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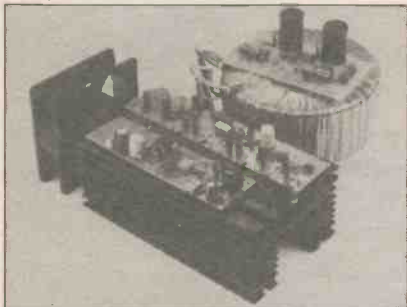
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C O N T E N T S

Electronics
THE MAPLIN MAGAZINE

1 KW HIGH POWER

MOSFET AMPLIFIER

by Dave Goodman

Prototype Specifications:
Single Channel (mono)
power output stage

Power supply. ±90VDC (180V) @ 7A
Rated Power output into 4Ω load.
(1) Peak Power   1.3 kW
                 (1300 Watts) PEAK
(2) RMS Power   775 Watts RMS
(3) Average Power 650 Watts RMS

Full Power
Bandwidth.   10Hz to 50kHz
Total Harmonic
Distortion.   0.2% @1kHz
                 (90% full power)
Slewing rate.   24V/µs
Damping factor. 110 (4Ω load)
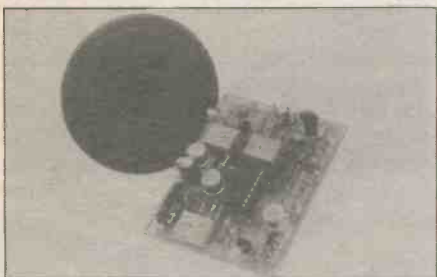
Input sensitivity. 775mV (0dB) into 30kΩ
                   for rated output.

The HP Mosfet amp is intended for use in halls, auditoriums or wherever the situation demands large scale audio amplification. Loud speaker loads down to a minimum of 3.5/4Ω can be driven by the amplifier at full power, before protection circuitry, on the monitor module, comes into effect. Mosfet devices have the capacity to limit conduction with increasing junction temperatures: meaning that running the amplifier at full power into loads of 1 to 2Ω, will cause the Mosfets to shut down all output signals, although heavy loads like this can be driven at reduced power levels. One function of the Monitor module is preventing the amplifier from delivering

power continuously into a short circuit. This situation can occur when loud speaker connecting cables are shorted together, rendering them liable to over-heat very quickly with disastrous results!

Modular System

The complete system is made up from four modules. Two modules form the power amplifier: a Driver module and an Output module both mounted onto the Mosfet heatsink assembly; a Monitor module and a Power Supply Module, both of which are mounted separately, as can be seen in Figure 1.

Driver Module

In the circuit diagram for the Driver module shown in Figure 2, TR1 and TR3 form a differential pre-amp on the signal input and feedback loop. R1, 2, 4 and C2, 3, 14 are low pass filtering components, which limit incoming signals to below 100kHz, and help to reduce breakthrough effects from local radio transmissions. TR2 is a constant current source supplying the emitters of TR1 and TR3 via balancing
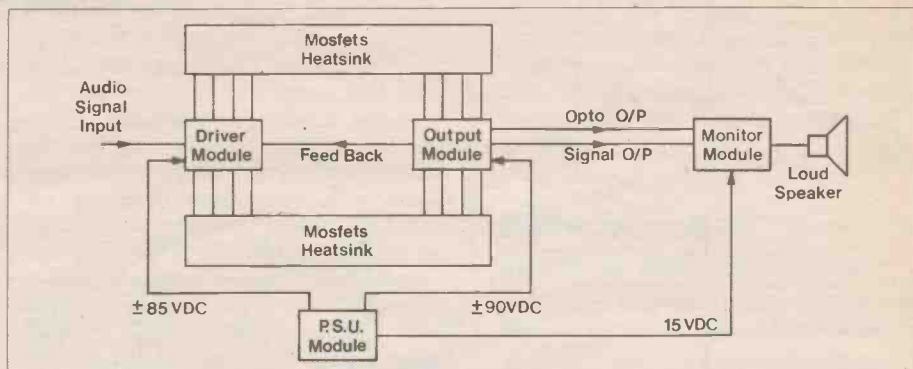
Figure 1. Block diagram.

resistors R3 & R7, both of which reduce offset differences caused by mismatch in these transistors. RV2 also allows a small amount of current control over the output DC offset, and wave form symmetry at higher signal frequencies. The differential output, from TR1, drives directly into TR6, which along with current source TR4, forms a voltage amplifier/driver stage. A current of 0·013A (13mA) flows in this stage: this is necessary for generating a small biassing voltage on each Mosfet gate, in the output stages. RV1 sets this bias voltage level, which can be measured as a potential difference across TR5 emitter and collector. With RV1 set fully clockwise (minimum resistance) TR5 base

is effectively coupled to its collector and the voltage across collector and emitter is approximately 0·67V or ±0·335V with respect to the virtual earth output pin 9. Rotating RV1 fully anticlockwise (maximum resistance) increases this voltage to approximately 1·5V or ±0·75V to pin 9. Further details on setting the bias voltage level, follows later on in the text.

Resistors R15 and R9 determine the AC gain of the amplifier, which in this case produce a gain of 70. Capacitor C7 has to be used to AC couple R9 to 0V otherwise TR5 would be pulled complete-ly out of its operating mode! The value chosen for C7 has been made quite large, for improved low frequency response, and
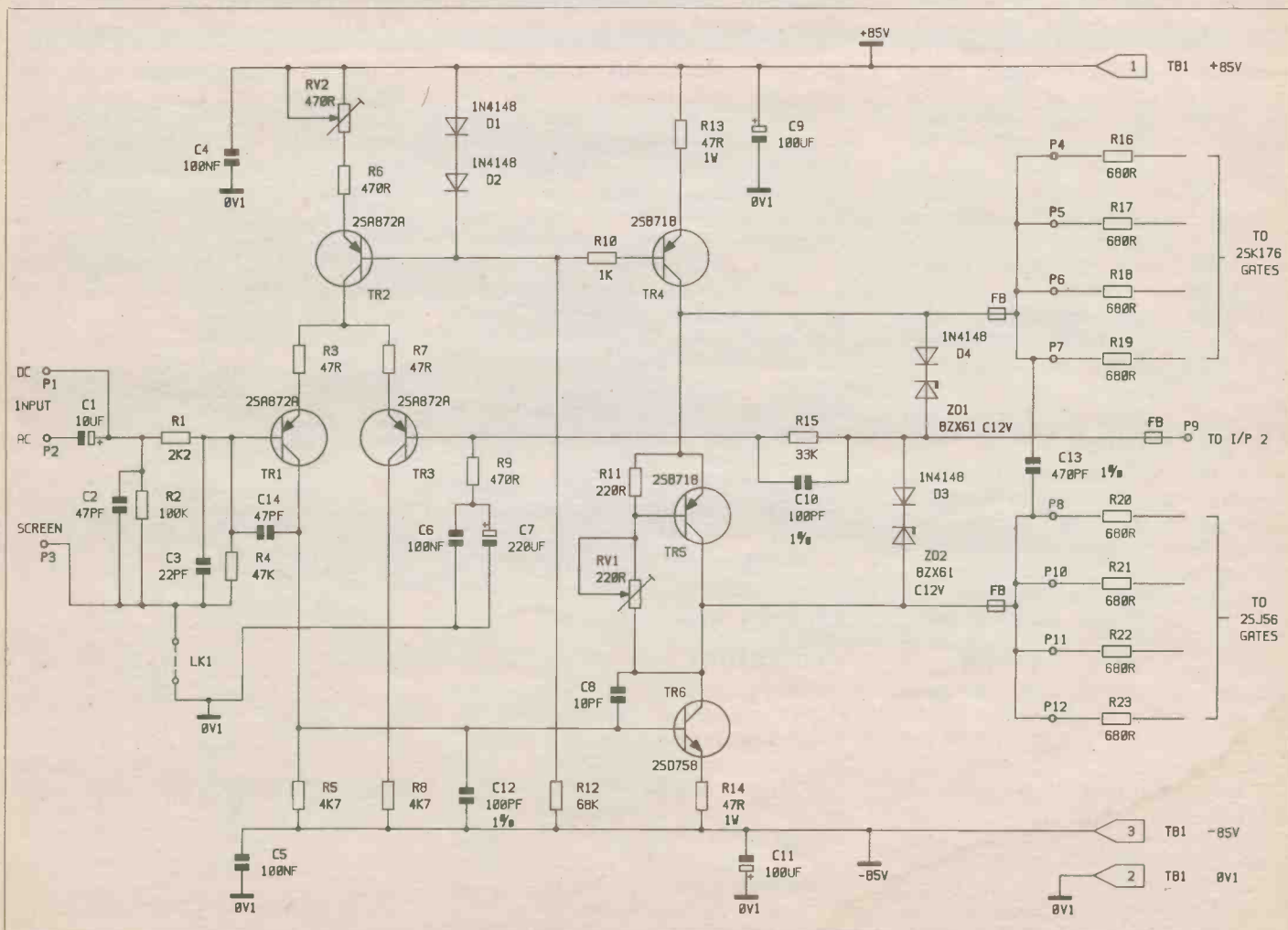
Figure 2. Driver PCB circuit.
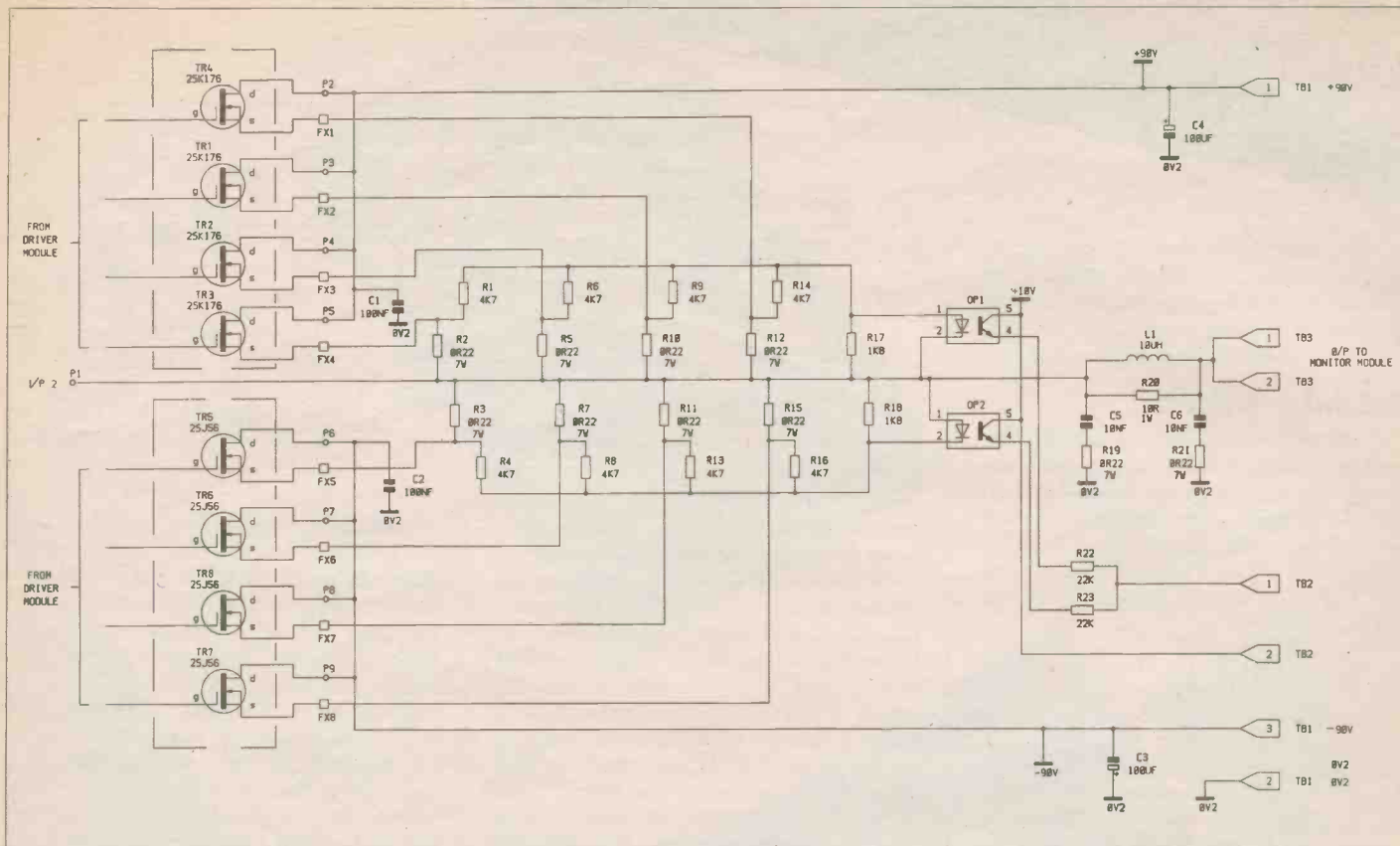
Figure 3. Output PCB circuit.

the inclusion of C6 overcomes the high impedance presented by C7 at higher frequencies. Zener diodes, ZD1 & ZD2, prevent voltage levels in excess of 14V from developing across the Gate & Source of the Mosfets, which would otherwise damage them permanently, even though they are 200V devices! The two coupling capacitors, C13 & C14, are used for stability purposes. H F instability can be a problem in Mosfet amplifiers, due to large variations in gate capacitances between N and P type devices, especially in class B output stages such as this. The combination of these capacitors and the value chosen for the 8 gate resistors ensure that any instability, likely to occur, is kept to an absolute minimum.

Output Module

Mosfet devices, as opposed to bipolar transistors, have been used in this design for several reasons: their excellent frequency response, easy parallel connection and low driving power requirements make them ideal for high power amplifier kits. The output stage, Figure 3, shows four 'N' type 2SK176 FET's grouped in parallel and four 'P' type 2SJ56 FET's also grouped in parallel. The eight gate inputs are effectively coupled together at the driver module end, and due to the FET enhancement mode transfer characteristic, complex biasing is not required. Enhancement type FET's are basically 'normally off' devices which means that when the gate voltage is at 0V, no drain current flows. Out of interest, the reverse effect 'depletion type' device is normally on and drain current flows even if the gate is at 0V! Thermal runaway, is an effect

exhibited by bipolar transistors due to their positive temperature coefficient. This situation occurs when the transistor is allowed to overheat, which lowers the junction resistance, thus increasing current flow and hence, increases the junction temperature. Fortunately, the Mosfet has a negative temperature coefficient, the effect of which is quite opposite to that of the bipolar device, and here the drain/source resistance increases with temperature. As the junction resistance increases, current flow is reduced, the junction temperature drops allowing current to flow again. This series of events happens at quite a slow pace; if it were not so, then the Mosfet would be prone to bursting into oscillation when heated. With all this internal self protection, it may be thought that output stage monitoring is, therefore, unnecessary on this module? In fact, the PCB tracks, speaker connecting cables and even loudspeakers used on a high voltage – high current – system such as this one, need protecting.

Output Stage Protection

TR1 to TR8 each have an associated 0.22Ω resistor inserted between the source lead and the common output rail. When the output is connected to a load, any current flowing in these stages – whether AC or DC – generates a small voltage across these resistors. The voltage is connected via 4k7 and 1k8 resistive potential dividers to an opto isolator, one in each half of the output, where OP1 handles positive going and OP2 handles negative going voltage transitions. An

input LED in the opto isolator conducts, and a corresponding signal is derived from the 10V supply on pin 5, and is presented via either R22 or R23 to Pin 1 on TB2. Choke L1 has been added at the final output, and due to its small value (approximately 5/10μH), offers a high impedance to upper harmonics when driving into a short circuit. Resistor R20 (actually mounted inside L1) dampens the coil and hence any ringing effect is prevented. The R/C filter Zobell circuits, C5/R19 & C6/R21, help absorb any EMF produced when driving the output into
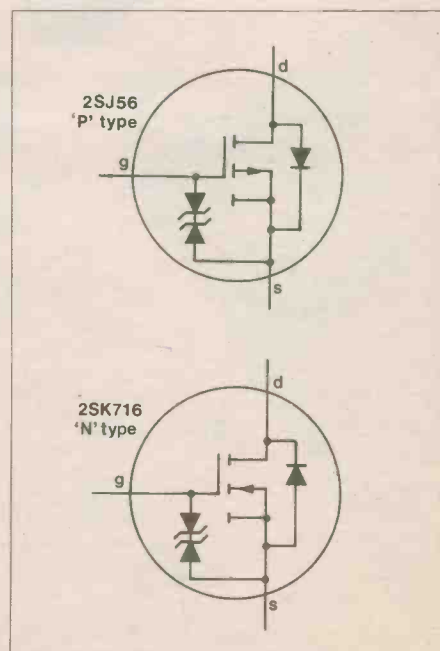
Figure 4. Mosfet schematic.

Figure 5. Monitor PCB circuit.

highly reactive circuits, such as combination speaker set ups and L/C crossover systems. The actual circuit reference for the two mosfet types is given in Figure 4. A diode exists parasitically between source and drain, which has very fast switching and recovery characteristics, and protects the FET from high level voltage spikes that would otherwise damage the substrate layers. Zener diodes are also internally connected between gate and source and these serve twofold reasons: as a secondary backup to the zeners fitted on the driver module, and to protect the device from static breakdown whilst being handled.

Monitor Module

The Monitor module, circuit shown in Figure 5, has several functions:

(1) Power up delay – Relay switched output delayed by approximately 10 seconds from when the main power is applied. Allows the positive and negative supply rails to settle down and the amplifier to stabilise itself before connecting the output to a load.

(2) Power off release – Immediate relay switch off when the mains is removed. Requirements being the same as for (1).

(3) DC offset detection – Output stage breakdown, causing supply rail voltage to be presented to the load, is detected and latches the O/P relay into an off state. The main power must be removed and re-applied to reset.

(4) Excessive signal clipping – If the amplifier is allowed to be overdriven by applying very high input signal

levels, or very low impedance loads, then the amplified signal peaks will be clipped. Excessive clipping could damage the PSU or loudspeakers, especially h.f. tweeters! The trip threshold is presettable to allow for load variations and operates as for (3).

(5) An external sensing input allows for a 0V signal level, or a resistance of less than 1·2kΩ, to trip the relay into a temporary off state. Once the 0V level is removed/allowed to rise above 3VDC, or the resistance increases above 1·5kΩ, then the relay will

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Monitor Module.

Figure 6. PSU circuit.
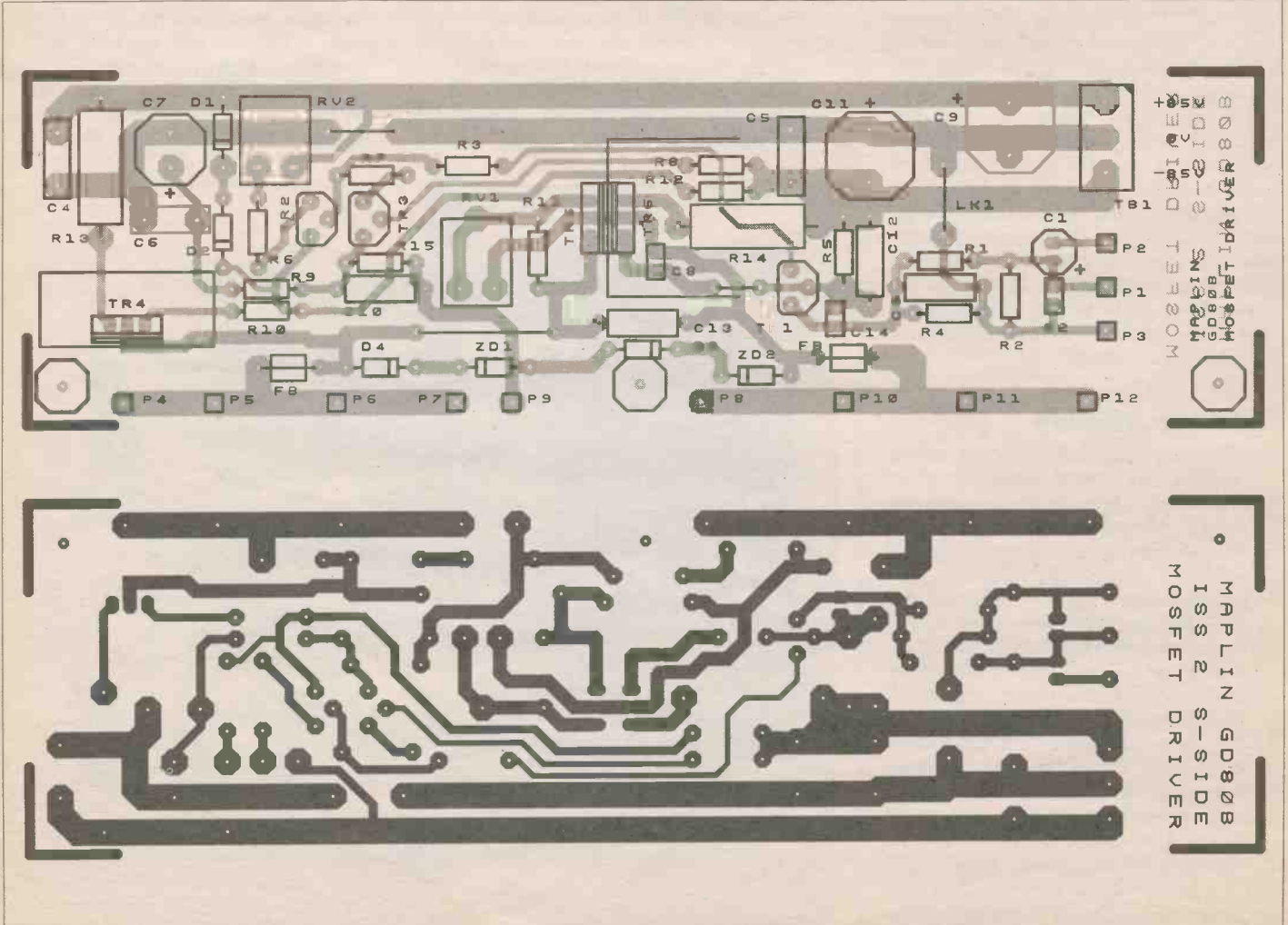
Figure 7. Track and overlay of the Driver PCB.

re-operate again without resorting to a power on reset. This input is useful for heatsink or cabinet, temperature monitoring and could be used to switch a cooling fan when required.

(6) Two LED indicators show when the relay is operated and when it is released while a third LED indicates for DC offset conditions and peak signal levels.

From initial power on the 16VDC supply, from the PSU module, is regulated by R13 and ZD1 and generates the +10V rail. This voltage level initially appears across C2, before it begins to charge through R10, and IC1 input (pins 5 & 6). IC1 pin 4 output is low, holding the two connected gate input pins 8 & 1, low also. Diodes D2 & D4 are reversed biassed, IC1 pin 11 output is high, and D3 conducts; TR3 switches on and LED 2 — 'relay released' — illuminates. TR4 conducts, holding TR5 in an off state, thus the output switching relay RL1 does not operate. Once C2 has charged after several seconds, IC1 pin 4 changes to a logic high level. Should there be a signal present at the input during this time, then the diode pump circuit charges C1 to a point where IC1 pin 2 reaches the same potential as the adjacent input pin 1. The gate output now flips low, D2 conducts via R9, IC1 pin 11 output goes high and IC1 pin 10 output latches low. D4 now conducts and the relay remains released. To reset from a latched situation, the mains supply must be removed and re-applied — a necessary step as this condition is an indication of a fault in the Output module!

If signals are not present at time out, then D3 is reverse biassed, TR3 switches off, LED 2 extinguishes, TR4 switches off and TR5 operates the relay RL1. Resistor R16 limits the unregulated supply current to RL1 and the small voltage drop is used to drive LED 3 – 'relay operated' – while RL1 is operating. Heavy duty, dual make action contacts, connect TB6 terminals 1 & 2 together. The contacts are 'dry', i.e. not electrically connected to supply rails or any part of the circuit, and should be wired between the amplifier output and loudspeaker loads.

Power Supply Module

The fourth module in this project is the PSU module, circuit shown in Figure 6. The module generates supplies for both amplifier modules and also for the Monitor module. Four items shown in the diagram are not fitted on the PCB, and they are torroidal mains transformer T1, bridge rectifier BR1 and capacit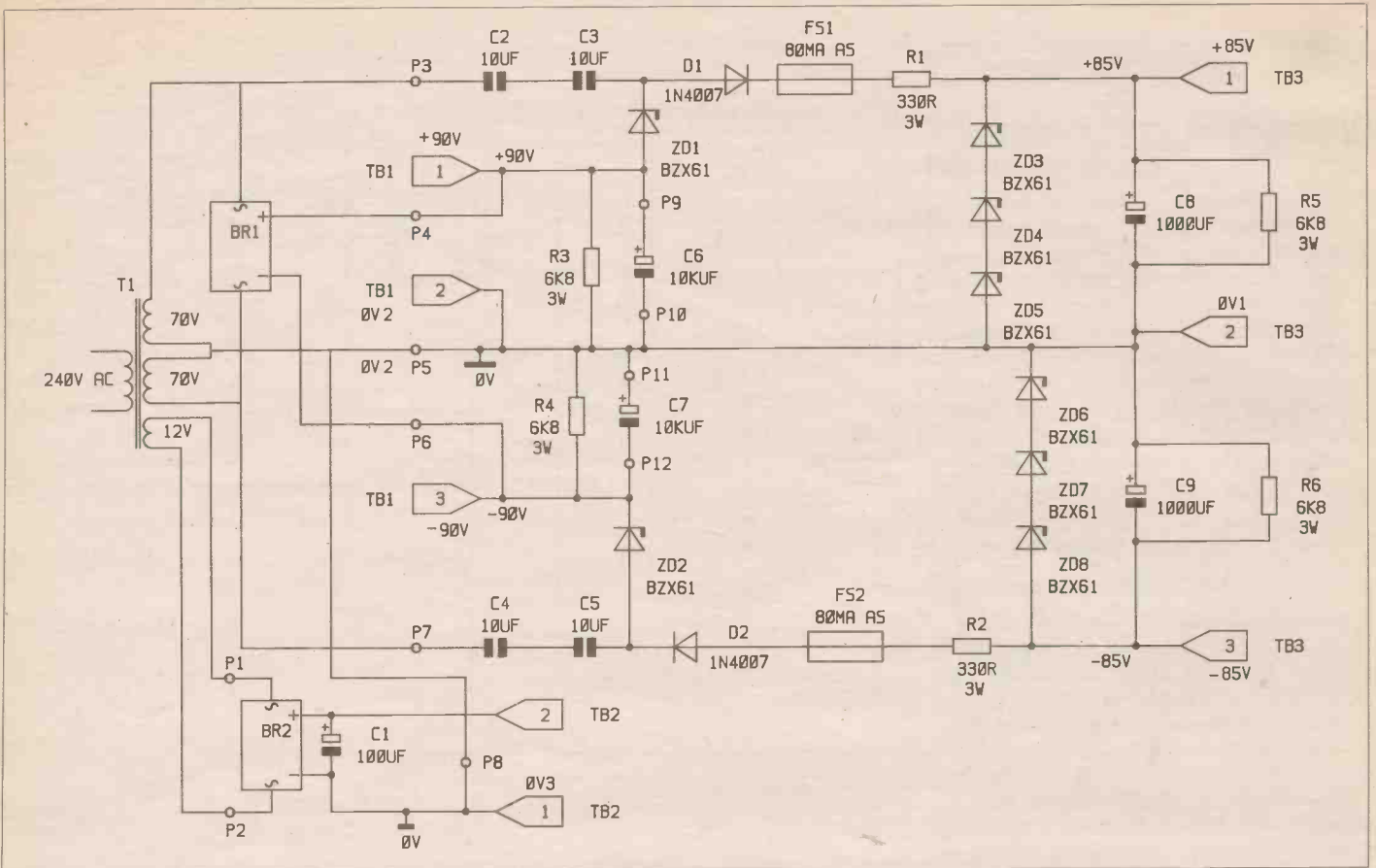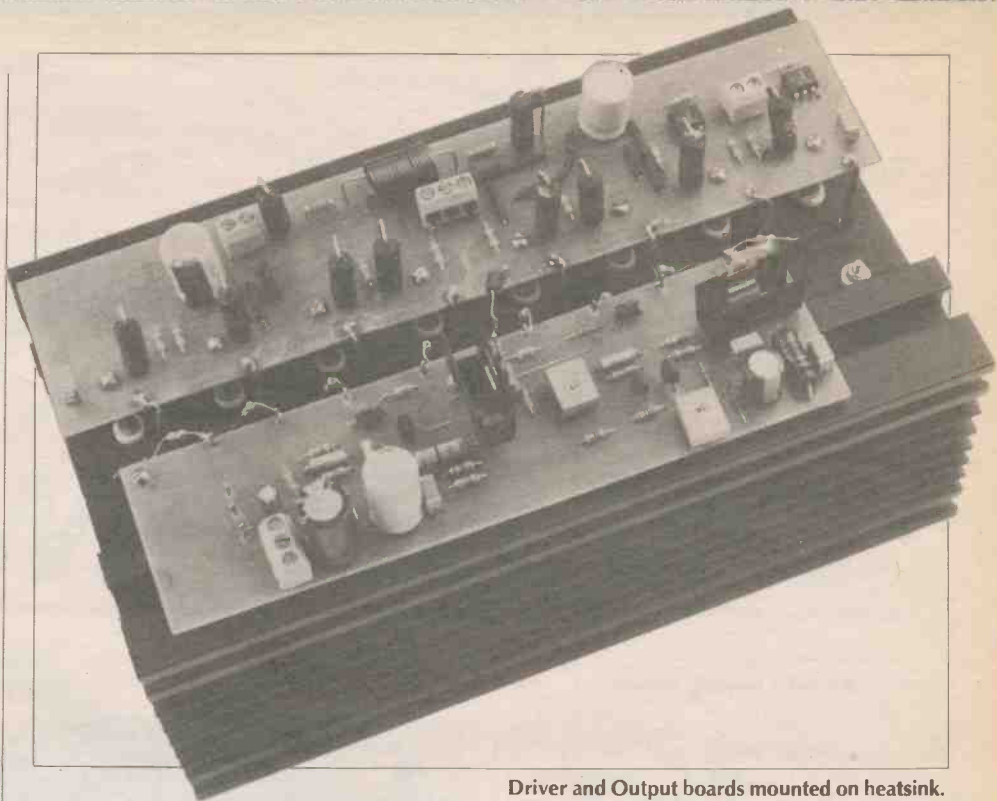ors C6 & C7. The transformer being rated at 1KVA is very large and heavy and will require substantial fixing arrangements when fitted into a cabinet. BR1 is also quite big and must be bolted onto a metal heatsink – not the Mosfet heatsink! The cabinet base could well suit this need. Also, for reasons of clarity, fusing arrangements have been omitted here, and follows later on in the article. T1, BR1, C6 & C7 are a straightforward full wave bridge configur-

ation, producing approximately +90VDC at TB1.1, and −90VDC at TB1.3. The actual DC rail voltages will vary between 85V and 95V depending on load, component tolerances, and the mains voltage. The lower voltage level of 85V would be expected when running the system at full power (6.5 to 7 amp average current) accompanied by an increase in 100Hz ripple level. To prevent any supply ripple from being injected into the front end pre-amplifying stages, the high voltage supply is split into two sections. Capacitors C2 & C3 AC couple the transformer secondary to ZD1 and D1. ZD1, being a 15V zener, will clamp the 50Hz sine wave at 15V above the base reference level of +90V and the resulting 105V is regulated by R1 and zeners ZD3 to ZD5. Final output voltage at TB3.1 is approximately +85VDC, varying by only a few volts under differing loads. The same system is used to generate the −85VDC rail at TB3.3. The amplifier Driver module is supplied from the ±85V at TB3, the amplifier Output module is supplied from ±90V at TB1, and the Monitor module is supplied from +15V at TB2.

