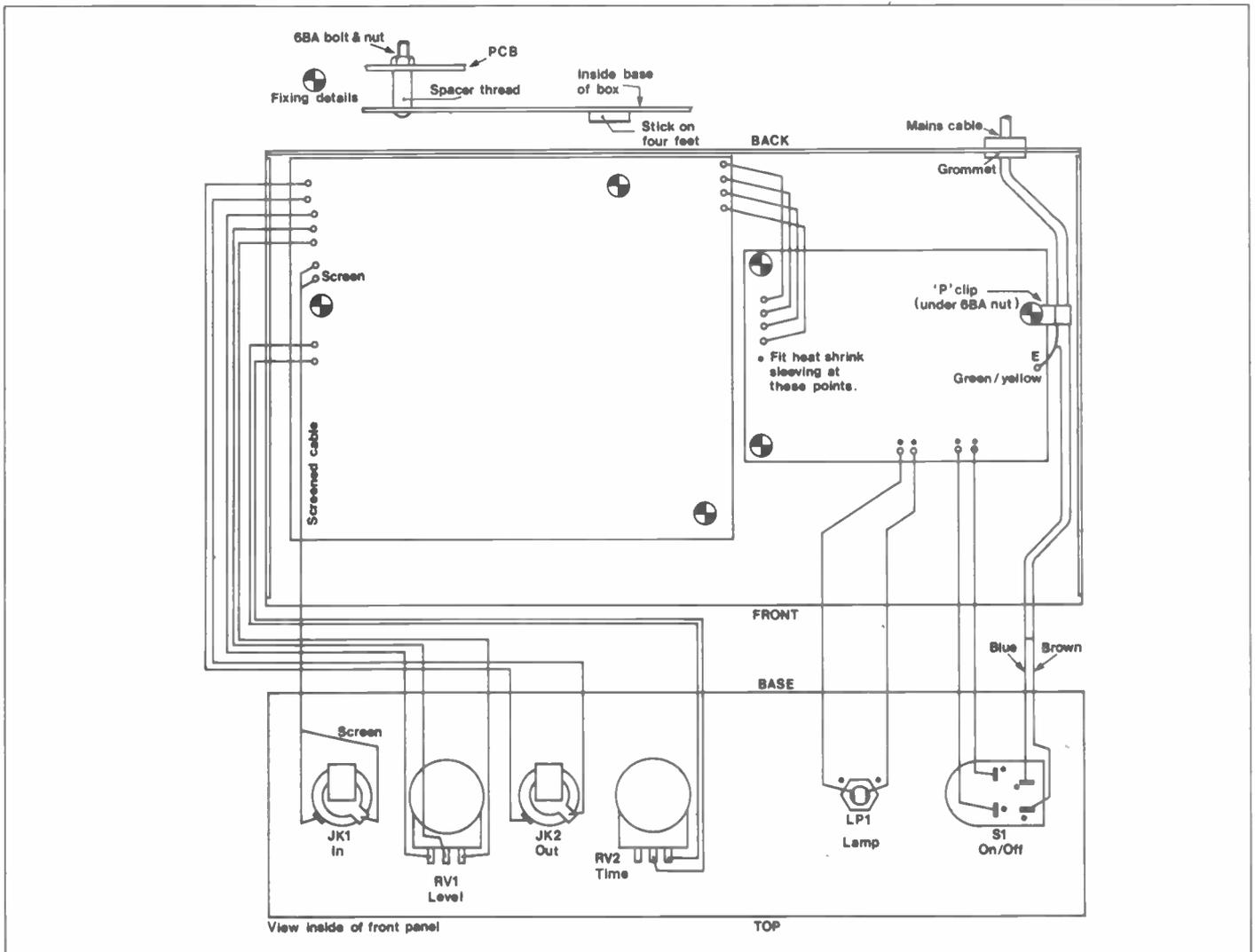
Figure 8. Wiring up the Project

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 × 159 × 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 PCB. 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 overwritten 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
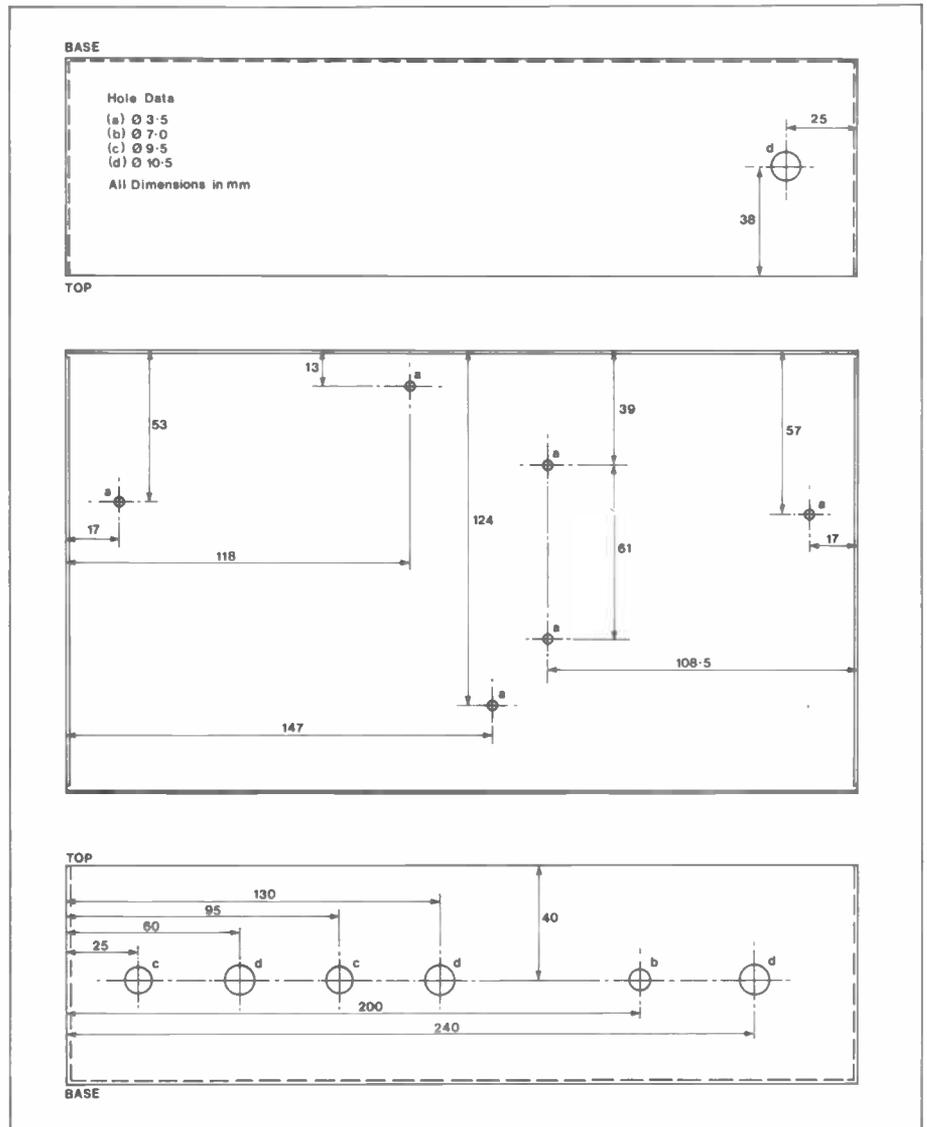

Figure 9. Box Drilling
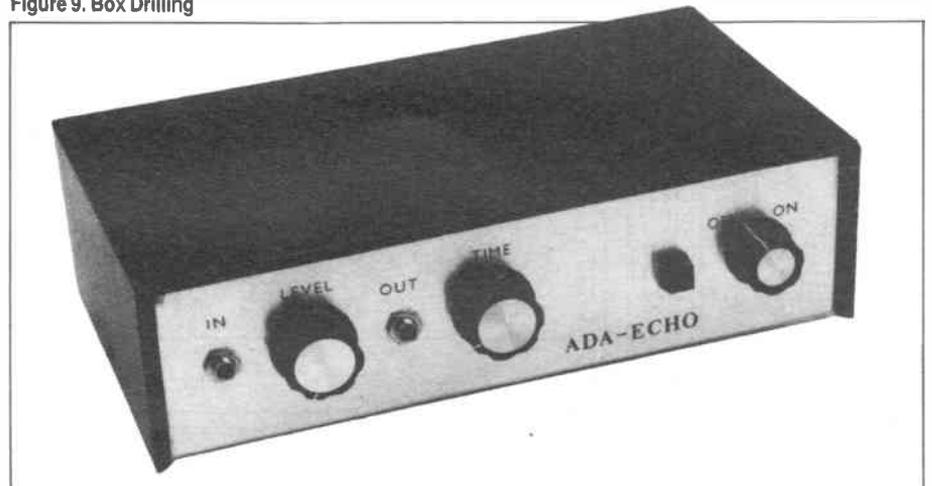
off, the echo level should be quite low, and the echoes should rapidly fade away to an inaudible level. By advancing RV1 the echo level should be boosted, and the decay time should be substantially prolonged. If RV1 is advanced too far the echo signal will be maintained indefinitely, or it will actually 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 mush. However, there

is an interesting technique whereby a short burst of input signal at a fairly 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 technique works best with fairly long echo times.

The unit can take input levels of up to 2·55V 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.

Modifications

The 'ADA-Echo' can produce some very good echo effects, but in its standard form the unit is not capable of other time domain effects, such as flanging or chorus. Since the 'ADA-Echo' project was first published and the kit made available, two optional modifications have been put forward which make some of these effects possible.

Delay Time

The minimum delay available from the ADA is around 75ms, which is far too long for flanging and chorus effects. Experiments with the delay line clock (IC6) proved fruitless, since in practice it is not possible to significantly increase the operating frequency while retaining effective operation of the delay. A more effective method was found for reducing the delay time by decreasing the
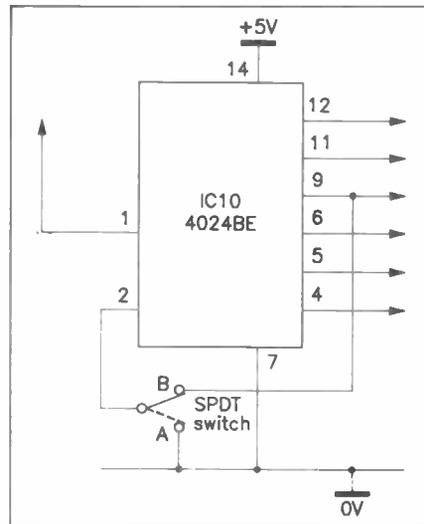
Figure 10. Modification to reduce delay time

number of counter stages from 13 to 9. To effect modification it is necessary to cut the PCB track between pin 2 of IC10 and 0V, and wire in a single-pole, double-throw switch as illustrated in Figure 10. With the switch in position 'A', the circuit operates as originally intended, but switching to position 'B' selects a much shorter delay time than was previously possible.

Modulating Oscillator

Reducing the minimum delay time of the ADA Echo is only half the answer, since for flanging and chorus effects the delay time must be constantly changing. Modulation of the delay time can be achieved by applying the output from a low frequency oscillator to pin 5 of IC6, and Figure 11 shows a simple oscillator that is suitable for this purpose. The oscillator produces an approximation of

ADA-ECHO PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

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 7·5mm Poly Layer	2	*Kit only*
C3,4,22	10µF 50V PC Elect	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 Elect	5	(FF03D)
C10,18	2µ2F 100V Axial	2	(FB15R)
C11	47nF Poly Layer	1	(WW37S)
C13,20	2µ2F 100V PC Elect	2	(FF02C)
C16,27	1µF 100V PC Elect	2	(FF01B)
C17,29	100pF Ceramic	2	(WX56L)
C19,34	100µF 25V PC Elect	2	(FF11M)
C28	220µF 16V PC Elect	1	(FF13P)
C30,32,33,35-38	100nF 16V Minidisc	7	(YR75S)
C31	1000µF 35V PC Elect	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-8	1	(UF41U)
IC6	NE555	1	(QH66W)
IC7	4017BE	1	(QX09K)
IC8	4001BE	1	(QX01B)
IC9,10	4024BE	2	(QX13P)
IC11	6264 150ns	1	(UF34M)
IC12	µA78M05UC	1	(QL28F)
IC13	µA79L05AWC	1	(WQ85G)
IC14	µA78L12AWC	1	(WQ77J)

MISCELLANEOUS

S1	Rotary Mains Switch	1	(FH57M)
JK1,2	Jack Socket Open ¼in.	2	(HF91Y)
T1	PCB Transformer 2 × 12V ·25A	1	(YJ54J)
LP1	Min Neon Red	1	(BK52G)
FS1	Anti-Surge 20mm Fuse 160mA	1	(RA05F)
	20mm Fuse Clip Type 1	2	(WH49D)
	Echo PCB	1	(GD20W)
	PSU PCB	1	(GD21X)
	Pin 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)
	Heat Shrink Sleeving CP24	1m	(BF87U)
	Cable Single White	1m	(XR14Q)
	Min Mains White	1m	(XR02C)
	Ribbon Cable 10-Way	1m	(XR06G)
	Knob K7B	1m	(YX02C)
	Knob K7C	2m	(YX03D)
	Thick Grommet 6·4mm	1 Pkt	(JX62S)
	Bolt 6BA × 1in.	1 Pkt	(BF07H)
	Nut 6BA	1 Pkt	(BF18U)
	Threaded Spacer 6BA × ½in.	1 Pkt	(LR72P)
	Case WB5 Vinyl	1	(LH40T)
	Cabinet Feet	1 Pkt	(FW19V)
	Instruction Leaflet	1	(XU13P)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit) *Circuit references are from Figure 10*

R1,2,4	47k	3	(M47K)
R3	4k7	1	(M4K7)
R5,6	10k	2	(M10K)
RV1	47k Pot Lin	1	(FW04E)
RV2	100k Pot Lin	1	(FW05F)
C1	10µF 50V PC Elect	1	(FF04E)
IC1	µA741C	1	(QL22Y)
TR1	BC182L	1	(QB55K)
	DIL Socket 8-Pin	1	(BL17T)
S1,'A/B'	Sub Min Toggle A	2	(FH00A)
	Stripboard	As req.	

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.
Order As LM04E (ADA Digital Delay Kit).
Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

Stepper Motor Driver

by Mark Brighton

★ *Simple to Use*
★ *Based on the SAA1027 IC*
★ *Easy to Construct*

The stepper motor is an increasingly popular means by which positional and/or speed control may be achieved in motor driven systems, especially those controlled by digital logic or microprocessor circuits. It is, however, rather awkward to control using simple digital electronics as it requires several sequential combinations of logic states on its control lines to cause it to rotate.

In Figure 1a, the SAA1027 is a Mullard IC designed to simplify the driving of 4-phase, unipolar stepping motors, such as that supplied by Maplin as FT53Q. It only requires a 12V pulse for each step of the motor, and a 12/0V logic state to control the direction of rotation. A reset pin is also available to internally re-initialise the stepping sequence within the chip. This chip, together with the necessary external parts and a PCB, is available as a kit and is small enough to be mounted on or near the motor, where available space is limited.

The stepper motor supplied with this kit may have different colour-coded wires than those shown in Figure 1a. In this event refer to Figure 1b for connections.
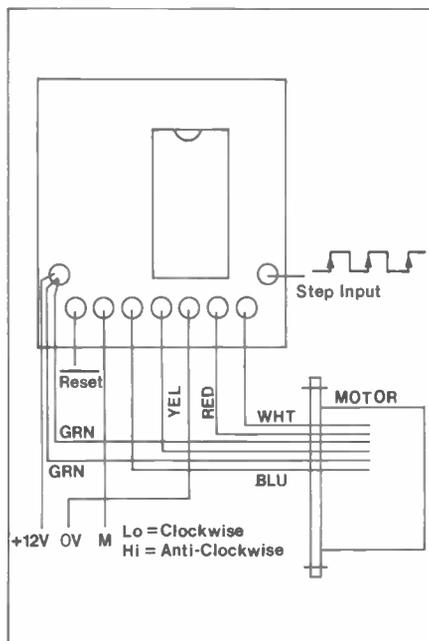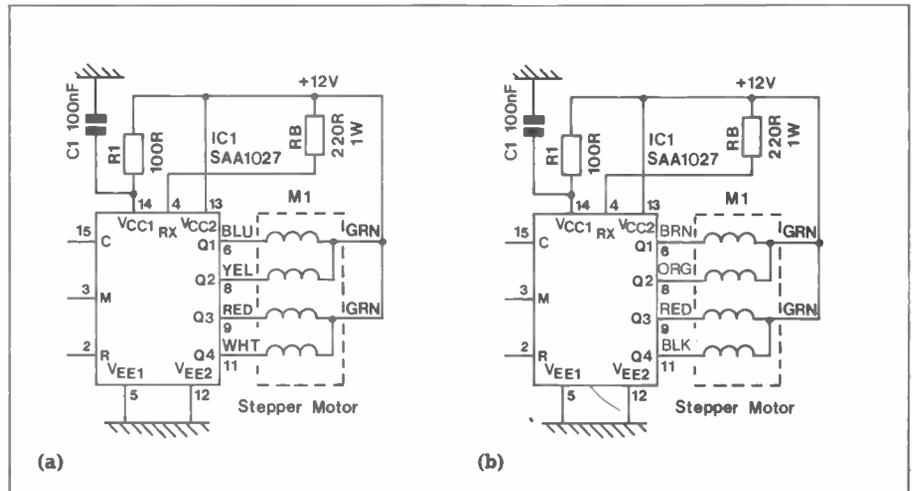
Figure 1. (a) circuit; (b) with alternative motor colour codes
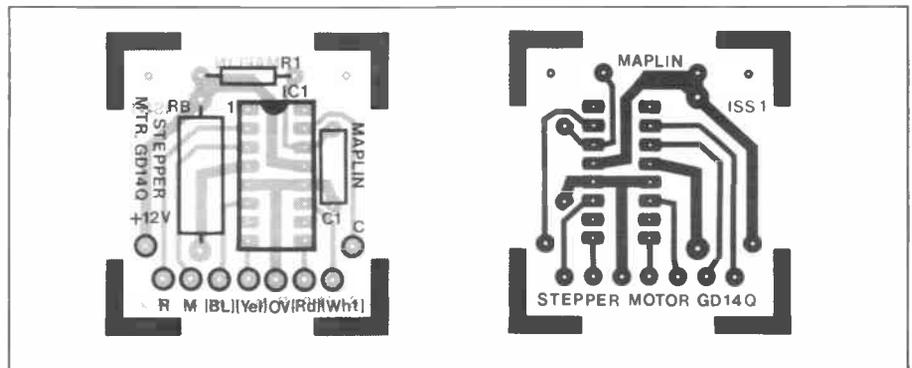
Figure 2. PCB layout

Construction

Referring to Figure 2, fully insert and solder all PCB-pins, then R1, RB, C1, and the IC socket onto the PCB noting the alignment mark on the legend. Fit the IC into its socket with the same orientation. Check for short circuits and wash off excess flux with PCB cleaner.

Testing

Wire the PCB to the motor as shown in Figure 3 (if the motor lead colours are different, cross reference these to Figure 1b). Connect the 'M' pin to 0V, and apply 12V pulses with a test lead to the 'C' pin. 'R' should be connected to +12V if reset is *not* required. The motor should rotate clockwise. On

Figure 3. Wiring
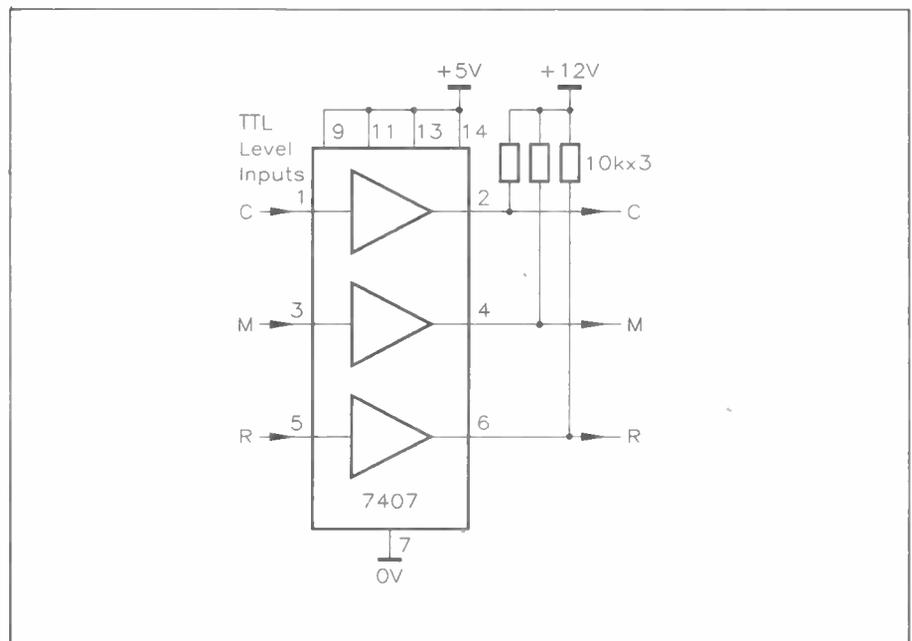
Figure 4. TTL level converter circuit

In Use

Although the inputs to the SAA1027 are of a digital type, they are not at normal logic levels! In order to enable a 5V TTL standardised system or a microprocessor system to drive the stepper motor, a means must be found to convert TTL levels to the 12V levels required by the controller IC. Figure 4 shows a simple method of doing this, although it will require an extra bit of circuitry to be added especially for this purpose, and if it cannot be incorporated into the host system then it can be made on a small piece of stripboard.

In the circuit of Figure 4 three parts of a hex non-inverting, open-collector buffer IC, a 7407, are employed to perform the conversion. TTL level inputs coming in at 'C', 'M' and 'R' on the left are duplicated at the outputs on the right, but raised to +12V levels in the logic 1 state. Each of these must have a pull-up resistor, and a nominal value of 10kΩ is usually perfectly adequate, taking just over 1mA each in the logic 0 state. The inputs of the unused gates, pins 9, 11 and 13, must be tied to +5V and not left floating. The inputs can then be directly driven from TTL or a microprocessor parallel I/O port.

connecting 'M' to +12V, it should run anti-clockwise.
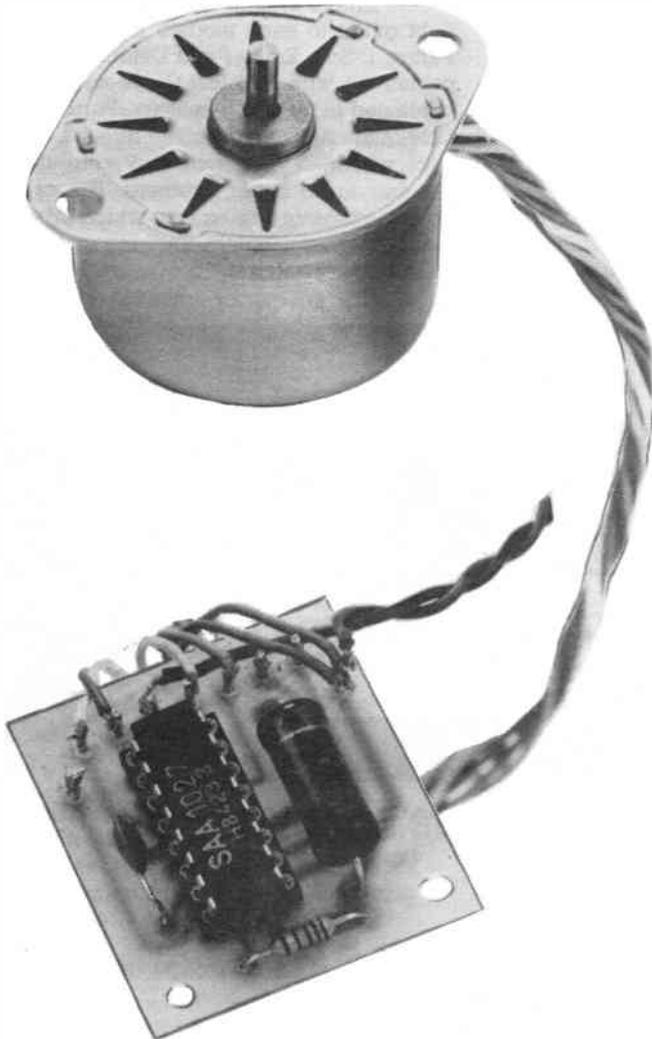
STEPPER MOTOR DRIVER PARTS LIST

RESISTORS: 0·6W 1% Metal Film (Unless specified)

R1	100Ω	1	(M100R)
RB	220Ω 1W Carbon	1	(C220R)

CAPACITORS

C1	100nF 50V Ceramic	1	(BX03D)

SEMICONDUCTORS

IC1	SAA1027	1	(QY76H)

MISCELLANEOUS

M1	Stepper Motor	1	(FT73Q)
	Pin 2145	1 Pkt	(FL24B)
	DIL Socket 16-Pin	1	(BL19V)
	PCB	1	(GD14Q)
	Instruction Leaflet	1	(XK04E)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)

10k		3	(M10K)
7407		1	(QX76H)
DIL-Socket 14-Pin		1	(BL18U)
Stripboard		As req.	

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.
Order As LK76H (Stepper Motor Driver Kit).
Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel etc.) the exact quantity required to build the project will be supplied in the kit.

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a triangular waveform, the frequency of which may be adjusted using RV1. Modulation depth is determined by the amplitude of the waveform and this is adjusted by RV2. Switch S1 in Figure 11 allows the modulation oscillator to be disconnected when required. The oscillator may be constructed on a small piece of stripboard and only need be held in place by the two potentiometers if these are panel mounted.

Suggestions from the Lab

It may be possible to produce different effects by changing the operating frequency of the modulation oscillator; try experimenting with different values of oscillator components RV1 and C1.
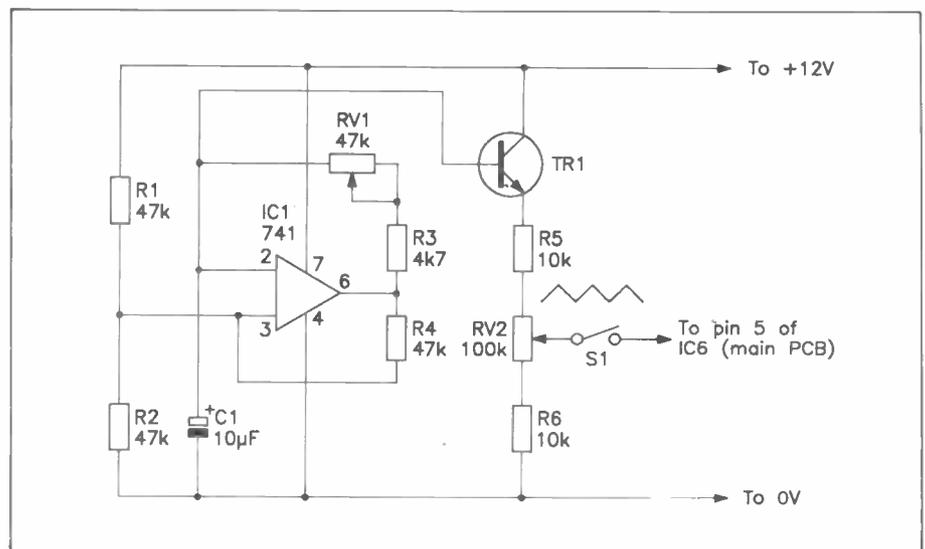

Figure 11. Circuit Diagram of the Modulation Oscillator

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

Optical Fibre

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

Therefore electrical signals must be converted into light and sent along the guide. At the far end, the light waves are re-converted back into electrical signals, closely resembling the original. Unfor-

Characteristics

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

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

tunately, fibres exhibit the luminal equivalent of resistance which increases proportionally with length and limits the maximum length of guide which can be used in any particular system. Attenuation effects can be measured at 1.2dB per metre, or approximately a 20% reduction with the light guide recommended for use with this project (XR56L).