Driver Module Assembly

Refer to Figure 7 and the Driver module parts list; further information on PCB assembly can be found in the Constructors guide supplied with the kit.

Begin assembly by inserting all 12 veropins (P1 to P12) into the PCB, from the solder side, push them down onto the track pad with a hot soldering iron and solder the heads. Locate and insert resistors R1 to R15, noting that the 1W types – R13 & R14 – are larger than the others. Resistors R16-23 are not mounted on the PCB and details regarding these

Driver and Output boards mounted on heatsink.

can be found under final assembly. Next, carefully shape the leads on diodes D1 to 4, ZD1, ZD2 and insert these six components into the PCB. Four links need to be made from any spare wire or BTC available and fitted on the PCB – link positions are shown as a line on the legend – the only link actually notated is LK1! The box shaped legend passing through TR5/6 position is not a link, although a small link should be fitted at the end of this legend, just below R14. Mount capacitors C1 to C13. Note the polarity symbols when fitting electrolytic types and take care not to break off any legs from polylayer capacitors. Insert TR1-3 and TR4, mount TR4 with the package front (stamped B718 or 2SB718) facing in-board toward R13/C6, so that the mounting tab is aligned correctly with the legend. Mount both preset pot's and fit 3-way terminal block, TB1, with the open terminal end facing out toward the narrow edge of the PCB. Solder all components fitted so far and cut off all excess wire. Refer to Figure 8 and make three chokes
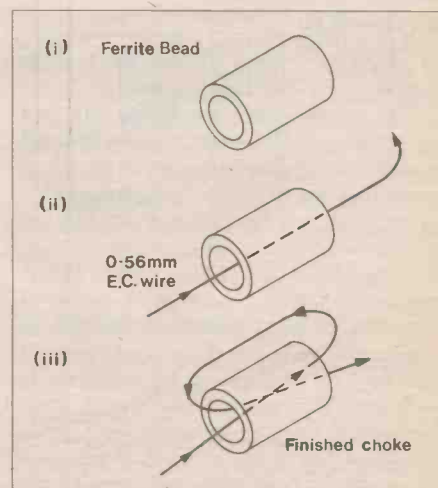
Figure 8. Ferrite bead chokes.
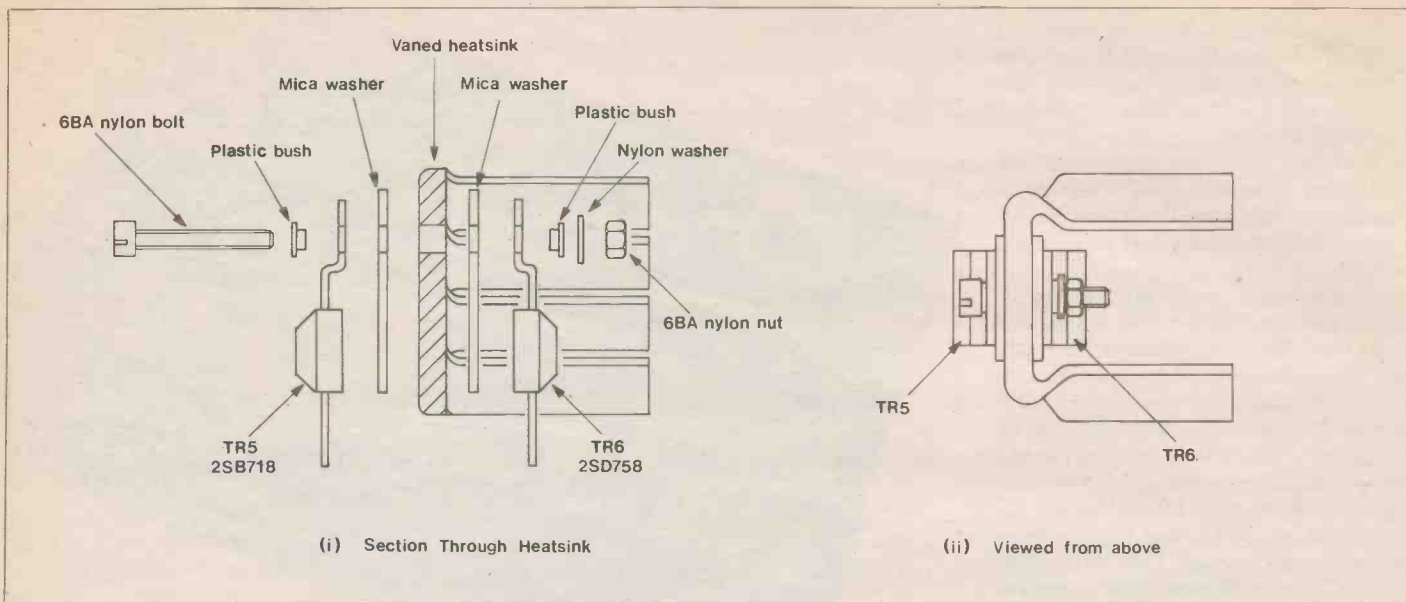
Figure 9. TR5 and 6 heatsink assembly.

from the ferrite beads and 24 SWG (0.56mm EC wire); all that is needed is to insert the wire through the bead and loop it around once only. Insert two of these chokes into the positions marked FB. The remaining choke is fitted later on with R16-23. Before fitting the remaining two transistors, TR5/6, it is simpler to make the assembly shown in Figure 9. Place a small plastic bush into TR5 (B718), from the front, and also the nylon bolt; position the mica sheet behind TR5 as shown and offer the sub-assembly up to the vaned heatsink, from the outside! From the inside of the vaned heatsink, repeat the previous procedure in reverse, starting with the second mica sheet, TR6 (B758), plastic bush, nylon washer and nylon nut. Tighten the nut & bolt, straighten the transistors and mount the whole assembly in line with the legend. Keep the heatsink clear of any components on the PCB and solder all remaining joints. Fit the clip on heatsink to TR4 and re-check all work done, especially soldering; any dry joints or short circuits could prove nasty when the PSU is run up later on!
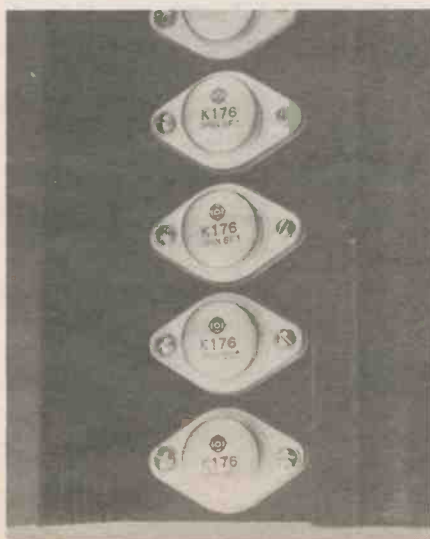
Output Module Assembly

Refer to Figure 10 and the Output module parts list. Begin construction by making seven links, (see Figure 11), use the 0.9mm tinned copper wire for this and insulate each link with a suitable length of heatshrink sleeve. Heatshrink should also be fitted to one lead of each of the ten 0.22Ω wire wound resistors as shown. Next construct coil L1 (see Figure 12). A temporary former, such as a piece of dowelling or an old retract pen body, of approximately 10mm diameter is required for the coil to be wound on, this is removed afterwards. Use the 0.9mm Enamelled Copper wire for this task, straighten any twists or kinks in the wire and keep each winding close up to the previous turn while making the coil. 16 turns are made on the former, this is not

Fet wiring.

Underside of the heatsink.

critical but the coil body must be able to fit between the mounting holes on the PCB! Once finished, the end leads should both be on the same side; scrape the enamel from these leads before mounting L1 onto the PCB. Insert nine veropins, P1 to P9, from the solder side of the PCB and push them down onto the board with a soldering iron. Locate and insert all twelve 'min' resistors into the PCB and the seven links. Fit both opto isolators, OP1 & OP2 and the four polylayer capacitors. Insert three terminal blocks TB1-3: the 3-way block TB1 is orientated with the open terminal side towards R1 & R4; 2-way block TB2 is fitted with the open terminal side facing the R22/23 side of the PCB; 2-way block TB3 also is also mounted facing the same way as TB2. Solder all components positioned thus far, to prevent them from falling out. Now place
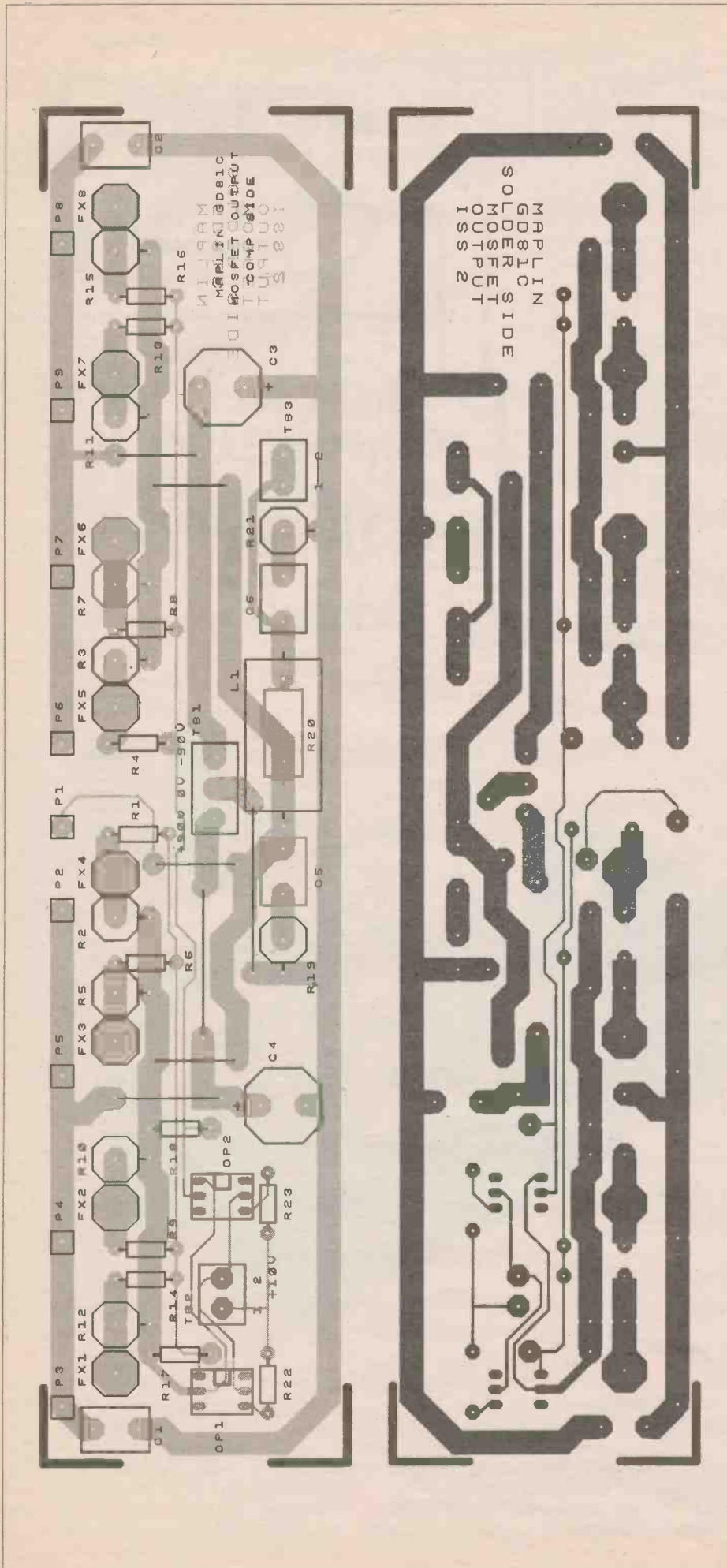
Figure 10. Track and layout of the Output PCB.
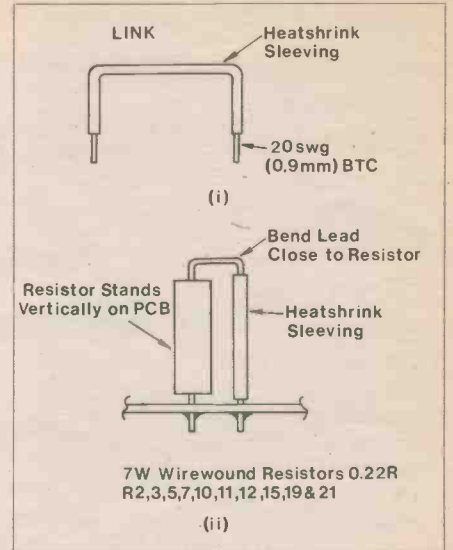
Figure 11. Fitting insulation sleeves.
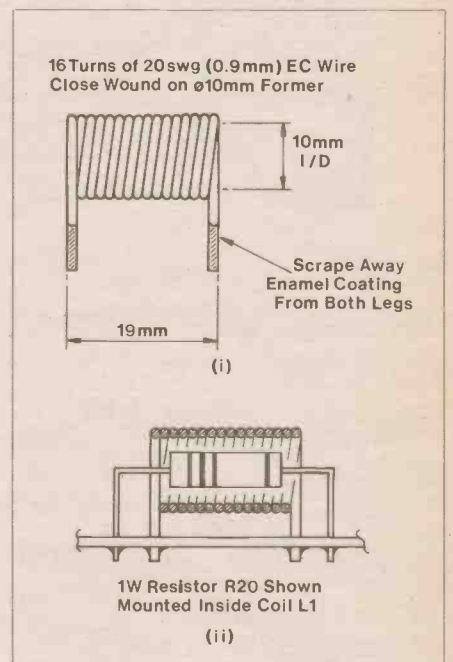
Figure 12. Coil assembly.

resistor R20 inside coil L1, bend both leads as shown in Figure 12(ii), and fit both to the PCB. Finally, insert the ten, previously prepared, 0.22Ω resistors as in Figure 11(ii) and capacitors C3 & C4. Solder all remaining components and check over the work done. Cut off excess wire ends and clean flux from the tracks; pay particular attention to dry joints and short circuits on this module.

Monitor Module Assembly

With reference to the Monitor parts list and Figure 13, make and insert a link into the PCB in the position between R12 & R14, locate resistors R1 to R16 and fit these on the PCB. Next insert diodes D1-5 and 10V zener ZD1. Take care not to confuse diodes with the zener as package styles are very similar! Fit the single veropin, P1, from the solder side first and push home with a soldering iron. The rest of the module assembly is quite straight-
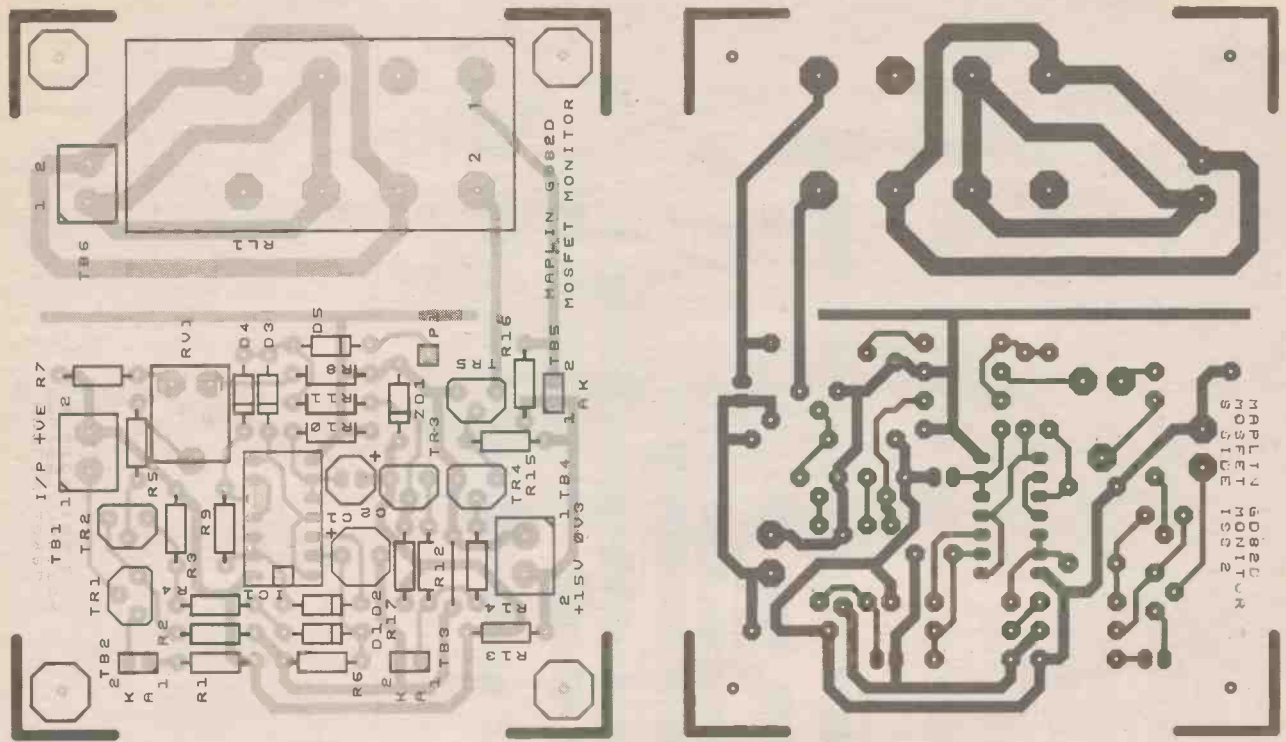
Figure 13. Track and overlay of the Monitor PCB.

forward, but note the orientation of certain components like IC1 and C1/C2. Mount terminal blocks TB1, 4 & 6 with their open terminal sides facing out, toward the edges of the PCB. LED's 1-3 can be fitted straight onto the PCB, if required, or the minicon latch plugs TB2, 3 & 5 could be used and the LED's wired to them via optional, 2 way minicon latch sockets. Once all components have been placed, solder each lead and remove excess wire, etc. Relay RL1 must be mounted with pins 1 & 2, stamped on the base, inserted into the PCB holes marked 1 & 2. It is physically possible to fit RL1 either way around, as the terminal pin positions are symmetrical; the relay will only function in one of these positions, so ensure that it is mounted correctly. Solder RL1 and clean the tracks for inspection.

PSU Module Assembly

Refer to the PSU parts list and Figure 14. Locate diodes D1 & D2, and zeners ZD1, 2 and ZD3 to ZD8. These components are very similar looking and will require close scrutiny to identify them. Mount all ten components onto the PCB along with miniature bridge rectifier BR2. Note that BR1 is NOT mounted on the module, details on this appear later on. Insert the four non-polarised capacitors C2 to C5, which may be inserted either way around, and the polarised capacitor C1, which must be fitted in one particular
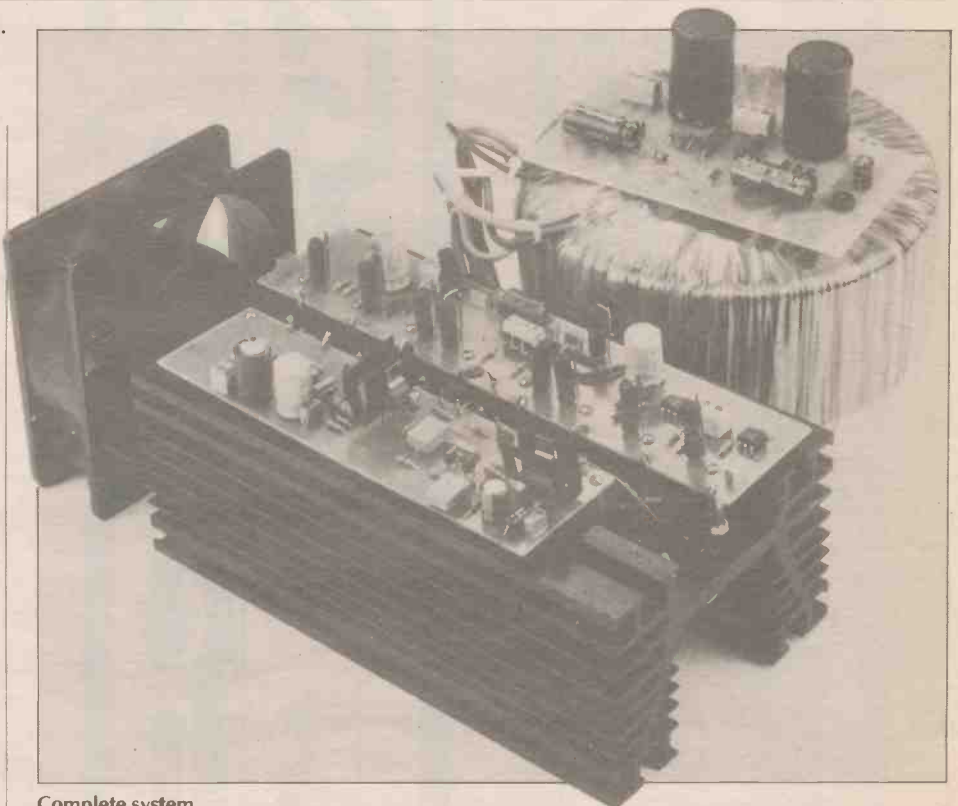
Complete system.

position. Mount the six 3W resistors R1 to R6, and the three terminal blocks, TB1 to TB3. Position these blocks with the open terminal side facing back towards the rear side of the PCB. The two middle sized cans, C8 & C9, are fitted on the PCB with their terminal lugs inserted into the large holes, and bent over the mounting pad to secure for soldering. Take note of the polarity symbols and colour reference on these capacitors! Next, fit the fuse clips in

positions FS1 & FS2. Lugs on the base of each clip should be inserted through the PCB and bent over the pad beneath. There is a small tag, on the inside of the clip, which is a 'stop' and prevents the fuse from sliding out; fit the clips with the stop orientated at each end of the fuse mounting position, and insert both 80mA fuses. Solder any remaining leads and cut off excess wire ends, ready for cleaning and inspection.
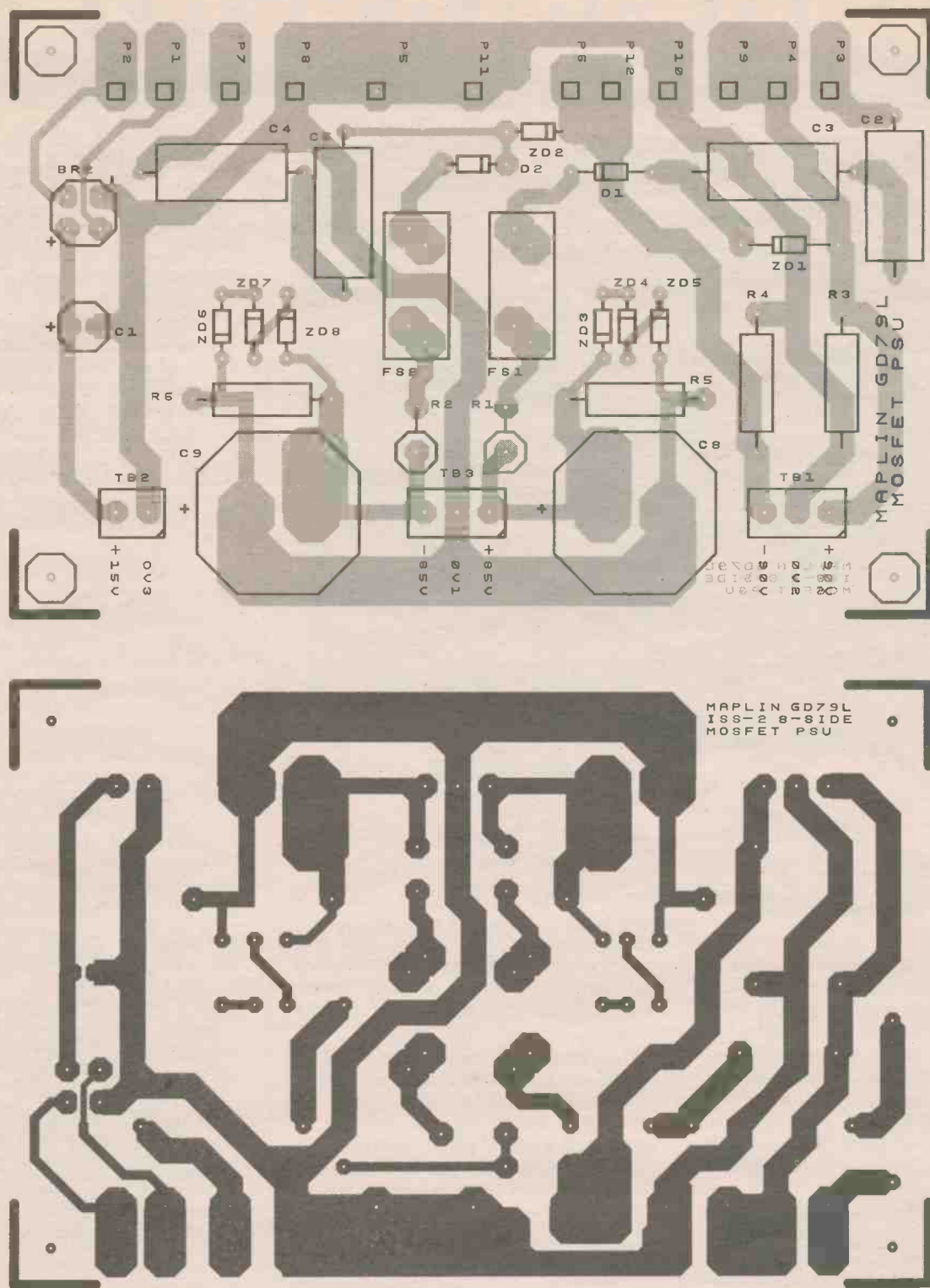
Figure 14. Track and overlay of the PSU PCB.