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

Fibre Optic Couplers

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

FIBRE OPTIC AUDIO LINE

by Dave Goodman
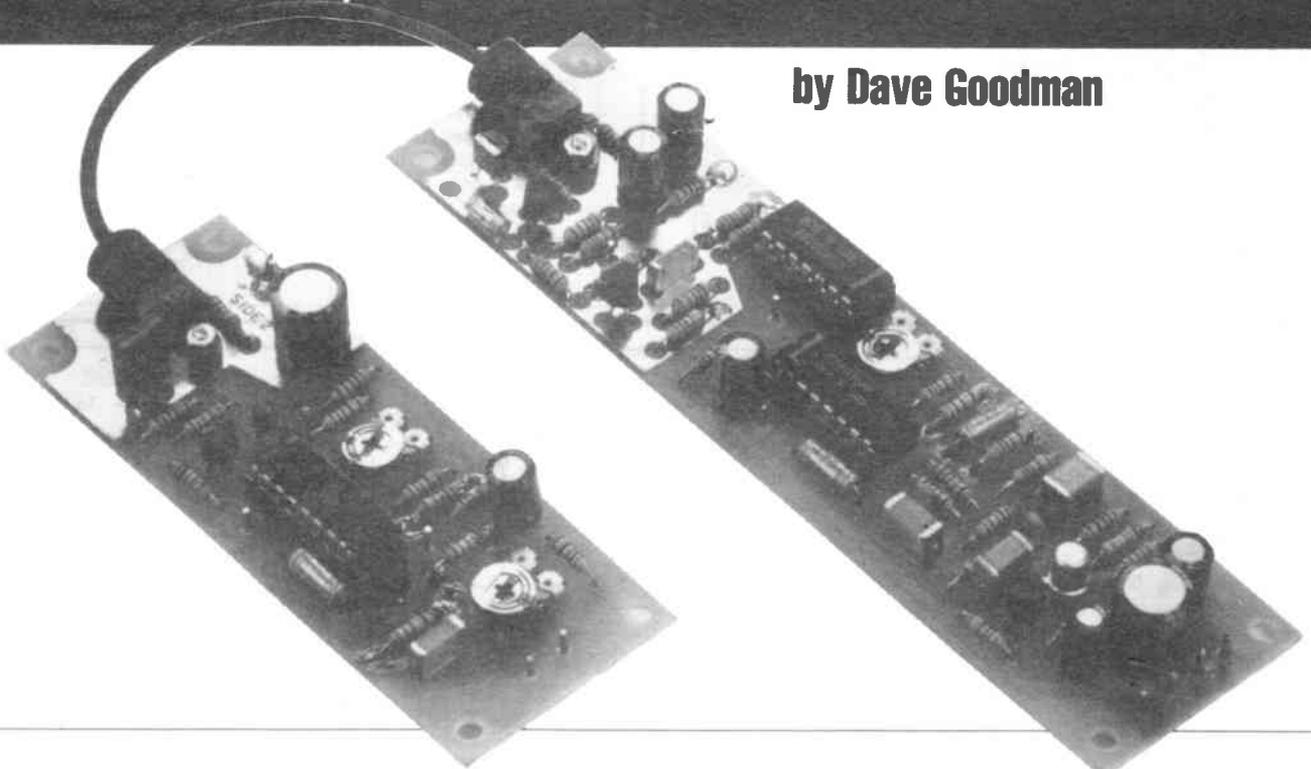
★ **Transmitter and Receiver modules for use with Speech or Music Signal Sources**

★ **Transmits over fibre optic light guide with up to 20M range**
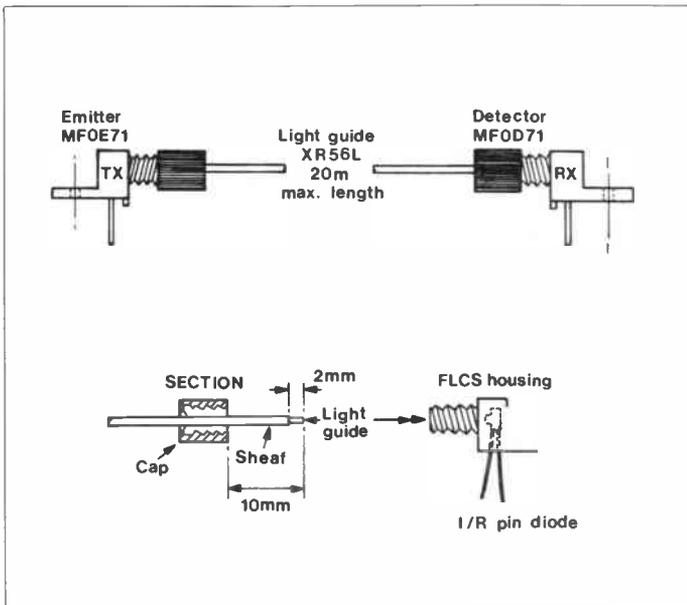
Figure 1. Connecting Light Guide.
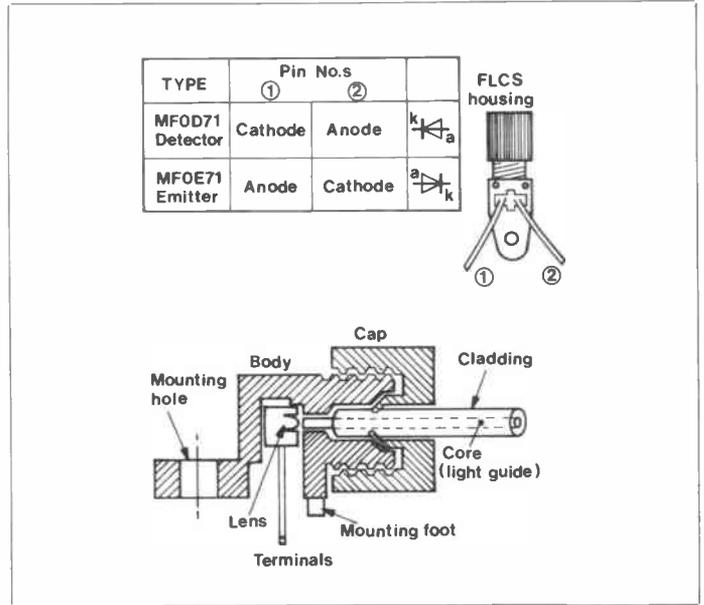
Figure 2. Emitter and Detector Pin-out and Construction.

| TYPE | Pin No.s | | FLCS housing |
	①	②	
MFOD71 Detector	Cathode	Anode	k ◁ a
MFOE71 Emitter	Anode	Cathode	a ▷ k

Preparation of Light Guide

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

Remove the end covering and cleanly cut the fibre core two millimetres long. Try to make a single, straight cut thus keeping the end as smooth as possible, this being important for maximum light transfer to the couplers. Use a sharp knife for this. Very fine emery paper, or the striking edge of a matchbox (but not glasspaper types!) can be gently rubbed, *squarely* across the cut fibre end to polish the surface. Liquid metal polish also helps to develop a smooth finish and could also be used to finish off.
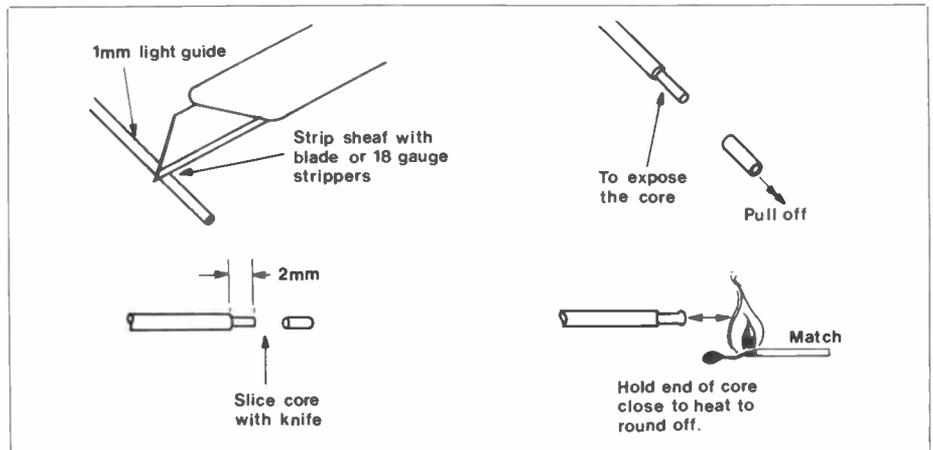
Figure 3. Preparing the Light Guide.

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

Circuit Description

The system has been developed for use with audio signals of a reasonably
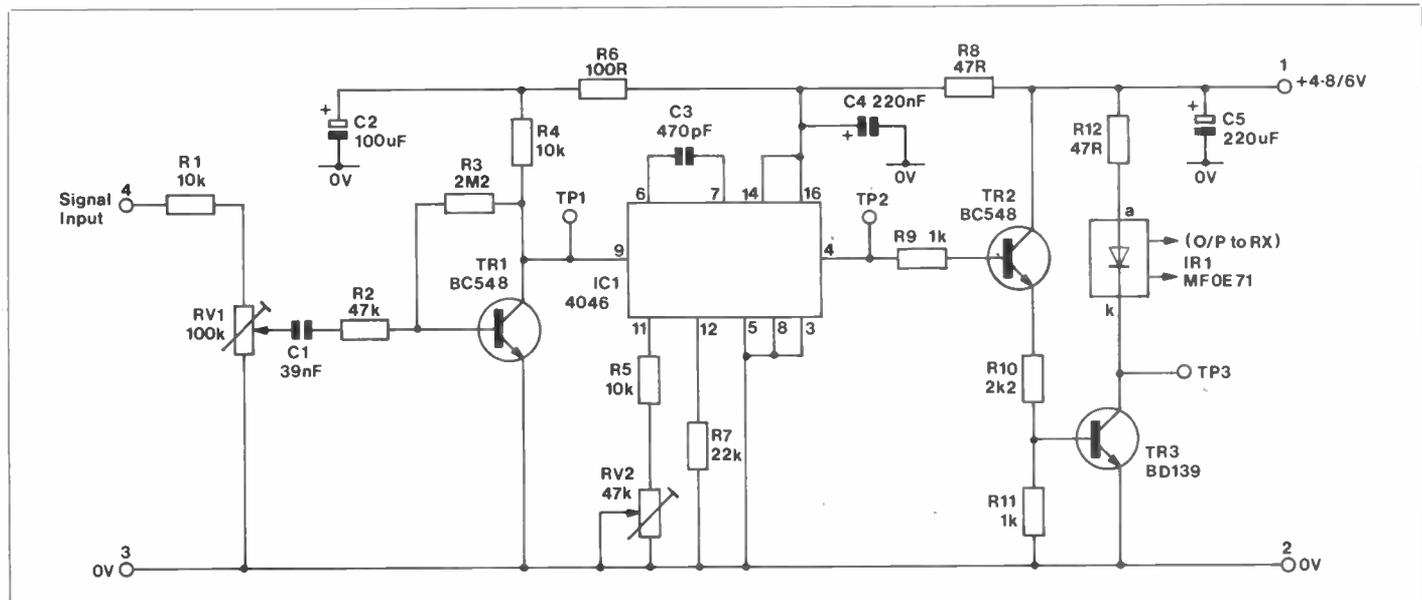
Figure 4. Transmitter Circuit.

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

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

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

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

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

Receiver

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

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

Figure 5. Receiver Circuit.

Please note that TR1 has changed since the PCB legend was designed. It should be placed in the board with the flat on the case facing in the *opposite* direction to that shown on the legend.

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

The carrier square wave is made available at TP2, which is also one of the Phase Locked Loop's phase comparator inputs. The comparator output controls a voltage controlled oscillator, via R14 and C7 which filter out harmonics and maintain a 90° phase shift at the VCO centre frequency. VCO timing components are C6, R13 and RV1. With no carrier signal applied to the receiver input, the VCO is free running at 110kHz; this frequency can be varied by RV1. The VCO square wave output from pin 4 feeds back to a second phase comparator input at pin 3.
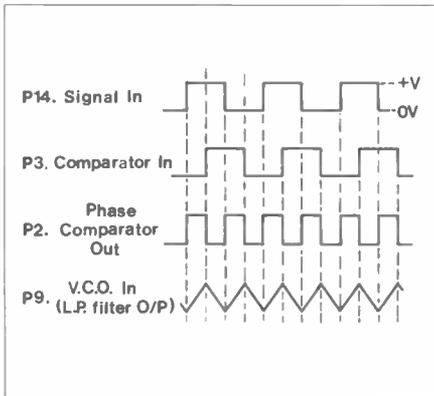
Figure 6. Waveforms.

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

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

Transmitter Construction

For information regarding component identification, assembly methods and soldering, please refer to the 'Constructors Guide' supplied with this
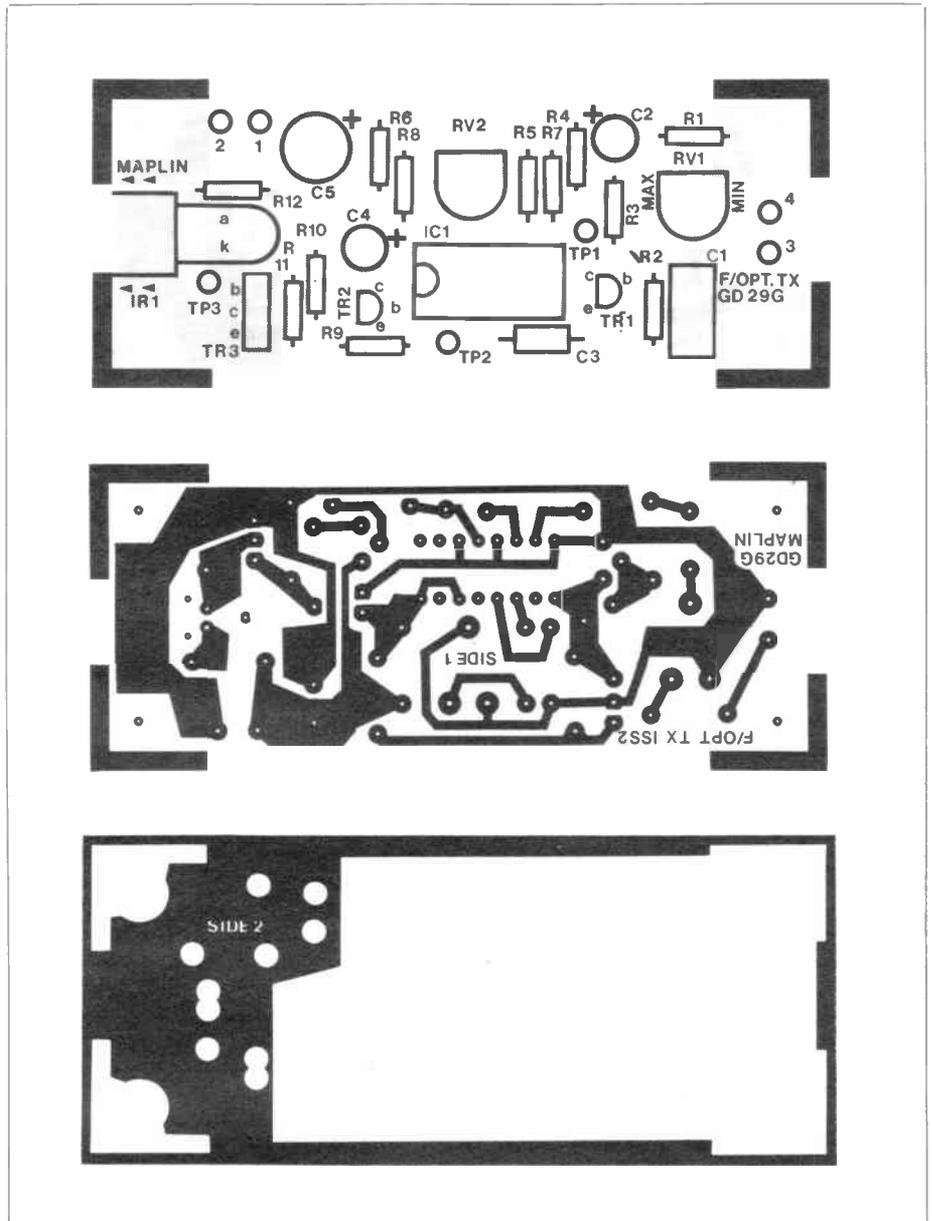

Figure 7. Transmitter Track and Legend.
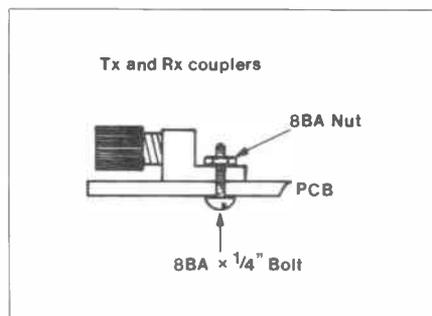
Figure 8. Coupler Mounting.

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

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

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

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

Mount the 16-pin IC socket and TR1, TR2. Bend a few legs of the socket over beneath the pcb to prevent it from falling

out. Mount RV1 and RV2 – note that their values are not identical so be sure to put the correct value in the required position – finally solder all remaining component leads, remove excess wire ends and clean the pcb tracks, before inserting the P.L.L. device, IC1.

Transmitter Testing

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

A current reading of approximately 30 to 40mA should be obtained. Any readings well outside of this may well point to a fault, unless the test meter is not connected properly or the wrong range selected; double check and repeat the procedure. If the error is genuine and a frequency counter or oscilloscope is available, connect either to test point TP2. Adjust RV2 for 110kHz, which will be some 45° displacement of the wiper of RV2 from its central position. The output stage can be monitored with a 'scope on
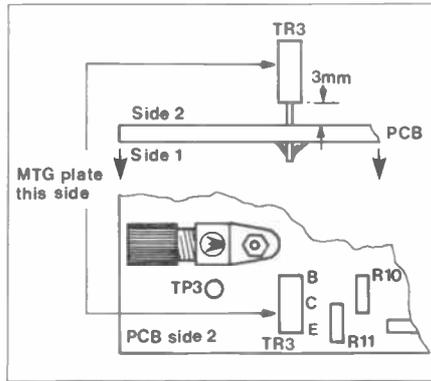
Figure 9. Mounting TR3.

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

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

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

Receiver Construction

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

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

Next, fit capacitors C1 to C16, noting polarity markings on electrolytic types.
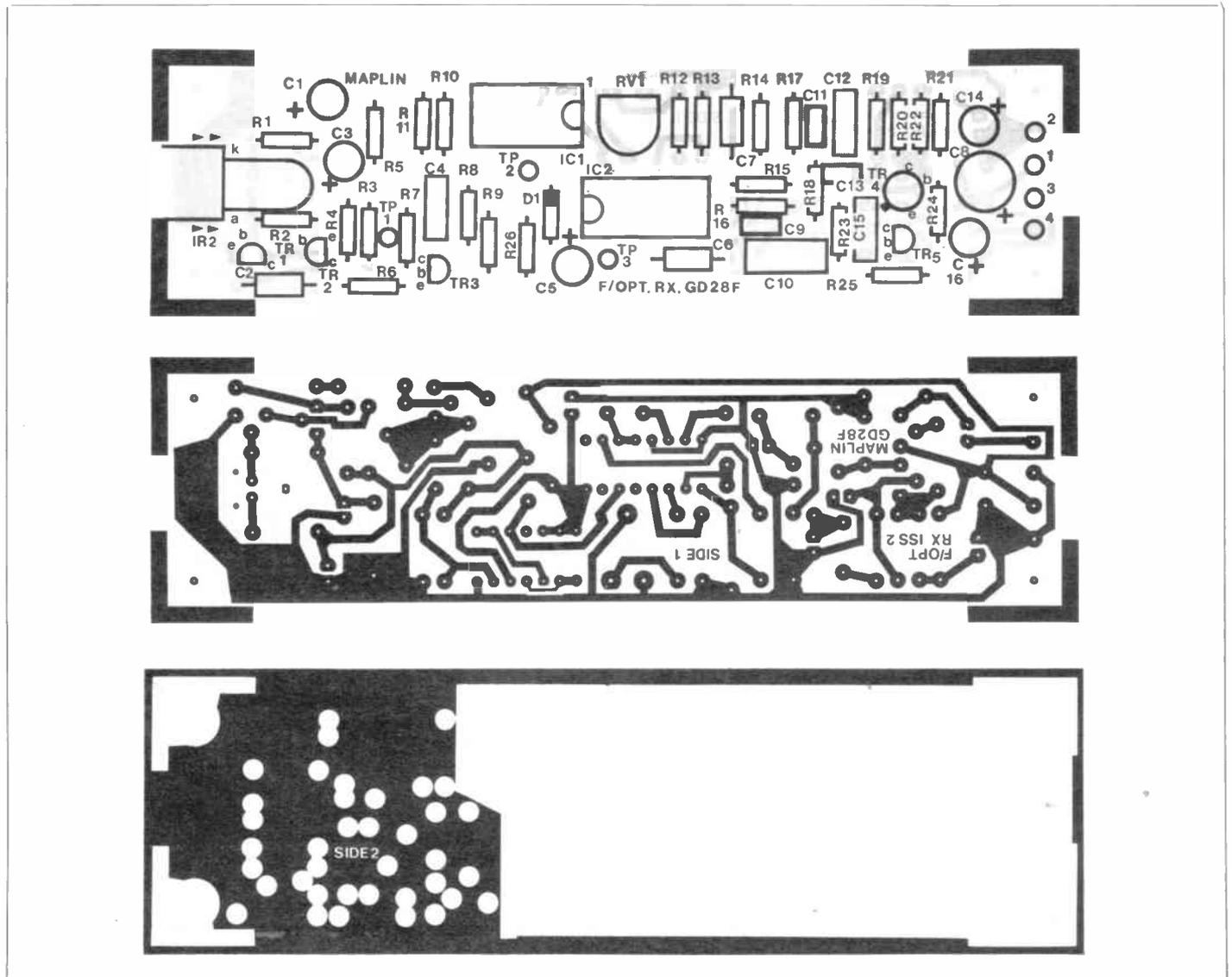
Figure 10. Receiver Track and Legend.

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

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

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

Receiver Testing

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

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

Monitoring the audio output, Pin 4, may produce a certain amount of carrier
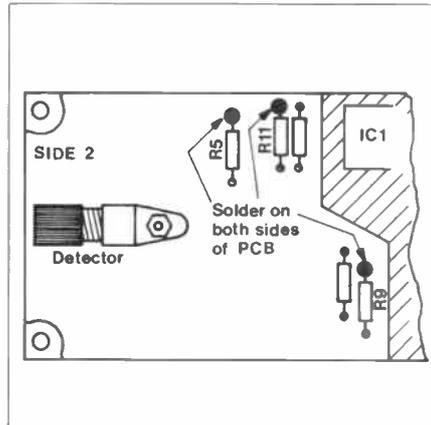
Figure 11. Some resistors are soldered both sides.

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

Connecting the System

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

Slide a fluted cap from the coupler over the light guide – it will be quite a tight fit – leaving about 1cm of prepared end protruding. Push the prepared end into the coupler, and offer up the cap. Tighten the cap with fingers only – do not use any tools to do this! Repeat the

procedure on the opposite end so that both Tx and Rx modules are secured to the light guide. It must be emphasised that careful preparation of the light guide core end is of vital importance if maximum range is required. Poorly prepared ends will produce noisy Rx output and may well limit useable cable length to below 10 metres or less!

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

Final Testing

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


Figure 13. Bending the Light Guide.

increase the audio signal level through the system, but too high a level will produce a distorted audio output from the receiver.

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

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

Figure 12. Connecting up the System.

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

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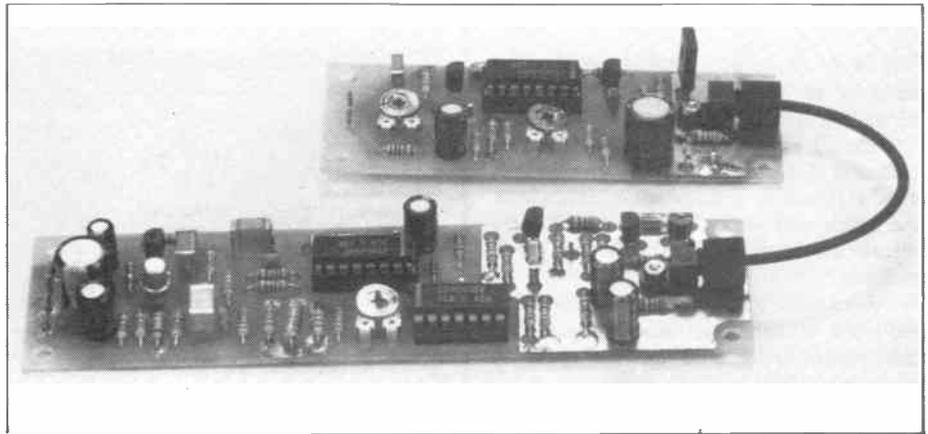
performance, especially if an expander is used at the receiver output.

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

FIBRE OPTIC LINK RECEIVER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1,2	22k	2	(M22K)
R3,8,12,15,16,24	10k	6	(M10K)
R4,22	4k7	2	(M4K7)
R5	1k2	1	(M1K2)
R6,13,17,19	47k	4	(M47K)
R7,20	470k	2	(M470K)
R9,23,25	470Ω	3	(M470R)
R10,11	100k	2	(M100K)
R14	43k	1	(M43K)
R18	15k	1	(M15K)
R26	100Ω	1	(M100R)
R21	1k	1	(M1K)
RV1	47k Hor Enclosed Preset	1	(UH05F)

CAPACITORS

C1,3,5,14	100µF 10V PC Elect	4	(FF10L)
C2	100pF Polystyrene	1	(BX28F)
C4	10nF Poly Layer	1	(WW29G)
C6	470pF 1% Polystyrene	1	(BX53H)
C7	330pF 1% Polystyrene	1	(BX51F)
C8	220µF 16V PC Elect	1	(FF13P)
C9,11,13	1nF Ceramic	3	(WX68Y)
C12	470nF Poly Layer	1	(WW49D)
C10,15	100nF Poly Layer	2	(WW41U)
C16	10µF 50V PC Elect	1	(FF04E)

SEMICONDUCTORS

D1	1N4148	1	(QL80B)
TR1	BC549	1	(QQ15R)
TR2,3,5	BC548	3	(QB73Q)
TR4	BC109C	1	(QB33L)
IC1	4093BE	1	(QW53H)
IC2	4046BE	1	(QW32K)
IR2	MF0D71 Fibre Optic Detector	1	(FD12N)

MISCELLANEOUS

PCB		1	(GD28F)
Pin 2145		1 Pkt	(FL24B)
DIL Socket 14-Pin		1	(BL18U)
DIL Socket 16-Pin		1	(BL19V)
Bolt 8BA × ¼in.		1 Pkt	(BF08J)
Nut 8BA		1 Pkt	(BF19V)
Instruction Leaflet		1	(XU14Q)
Constructors' Guide		1	(XH79L)

FIBRE OPTIC LINK TRANSMITTER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1,4,5	10k	3	(M10K)
R2	47k	1	(M47K)
R3	2M2	1	(M2M2)
R6	100Ω	1	(M100R)
R7	22k	1	(M22K)
R8,12	47Ω	2	(M47R)
R9,11	1k	2	(M1K)
R10	2k2	1	(M2K2)
RV1	47k Hor Enclosed Preset	1	(UH05F)
RV2	100k Hor Enclosed Preset	1	(UH06G)

CAPACITORS

C1	39nF Poly Layer	1	(WW36P)
C2	100µF 10V PC Elect	1	(FF10L)
C3	470pF 1% Polystyrene	1	(BX53H)
C4	220nF 35V Tantalum	1	(WW56L)
C5	220µF 16V PC Elect	1	(FF13P)

SEMICONDUCTORS

TR1,2	BC548	2	(QB73Q)
TR3	BD139	1	(QF07H)
IR1	MF0E71 Fibre Optic Emitter	1	(FD14Q)
IC1	4046BE	1	(QW32K)