Heatsink and MOSFET Assembly

Figures 15 to 18 show eight positions for Mosfets TR1 to TR8. It can be seen from the base view diagram of a Mosfet, that the drain & gate terminals are not positioned centrally across the body, but are offset to one side. Position the heatsink extrusion with the base upwards and the Mosfet drain/gate drilling offset to the right

hand side (Figure 15). TR1 (2SK176) now becomes the first device, at the nearest end, referred to as the 'front'.

The Output module will be installed on the right side of the heatsink (Figure 16) and the Driver module fitted on the left (Figure 18); both modules mount onto threaded pillars which are also part of the Mosfet mounting. Eleven pillars are shown in Figure 15, and it can be seen that every Mosfet has one pillar fitted on

the right hand side (under the Output module), but only TR2, 5 & TR8 have pillars fitted to both left & right hand sides.

A typical mounting arrangement for Mosfets is shown in Figure 19. The diagram refers directly to TR1, 3, 4, 6 & TR7, i.e. Mosfets that do not have pillars fitted at both ends; the remaining three Mosfets only differ in that the 6BA nut is replaced by a pillar, and an extra plastic bush is fitted to insulate the mounting
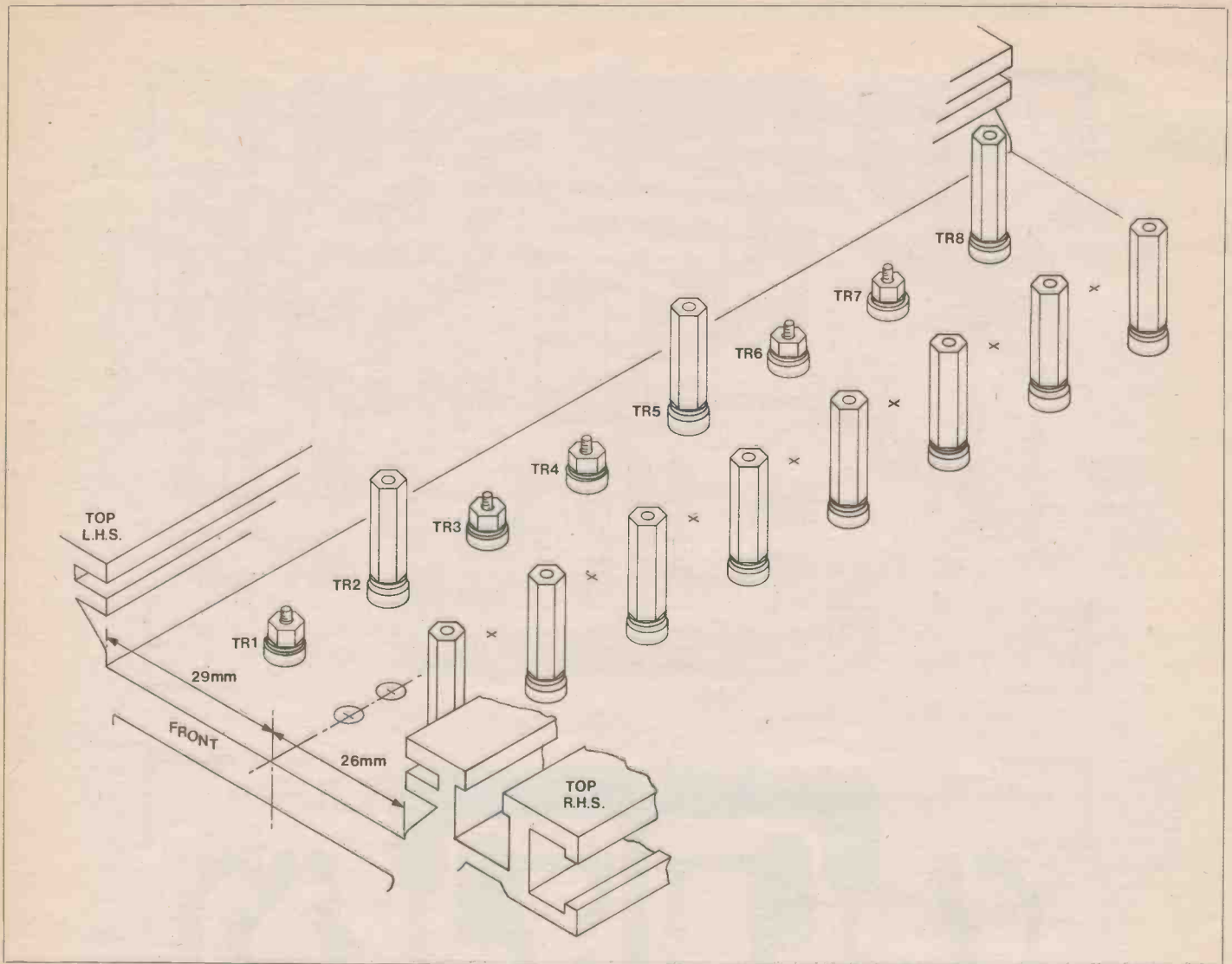
Figure 15. Putting pillars on the heatsink.

bolt-head from the Mosfet case.

(1) Fit a greaseless insulator, onto a 2SK176 Mosfet, and mount the device on the heatsink in position TR1.

(2) Place a shake washer onto a 6BA x 1in bolt and insert the bolt through the hole at the right hand side (nearest to the D & G terminals) of the Mosfet, insulator, and heatsink.

(3) Position a special plastic bush and 6BA plain washer onto the bolt and fit a 6BA x 22mm long pillar.

(4) In the left hand side hole, insert a 6BA x 1in bolt, & shake washer, through the Mosfet, insulator & heatsink.

(5) Position a special plastic bush and 6BA plain washer onto the bolt, and fit a 6BA nut.

Tighten up the nuts/pillars with a 6BA box spanner, but do not over-do this as bolt threads can easily be stripped off. Ensure the Mosfet is mounted firmly on the heatsink and test for short-circuits between the Mosfet case (source) and the heatsink. A resistance meter will be required for this job; scrape away a small area of adonising from one corner of the heatsink, and connect one of the meter probes here. Also, check for shorts on both gate & drain terminals and if any are found, strip down the assembly and inspect the insulator. Look for small pieces of swarf that may have been

compressed into the material and after re-assembly, ensure the Mosfet drain & gate terminals protrude centrally through the heatsink holes and do not foul the sides.

(6) Fit a greaseless insulator onto a 2SK176 Mosfet, and mount the device on the heatsink in position TR2.

(7) Repeat steps (2), (3), and (4).

(8) Position a special plastic bush and 6BA plain washer onto the bolt, and this time, fit a 6BA x 22mm pillar instead of the nut.

Repeat steps (1) to (5) for the remaining two 2SK176 Mosfets, TR3 & TR4, and test each one for shorting to the heatsink.

(9) Fit a greaseless insulator onto a 2SJ56 Mosfet, and mount the device on the heatsink in position TR5.

(10) Repeat steps (7) & (8).

For mounting TR6 & TR7, follow procedures (1) to (5) using the 2SJ56 Mosfets, and for the final Mosfet, repeat steps (6) to (8) for position TR8.

Test the Mosfets, as mentioned previously, and re-check the completed heatsink assembly with Figure 15.
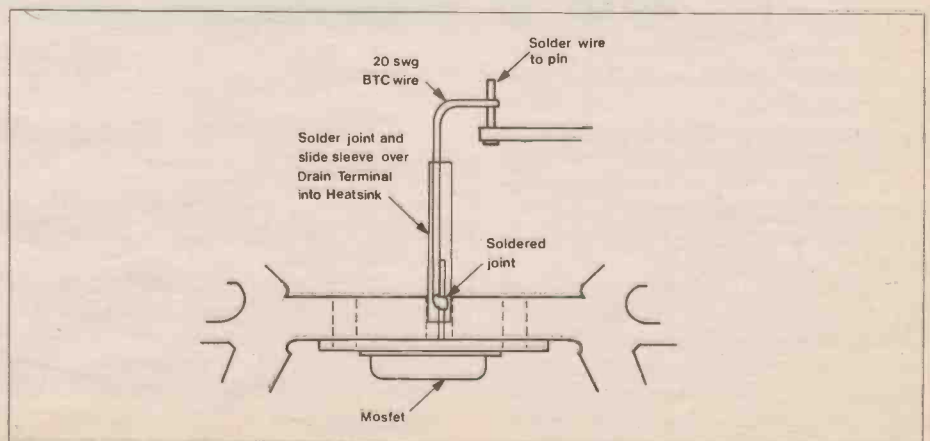
Figure 17. Close-up detail of Mosfet connection.
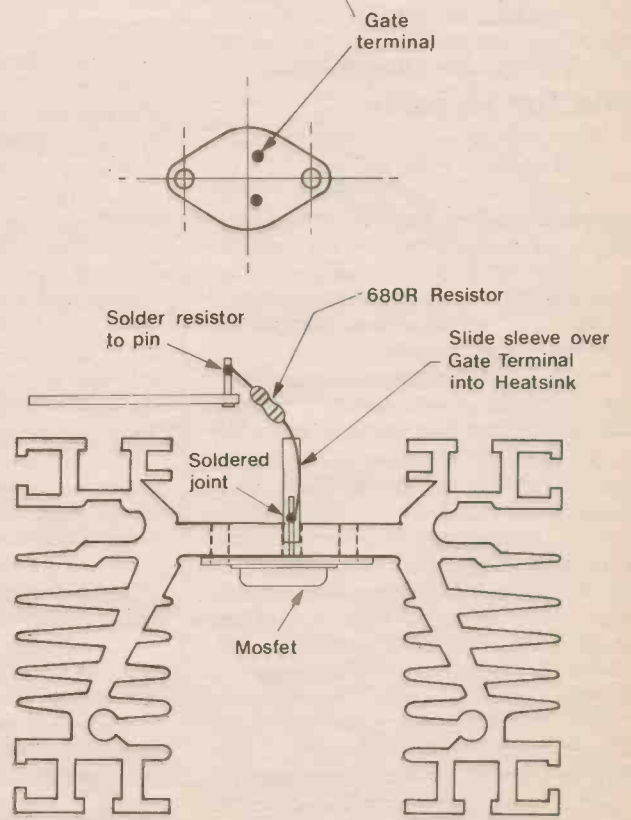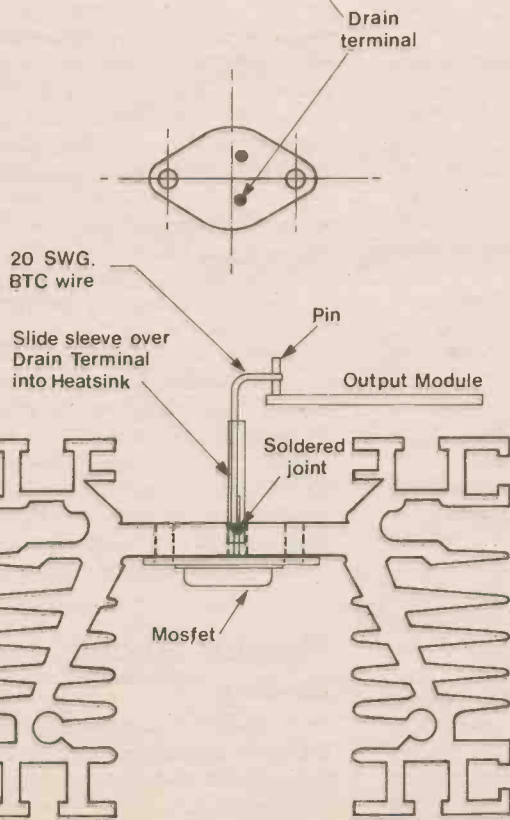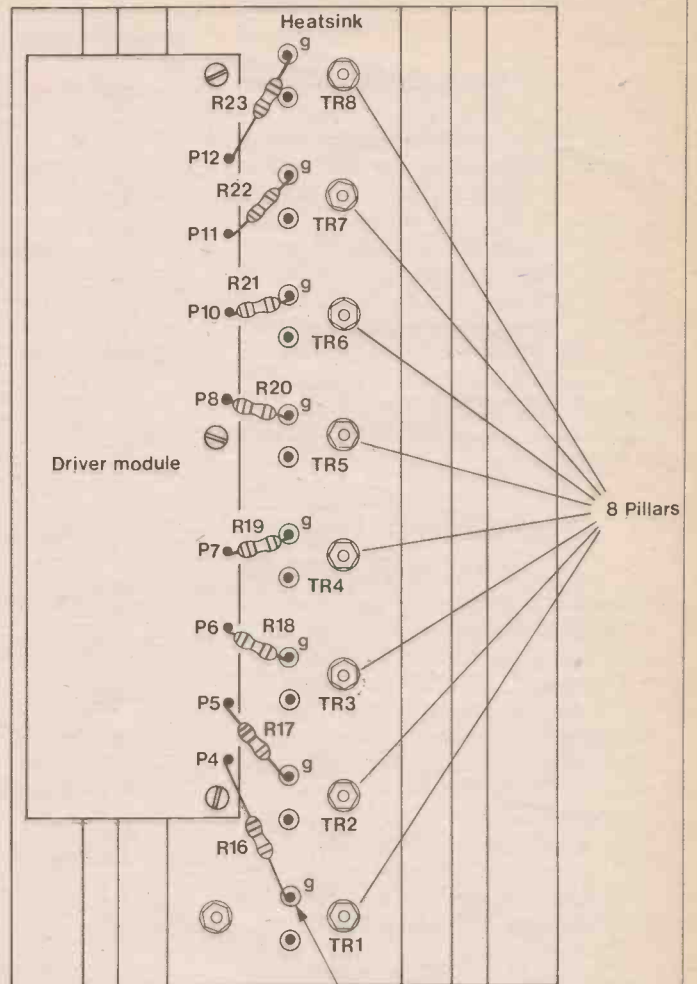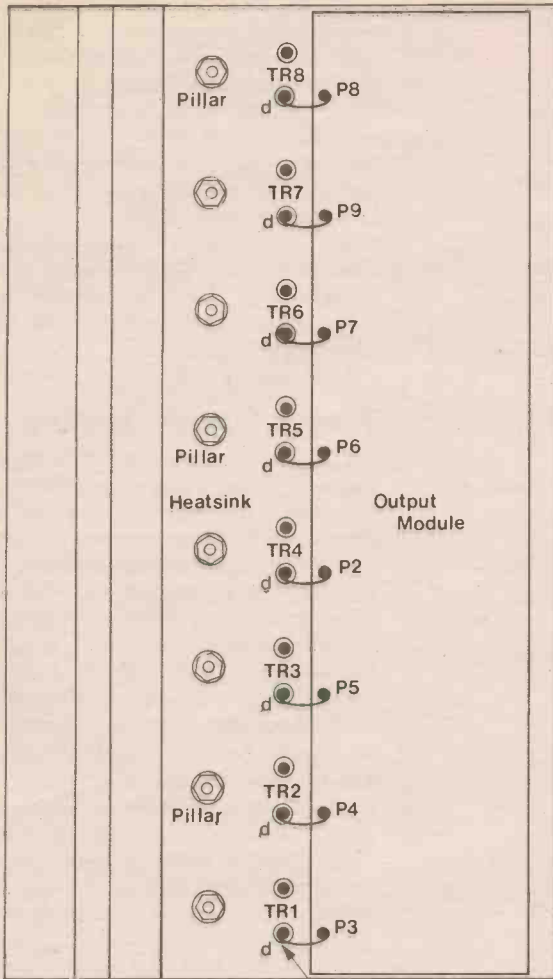
Figure 16. Mosfet drain wiring.

Figure 18. Mosfet gate wiring.
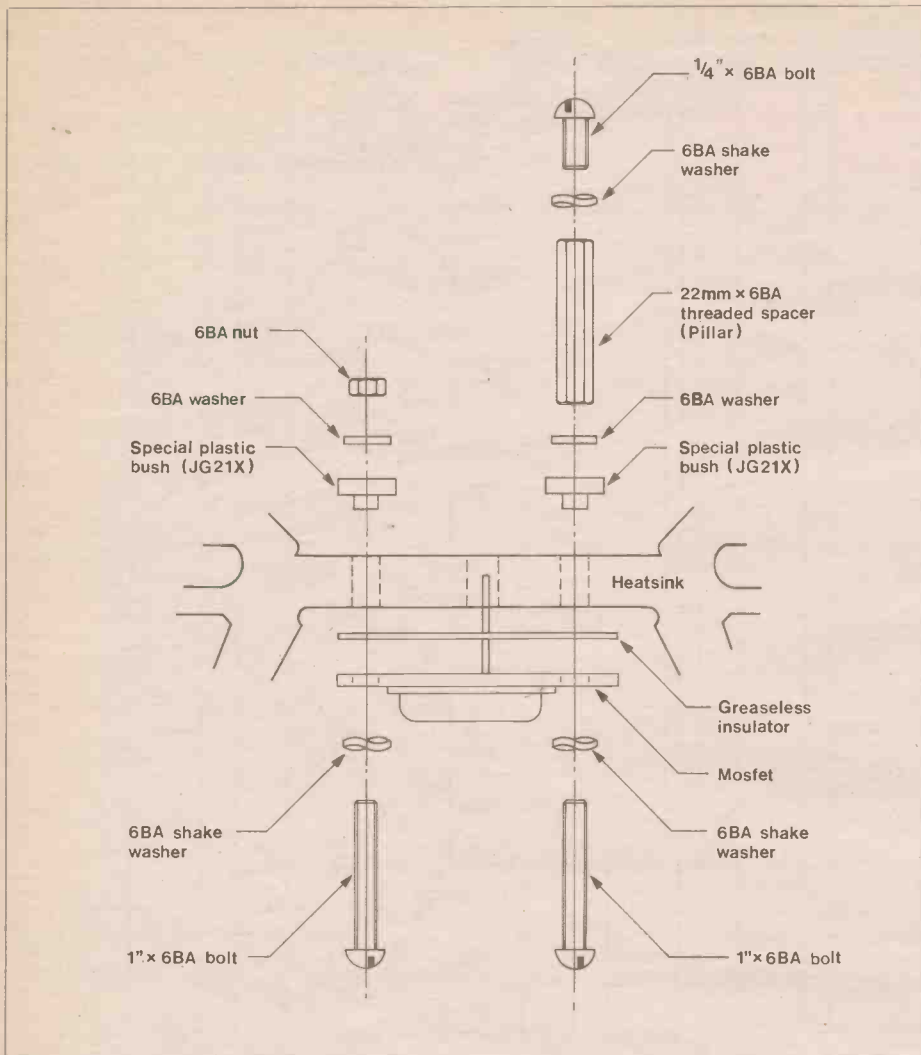
Figure 19. Mounting Mosfets to heatsink.

Labels in figure:
- ¼" × 6BA bolt
- 6BA shake washer
- 22mm × 6BA threaded spacer (Pillar)
- 6BA nut
- 6BA washer
- 6BA washer
- Special plastic bush (JG21X)
- Special plastic bush (JG21X)
- Heatsink
- Greaseless insulator
- Mosfet
- 6BA shake washer
- 6BA shake washer
- 1"× 6BA bolt
- 1"× 6BA bolt

Mounting Modules onto the Heatsink

Left over from the Driver module components were eight resistors, R16 to R23. Each resistor is connected to a Mosfet gate and one of the pins, P4-7 and P8, and P10-12. One pin, P9, at the centre edge of the driver PCB is wired via the remaining ferrite bead choke, to P1 on the Output module (see Figure 20). Do not wire these particular pins to the Mosfet!

Place a 10mm length of heatshrink sleeving over one end of a 680Ω resistor lead and solder this lead to the gate terminal of TR1, as shown in Figure 18; this is now R16. Repeat the same procedure on TR2-8, for resistors R17-23. Push the sleeving over the solder joint and onto the Mosfet gate terminal (Figure 17). Solder droplets must not be allowed to fall down into the hole, while soldering, otherwise the particular assembly will have to be stripped down to remove it.

The eight drain terminals are wired in similar fashion (see Figure 16) using 0.9mm tinned copper wire – NOT resistors! Cut and straighten a manageable length of wire, e.g. 100mm long, solder one end to the Mosfet drain terminal, cut a 30mm length of heatshrink sleeving, fit it onto the wire and slide it over the solder joint, onto the terminal.

Place the Output module in position over the eight pillars, so that the screw threads are visible through all eight mounting holes in the PCB. Fit a 6BA x 1/4" screw, and shake washer, into each mounting hole and tighten them down. Wrap the extended drain wire, from TR1, around pin 3 on the module and solder in position. Cut off excess wire ends and connect the remaining seven drain terminals, from TR2-8, to the PCB.

Place the Driver module in position over the three pillars (Figure 18), so that the screw threads are visible through all three mounting holes in the PCB. Fit a 6BA x 1/4" screw, and shake washer, into each mounting hole and tighten them down. Now wrap the wire end, of resistor R16, around pin 4 on the module and solder in position. Cut off the excess wire ends and connect the remaining seven resistors, R17-23, as in the diagram.

Locate the third ferrite bead choke, remove the enamel from each wire end, and connect between pin 9 on the Driver module, and pin 1 on the Output module (see Figure 20).

Power Supply Wiring

Off board components, such as T1, BR1, C6 and C7, are wired to the PSU module as shown in Figure 21. Keep the wiring to BR1, C6 and C7 as short as possible and note polarity symbols! BR1 runs very hot, when in operation, and therefore requires bolting to a heatsink panel (not the Mosfet heatsink!). The six secondary wires from T1, require the enamel insulation to be scraped off before tinning. Do not apply the heat for too long, while tinning the ends, as the outer plastic insulation will melt back up the wire. Once the PSU has been assembled to Figure 21, test the various output voltages before connecting to the Mosfet amplifier.

Power Supply Testing

Note: high AC and DC voltages are exposed in the power supply area. The constructor is urged to take full safety measures when taking measurements, e.g. do not wear rings, bracelets, watches or medallions; insulate the PCB tracks from any surrounding components or metallic objects. DO NOT under any circumstances connect the PSU directly to mains, use suitable fusing; better still, use a safeblock type distribution connector.

Apply 240VAC mains to transformer T1. If using a fused distribution block, then anti-surge fuses are necessary. Initial power up current is very high in this circuit and a 240V, 5 amp, anti-surge rating is recommended in the mains primary. Connect a DC voltmeter, set to read at least 100VDC, with the negative probe to TB1 0V2 and positive probe to TB1 +90V. Expected readings here should be between +94 and +98VDC approximately. Transfer the positive probe to TB1 −90V and check for a similar negative reading. Disconnect both probes from TB1 and reconnect the negative probe to TB3 0V1. Place the positive probe on TB3 +85V and a reading between +92 and +96VDC should be expected. Transfer the positive probe to TB3 −85V and check for a similar negative reading. Finally, disconnect both probes from TB3 and place the negative probe on TB2 0V3 and the positive probe on TB2 +15V. Expect readings between +15 and +18VDC.

While the PSU is not connected to the amplifier modules, voltage levels are slightly higher than would otherwise be the case. This means that the wirewound resistors run hotter and therefore dissipate more heat at this time. Although not a problem, do not allow the PSU to run for long periods in a disconnected state and avoid contact with the resistors.

Monitor Module Testing

Connect the PSU module TB2 (+15V & 0V3) to TB4 on the Monitor module, see Figure 20 and Figure 22. Temporarily wire the three LED's, LD1-3, noting that the longest lead, of the two on each LED, is the Anode. Connect a voltmeter, set to read +20VDC or more on TB4, apply mains to the PSU module and check the
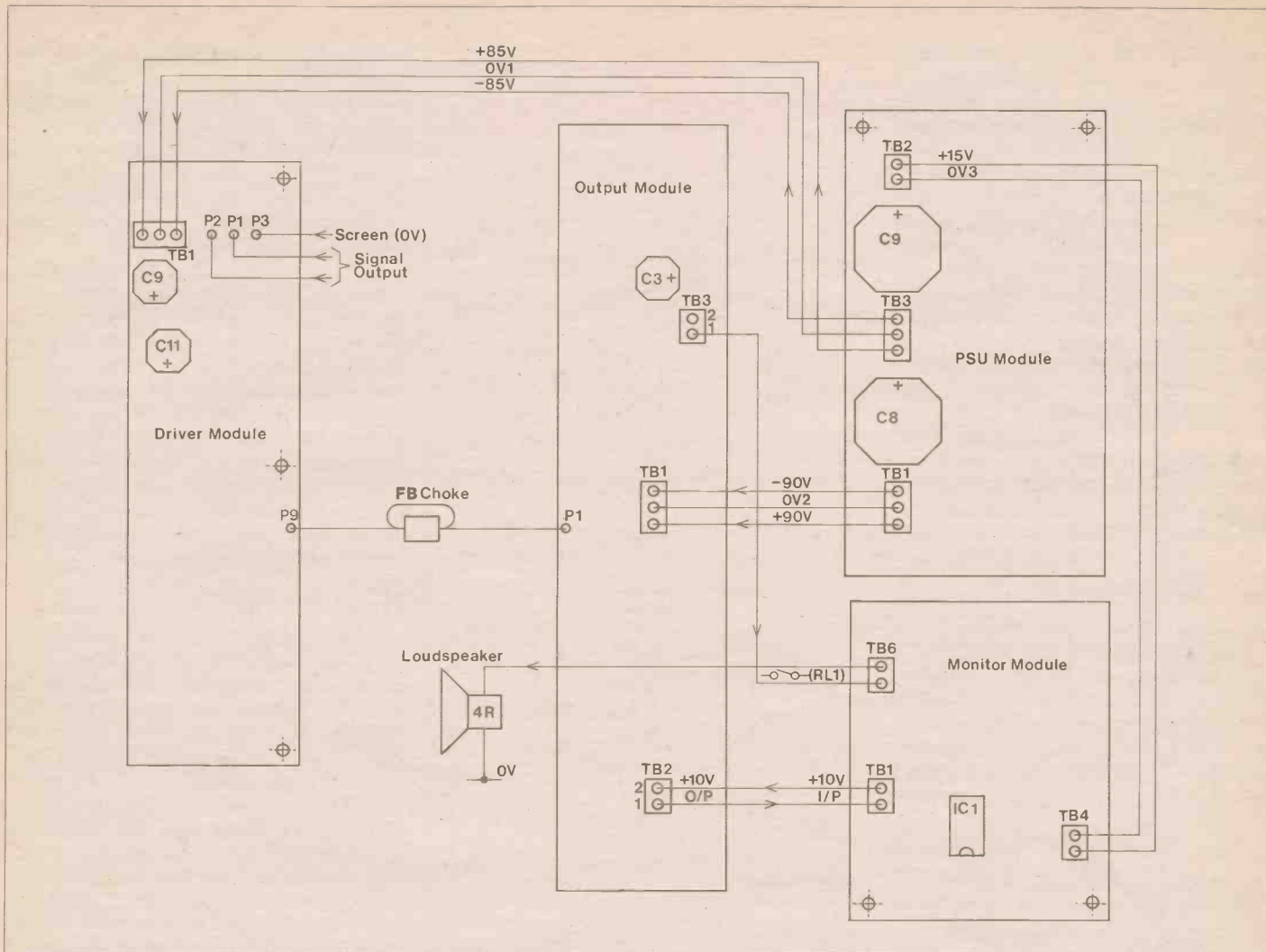
Figure 20. Module interwiring.

meter reads +15V approximately and LD2 illuminates. After 7 to 10 seconds time out has elapsed, relay RL1 should operate. Check that the meter reading reads approximately 14 to 15V, LD2 is off and LD3 is now illuminated.

Connect the External input pin to any of the 0V rails. RL1 should release, LD3 extinguishes and LD2 illuminates. Remove the 0V connection from P1, and RL1 re-operates, LD3 re-illuminates and LD2 extinguishes.

Connect the voltmeter between 0V and the wiper of RV1 (see Figure 5). With a small screwdriver, turn RV1 wiper full anti-clockwise (to the left), and check for a voltage reading of +1 to +1·5V. Turn the wiper full clockwise (to the right) and check the voltage reads between +6 to +6·5V. If any of these voltage readings vary significantly, check the 10V supply rail on pin 14 of IC1. The reading should not vary by more than ±0·5V from 10V.

To check the diode pump threshold voltage, connect the voltmeter between 0V and pin 2 of IC1. With RV1 fully clockwise the reading is approximately 0·7V, and 3V approximately when fully anticlockwise. Adjusting RV1 should not cause RL1 to operate or release and only LD3 should be active, unless a signal is present at the input of TB1 pin 1. Remove the power and discharge the PSU rails as before.

Power Amplifier Testing

Refer to Figure 20 and wire all four modules as shown. Use the mains cable supplied in the PSU kit for all supply connections. When wiring the signal output from TB on the Output module, either TB3.1 or TB3.2 terminals can be used. The same applies to the relay contact output from TB6 on the Monitor module. TB6.1 or TB6.2 can be used either way around, as an input or an output, as this connection is a dry relay contact. Do keep in mind the safety procedures before applying power to the amplifier and do not connect a loud speaker to the Monitor module, or Output module, before testing the output.

Once the complete system has been wired correctly, adjust the presets on the Driver module as follows: RV1 wiper set fully clockwise and RV2 wiper set approximately half travel. Apply mains power, and with a voltmeter set to read 100VDC or more, check the PSU voltage on the Output module at TB1 for ±88 to ±90VDC. Check for ±94 to ±96VDC on the Driver module at TB1 as well and note the four supply rail polarities are correct. Check for an offset voltage between TB3, on the Output module, and 0V. The offset voltage should be very small, less than ±0.01VDC.

Turn off the power, wait for the PSU capacitors to discharge and remove the +V wire from TB3 (+85V) on the PSU module. Place the test meter between the +V wire and +85V terminal on TB3 and choose a DC current range of 0·1A or so. Re-apply mains power and check the current reading is stable at 0·015A ±0·002A. The main bulk of this current is drawn by the voltage amplifying stage, see Figure 2, and any large variation from this reading may well point to a fault condition. Check resistors R13 & R14 are not overheating, if this is the case!

Output Stage Quiescent Current

Turn off the power. Again, wait for the PSU capacitors to discharge, remove the meter and re-connect the +V wire to TB3 (+85V). Now disconnect the +V wire from TB1 (+90V) on the PSU module, and with the test meter set to 5A DC, place the meter between this +V wire and +90V terminal on TB1. Re-apply the power and check for a current reading of 0·200A DC ±0·05A; the reading will vary from one amplifier to another. Turn RV1 on the Driver module anti-clockwise (left), for a current reading of 0·4A. This is the total current present in the Mosfet stage and ideally would represent 0·1A flowing

Figure 21 (PSU wiring)

240V AC

Or | Or

Transformer T1

Wht
Blk

Red
Gry

Blue
Yel

C7 C6

BR1

PSU Module

2 1 7 8 5 11 | 6 12 10 9 | 3 4

TB2
+V 0V3
15V DC Supply
To Monitor
Module

TB3
−85 0V1 +85
Regulated
Supply To
Driver Module

TB1
−90 0V2 +90
Unregulated
Supply To
Output Module
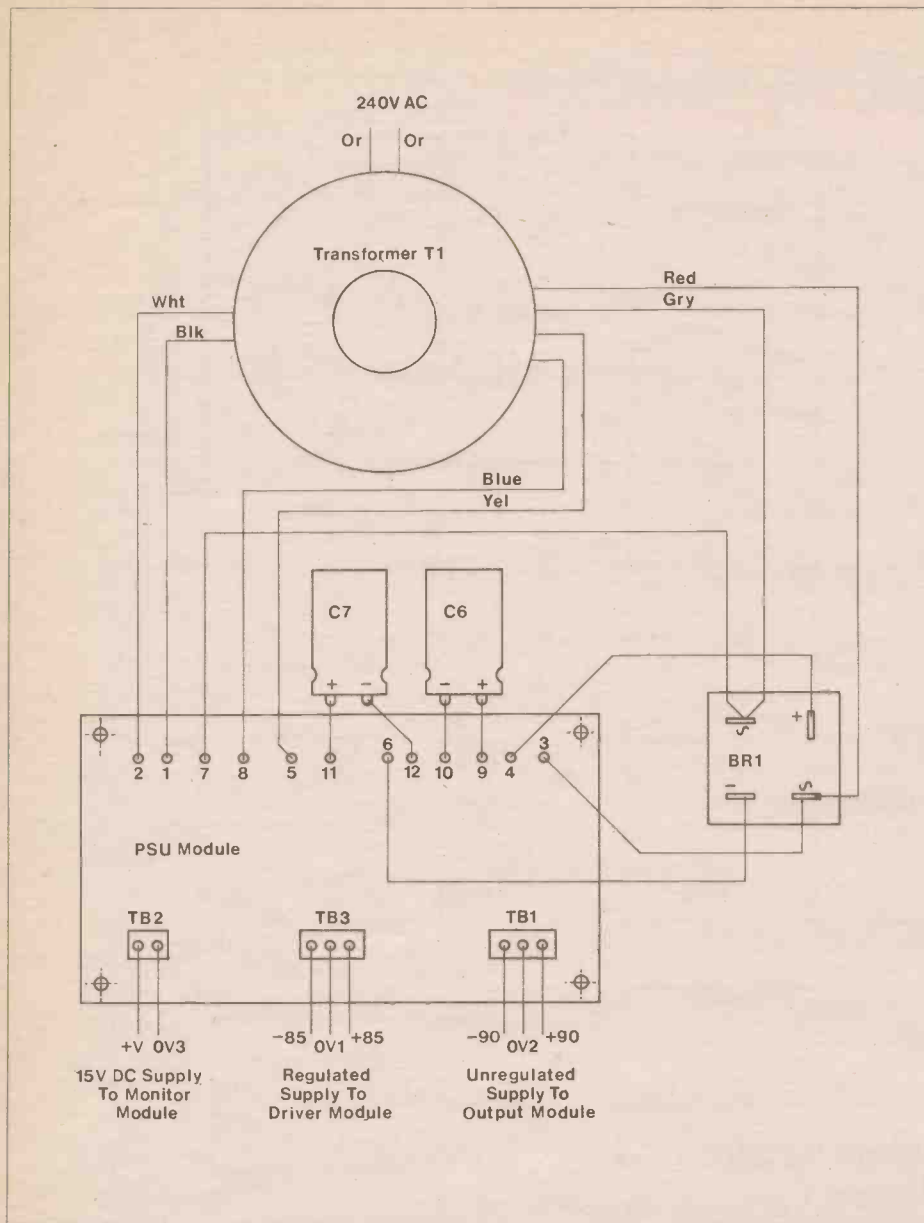
Figure 21. PSU wiring.

Figure 22 (Monitor PCB)

From TB2 on
O/P module
Signal | +10V

RL1 Dry Contacts

LD1
Peak
Detector
k
a TB2

1 | 2
TB1

1 | 2
TB6

IC 1

LD2
Relay
Released
k
a TB3

Monitor Module

TB4
2 | 1
TB5
a | k

LD3
+15V | 0V3
From TB2
on PSU

Relay
Operated

Figure 22. External connections to Monitor PCB.

---

in each of the four output pairs (see Figure 3). As the Mosfets are not completely matched, then for a fixed gate biassing voltage, the quiescent current in each Mosfet will be different. The volt drop across each 0.22Ω corresponds to the device current and readings between 0·15V and 0·27V can be expected across the 0·22Ω source resistors.

Turn off the power and, once the PSU capacitors have discharged, remove the test meter and re-connect the +V wire to TB1 (+90V) on the PSU module. By now the heatsink should be getting very warm and it will eventually be necessary to place the fan onto the front of the heatsink to cool the Mosfets. The fan should be orientated so that it blows air down the heatsink flutes, which exposes the un-guarded fan blade. Be extremely careful of the revolving blades and fit a wire guard to prevent possible injury!

Final Testing

Off load tests should be performed using an audio signal generator and oscilloscope capable of displaying 200VAC. Connect the generator to the amplifier AC input and screen (0V), and connect the 'scope probe between the amplifier output and 0V. Set the generator for 1kHz sine wave, at an output level of 0dB (0·775V RMS), and the 'scope to display a 200V signal. Turn on the power and, after the monitor time out, check the 'scope waveform for a sine wave of approximately 153V peak to peak. When using a test meter instead of a 'scope, check the amplifier output on 200V AC range, for a reading of 54V (RMS). Ensure the bandwidth of the meter will extend to 1kHz; digital meters should be o.k., but not all analogue movements respond accurately up at this frequency! It should be possible to increase the input signal level still further, by 1·5 to 2dB, and view the onset of clipping at the peaks of the waveform. This occurs at about 180V peak to peak. Increase the generator output frequency to 50kHz and view the amplified waveform. The signal amplitude will have dropped 3dB to 110V peak to peak and if the frequency is still increased to 100kHz, the signal level continues to drop to approximately 90V peak to peak (30V RMS) or −6dB. The wave form symmetry can be modified slightly by adjusting RV2 on the Driver module as required. The effect of RV2 on the waveform becomes more noticeable when driving the output into a load, so very little effect can be expected at this time.

In Conclusion

No matter what specifications say, the final proof of the amplifier's performance comes from running the system and listening to it. This is often the stage where constructors suffer disappointment and therefore is worthy of a few suggestions. This amplification system is capable of delivering peak power levels in excess of 1·3KW, or greater than 1300 Watts, into a

4Ω load! First, make sure your speaker system is adequate to handle the power. Remember that the speaker power rating is much reduced when NOT mounted in a cabinet of the correct design (or not in a cabinet at all!). The signal input requirement, being 0dB, is suitable for connecting to pre-amps or mixers with line outputs, i.e. do not connect microphones, guitars, synthesisers, tape recorders, record player pick ups or tuners, directly to the input. Suitable pre-amplification is necessary for these sources of audio. Fuses are not shown in the 90V DC supply rails between PSU and Output module. They can be fitted here, if required, actual types of holder, etc. must be left to the constructor, but remember to use slow blow fuses (anti-surge) rated 6.3A, such as RA13P, 20mm type. Keep all power wiring from PSU to Driver & Output modules as short as possible. If fitting the assembly into a cabinet, arrange the fan to be mounted into one of the sides and at one end of the Mosfet heatsink. This allows air to be drawn from outside and blown directly across the Mosfets.

OUTPUT PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,4,6,8,9, 13,14,16	4k7	8	(M4K7)
R2,3,5,7,10, 11,12,15,19, 21	0.22Ω 7W Wirewound	10	(L0.22)
R17,18	1k8	2	(M1K8)
R20	10Ω 1W Carbon Film	1	(C10R)
R22,23	22k	2	(M22K)

CAPACITORS

C1,2	100nF Polylayer	2	(WW41U)
C3,4	100μF 100V P.C. Electrolytic	2	(FD15R)
C5,6	10nF Polylayer	2	(WW29G)

SEMICONDUCTORS

OP1,2	Opto-Isolator	2	(WL35Q)
TR1-4	2SK176 Mosfet	4	(FD18U)
TR5-8	2SJ56 Mosfet	4	(FD19V)

MISCELLANEOUS

TB1	3 Way P.C. Terminal	1	(RK72P)
TB2,3	2 Way P.C. Terminal	2	(FT38R)
	Veropins 2141	1 Pkt	(FL21X)
	EC Wire 0.9mm 20 swg	1	(BL26D)
	TC Wire 0.9mm 20 swg	1	(BL13P)
	Heat Shrink CP24	1	(BF87U)
	HP Mosfet Output PCB	1	(GD81C)
	Heatsink drilled	1	(XJ66W)
	Insulator TO3	8	(QY44X)
	Threaded spacer	2 Pkts	(JG20W)
	Plastic bush	1 Pkts	(JG21X)
	Bolt 6BA 1in	2 Pkts	(BF07H)
	Bolt 6BA ¼in	1 Pkts	(BF05F)
	Nut 6BA	1 Pkt	(BF18U)
	Shake 6BA	3 Pkts	(BF26D)
	Washer 6BA	2 Pkts	(BF22Y)
	Standard 120mm Fan	1	(WY06J)

OPTIONAL

	Finger Guard 120mm	1	(FS20W)

DRIVER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	2k2	1	(M2K2)
R2	100k	1	(M100K)
R3,7	47Ω	2	(M47R)
R4	47k	1	(M47K)
R5,8	4k7	2	(M4K7)
R6,9	470Ω	2	(M470R)
R10	1k	1	(M1K)
R11	220Ω	1	(M220R)
R12	68k	1	(M68K)
R13,14	47Ω 1W Carbon Film	2	(C47R)
R15	33k	1	(M33K)
R16-23	680Ω	8	(M680R)
RV1	220Ω Hor Encl. Preset	1	(UF98G)
RV2	470Ω Hor Encl. Preset	1	(UF99H)

CAPACITORS

C1	10μF 50V P.C. Electrolytic	1	(FF04E)
C2,14	47pF Ceramic	2	(WX52G)
C3	22pF Polystyrene	1	(BX24B)
C4,5,6	100nF Polylayer	3	(WW41U)
C7	220μF 16V P.C. Electrolytic	1	(FF13P)
C8	10pF Ceramic	1	(WX44X)
C9,11	100μF 100V P.C. Electrolytic	2	(FD15R)
C10,12	100pF Polystyrene 1%	2	(BX46A)
C13	470pF Polystyrene 1%	1	(BX53H)

SEMICONDUCTORS

D1-4	1N4148	4	(QL80B)
TR1-3	2SA872A	3	(UF75S)
TR4,5	2SB718	2	(UF76H)
TR6	2SD758	1	(UF77J)
ZD1,2	BZX61C12V	2	(QF55K)

MISCELLANEOUS

TB1	3 Way P.C. Terminal	1	(RK72P)
	Veropins 2145	1 Pkt	(FL24B)
	HP Mosfet Driver PCB	1	(GD80B)
	A/P Beads	3	(LB62S)
	Heatsink Clip on TO220	1	(FG52G)
	Heatsink Vaned Plas.Pwr.	1	(FL58N)
	Kit (P) Plas	2	(WR23A)
	Bolt 6BA Nylon ½in	1 Pkt	(BF75S)
	Nut 6BA Nylon	1 Pkt	(BF80B)
	Washer 6BA Nylon	1 Pkt	(BF84F)
	EC Wire 0.56mm 24swg	1	(BL28F)
	TC Wire 0.56mm 24swg	1	(BL15R)
	Bolt 6BA ¼in	1 Pkt	(BF05F)
	Shake 6BA	1 Pkt	(BF22Y)

A complete kit, excluding Optional item, is available:
Order As LM51F (HP Mosfet Output Kit) Price £99.95
The following items in the above kit are also available separately,
but are not shown in our 1988 catalogue:
0R22 7W Wirewound **Order As L0.22 Price 35p**
100μF 100V P.C. Electrolytic **Order As FD15R Price 28p**
H.P. Mosfet Output PCB **Order As GD81C Price £4.50**
Heatsink drilled **Order As XJ66W Price £27.95**
10 Pk Threaded Spacer **Order As JG20W Price 60p**
20 Pk Plastic Bush **Order As JG21X Price 45p**

A complete kit is available.
Order As LM50E (HP Mosfet Driver Kit) Price £11.95
The following items in the above kit are also available separately,
but are not shown in our 1988 catalogue:
100μF 100V P.C. Electrolytic **Order As FD15R Price 28p**
HP Mosfet Driver PCB **Order As GD80B Price £3.50**

MONITOR PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,8,12	1k	3	(M1K)
R2,13	470Ω	2	(M470R)
R3,4,14	4k7	3	(M4K7)
R5,9,11,15	10k	4	(M10K)
R6	100k	1	(M100K)
R7,17	2k2	2	(M2K2)
R10	470k	1	(M470K)
R16	100Ω	1	(M100R)
RV1	4k7 Hor. Encl. Preset	1	(UH02C)

CAPACITORS

C1	1µF 35V Tantalum	1	(WW60Q)
C2	22µF 63V P.C. Electrolytic	1	(FF07H)

SEMICONDUCTORS

IC1	4093	1	(QW53H)
TR1,2,4	BC548	3	(QB73Q)
TR3	BC558	1	(QQ17T)
TR5	BC337	1	(QB68Y)
D1-8	1N4148	8	(QL80B)
ZD1	BZY88C10V	1	(QH14Q)
LD1,2,3	LED Red	3	(WL27E)

MISCELLANEOUS

RL1	Relay 16A 250VAC 12V	1	(JG22Y)
TB1,4,6	2 Way P.C. Terminal	3	(FT38R)
TB2,3,5	Minicon Latch Plug 2W	3	(RK65V)
	HP Mosfet Monitor PCB	1	(GD82D)
	DIL Skt. 14 Pin	1	(BL18U)
	Veropin 2145	1 Pkt	(FL24B)

OPTIONAL

	Latch Housing 2 way	3	(HB59P)
	Minicon Terminal	1Stp	(YW25C)
	7/0.2 Wire 10M Blk	1 Pkt	(BL00A)
	7/0.2 Wire 10M Red	1 Pkt	(BL07H)

A complete kit, excluding Optional items, is available.
Order As LM52G (HP Mosfet Monitor Kit) Price £19.95
The following items in the above kit are also available separately,
but are not shown in our 1988 catalogue
16A 250V AC Relay 12V **Order As JG22Y Price £12.95**
HP Mosfet Monitor PCB **Order As GD82D Price £3.50**

PSU PARTS LIST

RESISTORS

R1,2	330Ω 3W Metal Film	2	(W330R)
R3-6	6k8 3W Metal Film	4	(W6K8)

CAPACITORS

C1	100µF 25V P.C. Electrolytic	1	(FF11M)
C2-5	10µF 50V Reversolytic	4	(FB06G)
C6,7	10,000µF 100V Can Electrolytic	2	(FD16S)
C8,9	1,000µF 100V Can Electrolytic	2	(FF19V)

SEMICONDUCTORS

D1,2	1N4007	2	(QL79L)
ZD1,2	BZX61C15V	2	(QF57M)
ZD3-8	BZX61C30V	6	(QF64U)
BR1	K04	1	(BH48C)
BR2	W01	1	(QL38R)

MISCELLANEOUS

TB1,3	3 Way P.C. Terminal	2	(RK72P)
TB2	2 Way P.C. Terminal	1	(FT38R)
	HP Mosfet PSU PCB	1	(GD79L)
T1	Transformer	1	(XJ65V)
FS1,2	Fuse A/S 80mA	2	(RA04E)
	Fuse clips	4	(WH49D)
	HD Mains Black	2 Mtr	(XR09K)

OPTIONAL

Safefuse holder 20mm		(RX96E)
Fuse A/S 6.3A		(RA13P)

A complete kit, excluding Optional Items, is available.
Order As LM53H (HP Mosfet PSU kit) Price £89.95
The following items in the above kit are also available separately,
but are not shown in our 1988 catalogue:
10,000µF 100V Can Electrolytic **Order As FD16S Price £12.95**
HP Mosfet Transformer **Order As XJ65V Price £59.95**
HP Mosfet PSU PCB **Order As GD79L Price £3.95**

Note: These four kits will not be available until April 1988.

PRIZE DRAW WINNERS

During 1987, Maplin ran prize draws in which the winner could select as first prize either a fabulous Ford Escort XR3i or a stunning Ford Sapphire GL. The lucky winner is Mr W.L. Grint, from Norwich in Norfolk. He has selected the Sapphire GL as his prize, and was 'over-the-moon' when he heard the news. He says that he has been a long-time customer of Maplin's and confesses that now he is likely to remain so for the rest of his life! The icing on the cake is that this fabulous win has come at just the right time, as his old Cortina is just about on its last legs (wheels!). Maplin send him their heartiest congratulations and wish him many hours of happy, carefree motoring. In addition 500 other prizes of a highly decorative and functional 200 year calendar clock have been awarded to the runners-up. The 500 people are listed below:

R. Oakton, Derby; P. Bunney, Broughton-in-Furness; A.S. Foster, Helensburgh; M.J. Clay, Kettering; A. Brown, Letchworth; G.D. Brunette, Littlestone; Rev. W.H.C. Kingston, Honiton; A. Martyn, Christchurch; K.H. Lockyer, Oxford; Mrs S.C. Wilkinson, Eastbourne; A.R. Sparkes. Macclesfield; M. Taylor, Maidenhead; P.J. Turner, Castletown; W.H. Hunt, Beccles; P. Dunderdale, Ballaugh; D.J. Weller, Herne Bay; K.R. Maplesden, Gillingham; K. Watson, Selsey; D.A. Goodger, Hastings; T.F. Roberts, Swindon; M.R. Dudley, Oxford; M. Hodges, Crumlin; D. Wild, Saffron Walden; M. Massingham, Fareham; J. Duff, Belfast; P. Cummings, Coventry; M. Windsor-Hampton, Hampton; A. Pape, Carlisle; C. Downs, Colwyn Bay; C. Hancock, Marazion; I. Scott, Tewkesbury; B. Hiley, Nottingham; C. Kelly, Betchworth; J. Key, Sutton-in-Ashfield; J.E. Austin, Thorpe-on-Soken; T. Hutchinson, Lurgan; R. Middleton, Bangor;D.R. Court, Wargrave; R. Brain, Chulmleigh; D. Tabberer, Worcester; B.E.L. Roberts, Skelmersdale; W.R. Swan, St. Andrews; N. Sands, Chorley Wood; R. Thorley, Stoke-on-Trent; C. Caton, Bolton; D. Froggatt, Manchester;

B.P. Coley, Birmingham; E. Cheong, Liverpool; P. Lane, Great Yarmouth; C.F. Cheuk, Redditch; P. Burrows, Dovercourt; K. Marsh, Exeter; C. Street, Redhill; P.D. Gacon, Bedford; D. Kelly, Ystrad-Meurig; E. Abbott, Blackburn; K. Jupe, Attleborough; A.T. Chappell, Cardiff; R.M. Wheatley, Leeds; Mrs. U.K. Seldrup, Horsham; G.R. Bunting, Wallasey; M. Dabhi, Cheltenham; A. Glover, Daventry; R. Stone, Bradford; R.A. Gillingham, Arundel; A.E. Russell, Meopham; C.S. Maidstone, Maidstone; J. Huddleston, Caterham; A. Page, Bournemouth; P. Cooke, Bury St.Edmonds; Cpt. L.H. McBain, Tavistock; M. Drake, Callander; D.H. Boulton, Thame; G. Harris, Wimbledon; D.F. Carter, Brentwood; Mr. Weijman, Bramley; M.J. McCarthy, South Norwood; R.B. Davies, Market Harborough; P.J. Williams, Anglesey; S. Woodley, Cambridge; A. Twyman, Faversham; T.W. Williams, Powis; R. Pringle, Clacks; K. Waring, Nottingham; S.E. Plumtree, Eastbourne; M. Hooper, Staplefield; C.W. Williams, New Malden; K.J. Williams, Llanelli; M. Calvert, Braintree; J. Farmer, BFPO 29; D. Taylor, Leamington Spa; F.R. MacDonald, Dorking; N. Meigh, Stoke-on-Trent; J.A. Pollikett, Crawley; J. Gabryliszyn, Shipston-on-Stour; P. Cockayne, Cardiff; T.A. Mossman, Penarth; C. Jones, Knutsford; D.J. Lilley, Chelmsford; R. Alcock, Bristol; R.C. Mould, Whetstone; D.G. Waller, Colwyn Bay; E.S. Trenear, Alfreton; J. Sommerville, Stonehouse; J.P. Fowler, Dursley; N. Chescoe, Reading; K.W. Smart, Derby; J. Cuthbertson, Beeston; A.M. Kay, Wigan; P. Robbshaw, Aberdeen; B.F. Wilkinson, Sheffield; D.J. Otterburn, Berwick-upon-Tweed; D. Glover, Bexleyheath; D. Crowe, Glasgow; G.A. Parry, Pwllheli; D. Lewis, Holyhead; A.J. Turner, Wokingham; B. Stobbs, Wallsend; W.D.L. Fairclough, Chalfont St. Peter; T. Kuhn, Winkleigh; J. Waller, Rugby; R. Cox, Felixstowe; Dr. V. Markovic, Vienna, Austria; J.W. Dickin, Harlow; M. Gormley, Comber; R. Buswell, Woodbridge; J.R. Gough, Earley; J.J.C. Monk, Walton-on-the-Naze; L.C. Peterson, Tottenham; F. Fulcher, Abergavenny; W.R. Mitchell, Brentwood; I. Parsons,

Ripley; P. Foster, Grantham; S. Wright, Leeds; M. Burge, New Ollerton; F.J. Hall, Wootton Bassett; J. Chitty, Chelmsford; J. Tremaine, Lostwithiel; H. Marshall, Liss; P. Nesbit, Edinburgh; R.E. Haynes, Letchworth; P.L. Heaps, Chalfont St. Peter; S.M. Hindley, Cropwell Bishop; Dr. R.D. Firn, York; J. Waldron, St. Athan; J. Cunningham, Newry; A. McNeill, Solihull; C. Covell, Canterbury; K.A. Mason, Harlow; R.W. Hudson, Prudhoe; M.J. Darwin, Sheffield; P.D. Sutton, Exeter; D. Hills, Salisbury; G. Ma, Henley-on-Thames; J.K. Heald, Aberystwyth; M. Robinson, Slough; F.T. Ibrahim, Ilford; G.J. Wilson, St. Albans; P. Simpson, Hull; W. Gwyther, Taunton; B. Bunnell, Bristol; Mrs S. Hammond, Yarm; M. Wright, Ipswich; E. Hayward, South Harrow; L. Fisher, Canterbury; B. Veer, Bath; G.K. McKay, St. Neots; J.N. Trumpeter, Danbury; D.O. McFarlane, Hexham; D. Smedley, Ilkeston;G.N. Skelton, Bagshot; D. Mitchell, Perth; P. Storey, Worksop; S. Marsh, Belper; A.S. Grant, Macclesfield; M. Blair, Edinburgh; A. Ralston, Leicester; C. Clatworthy, Swansea; S. Clogg, Addlestone; R.J. Goodship, Cambridge; M.R. Collingwood, Bishops Stortford; D.J. Kirby, Birchington; P. Goacher, Rustington; Mrs M. Parnell, Carshalton; R.C. Blick, Bromsgrove; R.D. Ward, Dorking; E.P. Benedek, Oldham; S. Howlett, Teddington; D.R. Bradberry, Ballinamore; I. Ross, Ballyclare; L.V. Treeby, Plymouth; P. Woodlock, Kings Lynn; A.A. Finney, Tamworth; D. Jenkins, Newcastle; F. Fleming, Tamworth; G. Moorfoot, Spalding; S. Hibbs, Bristol; S. Wright, Burnham-on-Sea; P.G.N. Hoar, Tadley; G. Miller, Morville; R.J. Dodson, Bradford; K. Taylor, Hemel Hempstead; L. Peters, Weymouth; A. McRae, Templecombe; K. Moody, Leeds; M.J. Evans, London; C. Hewes, Nottingham; A.N. Pearce, Lincoln; K.E. Adamson, Liverpool; M.P. Gill, Leeds; P. Keen, Harrogate; A. Toney, Solihull; D.C. Bathurst, St. Albans; D.M. Johnson, Leicester; R. Smedley, Peterborough; J.W. Redfern, Haverfordwest; B. Woodcock, Leek; W.E. Reynolds, Stoke-on-Trent; S. Pitkin, Beccles; I. Parkinson, Stockport; A.M. Ellis, Mitcham; D. Grant, Gosport; P.B. Thomas,

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LOUDSPEAKER AND AMPLIFIER SPECIFICATIONS

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

When proposing to buy or build a loudspeaker or amplifier, most Maplin Magazine readers will naturally want to look at some specifications. Does the average specification prove helpful? Can you tell whether the amplifier and loudspeaker will work well together? Of course not! So we'd better try to do something about it, now.

First of all, you will probably find it best to forget all you know about the subject, and start again, because that is what professional designers have had to do over the last twenty years or so, as the emphasis has swung from small amplifiers and sensitive loudspeakers to large amplifiers and low sensitivity speakers. Naturally, there was a good reason for this change; most modern loudspeakers outperform, in terms of sound quality, those of twenty years ago by a very large factor. The following discussion is restricted to moving-coil loudspeakers, because electrostatic and piezoelectric loudspeakers present different problems which need separate treatment.

Voltage or power?

The first thing that we have to realise is that a loudspeaker is a *voltage-operated device*, and not a *power-operated device*. By that, I mean that the output sound pressure (which our ears interpret as the loudness of the sound) is proportional to the input voltage and not to the input power. This distinction would not be important if neither the impedance nor the directional response of the loudspeaker varied with frequency, because then the sound output power would be proportional to the square of the axial sound pressure, and the input power would be uniformly proportional to the square of the input voltage. But for all practical loudspeakers, even for a single drive-unit, varying impedance and varying directional response are the rule. So the

first thing we have to understand is that the amplifier must keep the voltage across the loudspeaker terminals independent of frequency, even though the impedance of the loudspeaker varies. This means that the amplifier must have a low *output source impedance*.

Where did the power go?

The next thing to consider is that, in spite of being a voltage-operated device, the loudspeaker definitely does consume power. If V is the rms input voltage, and R is the resistive part of the impedance, the power consumed is V^2/R, and may be upwards of 100W. This means that the amplifier must be capable of delivering sufficient power into the variable impedance of the loudspeaker at all frequencies, because if it cannot do this, gross distortion will occur. 'Sufficient power' means enough to maintain the required input voltage that produces the required loudness. Obviously this varies greatly from a personal stereo player to a disco rig!