MISCELLANEOUS

PCB		1	(GD29G)
DIL Socket 16-Pin		1	(BL19V)
Pin 2145		1 Pkt	(FL24B)
Bolt 8BA × ¼in.		1 Pkt	(BF08J)
Nut 8BA		1 Pkt	(BF19V)
Instruction Leaflet		1	(XU14Q)
Constructors' Guide		1	(XH79L)

OPTIONAL (Not in Kit)

Fibre Optic Light Guide 1mm		As req.	(XR56L)

Close-up of the complete detector PCB.
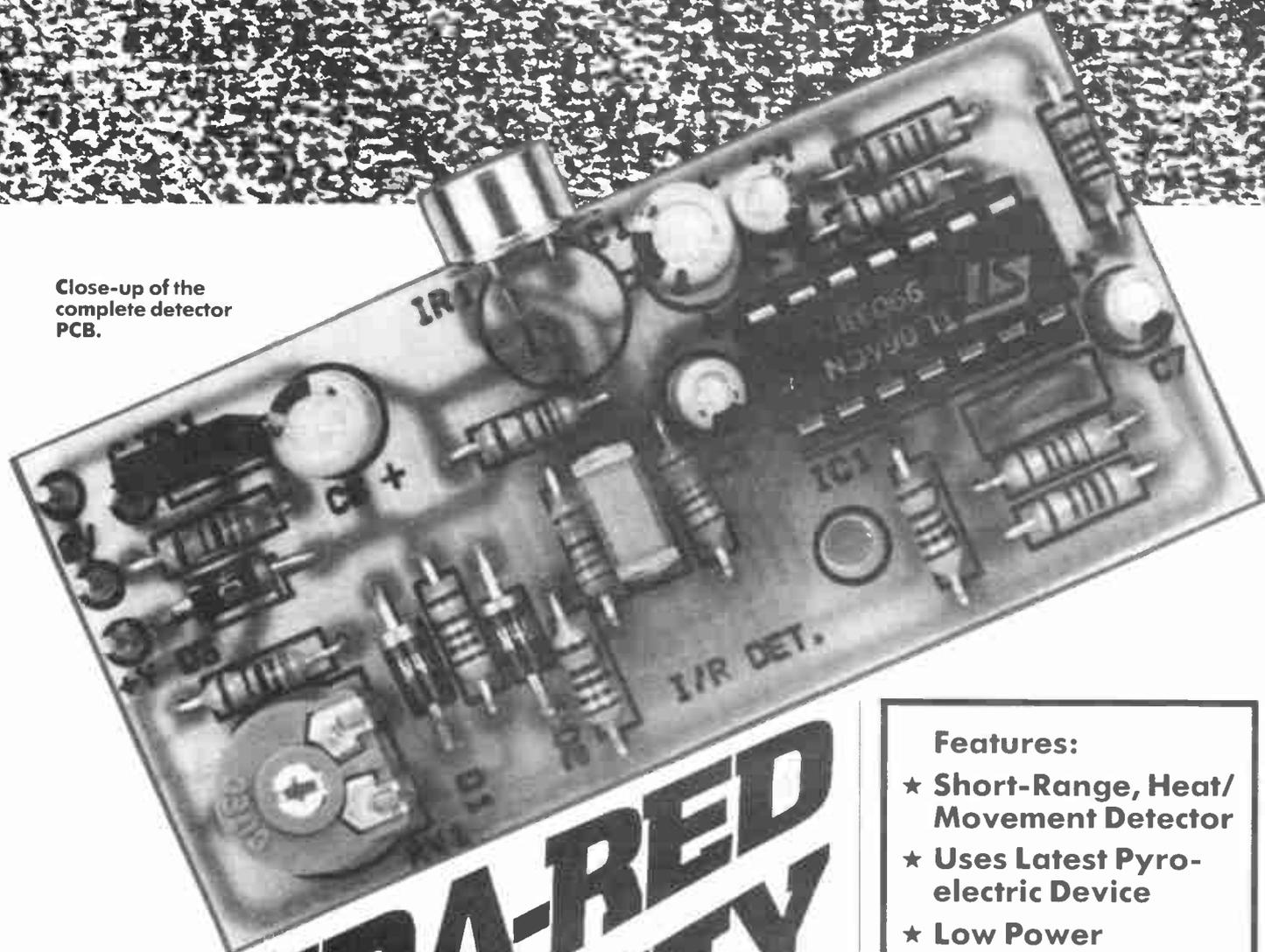
INFRA-RED PROXIMITY DETECTOR

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

By Alan Williamson

Features:
- ★ Short-Range, Heat/Movement Detector
- ★ Uses Latest Pyro-electric Device
- ★ Low Power Consumption for Long Battery Life

Application:
- ★ Ideal for Doorways, Stairs and Similar Proximity Systems

Pyroelectrics

The E100SV1 sensor uses a ceramic, ferroelectric element, which has the property of producing an electrical change due to a change in polarisation intensity. If a moving object enters the field of view of this sensor, changes in infra-red energy levels occur due to a difference in temperature between this object and the background. Infra-red energy is converted into heat by the surface electrode of the element, thus causing a change in temperature within the element itself, and a small electric charge is created as a result (see Figure 1).

This small charge appears across the gate resistance Rg in Figure 2, and is impedance buffered by the FET source follower, where a change in voltage appears across source resistance R13 (Figure 4).

A small DC bias voltage is produced across R13 by the quiescent current flowing through the FET while no signal is
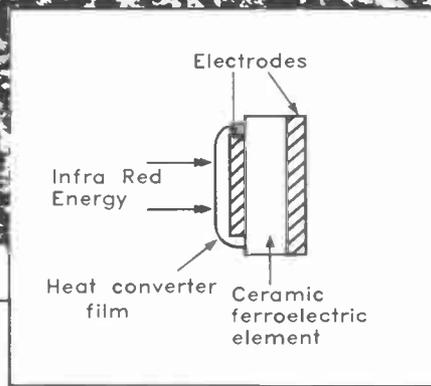
Figure 1. Pyroelectric element.
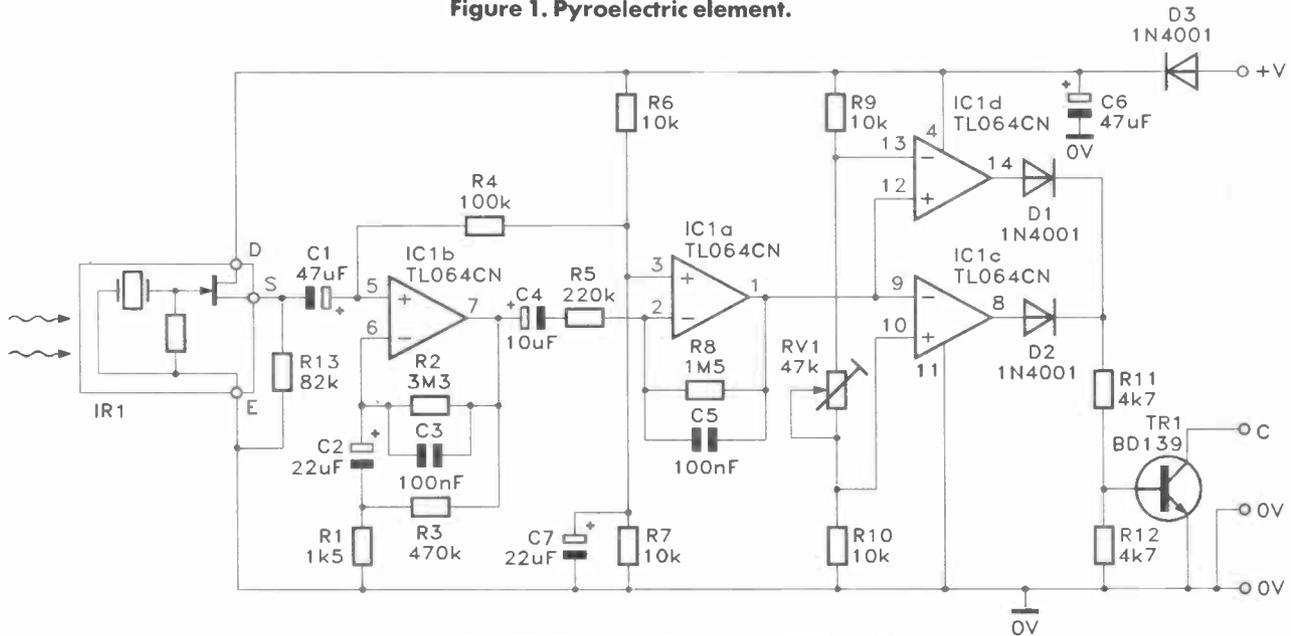
Figure 4. Circuit diagram.

Figure 2. Proximity detector – internal.
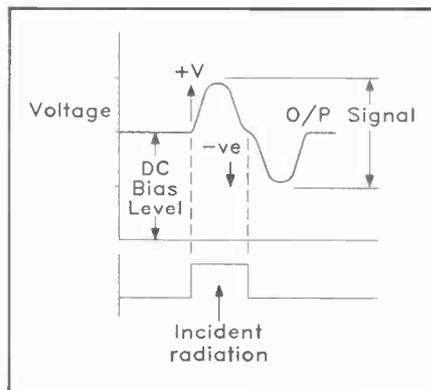
Figure 3. Source output voltage swing.

present, as can be seen in Figure 3. Output signals from the source terminal modulate the DC bias level with a $+V_e$ voltage swing.

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

Done with Mirrors!

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

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

As an infra-red emitting source crosses the field of view, radiated energy bounces off these facets in a sequence. The sensor responds with a series of related output pulses; detection electronics can determine the size, velocity and direction of the source while it is moving. Sophisticated PIRs are readily available in the Maplin catalogue and are more suitable for security and alarm use than this particular system.

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

Circuit Description

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

The somewhat unusual arrangement of resistors R1 and R4 allow C2 to charge slowly during initial power up. C2 is necessary for isolating IC1b $-V_e$ input from the 0V supply rail. With single supply op-amps, it is common to generate a half supply DC voltage reference to bias the differential inputs, thus allowing output voltage swings about this level. The effect of integration on the continuous input signals produces a very low-frequency output signal, which is applied to C2. The charge across C2 varies with the magnitude of the output signal (from Pin 7) and limits heavy transients which might saturate this stage.

IC1a is a standard inverting amplifier, again voltage referenced to half supply
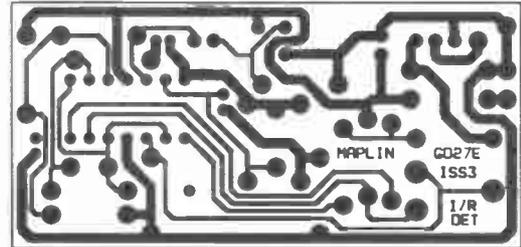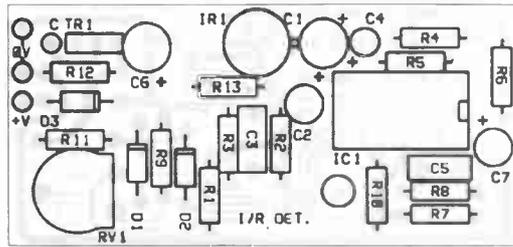
Figure 5. PCB legend and track.

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

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

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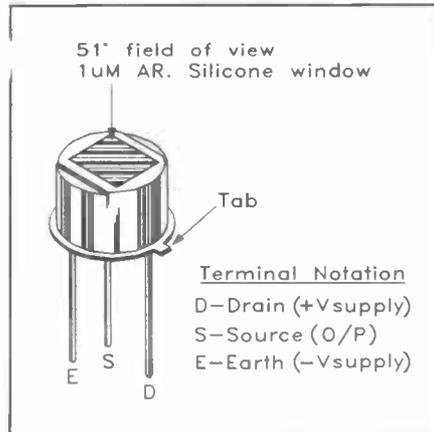

Figure 6. Sensor pin-outs.

Construction

For information on building details and components, refer to Figure 5 for the board layout and to the 'Constructors' Guide' supplied with this kit (if you do not intend to purchase the complete kit then see the Parts List for the order code of the Constructors' Guide). Identify and insert resistors R1 to R13. Solder these components and remove excess wire before continuing.

Mount diodes D1 to D3, and insert the four veropins into the holes marked with white circles. Next, insert a 14-Pin IC socket in position IC1 (taking note of the orientation notch), bend a few of the legs over the track pads to hold it in position. The PCB is quite small with tracks running close together, so a little extra care must be taken whilst soldering, as short circuits between tracks can easily occur.