So what happens to this power? Only about 1% or less appears as sound power and is radiated away. The other 99%+ just heats up the voice-coils of the drive units! Please make no mistake, this is literally true, apart from some small losses in crossover network components, if any. The ratio of sound power output to electrical power input is the *efficiency* of the loudspeaker, but it is NOT a characteristic that is very useful to consider for household loudspeakers: it is rather more important for sound reinforcement loudspeakers but is still not of major importance. Part of this is due to the problem of frequency-dependent, non-resistive impedance, which is usually 'swept under the carpet' in efficiency calculations by assuming that the impedance is resistive and equal to the 'rated value' (which will be explained later).

Hot under the collar!

The heating of the loudspeaker voice-coil produced by the input power has a number of consequences, none of which is good. The resistance of the wire rises, at 0.4% per degree C if the wire is copper. This may not appear much but the temperature rise may be 100 deg.C, giving a 40% increase which is dependent on both programme content and time. This is because the heating effect depends on the signal voltage and frequency and the cooling due to conduction, convention and radiation is progressive with time when the heating effect falls (see Figure 1). So this adds a further degree of variation to the impedance of the loudspeaker.

The second effect of the heating is to cause the voice-coil to expand. If it grows too big, it will scrape on the pole-pieces of the magnet and the wire will be broken or torn off. Clearly, this is a catastrophic failure. Even if the expansion is controlled, the heat will cause degradation of the material of the voice-coil former and any adhesives used in the coil or to attach it to the cone, and these will eventually fail. This represents a longer-term 'wear-out' mechanism.
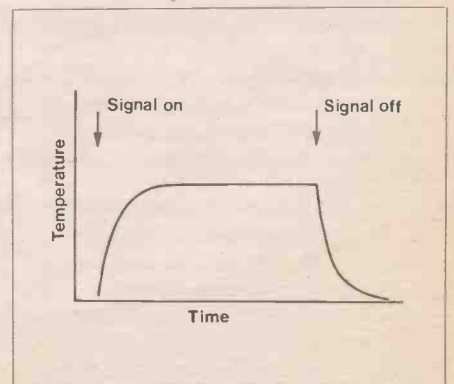

Figure 1. Heating and cooling of a voice coil: steady signal.

Shake, rattle and roll

Our list of disasters is not over yet. The voice-coil moves in and out in response to the signal, but it cannot move very far. If it goes into the magnet structure too far it will hit something, e.g. the dust cover will hit the pole tip. If it goes out too far, it may tear away from the cone, and if it doesn't do that, once the coil is driven out of the magnet gap, the thermal resistance is likely to rise considerably, thus increasing the heating, as the cooling effect of the pole tip is lost, so rapid failure due to high temperature is most probable.

Finally, we have the coil and cone vibrating to produce the sound, and this vibration itself tends to wear out the materials. Cones can split at the edge and adhesives can fail. The leads bringing the signal to the voice-coil are particularly vulnerable as they tend to vibrate a lot, and may even resonate at some frequencies. The vibration will eventually cause metal-fatigue and the leads will break. These effects are long-term, 'wear-out' mechanisms. The vibration may also cause fasteners to loosen, and joints in the enclosure of the loudspeaker to fail. The heat produced by the voice coils is eventually absorbed by the enclosure and any lining materials, which may be damaged in the long term in this way also.

Short-term performance

We can now see what the factors are that really control the short-term performance of the loudspeaker. They are the permissible maximum voice-coil temperature and the maximum coil excursion. The first of these is not very useful alone, because you also need to know the relation between input voltage, time and temperature, which would allow you to decide whether your proposed operating conditions (in terms of maximum input voltage and input frequency range) are satisfactory (see Figure 2). The second characteristic, however, the maximum excursion, is directly useful as its value can be plugged into some of the design

equations developed by Dr. Richard Small (Refs. 1 and 2).

Making a lot of DIN

In the long term, we can see three wear-out mechanisms, which can be lumped together for testing a design. Testing is essential because theoretical design for long-term reliability is very complex and depends on empirical factors, i.e. it is something of an art. The spectacular nature of the test procedure, and the spectacular failures it provoked when first introduced, are responsible for the fame (notoriety!) of the German standard in which it was first published, DIN 45573 Part 2. The test consists of applying a high-level, weighted and peak-amplitude limited, noise signal to the loudspeaker for 100 hours, after which time it is allowed to recover for 100 hours and must then meet its short-term performance specifications. Naturally, the test creates a great deal of noise and has to be carried out at a series of increasing input voltages until the final test is not passed. So it is expensive and difficult to do. But it must be realised that, far from being the ultimate test of fidelity or anything, this is nothing more than a LONG-TERM LIFE TEST! Of course, the DIN standard does include other tests that are more important in terms of sound quality.

The subject of maximum excursion is dealt with in another, even more famous, DIN standard, DIN 45500 Part 7. (It should be explained that most DIN standards are issued in a number of Parts. In the case if DIN 45500, the Parts deal with different items of high fidelity equipment; Part 4, for instance, deals with tape recorders). While it is clearly possible to design from theory for a given maximum excursion, a test procedure is also necessary. The DIN standard requires the application of 2 second bursts of sine wave signal at any frequency from 250Hz down to the lower limiting frequency (where the response is 8dB down when measured under half-space conditions, i.e. with the loudspeaker sunk flush into a large unobstructed plane surface). The signal voltage is increased

until the loudspeaker rattles.

These DIN standards only apply in Germany, and are being brought into agreement with IEC international standards, which are also being adopted by the British Standards Institution (BSI). The measuring methods for loudspeakers are included in IEC 268-5, which is under revision at present, and the new version will become British Standard BS6840 Part 5 (and DIN IEC268-5, replacing DIN 45573). However, this new standard does not include a DIN-type test for maximum excursion, as this is regarded as a destructive test. Manufacturers are expected to determine maximum excursion by measuring the distortion produced by the loudspeaker as the excursion is increased. The international performance standard for high fidelity loudspeakers, replacing DIN45500 Part 7 outside Germany, is IEC581-7, equivalent to BS5942 Part 7. It should be understood that this standard defines the lowest acceptable performance, not some unattainable ideal.

New standard tests

The new revised IEC 268-5 deals with the voice-coil temperature issue by introducing two maximum input voltage ratings, one based on the maximum permitted sinusoidal input voltage for 1 second, and the other the maximum permitted input voltage for 1 minute, the input signal being a weighted noise signal (different from the DIN 45573 signal), known as the 'simulated programme signal'. These effectively give two points on the input voltage/time/temperature curve, and the curve can be approximated by two straight lines on a logarithmic plot, one where V^2/t is constant, and one where V is constant, for constant temperature (see Figure 2). Alternatively, of course, the manufacturer could publish the whole curve.

A further measurement in the IEC standard relates to the maximum permissible sine-wave voltage input for a specified time period, normally 1 hour. This deals with long term heating effects, and the manufacturer of a multi-unit loudspeaker system may well quote different values for different frequencies, because the long-term average level of programme signals falls off considerably at high frequencies. It is important to realise, however, that the short-term average level (measured with constant percentage bandwidth) does NOT fall at high frequencies so that, in a bi- or tri-amplified system with equally sensitive drive units, you need the same amplifier specification for each drive unit if they cover the same number of octaves.

Moving closer to the amplifier

We now have those characteristics which affect the voice-coil and cone sorted out, and can pass on to the interface with the amplifier. Considering first an individual drive-unit, the voice coil clearly has resistance, even at DC, and because it is a
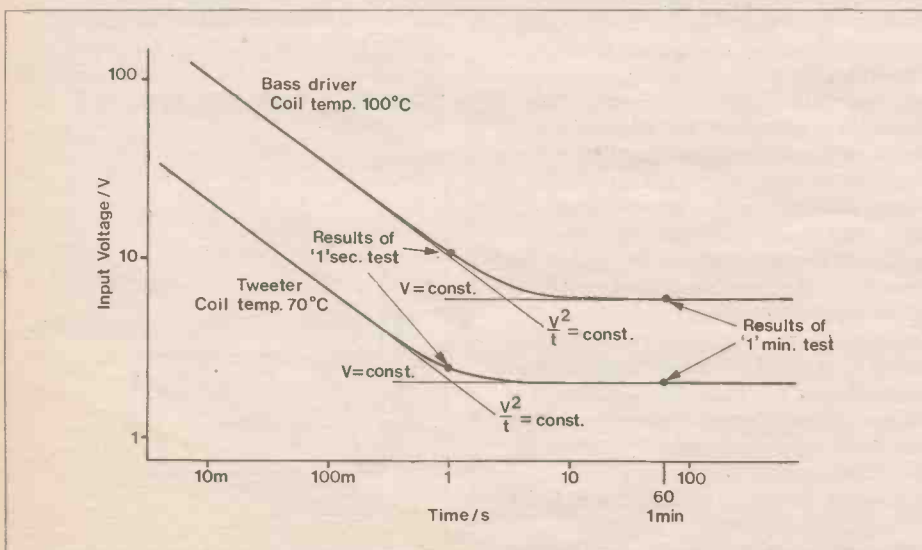

Figure 2. Input voltage/time/voice coil temperature curves for different drive units.

coil, it also has inductance. These would still be there even if the coil was not free to vibrate, but it is, and the movement of the coil in the magnetic field produced by the permanent magnet of the drive-unit induces a back-e.m.f. into the coil. This is quite inevitable, but I recently read a review in a 'hi-fi' magazine where it was clearly implied that better loudspeakers did not produce a back-e.m.f.! However, it is usual to consider, not the back-e.m.f. itself, which depends on the excursion, but the effective impedance that it introduces into the voice-coil circuit, which is largely independent of excursion. This impedance is called the 'motional impedance', and can be represented in a simplified form as a frequency-dependent resistance in series with a damped parallel-tuned circuit. The tuned circuit resonates at the resonance frequency of the drive-unit, which is not constant but depends on the enclosure in which the unit is mounted, and the impedance at resonance may be ten times the DC resistance of the coil. The frequency-dependent resistance actually represents the radiation of sound power, but the efficiency is so low that the resistance is usually negligible! (See Figure 3(a)).

Rated impedance

How, then, can we handle this effective impedance which may vary over a ten-to-one ratio? (See Figure 3(b)). Well by ignoring most of the variation. It turns out (and if it didn't, the moving-coil driver wouldn't be much use) that the rise in impedance at resonance does not necessarily result in either a rise or a fall in the frequency response (sound pressure level/input voltage), and that constant input voltage can give a substantially constant sound-pressure level, independent of frequency. This wouldn't happen if the cone vibrated in one piece at all frequencies, but in fact it effectively gets smaller as the frequency rises, and this 'break-up' effect greatly widens the bandwidth of the unit. So what manufacturers do is to measure the impedance at the frequency where it reaches its minimum value (see Figure 3(c)), which occurs above the resonance frequency but within the working frequency range of the unit, assume that this impedance is purely resistive (which is likely to be true), add a bit in case the sample is on the low side of the tolerance spread, and call the result the 'rated impedance'. You can now see that efficiency figures based on this rated impedance are fairly meaningless.

Sensitivity, and how not to state it!

However, the rated impedance is important for interfacing with the amplifier, and the other major characteristic that we need is the sensitivity, expressed in terms of sound pressure in pascals (newtons per square metre) per volt of input, or, more usually, as sound pressure level in decibels referred to 20μPa at 1 volt input. We also have to say how far away from the drive-unit the sound pressure is to be

Figure 3(a). Electrical equivalent circuit of a drive unit, showing typical values for an 8 ohm full-range drive unit.

Figure 3(b). Real (resistive) and imaginary (reactive) components of the impedance of a (simulated) full-range drive unit.

measured, and this is standardised at 1 metre for household and some sound reinforcement loudspeakers, and 3m for larger, especially directional, loudspeakers. The reference level of 20μPa is based on that being the standard threshold of hearing at 1kHz, i.e. the quietest 1kHz sound the average person can hear. Unfortunately, sensitivity is often quoted as so many dB PER WATT at 1 metre, or even worse, as so many dB per watt per metre! This is because the people who have brochures printed are 'salesmen', and they don't have to bother to understand what they are selling in order to sell it. The implication is that if you get, say, 90dB(20μPa) at 1W input at 1 metre, then you will get 9000dB with 10W input at 10 metres! The correct way to do the calculation is to express 10W/1W in decibels, i.e. +10dB, and 1m/10m in decibles *as if metres were volts*, i.e. −20dB, so the true answer is 90 + 10 − 20 = 80dB (20μPa), often written as 80dBSPL. This result applies in free air, of course, not in a room where reverberation would increase the level considerably.

Transient impedance

Unfortunately there is still a snag. When we build two or more drive units into a loudspeaker system with a crossover network, the impedance characteristic is made more complicated (see Figure 4). The crossover network introduces its own humps and bumps into the picture, and while these do not, in a correct design, result in uneven frequency response, the transient behaviour is much more complex. Ordinary sine-wave testing will not show this, but Dr. Matti Otala (Ref. 3) has produced some dramatic results using special test signals, showing current demands corresponding to an impedance as low as one-fifth of the steady-state impedance in some cases. The problem is caused by capacitors being charged and discharged, and possibly series resonance effects, in the crossover network. Note that, unlike interstage coupling capacitors in an amplifier, which should be large enough never to charge or discharge significantly even at the lowest signal frequency, capacitors in crossover networks do charge
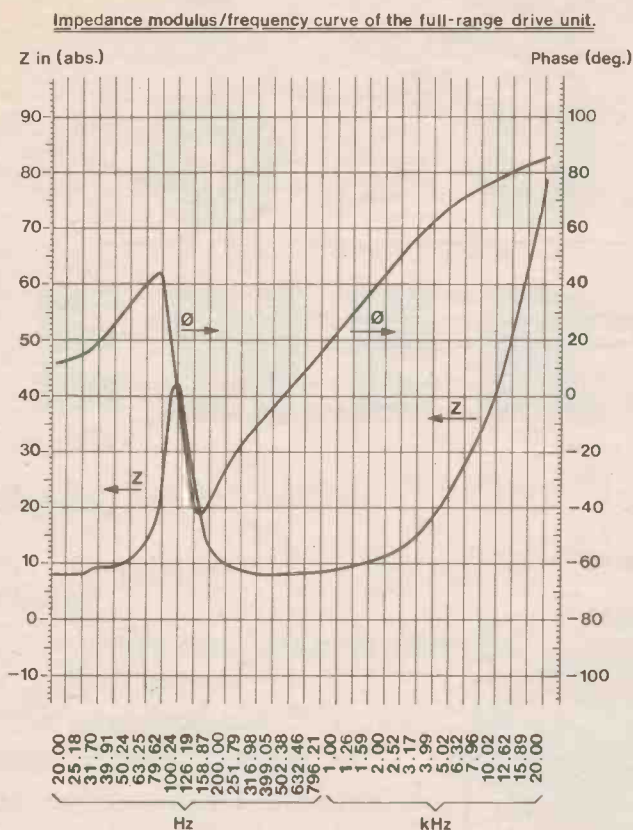
Figure 3(c). Modulus (Z) and phase-angle (∅) of the impedance of the (simulated) drive unit.
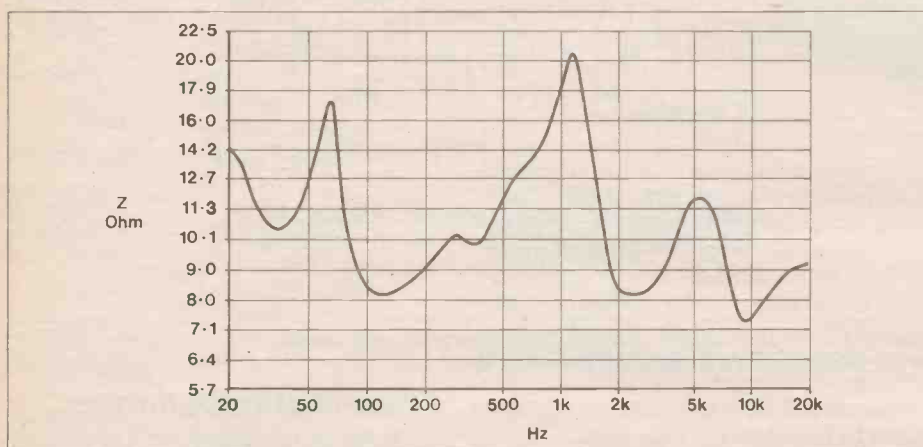

Figure 4. Impedance/frequency curve of a 3-way loudspeaker system. Note that the Z scale is logarithmic.

and discharge. Mr. Peter Baxandall (Ref. 4) has recently shown that, on normal programme signals, the current demands of several types of loudspeaker rarely exceed that measured with a *swept* sine-wave input, so a standard test on these lines is being studied. However, it is necessary to take this effect into account in designing and specifying amplifiers.

Frequency and directional responses

For open-back drive units (unlike sealed dome tweeters and mid-range units), the low frequency response depends very much on the free-air resonant frequency, the Q of the resonant system, and the characteristics (principally the volume if there is no reflex loading) of the enclosure. The rest of the frequency response

depends on how well the manufacturer has done his job; the user can't do much about it except to adjust the crossover network to provide some equalisation. But this is not easy to do: some irregularities seem to 'shout through' all attempts at equalisation. In any case, you need to be able to measure the frequency response, which is far from easy. The directional response depends very much on the dimensions of the unit in relation to the wavelength of the sound. It's no good looking for an omnidirectional 10cm tweeter, nor a directional 40cm sealed-box or reflex sub-woofer! But there is considerable variation between different designs, although it may be difficult to get information on many products.

Finally, the amplifier

You may well be wondering why

amplifier specifications quote power output when we have seen that the loudspeaker is a voltage-operated device. The answer is, basically, some shallow thinking a long time ago. The power matters, just as the horse-power of a car matters, but what gets you from A to B is the speed: compare a hot Fiesta with a tow-truck, for example. What we are interested in is the rated output voltage, specified at the rated value of total harmonic distortion (not some ridiculously low value like 0.005%!), and the rated minimum load impedance. The latter tells us what current the amplifier will deliver, and thus how it might cope with any transient impedance effects in a given loudspeaker system. If only it was as simple as that!

RMS and Music

These horrible terms are associated with power ratings, and if everyone goes over to voltage ratings they may disappear. Curiously, the 'RMS' term is actually more correct when applied to voltage, but it still doesn't represent what is intended to be meant, which is 'continuous sinusoidal'. It happens this way; whichever way you measure the output power with a sine wave signal, the result depends in some way on the equation:

$$W = \frac{V^2}{R}$$

The result gives the true power if V is the r.m.s. value of the output voltage, but you can get a figure twice as big either by using a sine-wave signal and measuring the peak voltage instead of the r.m.s., or by using a square-wave signal, for which the two values are equal. Some American manufacturers couldn't resist the temptation, and started to talk about 'peak power', twice as big as real power. This happened long ago, in the days of valves (tubes).

When transistor amplifiers were introduced, a further complication arose. Most valve amplifiers were Class A, and thus drew constant current from their power supplies, but most transistor amplifiers were Class B, and the current demand of a Class B amplifier is nearly proportional to the signal amplitude. The power supply voltage falls as the current increases, due to the increased resistive loss in the power supply. However, there is always a fat capacitor in the power unit, and the energy stored in this tends to maintain the power supply voltage for a short period in the face of increased current demand. So for a brief period (usually only tens of milliseconds) you can get more power from the amplifier than the continuous sine-wave test indicates. You can measure this higher power by hooking in an external stabilised power supply of the right voltage and measuring the resulting maximum (distortion-limited) output voltage with the sine-wave signal. This power is called 'music power', and, if the power supply is well-designed, it does give a little extra beef for short peaks of signal. In the USA, the ratio of music power to continuous sine-

wave power is expressed in decibels as 'dynamic headroom' (not you, Max!), but this sounds so much like a hype that the term hasn't really caught on elsewhere.

Now, if you are trying to sell ghetto-blasters, you want to claim as much output power as possible because it impresses the punters, so you measure (or perhaps guess) the music power, double it for peak power and then add the two channels together. The result is called Peak Music Power Output (PMPO), and ought to be measured in 'fibs'. Of course, if everybody does it, the only sufferer is the truth!

Short-term and long-term output voltages

There is a new (revised) international standard for amplifier measurements, IEC 268-1 (BS6840 Part 1), and this includes measurements designed to take account of the variation of maximum output voltage with time, and to correlate with the 1 second and 1 minute measurements on loudspeakers. These characteristics are new, and it will take time for manufacturers to begin to quote them in specifications, but they ought to be introduced as soon as possible. These measurements are made with the amplifier driven into hard clipping (if possible). By comparing the corresponding values for an amplifier and a loudspeaker, according to rules given in yet another standard (IEC 268-15, BS6840 Part 15), it can be seen whether the loudspeaker is at risk from the amplifier or not. Note that the manufacturer is required to state values which *no sample of the amplifier will EXCEED*, because this is the safe condition. In a recent amplifier test, I found a *continuous*, unclipped output voltage 20% higher than the rated value, and a lot of words in the manual about burning out loudspeakers! What a strange state of things.

Amplifier protection circuits

We saw early on in this discussion that the amplifier has to have a low output source impedance. There is a lot of nonsense talked about this being necessary to 'damp' the loudspeaker Q, and there might have been something in this when

amplifiers did not have lots of negative feedback. However, they now do, and the result is that the output source impedance of any reasonable amplifier is much lower than the voice-coil resistance. As far as damping is concerned, these resistances are in series, so there is no point in striving for milliohms of output source resistance when there is a 4 ohm voice-coil in series with it! The low source impedance is necessary to prevent impedance variations of the loudspeaker affecting the amplifier output voltage and hence the effective frequency response of the loudspeaker.

The low source impedance also means that if you put a low impedance, such as a short-circuit, across the amplifier output terminals, the amplifier will still try to maintain the output voltage constant. A very large current will flow through the short-circuit, and through the output transistors, which will probably melt. With bipolar output transistors there are other problems. Because the loudspeaker impedance is not resistive, there is a phase difference between the current through the transistors and the voltage across them. Apart from causing extra heating, this phase shift may carry the operating point of a transistor into an area where 'second breakdown' occurs, and the transistor will fail. There is no space here to go into a full explanation of second-breakdown: to avoid it you have to study the transistor data sheets, in particular the SOAR (Safe Operating ARea) graphs.

In order to prevent these failures, manufacturers of amplifiers fit protection circuits which detect unsafe combinations of transistor voltage and current and shut down the amplifier or attenuate the input signal. Unfortunately, these circuits themselves can cause problems. To begin with, their action is not easy to test, and Mr. Peter Baxandall (Ref. 4) has developed a new method of doing this, which has already proved its worth and is being progressed as an international standard. Details, perhaps, in a later article. The most important thing is that if the protection operates due to the amplifier being unable to deliver the required combination of instantaneous voltage and current to the loudspeaker, the reproduction will be badly distorted for a brief period. Such effects may be difficult to track down. So we need

to know the maximum voltage and current capability of the amplifier (from the above test), and the corresponding demands of the loudspeaker (from the Baxandall swept sine-wave test), and to see how they fit together.

A matching set of specifications

In an ideal world we should be able to match up meaningful loudspeaker and amplifier specifications, as shown in Table 1.

Loudspeaker	Amplifier
Sensitivity	Rated output voltage
(These two will give the SPL achievable)	
Rated impedance	Min. rated load impedance
Maximum voice-coil excursion	(No corresponding value)
(This is for checking that the above SPL can be achieved in the designed enclosure)	
Max. short-term input voltage	Max. short-term output voltage
Max long-term input voltage	Max. long-term output voltage
Max. life-test input voltage	Rated output voltage
Dynamic voltage and current demand	Max. voltage and current capability
(These last two are the new Baxandall tests)	

Table 1. Specifications.

Fry your tweeter with a low-power amplifier

If you turn up the wick on your amplifier and overload it, the output voltage waveform will be clipped, and the high-frequency content of the signal will be increased. Think of all those harmonics marching off into the low r.f. range! Now apply this distorted spectrum to a loudspeaker system where the manufacturer has carefully balanced the voice-coil temperatures on the basis of normal programme spectra. Your clipped signal will put far more energy into the tweeter than it should get, and it may well burn up. Now replace your overloaded amplifier with one of *higher output, producing the output voltage you were aiming at, but which does not clip*. Since there is no excess high-frequency energy in this case, the tweeter will survive! Paradoxes like this point up the reasons why this subject should be more thoroughly understood.

References
1. R.H. Small, Closed box loudspeaker systems, JAES, Dec. 1972/Jan-Feb 1973
2. R.H. Small, Vented box loudspeaker systems, JAES, June/July-Aug/Sept 1973
3. M. Otala and Huttunen, P., Peak current requirement of commercial loudspeaker systems, JAES, June 1987
4. P.J. Baxandall, A technique for displaying the current and voltage capability of amplifiers and relating this to the demands of loudspeakers, AES Preprint No. 2421, (82nd Convention, London, March 1987) (To be published in JAES)
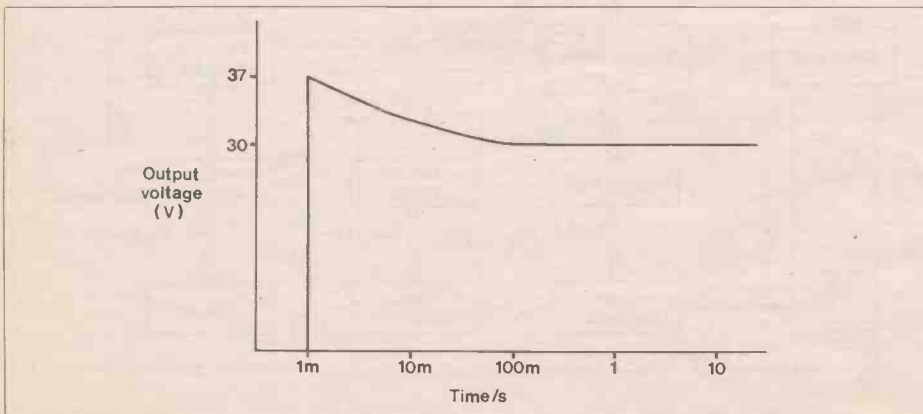
Figure 5. Maximum output voltage available from an amplifier versus time from applying a 1kHz tone-burst at t = 1ms.

SIMPLE MELODY GENERATOR

by Chris Barlow

★ **Simple construction**
★ **Small size**
★ **4 different versions**

Introduction

The UM66 series of CMOS LSI chips are designed for use in door bell, telephone and toy applications. The 64 note Read Only Memory (ROM) is programmed for the musical performance by the manufacturer. Four chips are available as follows:

Type 1 : A medley of Jingle Bells, Santa Claus is Coming to Town, and We Wish You A Merry Christmas
Type 2 : Happy Birthday to You
Type 3 : Wedding March
Type 4 : Love Me Tender, Love Me True

Be sure to order the correct kit code for the desired melody.

Specification of prototype
64 Note ROM Memory
Tone Generator Range : C_4 to C_6
Operating Voltage : 1.3V to 15V
Stand-By Supply Current : $1\mu A$ at 1.3V
Reverse Polarity Protection
Output : Piezo Sounder or 8Ω Loudspeaker
External Amplifier Output : 1V Square Wave at $10k\Omega$
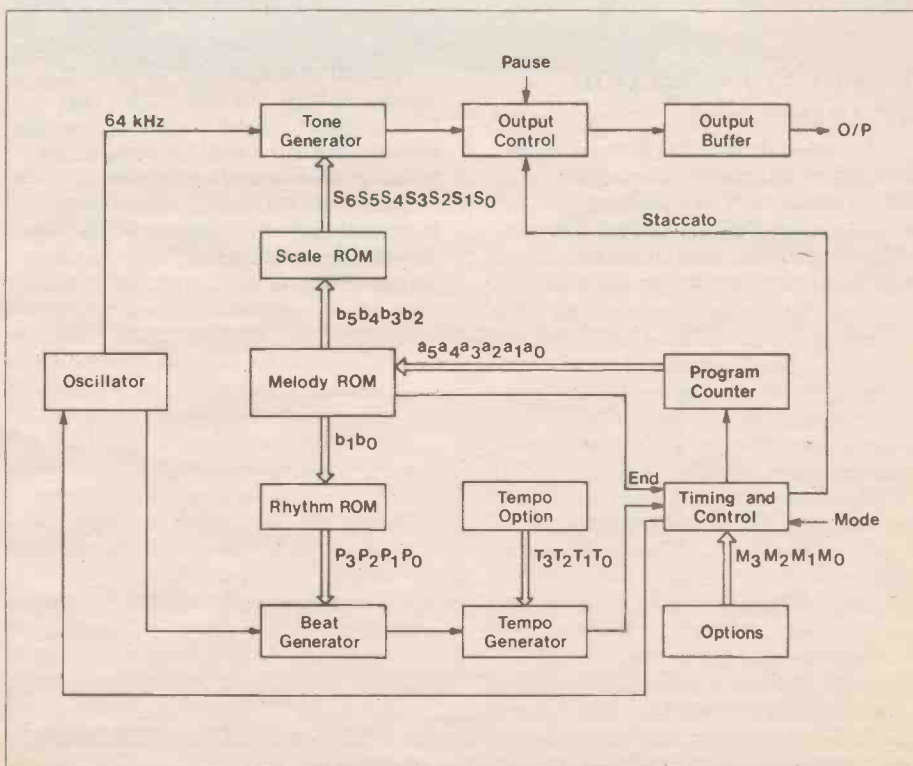
Figure 1. Block diagram.