Identify and insert capacitors C1 to C7. Polylayer type C3 should be fitted carefully to avoid breaking off the lead-out wires from the ends of the package. Fit preset RV1 and solder all components in position. Again cut off all excess leads, then fit TR1 and the sensor IR1 shown in Figure 6. One side of TR1 has a metal, heat transfer mounting plate fitted. Insert TR1 with this plate facing outward towards the edge of the PCB. The sensor IR1 shown in Figure 7 could be mounted vertically above the PCB, or horizontally off the PCB as detailed. In either case,
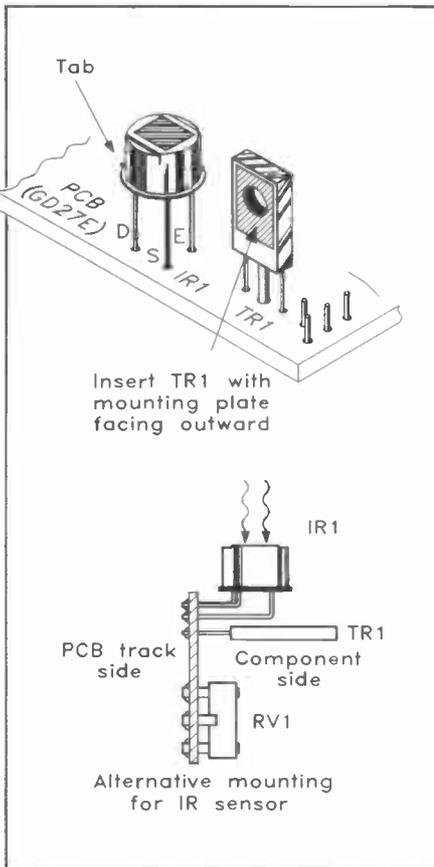

**Figure 7. Mounting arrangements.**
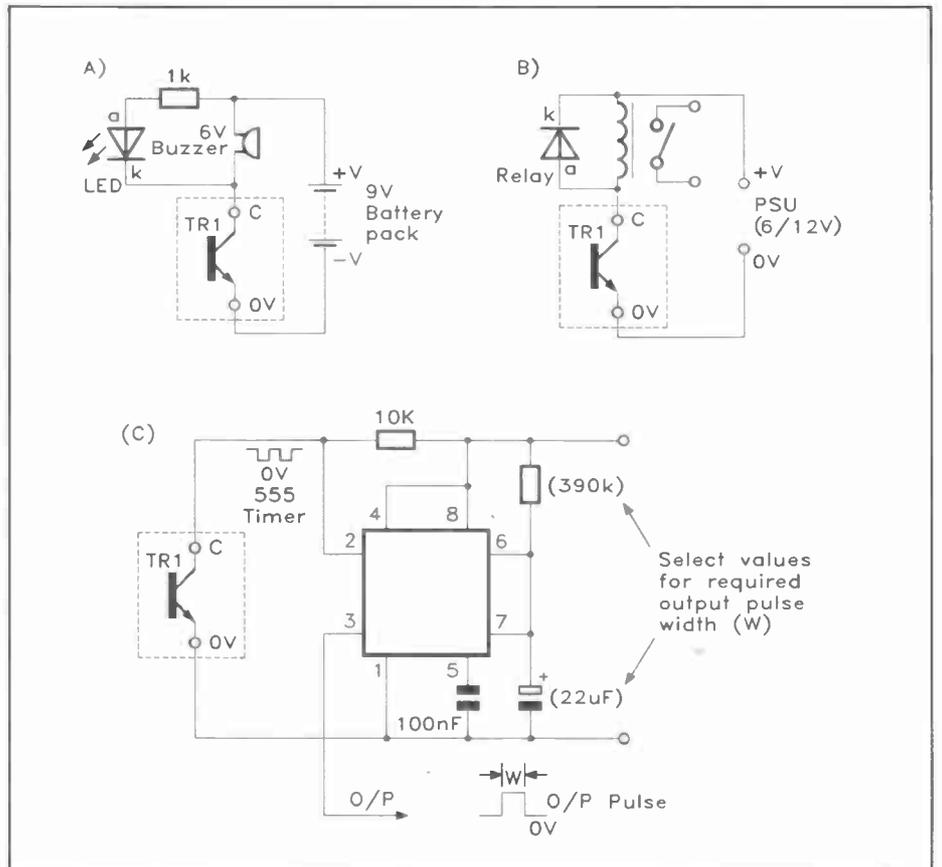

Figure 8. A, B, C, external circuit connections.

57
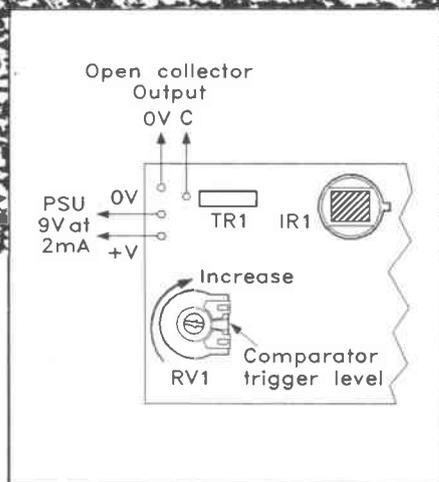
Figure 9. External PCB connections.

Figure 10. Spectral response of the sensor window.

mount the sensor as close as possible to the PCB in order to reduce noise induced into this area.

Either sensor mounting position will have to take into account the enclosure (case) requirements, and this is left to be fitted as required by the constructor. Last of all, fit a TL064 into the IC socket — taking note of the orientation; cut off all excess wires and clean up the track area to facilitate inspection.

Testing

Supply requirements for the module are 9V DC at 2 to 3mA. Current consumption is low, which allows long periods of use from small battery packs such as the PP3. Connect the battery $+V_e$ to the Pin marked +V, and $-V_e$ to either 0V Pin; diode D3 prevents damage to components in the event of accidental battery or supply reversal.

Check the supply current with an milliammeter which will be around 2·5mA for a minute or so dropping to between 1 and 1·5mA after this period. Current consumption increases by approximately 1mA while the comparator stages are operating.

The output transistor TR1 does not source current, but being open collector will sink current from an externally supplied load. Figure 8 suggests various methods of switching external loads, and diagram (a) could be used for testing purposes. Connect the LED cathode (k) to collector of TR1, the Pin marked C, then connect a 1kΩ resistor between the LED anode (a) and the $+V_e$ supply (battery + V_e or +V Pin).

If using the same battery for both module supply and LED supply, then the second battery $-V_e$ connection is not required (Pin 3).

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

Using the Module

TR1 is not capable of switching heavy loads and should only be used with external systems up to 12V DC and current levels below 100mA. Relays could be used for controlling larger voltage/current devices (Figure 8b), or a timer could be employed to generate long operating periods once triggered (Figure 8c). On the prototype, a 6V at 35mA buzzer was used on a separate supply to good effect.

Any battery supplying the electronics should NOT also be used for supplying the external devices as well (if more than a simple LED arrangement is to be used). Battery connections to Pins 1 and 2 should be kept short — a PP3 clip lead is ideal for this — mount both module and battery together in the same housing with a suitable ON/OFF switch.

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

INFRA-RED PROXIMITY DETECTOR PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)

R1	Min Res 1k5	1	(M1K5)
R2	Min Res 3M3	1	(M3M3)
R3	Min Res 470k	1	(M470K)
R4	Min Res 100k	1	(M100K)
R5	Min Res 220k	1	(M220K)
R6,7,9,10	Min Res 10k	4	(M10K)
R8	Min Res 1M5	1	(M1M5)
R11,12	Min Res 4k7	2	(M4K7)
R13	Min Res 82k	1	(M82K)
RV1	Hor Encl Preset 47k	1	(UH05F)

CAPACITORS

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

SEMICONDUCTORS

D1,2,3	1N4001	3	(QL73Q)
TR1	BD139	1	(QF07H)
IC1	TL064CN	1	(RA66W)

MISCELLANEOUS

IRD1	I/R Detector E100SV1	1		(UR69A)
	PCB	1		(GD27E)
	Pin 2145	1 Pkt		(FL24B)
	DIL Socket 14-pin	1		(BL18U)
	Instruction Leaflet	1		(XT72P)
	Constructors' Guide	1		(XH79L)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items are available as a kit which offers a saving over buying the parts separately. Order As LT00A (I/R Prox Detectr Kit).

Please Note: where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new item (which is included in the kit) is also available separately.
I/R Detector E100SV1 **Order As UR69A.**

·F·A·N·T·A·S·T·I·C·
FIVE

Lowpass Filter Effects Unit

by Robert Penfold

There are a great many forms of musical effects unit, and most rely on some form of frequency selective filtering for their operation. The unit featured here is in this category, and it is basically just a 12dB per octabe lowpass filter which is swept by a low frequency oscillator. This gives a sort of tremolo effect on the high frequency content of the processed signal, producing a relatively mild but useful effect. It is an effect that is available on many synthesisers, but which seems to be something of a rarity as far as stand-alone effects units are concerned.

The circuit breaks down into two sections; the filter which is built around IC1, and the oscillator which is based on IC2 and IC3. Starting with the filter, this uses two transconductance operational amplifiers which are contained in a single LM13700N device. A darlington pair emitter follower output stage is also included for each amplifier, and these have discrete load resistors R8 and R12.
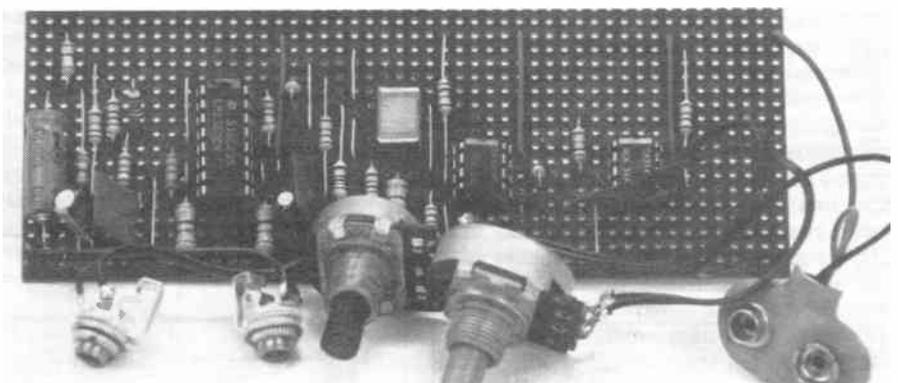
The two amplifiers are connected in series, and in this application function more as voltage controlled resistors than amplifiers. They act as simple 6dB per octave lowpass filters in conjunction with C3 and C4, giving a combined attenuation rate of 12dB per octave. Feedback through R6 and R7 gives what is actually a bandpass response at pin 8 of IC1, and by taking the output signal from here a form of waa-waa effect can be obtained. IC1 is current rather than voltage

operated, but the inclusion of R14 in series with the control inputs gives a current flow that is roughly proportional to the applied voltage, and effectively converts the filter to voltage controlled operation. R13 reduces the input voltage range from the oscillator slightly, bringing it into a more suitable range to drive the filter.

The oscillator uses IC3 in a well known configuration which is based on a Millier Integrator (IC3a) and a Schmitt
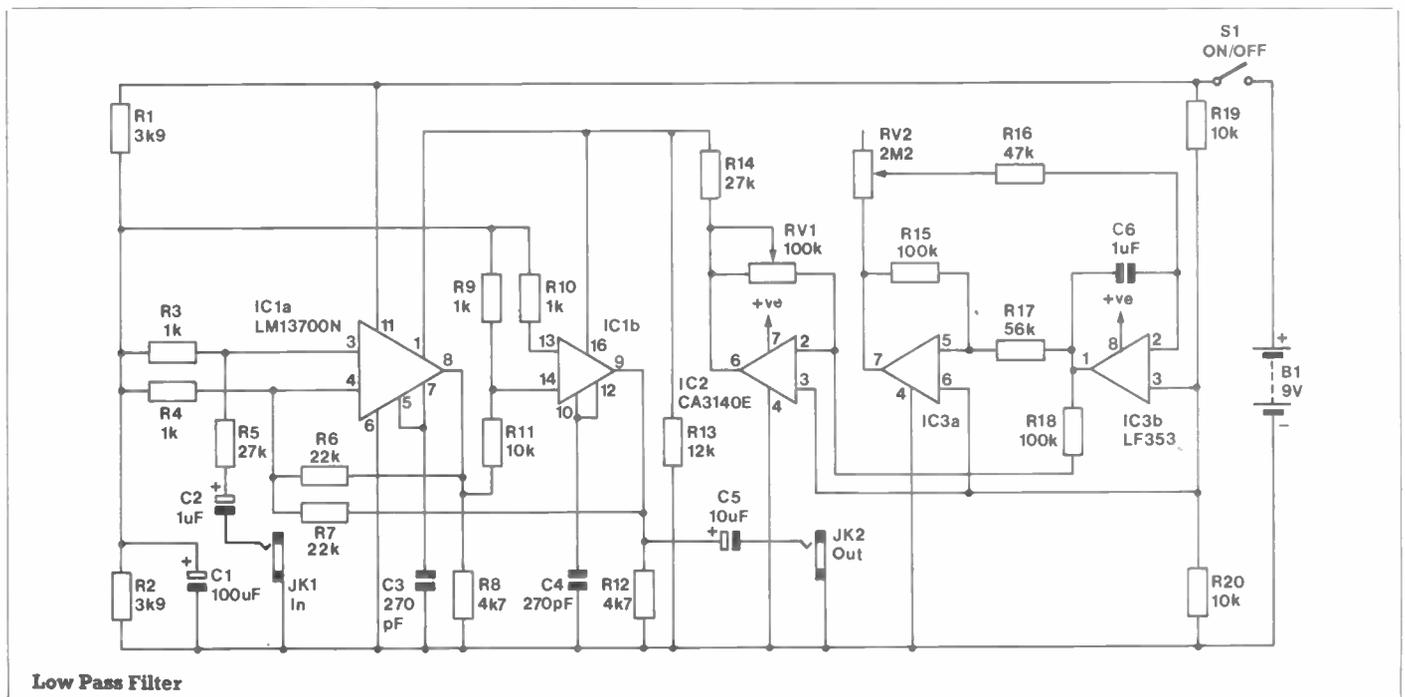
Low Pass Filter

Trigger (IC3b). This type of circuit gives both squarewave and triangular outputs. In this application a triangular waveform gives good results with a smooth sweeping of the filter frequency, and it is this output that is utilized. The operating frequency can be varied by means of RV2, and the nominal frequency range is from 10Hz at minimum resistance to 0.2Hz (one cycle every five seconds) at maximum resistance.

It is more than a little useful to have some control over the sweep range, and this is provided by RV1. This controls the feedback applied to IC2, and hence the voltage gain of this device. When set at a low value IC2 has only a low voltage gain, resulting in the cut-off frequency of the filter being varied over a narrow range of frequencies in the lower treble range. Higher resistance gives greater sweep width, with the cut-off frequency being

swept over most of the audio frequency range with RV1 set at maximum value.

As with any effects unit, it is advisable to build the unit into a strong metal case such as a diecast aluminium type. If a bypass switch is needed a standard DPDT bypass configuration can be used, and the switch should be a heavy duty push button type mounted on the top of the case so that it can be operated by foot.

Low Resistance Meter

Normal multimeters, including some quite expensive digital types, do not give very good results at low resistances. This is something that obviously varies from one instrument to another, but a resolution of one ohm or more is not uncommon, and this is obviously inadequate when testing very low value resistors. Open circuit or seriously over-value components can be detected well enough, but it could prove to be impossible to distinguish between a closed circuit component and a service-able one. This is often important as low value resistors are commonly used in applications such as current limiters in power supplies, where a faulty component could result in expensive damage.

This resistance meter has two ranges with full scale values of one ohm and ten ohms. It can therefore give an accurate assessment of resistances as low as a fraction of an ohm. It is an analogue instrument, but unlike conventional analogue resistance meters it has a forward reading linear scale. With an in-range resistance across the test prods, it uses a test voltage of no more than about 10 millivolts, and it will consequently not respond to semiconductor junctions. This can be useful when making continuity checks on circuit boards, where forward biased semiconductor junctions can often give misleading results by suggesting the presence of a short circuit where none exists.

The system used in this meter is to feed a constant current to the test resistance, and to measure the voltage developed across it. As this voltage is proportional to the resistance present, the meter can be calibrated dirctly in ohms using a forward reading linear scale, rather than the awkward reverse reading logarithmic type which is normally associated with analogue resistance meters. Here the constant current is provided by IC1 which is an integrated circuit designed specifically for current regulator applications. The current is controlled by a discrete resistor, and in this circuit two switched resistors (R1 and R2) give current options of 1 and 10 milliamps. M1, RV2, and R5 form the voltmeter circuit, and the nominal full scale value is 1 volt. However, IC2 boosts the sensitivity by a factor of about one hundred, giving a full scale value of 10 millivolts to the voltmeter circuit as a whole. Using Ohm's Law this gives full


Low Resistance Meter

scale values of 1 ohm with a 10 milliamp test current, and 10 ohms with a 1 milliamp test current. RV2 is adjusted to give good accuracy, and RV1 compensates for offset voltages in IC2.

One problem with the basic circuit is that the meter would be driven hard against its end stop with no in-range resistance across the test prods. This is overcome by using TR1 as an electronic switch, which bypasses the meter circuit if the output of IC2 goes to more than about +1.2 volts. This prevents serious overloads of the meter, but makes it impossible to determine whether a valid reading or an overload is present. This is overcome by using TR2 to switch on LED indicator D1 if an overload is present. D1

switching off therefore indicates that a valid meter reading is present.

The unit is calibrated on the 10 ohm range using 1 and 10 ohm 1% resistors. First RV2 is adjusted for fsd with the 10 ohm resistor in circuit, after which the 1 ohm resistor is connected across the test prods and RV1 is adjusted for the correct reading of one tenth fsd. This procedure is repeated until no further adjustment is necessary.

In the interest of good accuracy it is important to keep resistances at the input of the circuit as low as possible. In particular, use short test leads of heavy gauge wire, and test prods that provide a low resistance (some spring types seem to be unsuitable).
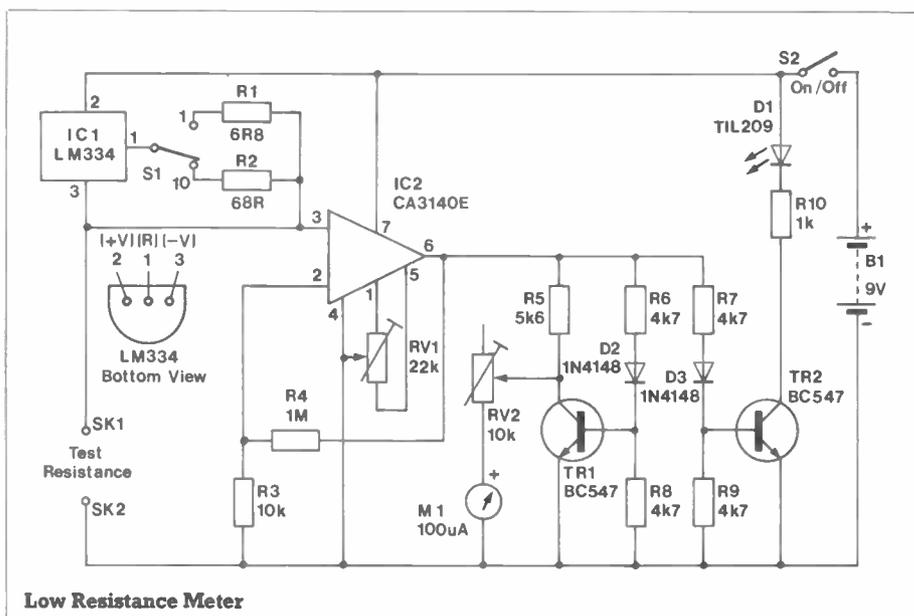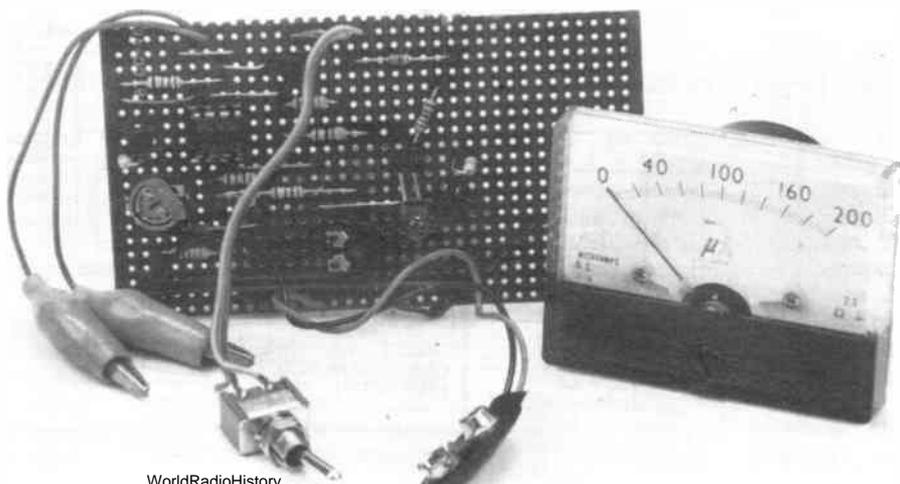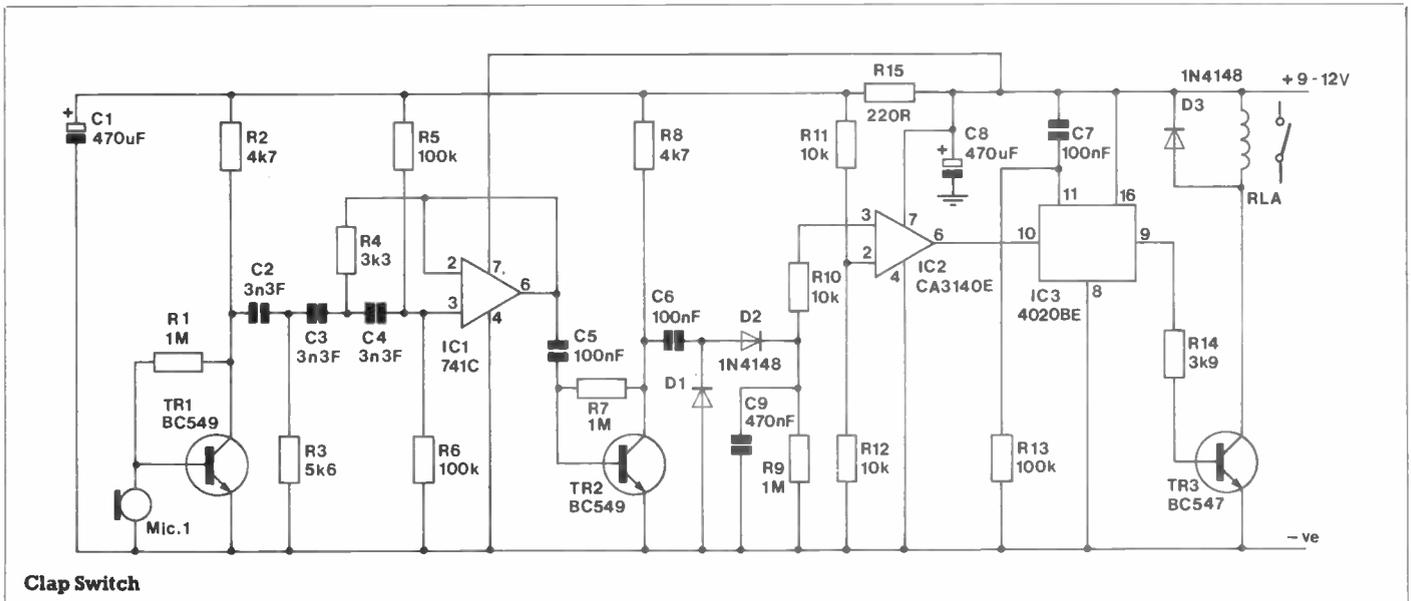
Clap Switch

Clap Switch

This circuit was designed mainly as a novelty project, but although intended to be in the 'impress your friends' category, it could in fact be used as a practical alternative to simple ultrasonic and infra-red remote control systems. It is merely necessary to clap once in order to switch on the piece of controlled equipment, and to clap once more in order to switch it off again. Being a sound activated switch it is not totally immune to sounds other than handclaps, but a combination of moderate sensitivity and built-in filtering minimise the risk of spurious triggering.

TR1 operates as a high gain common emitter preamplifier, and its input is fed direct from a crystal microphone. This can be an inexpensive microphone insert, although many of these seem to give poor sensitivity, and a ceramic resonator was found to provide better results. A crystal microphone needs to feed into a very high load impedance in order to give a flat frequency response, and a fairly low input impedance (such as that of TR1) gives poor bass and middle frequency response. In this case though, we are only interested in the predominantly high frequency content of a handclap, and the lack of bass and middle frequency response is an advantage as it reduces the risk of spurious triggering. In fact, the input stage is followed by an active highpass filter based on IC1 which gives an 18dB per octave roll-off below about 7kHz. The output of the filter feeds the input of a second high gain common emitter amplifier, this time based on TR2.

The output from TR2 is rectified and smoothed by D1, D2, and C6, but under stand-by conditions there will be no significant output signal. However, a handclap will produce a strong positive DC bias across C6 that will decay over a period of a few hundred milliseconds. IC2 operates as a comparator which converts this signal into a pulse that will reliably drive the next stage, which is a CMOS divide by two circuit. In fact the
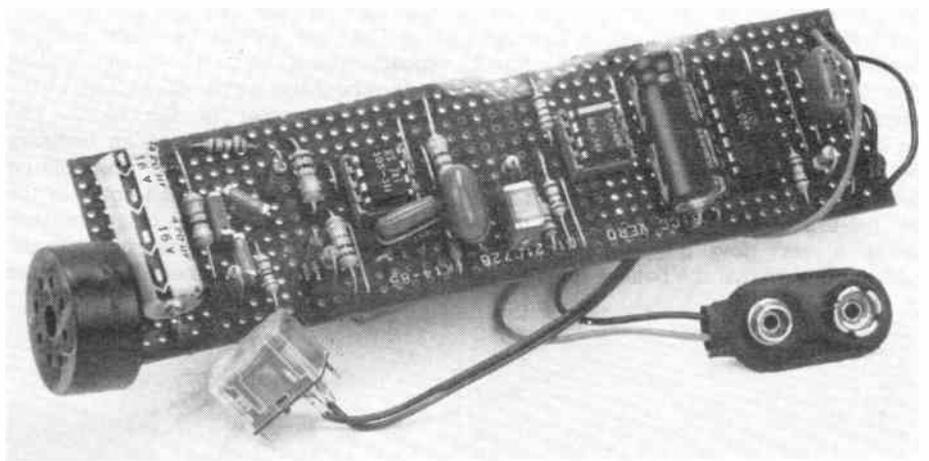
4020BE used for IC3 is a 14 stage type, but only one stage is used here. This drives the relay via switching transistor TR3, and the purpose of the divider circuit is to give the required successive type of operation, with alternate input pulses switching the relay on and off. C7 and R13 provide a reset pulse to IC3 at switch on, starting the relay in the off state. D3 is the usual protection diode.

The specified relay has a change-over contact with a rating of 5A at 240 volts AC. However, the unit should work properly using any relay having adequate contact ratings for your intended application, and a 6 volt coil with a resistance of about 200 ohms or more. Of course, a relay having a nominal 12 volt operating voltage is suitable if the unit is used with a 12 volt supply. If a mains load is controlled by the unit it is essential to observe all the normal safety precautions, and beginners would be well advised not to attempt control of mains powered equipment. The microphone must be reasonably well acoustically isolated from the relay if oscillation due to acoustic feedback is to be avoided. The current consumption is about 5 milliamps with the relay switched off, and around 40 milliamps when it is activated. In most cases battery operation will only be viable if some form of rechargeable type is used.

Snooze Timer

Virtually all clock radios include a 'snooze' or 'sleep' facility which simply switches off the set after a preset time has elapsed. The general idea is to activate the timer when going to bed, and the radio then switches itself off when the user has become drowsy and is just dropping off to sleep. A somewhat simpler version of this feature (with non-adjustable delay) is sometimes found in other types of radio, ranging from cheap portable radios to expensive communications receivers, and it is quite easy to add a simple 'sleep' function to small battery operated radios. A suitable circuit is shown here, and this gives a switch-off delay of about 10 minutes. However, by changing the value of one component it is possible to obtain virtually any required delay time.

Simple C – R timing circuits work quite well when only short pulse lengths are required, but for periods of about a minute or more, the required values become impractically high. The standard solution to the problem, and the one adopted here, is to use an oscillator and divider chain arrangement. In this circuit two CMOS NOR gates (IC1a and IC1b) are used as inverters and connected in a standard CMOS astable configuration. IC2 is the divider, and is a CMOS 7 stage binary type, giving a total division rate

of 128 with all seven stages used (as they are here). TR1 operates as a common emitter switch which is driven from the output of stage seven of IC2. TR2 is cut off when this output is high, and turned on when it is low. C3 and R2 provide a reset pulse to IC2 at switch-on, and this takes all seven outputs low, causing TR1 to turn on and supply power to the radio set.

After 64 clock pulses from IC1, the output of the final binary divider goes high, switching off both TR1 and the radio set. After a further 64 clock pulses the circuit would revert back to its original state, and it would continue to cycle indefinitely in this way. This problem is overcome by using a gated astable clock oscillator, with the gate input being fed from pin 3 of IC2. The clock is therefore muted when pin 3 of IC2 goes high at the end of the switch-off delay.