UM66 How it Works

The UM66 melody generator chip is a compact module containing a logic controlled tone generator, see Figure 1. The oscillator runs at 64kHz and its accuracy affects the quality of the music. Its output is used as a time base for the tone and beat generators.

The tone generator is a programmed divider, its range of scales is from 'C4' to 'C6' and is controlled by the scale ROM. The beat generator is also a programmed divider, controlled by the rhythm ROM. Its output then passes to the tempo generator before entering the timing and control circuits. This produces two main signals, one is fed to the program counter and the other to the output control circuit. A power on reset signal is also generated for the oscillator and program counter. This ensures that the melody begins from the first note each time power is applied to the chip. The tempo options T0 to T3 and the control options M0 to M3 are set at the time of manufacture.

The program counter steps through the memory addresses of the melody ROM until the END signal is fed back to the timing and control stage. Four of the six bits of data from the melody ROM are used to control the scale and the remaining two are used by the rhythm circuit. The melody play option that MAPLIN have chosen is as follows: After connecting the power, the tune will play once and stop. The voltage supply to the chip must be removed then re-applied to retrigger it.

The output control stage acts as a sound gate, turning on and off under the command of the timing circuit. The output buffer can supply 1.5mA of drive current, enough for a piezo sounder to be driven directly by the chip.

All this hi-tech circuitry is contained in a three pin plastic package, looking more like a transistor than a complex CMOS LSI chip, see Figure 2.
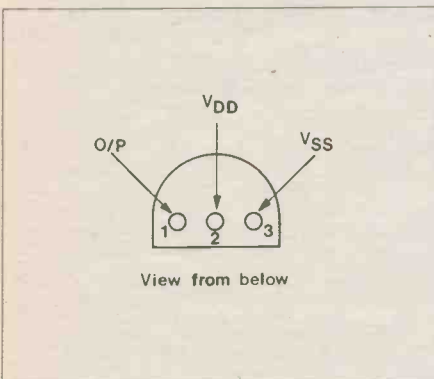
Figure 2. Pin configuration.

Circuit Description

As can be seen from the circuit diagram in Figure 3 only a few additional components are required to complete the project. The DC supply entering the circuit must have the correct polarity, otherwise damage will occur to the semiconductors. To prevent this, a diode, D1, has to have the positive supply voltage applied to its anode before the DC power can pass to the rest of the circuit.

The maximum operating voltage that can be applied to pins 2 and 3 of the UM66, IC1, is 3.3 volts. Over voltage protection is provided
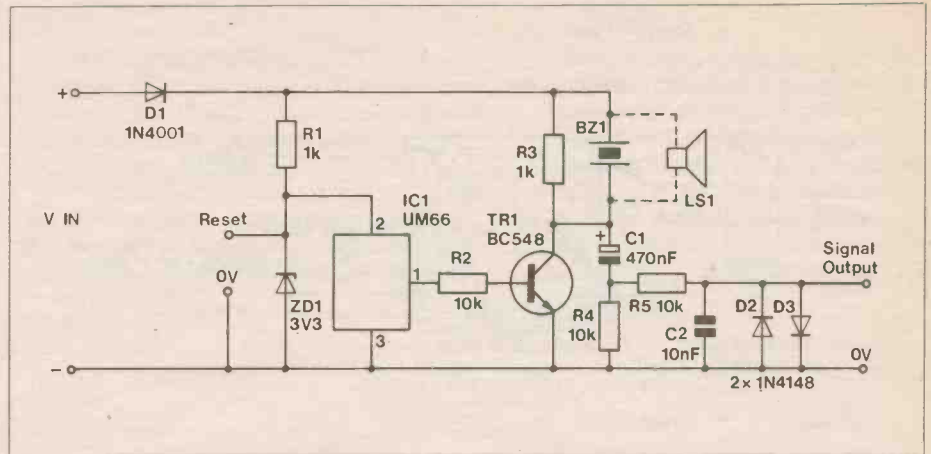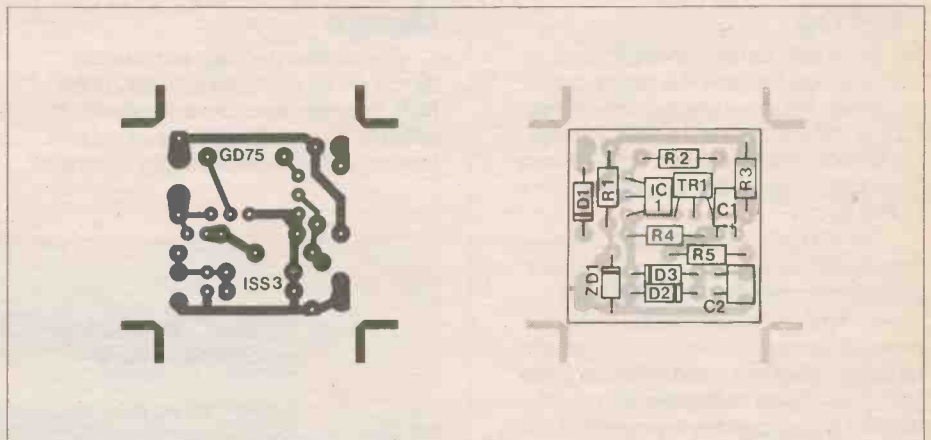
Figure 3. Circuit.

Figure 4. Track and layout of the PCB.

by ZD1 a 3.3 volt zener diode and R1 a 1kΩ resistor to limit the supply current. The chip reset condition occurs when a momentary short circuit is switched between the reset pads. The melody output on pin 1 of IC1 is fed to the base of TR1 via R2, a 10kΩ resistor.

An NPN silicon transistor, TR1, is used to provide sufficient drive current for a piezo sounder or low impedance loudspeaker. Because of the high impedance of the piezo sounder a 1kΩ collector load resistor, R3, must be included. An amplifier output is provided by taking the square wave signal at the collector of TR1 through C3, a 470nF capacitor to R4 and R5. C4 is a 10nF capacitor that then removes any high frequency signals and D2/D3 limit the output to approximately 1 volt peak to peak. This signal can now be fed to an additional amplifier if higher sound levels are required.

PCB Assembly

The PCB is a single-sided fibre glass type and a component overlay is shown in Figure 4. Removal of a misplaced component is quite difficult, so please double-check each component type, value and its polarity where appropriate, before soldering! For further information on component identification and soldering techniques please refer to the constructor's guide which is included in the kit. The sequence in which the components are fitted is not critical. However, it is easier to start with the smaller components. When installing IC1, TR1, C3 and C4 you should lay them flat on the PCB as shown in Figure 6.

The circuit shown in Figure 3 is for use on a voltage supply of 2V to 15V and has reverse

polarity protection. However, the circuit can be adapted for use over different voltages and lower stand-by currents. The following options are possible:

1: Operating voltage, 1.3V to 3.3V no reverse polarity protection and low stand-by current. Replace D1 with a wire link and remove ZD1.
2: Operating voltage, 2V to 4V reverse polarity protection and low stand-by current. Remove ZD1.
3: Operating voltage, 1.3V to 15V no reverse polarity. Replace D1 with a wire link.
4: Using a piezo sounder R3 must be fitted.
5: When using a loudspeaker R3 can be omitted.

This completes the assembly of the PCB and you should now check your work very carefully ensuring that all the solder joints are sound. It is also important that the bottom, track side, of the circuit board does not have any trimmed component leads standing proud by more than 1mm.

Wiring

Carefully follow the wiring shown in Figure 5. The piezo sounder, BZ1, may have different coloured leads but may be connected either way to the PCB. The retrigger switch and amplifier screened cable are optional. The retrigger switch must be a non-locking push to make type and the length of the amplifier cable should be no more than three metres. A self-adhesive pad is then mounted to the back of the sounder. Do not fit the PCB to the back of the sounder until the testing stage is successfully completed.
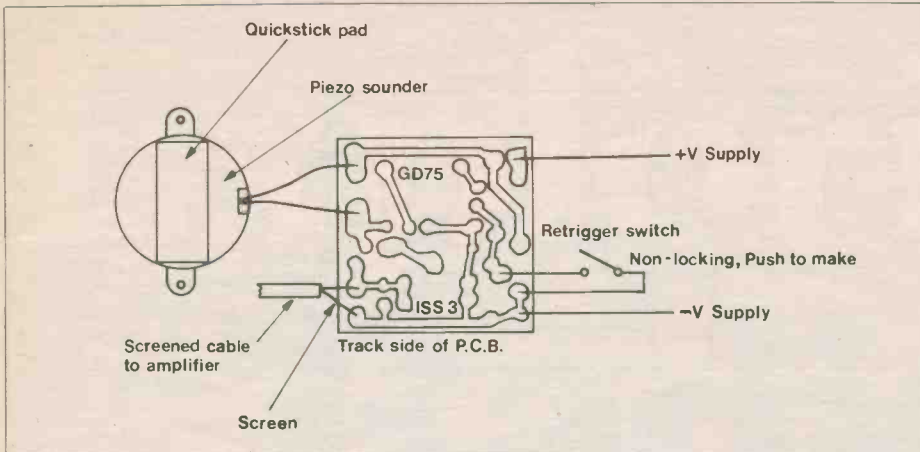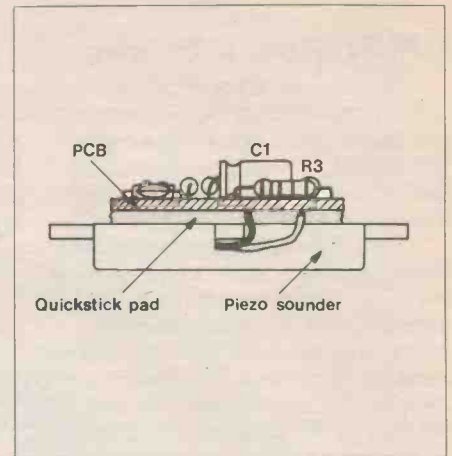
Figure 5. Wiring.


Figure 6. Fixing the PCB.

Testing

All the tests can be made with an electronic digital, or analogue moving coil, multimeter. The circuit was as shown in Figure 3, 2V to 15V operation and a piezo sounder. The following test results were obtained from the prototype using a digital multimeter and a 9V PP3 battery.

The first test is to ensure that there are n short circuits before you connect the battery. Set your multimeter to read OHMS on its resistance range and connect the probes to the supply cables. The reading obtained with the probes either way round should be great than 1000Ω. Some multimeters will provide sufficient current to power the melody generator during this test.

Next monitor the supply current, set your meter to read DC mA and place it in the positive line to the PCB. When the battery is connected the unit should start to play its melody and a current reading of approximately 9mA should be seen. When th tune ends the current reading should drop to approximately 4mA. If the retrigger switch is pressed the current will increase to approximately 8mA, when the switch is released the melody should start again.

This completes the testing of the simple melody generator. Finally secure the track side of the PCB to the quick stick pad as shown in Figure 6.
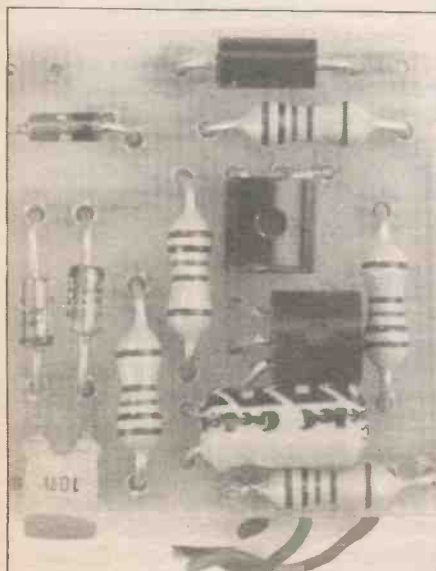
Usage

The operating voltage and stand-by current are set during the assembly of the PCB. You must determine the option most suited for your application. The sound level from the unit can be increased by using a low impedance loudspeaker, such as the 8Ω 768 type (WF57M). A high efficiency horn speaker (XQ73Q) will give a further increase in sound level from the basic unit. However, if louder volumes are required then an amplifier can be used to achieve the desired sound level.

SIMPLE MELODY GENERATOR PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

| R1,3 | 1k | 2 | (M1K) |
| R2,4,5 | 10k | 3 | (M10K) |

CAPACITORS

| C1 | 470nF 16V Minelect | 1 | (YY30H) |
| C2 | 10nF 63V Ceramic | 1 | (WX77J) |

SEMICONDUCTORS

IC1	UM66 Type 1	1	(UJ40T)
	or UM66 Type 2	1	(UJ41U)
	or UM66 Type 3	1	(UJ42V)
	or UM66 TYpe 4	1	(UJ43W)
ZD1	BZY88C3V3	1	(QH02C)
D1	1N4001	1	(QL73Q)
D2,3	1N4148	2	(QL80B)
TR1	BC548	1	(QB73Q)

MISCELLANEOUS

	Simple Melody PCB	1	(GD75S)
	Piezo Sounder	1	(FM59P)
	Quickstick Pad	1 Stp	(HB22Y)
	Constructor's Guide	1	(XH79L)

OPTIONAL

	Miniature Loudspeaker	1	(WF57M)
	Push Switch	1	(FH59P)
	5in. Horn Speaker	1	(XQ73Q)

Four complete kits, excluding optional items, are available for this project:

Simple Melody Generator (V1) Kit (LM43W) Price £2.50
Simple Melody Generator (V2) Kit (LM44X) Price £2.50
Simple Melody Generator (V3) Kit (LM45Y) Price £2.50
Simple Melody Generator (V4) Kit (LM46A) Price £2.50
Note: each kit contains the appropriate IC.

The following item used in the above kits is also available separately, and is not shown in our 1988 catalogue.

Simple Melody PCB **Order As GD75S Price 50p**

ELECTRONICS BY EXPERIMENT

Part 2   by **Graham Dixey C.Eng., M.I.E.R.E.**

Introduction

If you actually wired up the 'three-gate' circuits of Figure 6, in Part One of this series, you will now know that circuit 6(a) was the OR function in disguise and 6(b) was the AND function. It would be perfectly reasonable to ask why anyone would go to the trouble to use three gates to implement a function for which a single gate already exists. Well it isn't quite as silly as it seems. You will have noticed that the two input gates, in both cases, had their inputs strapped and acted as inverters. Thus, the inputs to the final gate are just the inversions of A and B. It so happens that in many practical circuits these inversions already exist (we shall meet actual examples of this later on) so that it isn't always necessary to provide separate inverters as here. What these NAND and NOR 'implementations' should show is that 'the NAND gate provides the OR function for inverted inputs' and 'the NOR gate provides the AND function' in a similar fashion. By using this fact it becomes possible to design quite complex logic circuits that use almost exclusively either NAND or NOR logic. This usually reduces the chip count and makes economic sense as well.

Figure 1 shows these implementations assuming now that the inversions of A and B are available and also introduces an important theorem, known as 'de Morgan's theorem'. This is nothing more than an algebraic statement of what has already been demonstrated in practice. Note that it has two forms, one for each type of circuit.
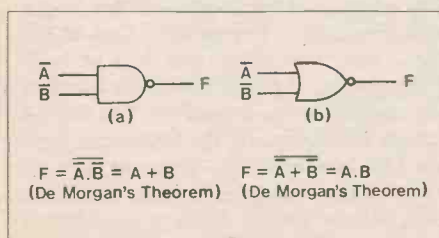
Two More Useful Gate Functions

The OR function is sometimes referred to as 'inclusive-OR', for the reason that, not only is the output of the gate equal to ONE when A OR B is ONE but also 'includes' the case when A and B are BOTH ONE.

There is another OR function known as Exclusive-OR; no prizes for guessing what this one does! The truth table of Figure 2(a) shows the answer. The output F1 is only ONE for the two cases when A or B = 1 separately and 'excludes' the case when they are both ONE. This fact is quite nicely expressed in the Boolean algebraic statement:

$$F1 = \overline{A}.B + A.\overline{B}$$

Notice that the two terms on the right-hand side represent the second and third lines of the truth table, respectively.

If the XOR function (as it is sometimes written) corresponds to the second and third lines of the truth table, it is reasonable to suppose there might be another function that corresponds to the first and fourth lines. As a Boolean statement these are:

$$F2 = \overline{A}.\overline{B} + A.B$$

Is there any obvious inference that can be drawn from this, any apparent identity between inputs and output? Yes! The output is ONE whenever both inputs are the same, either both ONE or both ZERO. It is, therefore, expressing EQUIVALENCE (EQV), and that is what it is called. What is the relation between this and the XOR function?

This can be answered by the application of pure logic, namely, that each occupies half the total possibilities of the truth table and one half is NOT the other! Still not clear? It just means that XOR is the inverse of EQV. EQV is sometimes known as XNOR (Exclusive NOR). This is output F2 in the truth table of Figure 2(b). Now why not prove to yourself the truth of these relations by breadboarding them and examining the input/output relationship?

Figure 2(c) shows how to implement the XOR function using four two-input NAND gates (i.e. a single 7400 chip). Connect switches to inputs A and B to provide the four combinations of logic levels and an LED to the output F1 to see which combinations give a logic 1 output; they should agree with the truth table for the XOR function. Having satisfied yourself on this point, follow F1 with an inverter to give output F2, which should be the EQV function. The choice of inverter is yours. Either press another 7400 into service, using one NAND gate with its inputs strapped, or use one ready made inverter out of the 7404 hex inverter chip. Pin-outs for these appeared in the last issue.
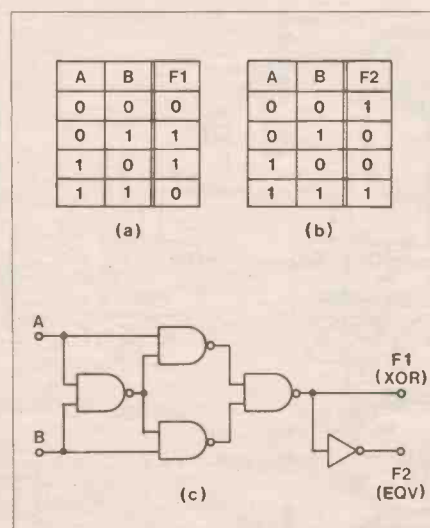
More Complex Circuits - Addition and Subtraction

The truth tables of Figure 3 describe the performance of circuits known as the 'half adder' and the 'full adder' respectively. To understand what these titles
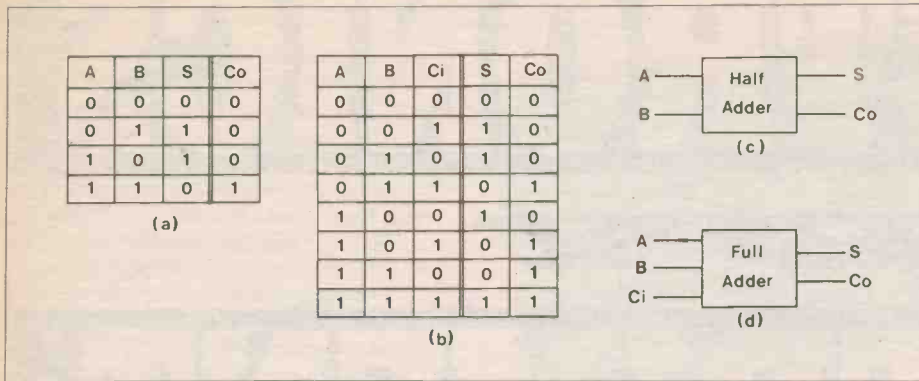
A	B	F1
0	0	0
0	1	1
1	0	1
1	1	0

A	B	F2
0	0	1
0	1	0
1	0	0
1	1	1

(a)   (b)

(c)   F1 (XOR)   F2 (EQV)

Figure 2. Truth tables for (a) XOR and (b) EQV functions and (c) a possible implementation.

(a)   (b)

$F = \overline{A.B} = A + B$
(De Morgan's Theorem)

$F = \overline{A + B} = A.B$
(De Morgan's Theorem)

Figure 1a. The OR function with NAND logic.
Figure 1b. The AND function with NOR logic.

A	B	S	Co
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

(a)

A	B	Ci	S	Co
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

(b)

Figure 3. Truth tables for (a) half adder and (b) full adder. Block forms are shown in (c) and (d).

mean, consider what possible results we get by adding just two binary digits. Here they are.

$0 + 0 = 0$
$0 + 1 = 1$
$1 + 0 = 1$
$1 + 1 = 10$

The first three sums should be obvious; the last is NOT saying that one plus one equals ten! The term 10 is, of course, binary 2 and the '1' represents a 'carry out' of the first column into the second column. Thus when adding two bits together called, for example, A and B, we must allow for two outputs, the 'sum S' and the 'carry out Co'. The block of Figure 3(c) represents this case.

Now consider what must be allowed

for if, when we are adding together two inputs, A and B, we also have to include a 1 'carried' from a previous column of addition. Easy isn't it? All we have to do is include an extra input which will be used for the 'carry in' from the previous addition. This can be represented by Ci and is shown in the block of Figure 3(d).

Thus, Figures 3(c) and 3(d) represent the circuits for a half adder and full adder respectively. It is quite easy to see how the half adder can be implemented merely by looking at the columns for S and Co and writing down the Boolean expressions from them. Notice that the S column is nothing more than the XOR function recently met, while the Co column is even easier, being just the AND of A and B. The circuit of a half adder is shown in Figure 4(a) and its derivation from XOR com-
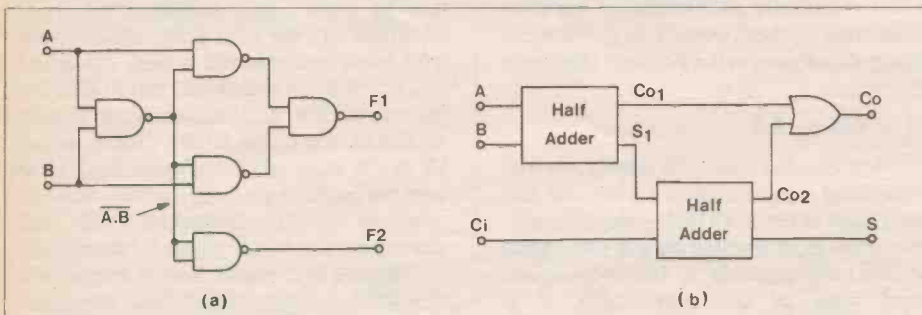
bined with AND is obvious. Notice that it hasn't been necessary to use an actual AND gate. It is only necessary to invert the output of Gate 1 to get it.
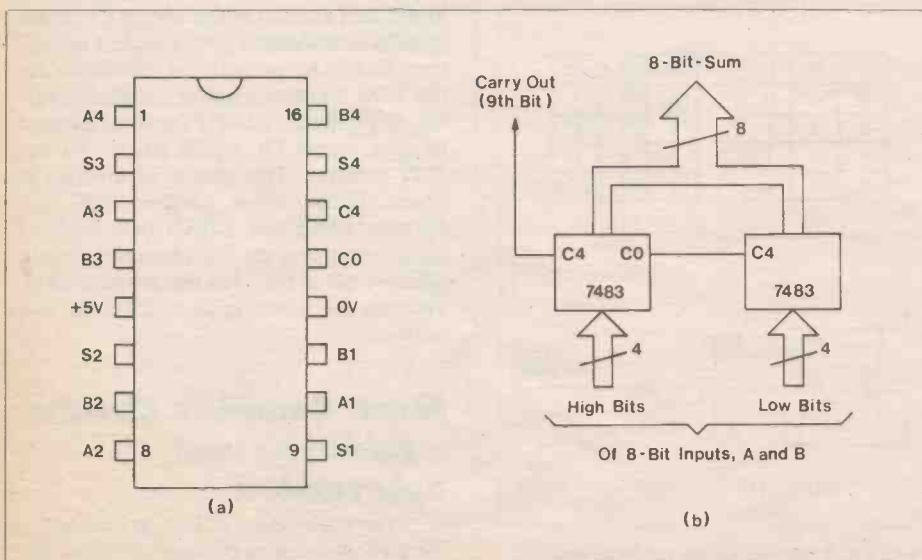
You might think that two halves would make a whole but a full adder actually consists of two half adders PLUS an OR gate! I'm not going to prove this; we (meaning you really!) are supposed to be experimenting, so you can prove it to yourself on the bench. The circuit is shown in Figure 4(b). Each half adder can be made up from a 7400 chip plus one inverter, as in Figure 4(a). This inverter could be a NAND gate with inputs strapped, or taken from a 7404 hex inverter. To complete the full adder is going to need another chip, whichever way you go. Either use one OR gate out of a 7432 chip (easier to wire) or use three NAND gates (wired as already described for the OR function) from a 7400 chip. To prove the operation of either circuit, connect switches to the inputs (thus the full adder will need three) and LEDs to the outputs.

Of course it would be very tedious if the only way to obtain an adder, half or full, was to connect up a number of gates, especially when adding more than two bits together, as would usually be the case. Fortunately, this work has been done for us and this is where MSI comes in. MSI? This stands for Medium Scale Integration and is a level of integration in ICs that produces a range of moderately complex, and extremely useful, circuit functions.

The TTL four-bit full adder 7483 is shown in pin-out form in Figure 5(a). The two numbers are A and B, the order of columns, from most significant to least significant, being A4 A3 A2 A1 : B4 B3 B2 B1. The sum of each column is, respectively, S4 S3 S2 S1. The terminal C4 is the carry out in the event that the total sum exceeds the maximum for four bits, namely 1111 (binary) = 15 (denary). So if one performs the addition 1000 + 1000 (8 + 8 = 16), a carry will result since the answer is 10000. This carry appears at pin C4.

```
  1000
+ 1000
 10000
   ↑
```
Carry out (C4)

There is another pin marked C0. This is used when two 7483s are cascaded in order to perform an 8-bit sum; otherwise it should be connected to 0V. All that one has to do is connect C4 of the 'low order four bits' to C0 of the 'high order four bits'. The addition of two 8-bit numbers in this way is shown in Figure 5(b). One of the 7483s adds the lower four bits of each input number, A and B; the higher four bits are handled by the other 7483. The two full adders are linked by the 'carry out' from the low bits addition. The two four-bit sums 'run alongside each other' to give an 8-bit parallel output. A carry can occur if the sum of the two inputs A and B exceeds the capacity of eight bits; a final carry out is therefore provided. This is known as

Figure 4. (a) A NAND half adder circuit. (b) A full adder constructed from two half adders plus an OR gate.

Figure 5. (a) Pin out of 7483 four bit full adder. (b) Connecting two 7483s to add eight bit numbers.

'parallel addition', since all bits are added at once. Note the convention for the number of wires on each 'bus', a slash through it with the number of wires written alongside.

Decoders

In general terms a decoder is a logic circuit that converts one code to another. An example of this is the conversion of a BCD number (Binary Coded Decimal) into seven segment code to drive a seven segment display. Another conversion that is perhaps less obvious is when address lines in a computer are decoded in order to access a certain area of memory. The decoder looks at some of the address lines and works out which of 'n' memory chips is the one required. Using logic in this way is quite straightforward.

Suppose, as in Figure 6(a), there are four memory chips. Any one of these will be selected if the pin marked CE (Chip Enable) is taken low. What is needed is a logic circuit with four outputs, one to drive each of the CE pins. Only one output is allowed to go low at any instant, otherwise more than one memory chip will be selected. The question is, what are the inputs to this circuit? The answer is, as many inputs as will give a number of combinations equal to the number of outputs required.

The truth table of Figure 6(b) describes the circuit. The rule for this was given in Part One but is repeated here. The number of combinations equals 2^n where 'n' equals the number of inputs. Thus, we have $2^n = 4$, from which n = 2. This example assumes that address line A10 and A11 have been used.

This type of decoder is known as a '2 to 4 line decoder' or, alternatively, as a '1 of 4 decoder'. It is quite easy to implement, its circuit being shown in Figure 7. It uses four 3-input NAND gates and three inverters, including the one required for its own CE input. It is worth noting that this circuit diagram includes a convention that is sometimes found and may be confusing at first sight. The inverter for CE has its inversion 'bubble' at the input instead of the usual position at the output. However, it in no way differs from the other inverters. It is drawn in this way to indicate that its 'input must be low to produce a logic 1 output'. Thus it emphasises that the logic level at this input for normal operation is a logic low. This bubble is commonly shown at the actual chip pins in circuit drawings. It applies to a variety of logic chips, as well as flip-flops, memories and other microprocessor oriented chips.

It is recommended that you wire up this circuit as good experience in handling and investigating logic circuits. You will need two 7410s (triple 3-input NAND gates) and a 7404 (hex inverter). The pin-out for a 7410 is shown in Figure 8, where will also be found the pin-out for the 74LS139. The latter is a chip which houses two of the types of decoder just descri-

bed. So, if you don't feel like wiring up the circuit of Figure 7 you can pop a 74LS139 into your breadboard and check that out instead.

To test the above circuit, three input switches and four LED indicators will be needed (you can use your logic probe for the latter if you wish). You should note that, if the CE input is held high, the other two inputs will have no effect; in fact all four outputs will be high irrespective of the values of these inputs.

Naturally, there has to be provision for decoding a larger number of memory chips than four. Other decoders exist such as the '3 to 8 line decoder' and the '4 to 16 line decoder'.

BCD to Seven Segment Decoders

Another quite different type of decoder worth knowing something about is used to provide the correct codes for driving seven segment displays from BCD inputs. A BCD code is a 4-bit code that encodes the denary numbers 0 to 9 with the equivalent groups 0000 to 1001, the remaining 4-bit groups 1010 to 1111 being invalid. The actual seven segment codes required depend upon whether the particular display is 'common-cathode' or 'common-anode', one set of codes being the exact inverse of the other.

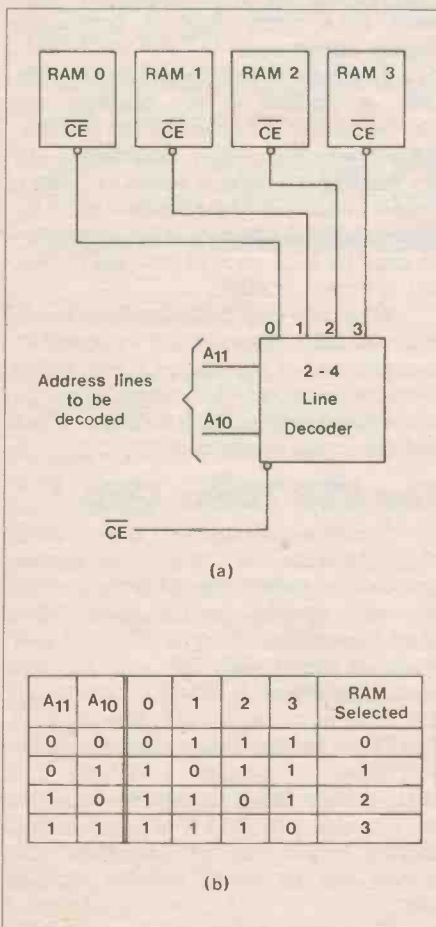In a common cathode display the cathodes of all segments are strapped

Figure 6. (a) Using a 2 - 4 line decoder to select '1 of 4' RAM chips. (b) Truth table for 2 - 4 decoder with CE taken 'low'.

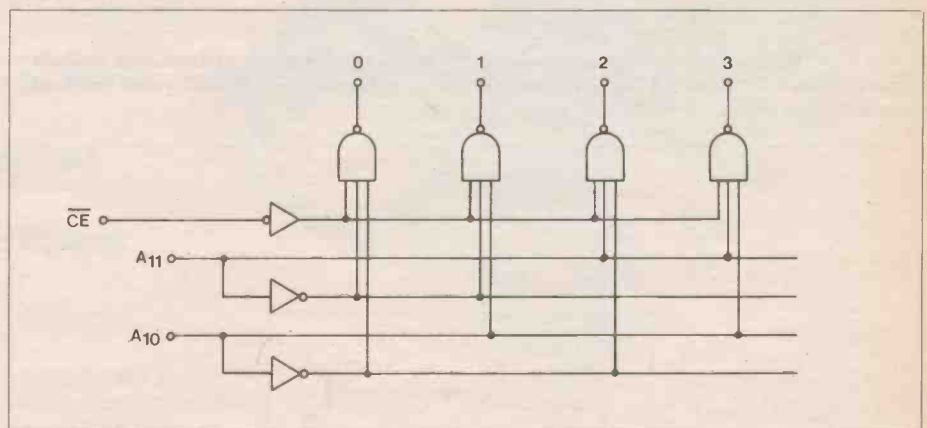| A11	A10	0	1	2	3	RAM Selected
0	0	0	1	1	1	0
0	1	1	0	1	1	1
1	0	1	1	0	1	2
1	1	1	1	1	0	3

(b)

Figure 7. Logic diagram for 2 - 4 line decoder.
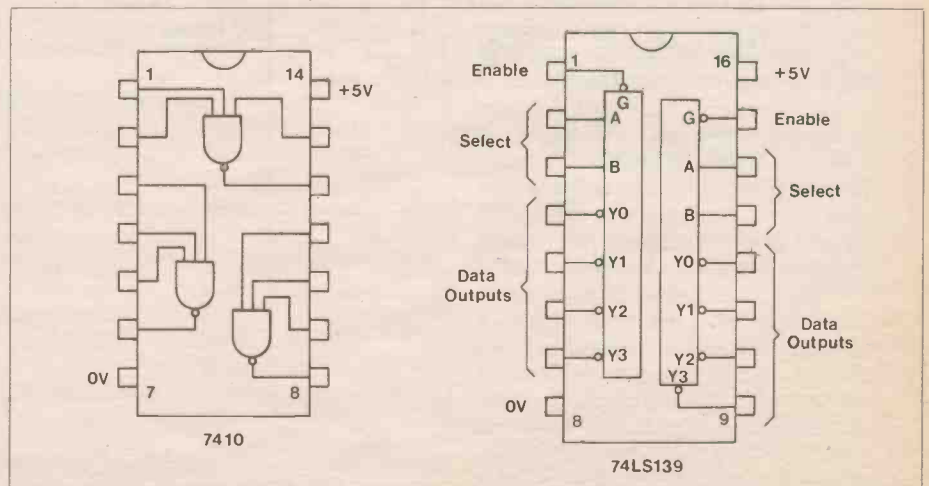
Figure 8. Pin outs for 7410 and 74LS139.

Denary	BCD	COMMON-ANODE							COMMON-CATHODE						
		a	b	c	d	e	f	g	a	b	c	d	e	f	g
0	0000	0	0	0	0	0	0	1	1	1	1	1	1	1	0
1	0001	1	0	0	1	1	1	1	0	1	1	0	0	0	0
2	0010	0	0	1	0	0	1	0	1	1	0	1	1	0	1
3	0011	0	0	0	0	1	1	0	1	1	1	1	0	0	1
4	0100	1	0	0	1	1	0	0	0	1	1	0	0	1	1
5	0101	0	1	0	0	1	0	0	1	0	1	1	0	1	1
6	0110	0	1	0	0	0	0	0	1	0	1	1	1	1	1
7	0111	0	0	0	1	1	1	1	1	1	1	0	0	0	0
8	1000	0	0	0	0	0	0	0	1	1	1	1	1	1	1
9	1001	0	0	0	1	1	0	0	1	1	1	0	0	1	1

(a)
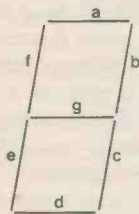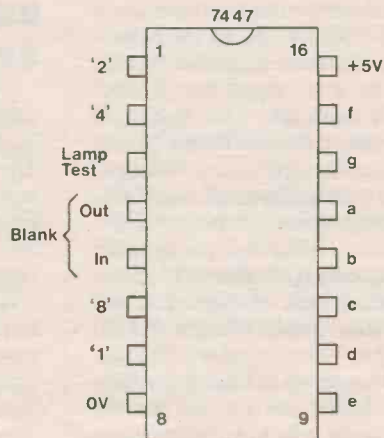
Figure 9. (a) Table of logic levels required to drive both common anode and common cathode displays from BCD input. (b) Segment identification. (c) Pin out for 7447 BCD seven segment decoder/driver (common anode displays).
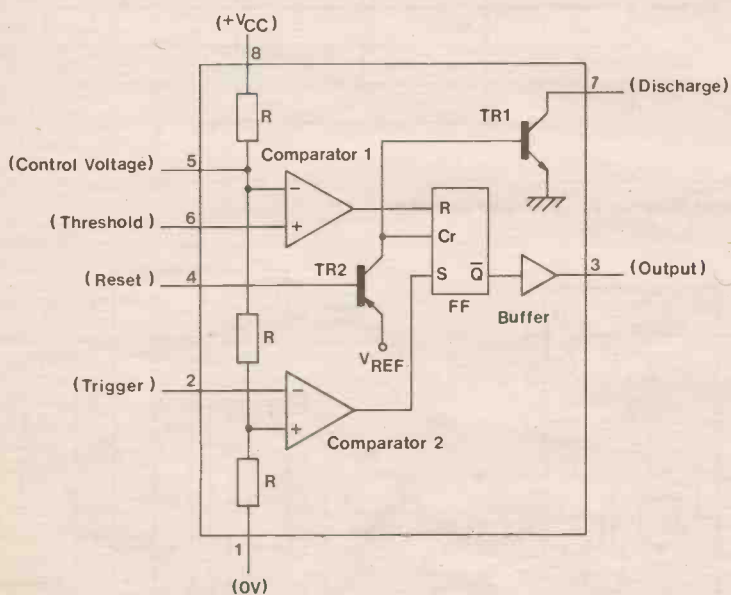

Figure 10. Pin out and internal details of 555 timer chip.

together and taken to 0V; the anodes are energised by external drive circuits to illuminate the required segments. In the common anode type of display it is the anodes that are strapped (to +5V) and the cathodes that are driven. Thus, in common cathode displays, a segment must be taken to logic 1 to energise it and in common anode it has to be taken to logic 0.

Figure 9 shows the identification of segments, the tables for driving both types of display and the pin-out for the 7447 BCD to seven segment decoder driver. The pins for driving the segments a to g and the 8421 BCD input are readily identified but some other pins may need some explanation.

For example, the terminal marked LAMP TEST must usually be taken to +5V; when it is taken to logic 0 all segments are driven at once, hence the name. Two terminals are marked BLANK, IN and OUT. These are provided when it is required to blank 'leading zeros' in a display. For example, if a 4-digit voltmeter is to display 2.3V; what is not wanted is 002.3 but 2.3, the leading zeros being suppressed or blanked. A low on the blanking input will extinguish the zero character; when this happens a low also appears on blanking out, which can be sent to the next most significant display to blank that as well. If a logic low is deliberately applied to the blanking OUTPUT the display is extinguished for ALL characters. This leads to a crafty way of controlling display brightness.

If a squarewave, of equal mark/space ratio, is applied to the blanking out pin, the display will be off for half the time, thus reducing its brightness. If the mark/space ratio is made variable a wide range of brightness can be obtained. The frequency of the squarewave must be high enough to avoid flicker, say in excess of 50Hz.

When this chip is used to drive seven segment LED displays (as opposed to incandescent or fluorescent types) series resistors of about 330 ohms must be connected between each segment output and the actual segment of the display.

The 555 Timer Chip

This is loosely referred to as a 'timer' chip because it performs certain time-related events. One of these is to act as an astable multivibrator, that is as a generator of squarewaves. Other ways of using the 555 will be met during the series. It is worth introducing the 555 now as it will be used in Part Three for generating clock pulses for sequential circuits. Also, if anyone feels like trying out the variable mark/space method of controlling display brightness just described, this device will be found suitable for the job.

The pin-out and some internal details are shown in Figure 10. The essential functions provided by the chip can be described by taking each pin in turn.

Trigger Terminal (Pin 2)

When a negative-going trigger pulse is applied to this input, at some point it will pass through the reference voltage $V_{CC}/3$, causing the output of Comparator 2 to SET the flip-flop; the output of the 555 then goes HIGH.

Output Terminal (Pin 3)

The output can be used to 'sink' (logic LOW output) or 'source' (logic HIGH output) a current of up to 200mA. For sinking the load is connected between pin 3 and $+V_{CC}$, while for sourcing the load is connected between pin 3 and 0V.

Reset Terminal (Pin 4)

This permits the 555 to be disabled by taking this pin low. In normal operation it should be connected to $+V_{CC}$. In the disabled state the signals at the trigger input are over-ridden.

Control Voltage Terminal (Pin 5)

It is possible to connect a separate source of voltage to this terminal to change the threshold voltages. Otherwise it is normally connected to pin 1 (0V) via a 10nF capacitor.

Threshold Terminal (Pin 6)

If a positive-going voltage (e.g. the rising voltage across a charging capacitor) is applied to this pin, at some point it will pass through the reference voltage 2/3 V_{CC}, causing the output of Comparator 1 to reset the flip-flop. The 555 output then goes LOW.

Discharge Terminal (Pin 7)

At the end of the timed period the transistor connected to this terminal switches into the conducting state. This discharges the timing capacitor prior to another timing cycle commencing.

Using the 555 as a Variable Mark/Space Generator

Figure 11 shows the 555 connected as an astable multivibrator, that is as a circuit that generates continuous square waves. For a fixed mark/space ratio, it is usual to wire a resistor between pin 7 and $+V_{CC}$, and another between pin 7 and pins 2, 6 (strapped). The relative values of these determine the mark/space ratio and their total value together with the capacitor between pins 2, 6 and 0V determines the frequency. In the circuit shown the frequency should be about 100Hz with a mark/space variation between 1:5 5:1.
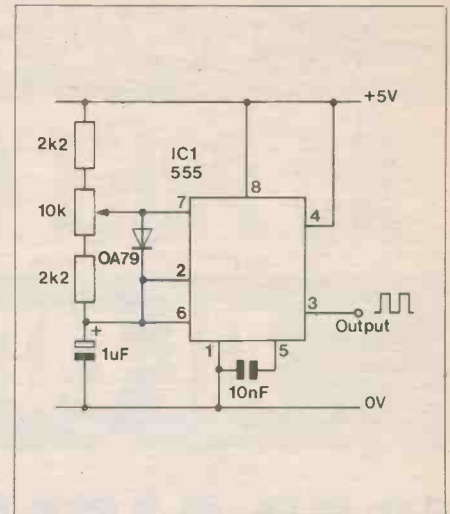

Figure 11. The 555 used as a variable mark/space ratio pulse generator.

Conclusion

There should be enough 'meat' in this article to give you something to think about and to experiment with between now and the next issue. The diagrams should help with the practical side. Next time we shall be looking at 'sequential' circuits, that is those that use the ubiquitous flip-flops to form a variety of counters and registers.

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4.	(3)	◆ 150W Mosfet Amplifier	LW51F	£19.95	Best of E&MM
5.	(2)	◆ U/Sonic Car Alarm	LK75S	£17.95	15 (XA15R)
6.	(4)	◆ Partylite	LW93B	£9.95	Best of E&MM
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13.	(5)	◆ PWM Motor Driver	LK54J	£9.95	12 (XA12N)
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The price changes shown in this list are valid from 15th February 1988 to 14th May 1988. Prices charged will be those ruling on the day of despatch.

For further details please see 'Prices' on catalogue page 20.

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Although prices have been held some items have been discontinued since the publication of the 1988 catalogue and these are listed below.
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‡	An additional £5.50 carriage charge must be added.
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★	See 'Amendments To Catalogue'. Note that not all items that require amendments are shown in this list.

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AUDIO, VIDEO & COMPUTERS		**Page 90** WP13P Easy Prog Atari Micr ... DIS		**KNOBS**		**PCB EQUIPMENT**		**Page 331** BL34M AD162 ... DIS	
Page 55 CT33L Scotch XS MIV-C90 ... DIS CT31J TDK HXS-90 ... DIS		**COMMUNICATIONS**		**Page 195** HB40T Knob K45 ... DIS		RK40T Film FPF012 ... DIS YJ43W Film Sheet Large ... DIS RK42V PCB006 Pack ... DIS YJ40T Developer FDB ... DIS		**SPEAKERS & SOUNDERS**	
Page 61 YK97F Minibox 10 ... DIS		**Page 128** YM95D Traveler Clock Radio ... DIS						**Page 425** FQ09K Nameplate Bell Push ... DIS	
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Page 79 WP41U Proj in Microelect ... TEMP		**Page 193** HK93B 1MA-100-10 DC Probe ... DIS		**Page 224** HB09K LDR RPY58A ... DIS		**Page 324** BL34M AD162 ... DIS		**Page 436** YP72P Extendispeakers ... DIS	

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LM40T 12V Rapid Charger Kit Price **£19.95**
LM41U Disco Partylite Kit Price **£17.95**

AMENDMENTS TO 1988 CATALOGUE

Cordless Phone (Page 130). The range of our cordless phone, YM81C, is 100m not 200m.
Light Fittings (Page 170). Lampholder FQ02C and batten holder LB63T are approved to BS 5042, BS52 is now withdrawn.
Guitar Amp (Page 205). A strap is not provided with Guitar Amp YP49D.
Gold Contact Wire (Page 230). Due to a change by the supplier, this product is now supplied in 1 yard lengths, not 1 metre lengths.
Ultrasonic Intruder Detector (Page 245). The pcb's for this kit are: GB00A (Ultrasonic Xvr PCB) Price £1.95 and GB01B (Ultrasonic IF PCB) Price £1.95.
Spectrum RS232 Interface (Page 294). The pictures for this and the VIC 20 Talkback have been transposed.

Chassis 1¼in. Fuseholder (Page 300). A new style is now being supplied. Dimensions are 53mm long x 18mm high x 12mm wide, and a solder or screw connection is available.
R-C Network (Page 301). Due to a change by the supplier, the contact suppressor is now made up from a 120Ω resistor (±30%) and a 0.1μF (±20%) capacitor.
Door Guard Battery (Page 307). The order code for the recommended battery for use by 'Door Guard' should be FK67X and not FK64U.
2764 EPROM (Page 412). The Vpp of this device is +12.5V not +21V.
Fan (Page 423). Standard fan WY08J's cable has no earth connection and should only be used inside equipment that is suitably insulated or earthed.

CORRIGENDA

Vol. 3 No. 9. Oric Talkback. L1 has been omitted from the Parts List. It is a 100μH choke, code WH41U.

Vol. 5 No. 20. I/R Proximity Detector. The second paragraph under the heading 'Pyroelectrics', the first sentence mentioning the gate resistance Rg is shown in Figure 4 not 2.

Vol. 7 No. 25. Bob's Mini Circuits. In the Parts List for the Pulsed Speed Controller, the code for IC2, the CA3140E, should be QH29G. Also in the Parts List for the Train Controller, the code for PB1, 2 and 3 should be FH59P.

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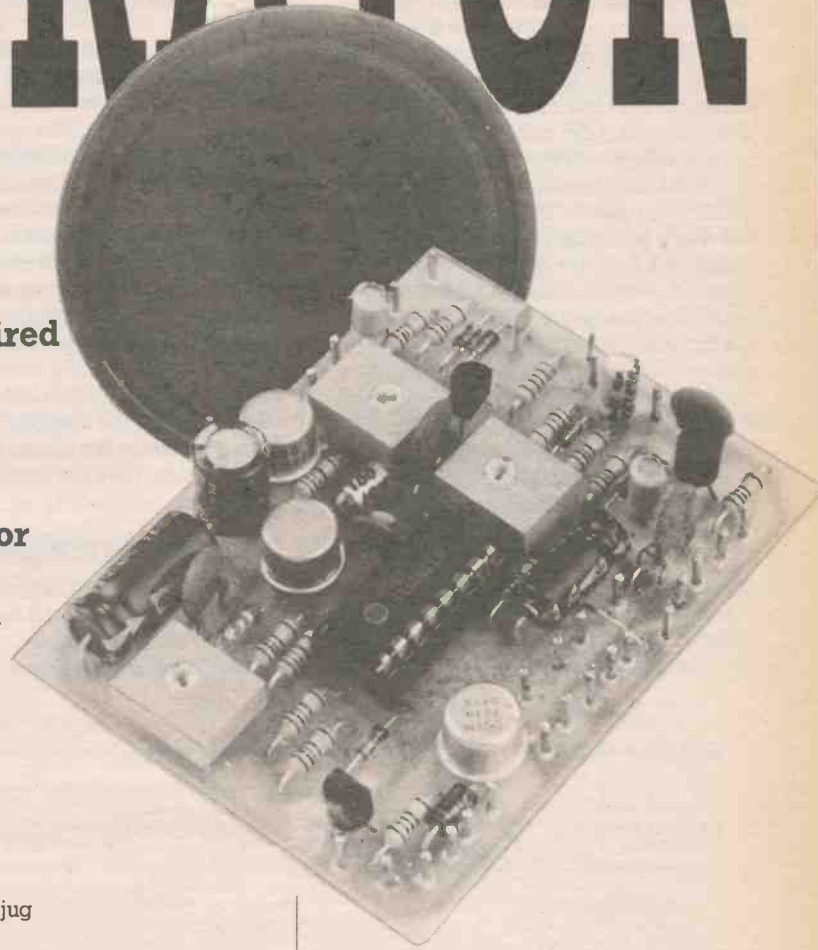
by Chris Barlow

Specification of Prototype

Integrated circuit	: UM34811A low-power CMOS LSI
Operating voltage	: 1.5V to 4.5V
Supply current	: 150mA at 4.5V
Stand-by supply current	: 2.5µA at 4.5V
Transistor switched supply output	: 1.5V to 12V
Output current	: 200mA at 12V maximum
Memory	: masked Read Only Memory (ROM) 512 words by 7 bits
Number of tunes	: 16

1: Twinkle, twinkle, little star
2: Cuckoo waltz (1)
3: Eency Weency spider
4: Lullaby
5: Santa lucia
6: Oh my darling clementine
7: Are you sleeping
8: Rock-a-bye baby
9: London bridge is falling down
10: Little brown jug
11: Butterfly
12: Long long ago
13: Cuckoo waltz (2)
14: Mary had a little lamb
15: The train is running fast
16: Dream of home and mother

Master Oscillator tuning range	: 50kHz to 175kHz
Tone generator	: logic controlled divider
Amplifier output	: 8Ω loudspeaker
External amplifier output	: 1V square wave at 10kΩ
Printed circuit board (PCB)	: single-sided fibre glass
PCB dimensions	: 70mm x 68mm

Introduction

The UM34811A is a low-cost, low-power CMOS LSI chip designed for use in door bell and music box applications. Inside the chip is a pre-programmed memory containing 512 notes and is capable of generating 16 different tunes. To trigger the unit two pulse generator circuits have been incorporated. A bell push, mercury tilt, pressure mat or microswitch can be used to start the tune playing. The comprehensive control facilities enable the playing of all tunes repeatedly or stopping at the end of each tune. Three preset resistors on the PCB control the volume, pitch and envelope. An on-board amplifier capable of driving a small loudspeaker is included in the design. However, provision has been made for an external amplifier if louder volumes are required. In the following article the operation of the UM34811A chip and the rest of the circuit will be described. In addition, the PCB assembly and testing procedure should ensure the successful completion of the project.

How the chip works

The UM34811A multi-tune chip is a compact module containing a logic controlled note generator, see Figure 1. All this hi-tech circuitry is contained in a small 16 pin plastic package, see Figure 2.

The output of the oscillator circuit is used as a clock by the rhythm generator and as the master frequency for the tone generator. To produce the correct tonal range and tempo the oscillator should run at approximately 100kHz. This frequency is set by an external resistor on pin 14 and a capacitor on pin 13, see Figure 3. An additional resistor in series with the inverter input on pin 15 will reduce frequency drift if a variation in supply voltage should occur. When in the stand-by condition the operation of the oscillator is inhibited. This will happen at the end of the tune if the auto-stop mode is selected, or if the chip enable pin (CE pin 2) is connected to ground ($-V$).

The tone generator is a programmed divider, its range of scales is from 'C4' to 'C6' and is controlled by some of the output data from the melody ROM. The remaining bits of data are used to control the rhythm generator. Part of this circuit is a programmed divider similar to the tone generator. In addition the rhythm generator receives control signals from the timbre and tempo select circuits. This results in two output signals from the rhythm unit. One is used by the timbre generator and the other by the program counter in the melody ROM circuit.

The melody ROM stores the data patterns of the 16 tunes. It is the combined function of the control, address selector and program counter to select a block of memory and step through it. The control circuit has four inputs used to select the mode of operation. The chip enable (CE) pin, if connected to the positive supply, will allow the chip to run. If connected to the negative supply the chip is put into its stand-by mode. The auto-stop (AS) pin, if connected to the positive supply, will repeat the tune. If connected to the negative supply the tune will stop automatically at the end of its memory block. The long play (LP) pin, if connected to the positive supply, will only play one tune. If connected to the negative supply all the tunes will be played. Finally, if the tune select (SL) pin has a positive going pulse applied to it the tune will change to the next memory block.

The modulator stage acts as a sound gate, turning on and off under the command of the timbre generator. The duration of the timbre signal sets the length of each note to be played. The on/off transition time, or envelope is set by an external resistor and capacitor on the ENV pin. Proper selection of charge and discharge times will produce envelopes from piano to organ type sounds. The output from the modulator on the MTO pin can not drive a loudspeaker directly. A pre-amplifier and push pull driver stage have been included inside the chip. This reduces the number of external components in the power amplifier required to drive the loudspeaker.

Circuit description

The positive DC supply entering the unit is applied to P3 and the negative to P1. Any electrical noise on the supply rail is suppressed by the decoupling capacitors, C3 and C5. Transistors TR5 and TR6 provide the switched supply output on P6, P7. This circuit is controlled by the output flag on pin 1 of IC1, which is low when a tune is being played. When this occurs TR5 turns on and a bias voltage is fed via R16 to the base of TR6, which acts as an open collector switch. The voltage source can be either the main 4.5V supply, or a secondary supply of between 1.5V to 12V. If an inductive load such as a small motor, or relay coil is used, the high reverse voltage spikes that are generated could destroy TR6. To prevent this a high voltage diode, D6 is used in the collector circuit.

The frequency of the oscillator inside IC1 is set by the value of C8, R8 and RV3. Resistor R9 is connected to the inverting input of the oscillator to increase frequency stability. So the unit can be triggered from a number of different switches, two pulse generator circuits have been included in the design. The output of TR1 is normally low, but when S2 is pressed it pulses high for approximately 10ms. When S1 is pressed the normally high output of TR2 goes low for approximately 2ms.

The modulator envelope timing is set by the value of C6, a $4.7\mu F$ capacitor, and resistors R7 and RV1. The modulator output signal on pin 9 is then connected to the volume control RV2 and fed via C9, R10 to the pre-amplifier input. The push pull drive output on pins 10 and 11 of IC1 are directly connected to the bases of TR3, TR4. This NPN, PNP transistor configuration is used to provide sufficient output for a small loudspeaker. There is a DC bias at the junction of the collectors where the speaker is to be connected.