In order to reactivate the circuit it is merely necessary to switch off using S1, and then switch the unit on again. S1 and R4 ensure that the capacitors in the circuit discharge rapidly, leaving the circuit ready to operate from the beginning once again. S2 can be used to bypass the unit when normal operation of the radio is required. An important point is that the use of CMOS devices gives the circuit a very low quiescent current consumption so that the battery does not


Snooze Timer
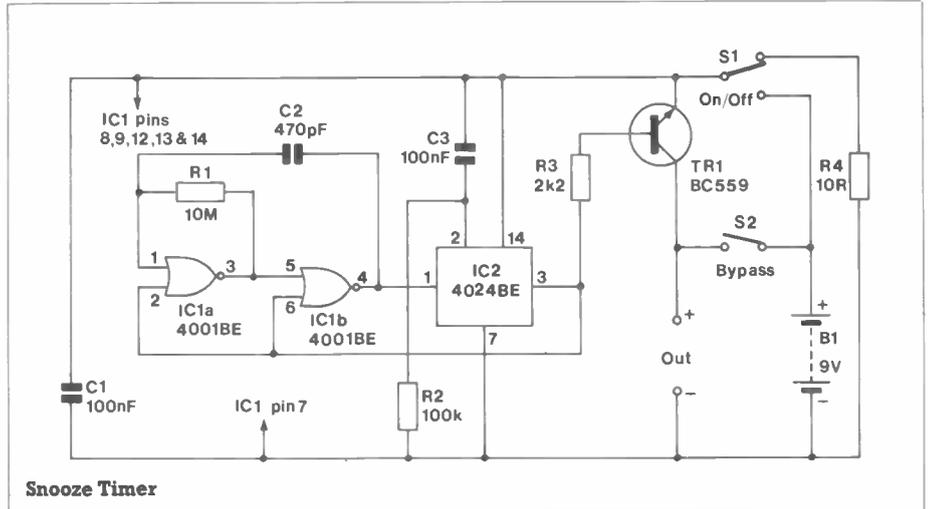
run down significantly when the radio is switched off. In fact, the quiescent current consumption is typically only a fraction of a microamp.

The unit should be quite easy to construct, and the only real complication is in taking the output of the unit to the battery connector of the radio. The output can be carried via an ordinary battery clip lead, but it will probably be necessary to make a small notch in the lid of the radio's battery compartment to enable the lead to pass through into the set. Be careful to connect the lead the

right way round. The circuit can handle currents of up to 100 milliamps, and it will also work with a 6 volt battery. It will therefore function properly with the majority of transistor radios.

The switch-off delay is proportional to the value of C2, and also to that of R1. Different times can therefore be obtained by altering the value of one or both of these. For instance, a value of 220nF for C2 would give a delay of just under 5 minute, or using two 10M components in series for R1 would increase the delay to around 20 minutes.
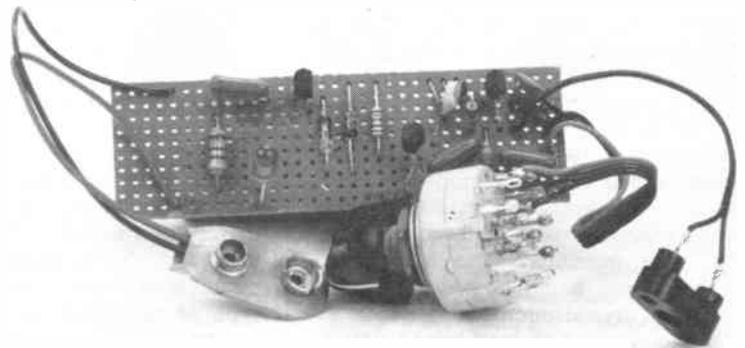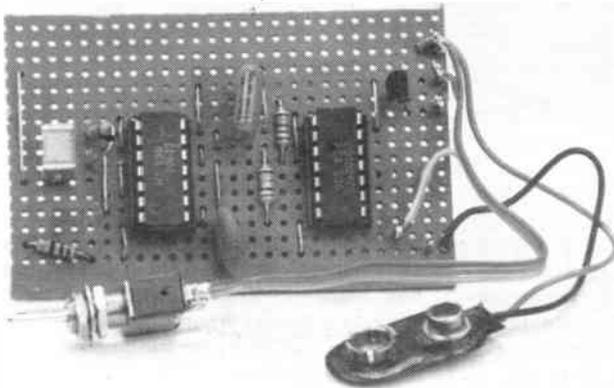
Crystal Checker

Although at one time crystals seemed to be vanishing from the amateur electronics scene, with the revival in the popularity of radio and the increasing use of crystal oscillators in digital and micro circuits, these components are probably more widely used now than at any time in the past. Crystals are not components that can be checked properly using an ordinary multimeter, and a more elaborate system of testing is required. In its most simple form a crystal checker can consist of an oscillator circuit into which the suspect component is connected, and some form of detector circuit to indicate whether or not oscillation is present. An oscillator output socket is useful as it enables a check on the output frequency to be made with the aid of a suitable frequency meter or radio receiver.

This checker is of the basic type outlined above, and it has a LED indicator

Crystal Checker
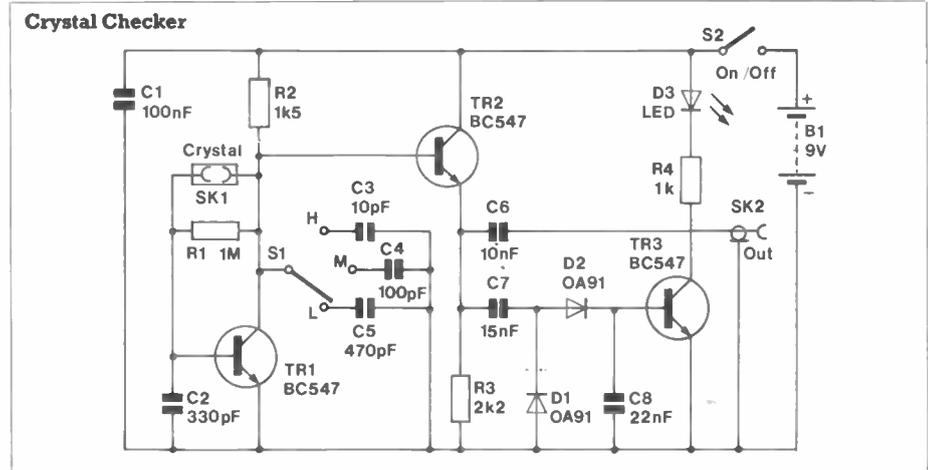
which switches on if the test component is producing oscillation. The circuit will work with crystals having fundamental frequencies from around 100kHz to about 20MHz or so. Most crystals are in this category since those having marked

frequencies of more than 20MHz are usually overtone types which have fundamental frequencies at typically only a third or a fifth of the marked frequency. This checker will not work with very low frequency crystals having operating

HIGH FREQUENCY TREMOLO PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,2	3k9	2	(M3K9)
R3,4,9,10	1k	4	(M1K)
R5,14	27k	2	(M27K)
R6,7	22k	2	(M22K)
R8,12	4k7	2	(M4K7)
R11,19,20	10k	3	(M10K)
R13	12k	1	(M12K)
R15,18	100k	2	(M100K)
R16	47k	1	(M47K)
R17	56k	1	(M56K)
RV1	100k Lin. Pot	1	(FW05F)
RV2	2M2 Lin. Pot	1	(FW09K)

CAPACITORS

C1	100µF Axial Electrolytic 10V	1	(FB48C)
C2	1µF Axial Electrolytic 100V	1	(FB12N)
C3,4	270pF Ceramic	2	(WX61R)
C5	10µF Axial Electrolytic 25V	1	(FB22Y)
C6	1µF Poly Layer	1	(WW53H)

SEMICONDUCTORS

IC1	LM13700N	1	(YH64U)
IC2	CA3140E	1	(QH29G)
IC3	LF353	1	(WQ31J)

MISCELLANEOUS

SK1,2	Jack Socket	2	(HF90X)
S1	SPST Ultra-Min Toggle	1	(FH97F)
B1	PP7 9V Battery	1	(FM04E)
	Battery Clips	1	(HF27E)
	DIL Socket 16-pin	1	(BL19V)
	DIL Socket 8-pin	2	(BL17T)

LOW RESISTANCE METER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	6R8	1	(M6R8)
R2	68R	1	(M68R)
R3	10k	1	(M10K)
R4	1M	1	(M1M)
R5	5k6	1	(M5K6)
R6,7,8,9	4k7	4	(M4K7)
R10	1k	1	(M1K)
RV1	22k Sub-min Hor Preset	1	(WR59P)
RV2	10k Sub-min Hor Preset	1	(WR58N)

SEMICONDUCTORS

IC1	LM334	1	(WQ32K)
IC2	CA3140E	1	(QH29G)
TR1,2	BC547	2	(QQ14Q)
D1	Red LED	1	(WL27E)
D2,3	1N4148	2	(QL80B)

MISCELLANEOUS

SK1,2	1mm Socket	2	(WL59P)
S1	SPDT Ultra-Min Toggle	1	(FH98G)
S2	SPST Ultra-Min Toggle	1	(FH97F)
M1	100µA Panel Meter	1	(RW92A)
B1	PP7 9V Battery	1	(FM04E)
	Battery Clip	1	(HF27E)
	DIL Socket 8-pin	1	(BL17T)

CLAP SWITCH PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,7,9	1M	3	(M1M)
R2,8	4k7	2	(M4K7)
R3	5k6	1	(M5K6)
R4	3k3	1	(M3K3)
R5,6,13	100k	3	(M100K)
R10,11,12	10k	3	(M10K)
R14	3k9	1	(M3K9)
R15	220R	1	(M220R)

CAPACITORS

C1,8	470µF Axial Electrolytic 10V	2	(FB71N)
C2,3,4	3n3F Poly Layer	3	(WW25C)
C5,6,7	100nF Polyester	3	(BX76H)
C9	470nF Poly Layer	1	(WW49D)

SEMICONDUCTORS

D1,2,3	1N4148	3	(QL80B)
TR1,2	BC549	2	(QQ15R)
TR3	BC547	1	(QQ14Q)
IC1	µA741C	1	(QL22Y)
IC2	CA3140E	1	(QH29G)
IC3	4020BE	1	(QX11M)

MISCELLANEOUS

Mic 1	Min-Piezo Sounder	1	(FM59P)
RLA	Open Relay 6V	1	(FX23A)
	DIL Socket 8-pin	2	(BL17T)
	DIL Socket 16-pin	1	(BL19V)

SNOOZE TIMER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	10M	1	(M10M)
R2	100k	1	(M100K)
R3	2k2	1	(M2K2)
R4	10R	1	(M10R)

CAPACITORS

C1,3	100nF Disc Ceramic	2	(BX03D)
C2	470pF Ceramic	1	(WX64U)

SEMICONDUCTORS

IC1	4001BE	1	(QX01B)
IC2	4024BE	1	(QX13P)
TR1	BC559	1	(QQ18U)

MISCELLANEOUS

S1	SPDT Ultra-Min Toggle	1	(FH98G)
S2	SPST Ultra-Min Toggle	1	(FH97F)
B1	PP9 9V Battery	1	(FM05F)
	Battery Clips	1	(HF27E)
	DIL Socket 14-pin	2	(BL18U)

CRYSTAL CHECKER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	1M	1	(M1M)
R2	1k5	1	(M1K5)
R3	2k2	1	(M2K2)
R4	1k	1	(M1K)

CAPACITORS

C1	100nF Disc Ceramic	1	(BX03D)
C2	330pF Ceramic	1	(WX62S)
C3	10pF Ceramic	1	(WX44X)
C4	100pF Ceramic	1	(WX56L)
C5	470pF Ceramic	1	(WX64U)
C6	10nF Polyester	1	(BX70M)
C7	15nF Polyester	1	(BX71N)
C8	22nF Polyester	1	(BX72P)

SEMICONDUCTORS

TR1,2,3	BC547	3	(QQ14Q)
D1,2	OA91	2	(QH72P)
D3	Red LED	1	(WL27E)

MISCELLANEOUS

SK1	Crystal Socket	1	(HX61R)
SK2	Coaxial Socket Flush	1	(HH09K)
S1	3-way 4 pole Rotary	1	(FB76H)
S2	SPST Ultra-min Toggle	1	(FH97F)
B1	PP3 Battery	1	(FK58N)
	Battery Clips	1	(HF28F)

frequencies of around 10 to 40kHz as these require special oscillator circuits.

TR1 acts as the basis of the oscillator, and this is a standard configuration which uses two capacitors to form a tapping on the crystal which operates as a parallel resonant tuned circuit. The crystal and capacitive tapping effectively form a single-wound resonant transformer, connected so that it provides a signal inversion. Thus, although the base and collector of common emitter transistor TR1 are out-of-phase, the inversion through the tuned circuit gives positive feedback over the circuit, and oscillation results provided the losses through the tuned circuit are not too high. Any reasonably active crystal will produce oscillation, but the values of the capacitors in the tapping circuit must have suitable values for the frequency of the test component. In this case one capacitor (C2) has a fixed value, while the other capacitor is one of three switched components (C3 to C5). Use C5 for low frequency (about 100kHz to 500kHz) types, C4 for medium frequency (500kHz to 6MHz) components, and C3 for high frequency (above 6MHz) types.

TR2 is an emitter follower output stage which can be used to drive a receiver or a frequency meter connected to SK2. TR2 is also used to drive a simple rectifier and smoothing circuit comprising D1, D2, and C8. If oscillation is produced, the strong positive bias generated across C8 is sufficient to turn on TR3 which in turn switches on LED indicator D3.

The circuit is quite easy to construct, and the only slight complication is in making the connections to the test crystals. One approach is to use several front panel mounted crystal holders wired in parallel in the SK1 position. These should be of different types so that any normal type of crystal will connect to the unit via one or other of the holders (even wire ended types can normally be connected to one of the holders well enough to facilitate testing). Of course, if you only use crystals with one type of base, a single holder will suffice. Another approach is to use two short leads terminated with small crocodile clips which fit onto the pins or leadout wires of test components.