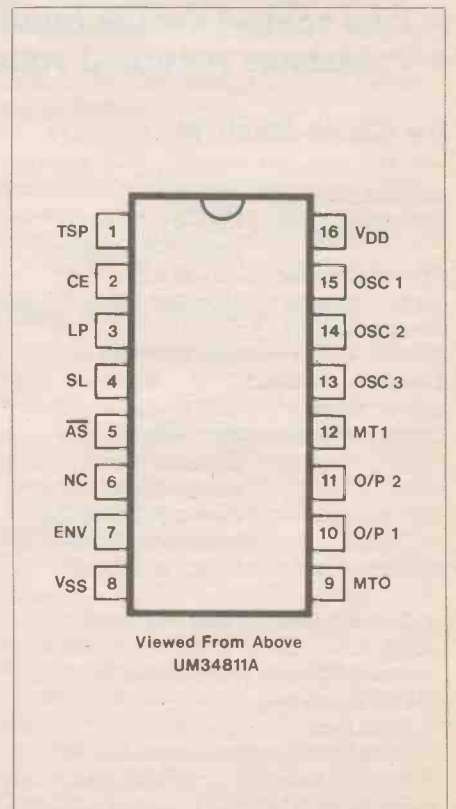**Figure 1. Block diagram.**

Viewed From Above
UM34811A
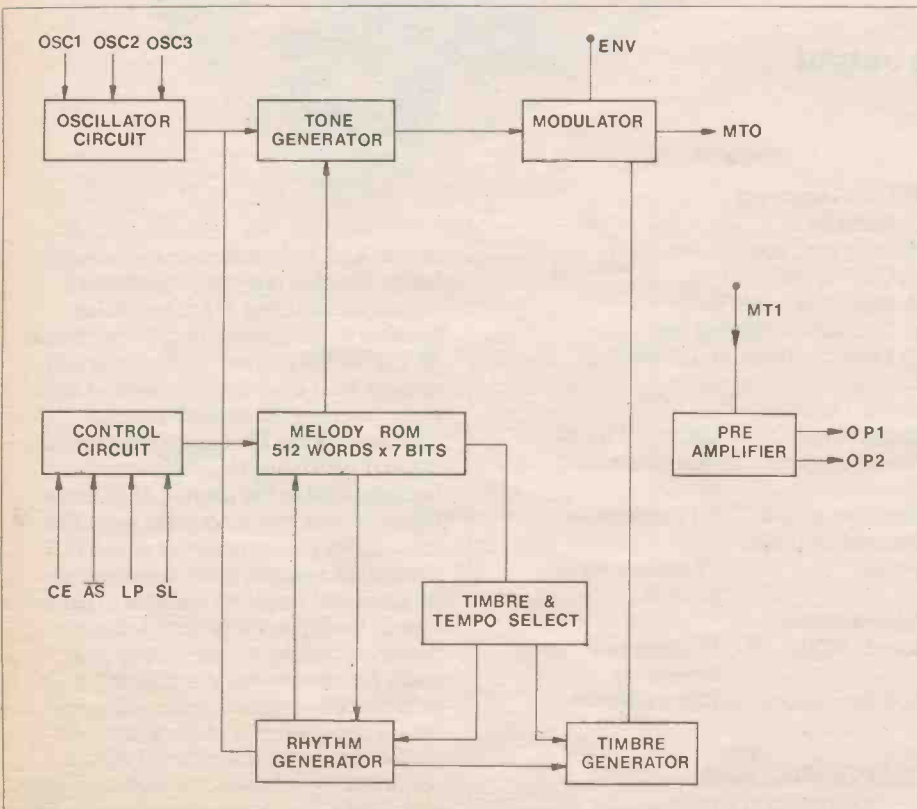
Figure 2. Pin configuration.

This voltage is fed back via R12 to pin 12 of IC1, ensuring that the operation of the pre-amp and driver stages are properly set. However, to prevent any DC current flow in the speaker, a capacitor, C13 is used to couple the output. The three capacitors, C10, C11 and C12 are used to reduce the level of any high frequency clock signals in the output stage. An external amplifier output is provided by taking the signal at C13 through C14, a 470nF capacitor, to R11 and R15. C15, a 10nF capacitor, then removes any high frequency signals and D4, D5 limit the output to approximately one volt peak to peak. This square wave signal on P26 can now be fed to an additional amplifier if higher sound levels are required.

PCB assembly

The PCB is a single-sided fibre glass type, chosen for maximum reliability and stability. It has a printed legend to assist you in correctly positioning each item, see Figure 4. However, removal of a misplaced component is quite difficult so please double-check each component type, value and its polarity where appropriate, before soldering! The sequence in which the components are fitted is not critical. However, it is easier to start with the smaller components. When installing the electrolytic capacitors the positive lead must go to the plus sign (+) on the legend. On some
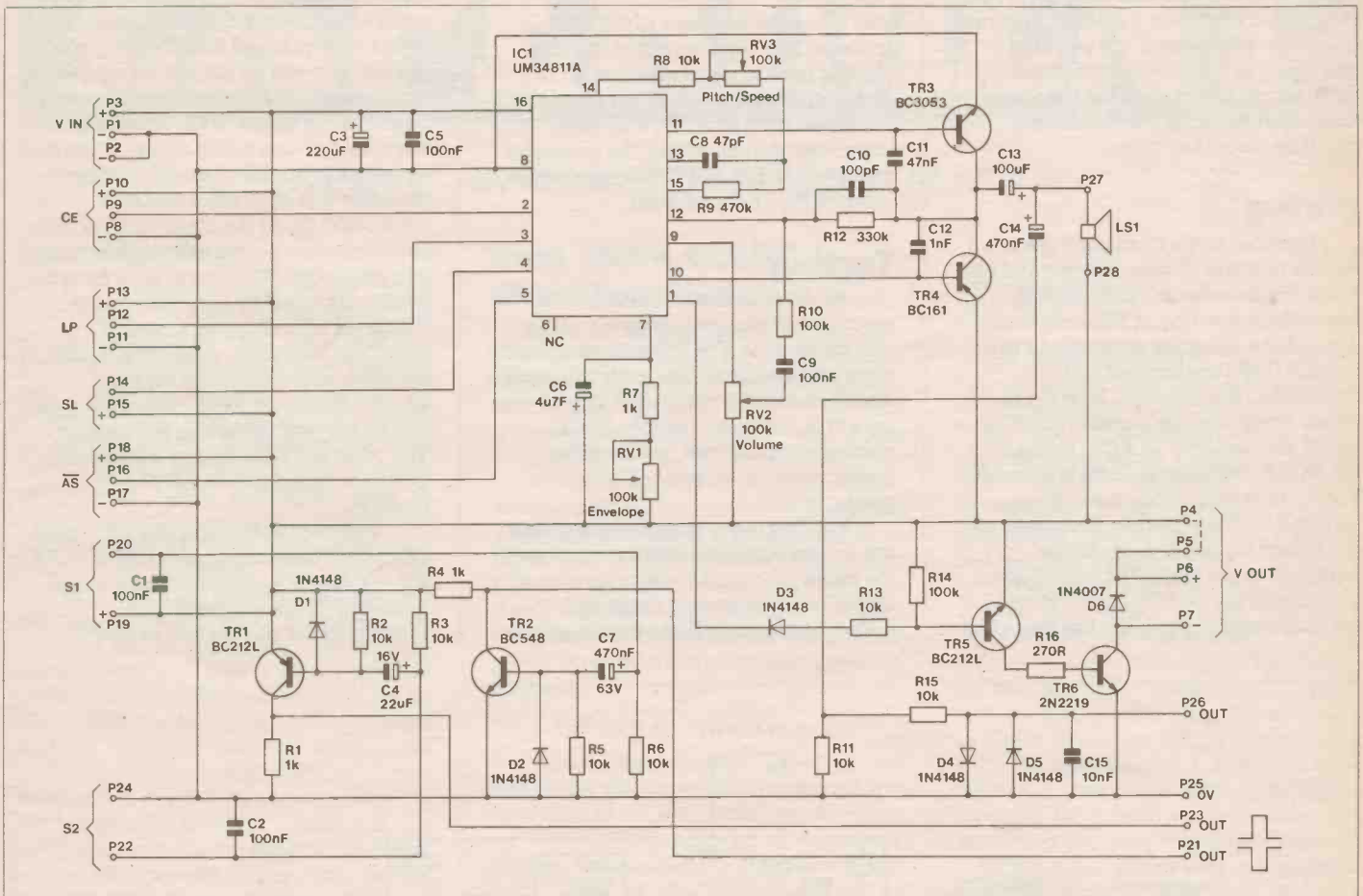
Figure 3. Circuit.
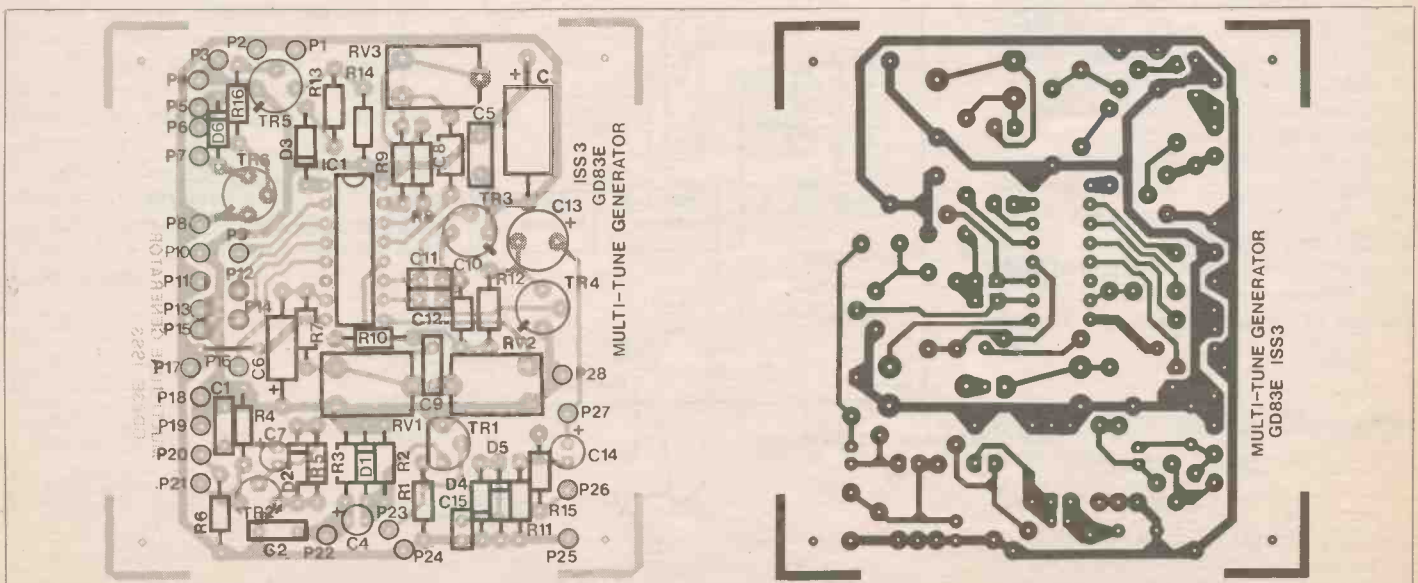
Figure 4. Track and layout of the PCB.

capacitors the polarity is designated by a negative symbol (−), in which case the lead nearest this symbol goes away from the positive sign on the legend. When fitting the semiconductors you must carefully match the case to the outline shown. The diodes all have a band at one end to identify the cathode connection. Be sure to position them accordingly. For further information on component identification and soldering techniques please refer to the Constructors' Guide included in the kit. This completes the assembly of the PCB and you should now check your work very carefully, ensuring that all the solder joints are sound. It is also important that the bottom, track side of the circuit board does not have any trimmed component leads standing proud by more than 2mm.

Wiring

Included in the kit of parts are two lengths of hook-up wire, one red and one black. Position the unit and carefully follow the test wiring as shown in Figure 5. Install the five links, numbered 2 to 6 ensuring that they connect to the appropriate pin numbers. Next fit the power supply cables, positive (RED) to pin P3 and negative (BLACK) to pin P1. DO NOT fit the battery until it is called for during the testing procedure. When handling the loudspeaker, be careful not to damage the paper cone, or the terminals on the back. The loudspeaker is connected to the PCB at pins P27 and P28, disregard any polarity markings that
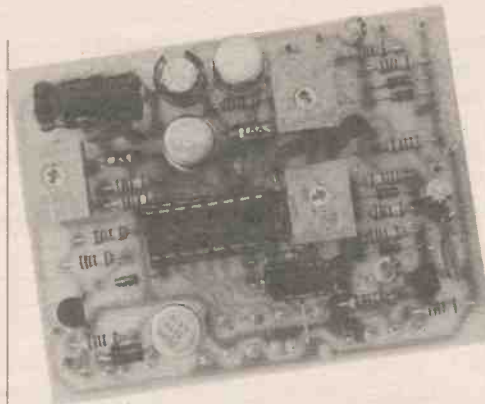
may be on the terminals of the loudspeaker. Next install the two non-locking push to make switches, S1 is connected to pins P19, P20 and switch S2 is connected to pins P22, P24. This completes the test wiring, the screened cable at P25, P26 and the voltage output wires at P6, P7 are optional.

Testing

All the tests can be made with an electronic digital, or analogue moving coil, multimeter. The following test results were obtained from the prototype using a digital multimeter and a type 126, 4.5 volt battery as the power supply. Before commencing the tests, set the three preset resistors to their half way positions.

The first test is to ensure that there are no short circuits before you connect the battery. Set your multimeter to read OHMS on its resistance range and connect the probes to the supply cables.

The reading obtained with the probes either way round should be greater than 100Ω. Some multimeters will provide sufficient current to power the multi-tune generator during this test.

Next monitor the supply current, set your meter to read DC mA and place it in the positive line to the PCB. When the battery is connected, the unit may start to play a tune and a current reading of approximately 130mA should be seen. After the tune stops the current reading should eventually drop to approximately $2.5\mu A$. If switch S1 is then pressed the same tune should be played. However, if switch S2 is pressed then the next tune in the memory will be played. Using a small screwdriver, or flat blade trimming tool, adjust RV1, RV2 and RV3, observing their effect on the tune being played. With the envelope control RV1 set fully clockwise the notes will be of short duration (STACCATO). At the other extreme, fully anticlockwise, the notes will tend to run into each other. The sound level from the loudspeaker will be at minimum when RV2 is set fully anticlockwise and maximum when fully clockwise. Finally, if the pitch/speed control is set fully anticlockwise, the frequency of the notes will be low and the tempo will be slow. The other extreme, fully clockwise, the notes are high pitched and played rapidly.

Remove the meter and set it to read DC volts. Place its negative probe on P7, the −V output and connect its positive probe to P6, the +V output pin. Reconnect the battery and press S1,

Figure 5. Test Wiring.

[Links table from figure]

Links

LK 2   P4 − P5
LK 3   P12 − P13
LK 4   P16 − P17
LK 5   P9 − P21
LK 6   P14 − P23
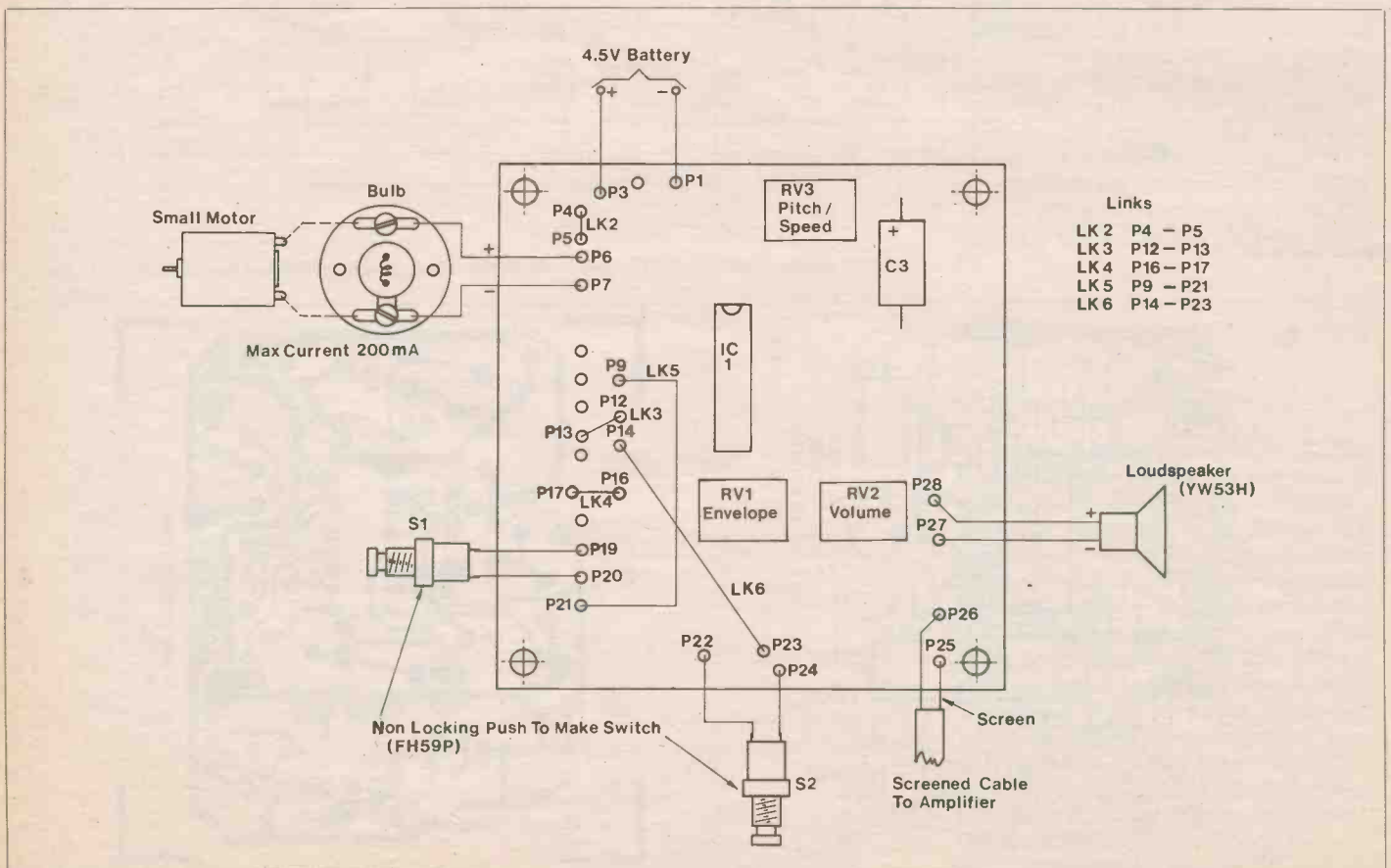
observe the voltage reading which should be very close to the batteries potential. When the tune stops this reading should fall to approximately +0.6V, with no load connected. To test this output under load conditions, a low voltage filament bulb, or small motor is temporarily placed across P6 and P7. When a 6V 100mA bulb is used, a current reading of approximately 80mA should be seen and the output voltage should remain close to the battery potential. At the end of the tune the bulb should go out and the voltage reading will drop to 0V. If using a small motor ensure that it does not draw more than 200mA, otherwise damage may occur in the transistor switching stage. The motor used on the prototype was the miniature YG12N and with no mechanical load on the shaft it drew approximately 80mA. Remove your meter and temporary load from P6 and P7. This completes the testing of the multi-tune generator and it is now ready for use.

Using the project

The type of battery you use will be determined by the available space in your particular application. You can use one 4.5 volt pack, such as the EVER READY 126, 1289, or AD28. Alternatively, three 1.5 volt C or D type cells can be used in series to produce a 4.5V supply. If using a battery eliminator ensure that it is a 4.5V REGULATED type, capable of supplying currents up to 350mA. The transistor switched voltage output on P6 and P7 can be fed from a second battery of between 1.5V to 12V, see Figure 6.

NOTE LINK 2 MUST BE REMOVED. Using this dual voltage system will allow you to use 12 volt operated bulbs, motors, or relays, but remember not to exceed the 200mA maximum power load.

The switches used to trigger the unit can vary from a simple bell push to a mercury tilt switch or pressure mat. It can be connected to the unit using up to 100 metres of inexpensive ZIP wire. The multi-tune generator play option can be changed by altering the links on the PCB, see Figure 7. A high efficiency horn speaker (XQ73Q) will give an increase in the sound level from the basic unit. However, if greater volumes are required then a power amplifier can be connected to the signal output pins, see Figure 5.
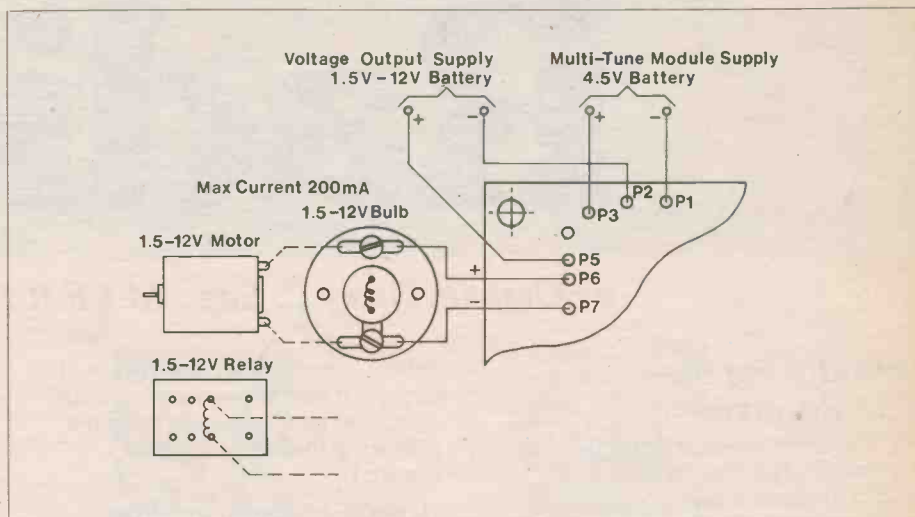
Figure 6. Dual voltage system.

Play Option	CE Link	SL Link	LP Link	AS Link	Switch
Play present tune then stop.	P9 - P21	P14 - P23	P12 - P13	P16 - P17	S1
Play next tune then stop.	P9 - P21	P14 - P23	P12 - P13	P16 - P17	S2
Play all tunes then stop.	P9 - P21	P14 - P23	P12 - P11	P16 - P17	S1
Play all tunes continuously.	P9 - P21	P14 - P15	P12 - P11	P16 - P18	+V supply

Figure 7. Play options.

MULTI-TUNE GENERATOR PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,4,7	1k	3	(M1K)
R2,3,5,6,8, 11,13,15	10k	8	(M10K)
R9	470k	1	(M470K)
R10,14	100k	2	(M100K)
R12	330k	1	(M330K)
R16	270Ω	1	(M270R)
RV1,2,3	100k Hor Encl Preset	3	(UH06G)

CAPACITORS

C1,2,5,9	100nF Mini Disc	4	(YR75S)
C3	220µF 10V Axial Electrolytic	1	(FB60Q)
C4	22µF 16V Mini Electrolytic	1	(YY36P)
C6	4u7F 100V Axial Electrolytic	1	(FB18U)
C7,14	470nF 63V Mini Electrolytic	2	(YY30H)
C8	47pF Polystyrene	1	(BX26D)
C10	100pF Polystyrene	1	(BX28F)
C11	47nF Mini Disc	1	(YR74R)
C12	1nF Ceramic	1	(WX68Y)
C13	100µF 25V PC Electrolytic	1	(FF11M)
C15	10nF Ceramic	1	(WX77J)

SEMICONDUCTORS

D1,2,3,4,5	1N4148	5	(QL80B)
D6	1N4007	1	(QL79L)
TR1,5	BC212L	2	(QB60Q)
TR2	BC548	1	(QB73Q)
TR3	2N3053	1	(QR23A)
TR4	BC161	1	(QB49D)
TR6	2N2219	1	(QR11M)
IC1	UM34811A	1	(UJ44X)

MISCELLANEOUS

	Multi-Tune Generator P.C.B	1	(GD83E)
	Veropins 2145	1 Pkt	(FL24B)
	DIL Socket 16 pin	1	(BL19V)
LS1	Miniature Loudspeaker LO-Z 768 8Ω	1	(YW53H)
S1,2	Push Switch	2	(FH59P)
	Hook-Up Wire Red	1 Pkt	(BL07H)
	Hook-Up Wire Black	1 Pkt	(BL00A)

OPTIONAL

	Zip Wire	As Req	(XR39N)
	Horn Speaker	1	(XQ73Q)
	Bell Push	As Req	(FS17T)
	Min Microswitch	As Req	(FP41U)
	Miniature Mercury Tilt Switch	As Req	(FE11M)
	Pressure Mat	As Req	(YB91Y)
	Bulb MES 6V 0.6W	1	(WL78K)
	MES Batten Holder	1	(RX86T)
	Miniature Motor	1	(YG12N)

A complete kit of all parts, excluding Optional items, is available:
Order As LM47B (Multi-Tune Generator Kit) Price £8.95
The following item used in the above kit is also available separately, and is not shown in our 1988 catalogue.
Multi-Tune Generator PCB **Order As GD83E Price £2.50**

Exploring Radio

by Graham Dixey C. Eng., M.I.E.R.E.   Part 2

Introducing the TRF Receiver

The most obvious limitation of the simple crystal set is its lack of output. It needs a very good aerial and earth system in order to get enough signal to drive an earphone of any sort, without any amplification being used. Strange as it may seem, we are now worse off in this way than in earlier days. In the heyday of the crystal set; indeed for several decades afterwards into the 1950s at least, it was quite easy to buy a pair of high impedance moving-coil headphones. These days no one seems to use them, which is a shame, for they were far more sensitive than the modern crystal earpiece, the main merits of the latter being small size and low cost. This means that, for any form of serious listening, amplification at either audio or radio frequencies, or both, will be necessary.

In the 1940s the components available to the radio experimenter were much the same as those that could be had just pre-war. The natural progression was to build a crystal set, then to add a stage of audio amplification, to make a 'one valver', progressing to a 'three valve design' if you felt really ambitious! The latter would usually have the following line-up (shown in Figure 1).

(1) Radio-frequency amplifier
(2) Detector
(3) Audio-frequency amplifier

The detector used would not normally be of the diode type, it being found more advantageous to use one with some gain of its own, such as the 'leaky grid' or 'anode bend' types. For the average experimenter this line-up offered a combination of fair performance, low cost and reasonable ease of setting up (compared with a superhet).

Today the 'Tuned Radio Frequency' (TRF or 'straight') type of receiver still can offer a simple unfussy design, quite suitable for listening on local or regional wavelengths. If only one tuned circuit is used there is actually no alignment to do, except for 'trimming' it to match a calibrated dial, but this is hardly a priority anyway.

Selectivity

This is defined as the ability of the receiver to discriminate between the frequency of the required station and that of stations on frequencies close to it. Figure 2 compares the response of two tuned circuits, one with reasonably high selectivity, the other with low selectivity. Notice that the ratio of 'wanted/unwanted' signal is much greater for circuit (a) than for circuit (b). It will, therefore, give much greater amplification for the former than for the latter. If several tuned circuits are used in a receiver the selectivity improves even further. In fact the more tuned ciruits, the better the receiver's ability to reject unwanted stations. Interference caused by stations on adjacent frequencies is known, logically enough, as 'adjacent channel interference'.

It would seem that all that is necessary to get good selectivity is to use several stages of amplification with tuned inputs and outputs. However, this causes further problems because the tuning of all the circuits has to vary in step, not nearly as easy as it seems. It is also possible to get the situation where the gain is relatively low at one end of the waveband and so high at the other that the receiver becomes unstable.
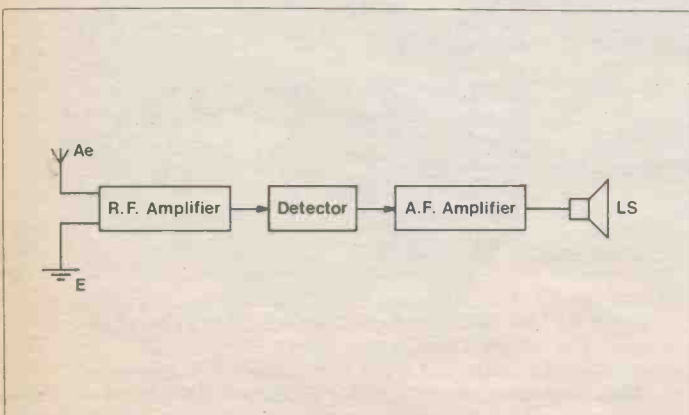
Figure 1. Typical line-up for T.R.F. or 'Straight' receiver.
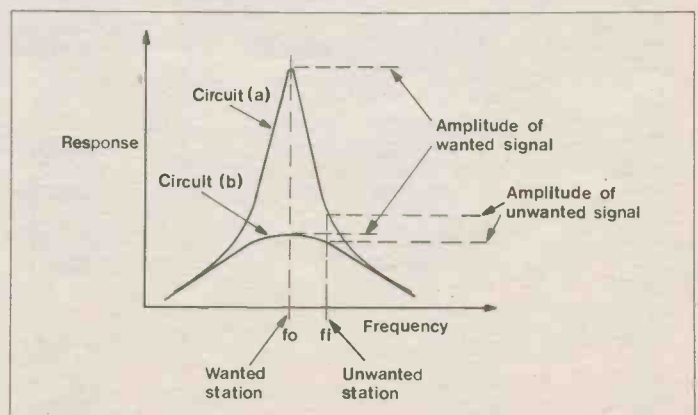
Figure 2. The response of a high selectivity circuit (a) compared with that of a low selectivity circuit (b). The ratio of wanted/unwanted signal is clearly greater for circuit (a).

A Practical TRF Receiver

The receiver presented here, whose circuit appears in Figure 3 and is shown in Photograph 1, uses only a single tuned circuit. Nonetheless, this is loosely coupled to the receiver input so as to obtain good selectivity. The tuning coil is wound on a length of ferrite rod, using standard equipment wire. A two-turn coupling coil is wound at one end. The ideal tuning capacitor is a 300pF type and if you either have, or can afford, one of the large 'mica dielectric' or air-spaced types, then these are nice to use and have a standard 1/4" shaft, which makes fitting a knob easy. However, the performance of the receiver is not in the least impaired by using the quite inexpensive AM tuning capacitor specified, except as follows.

The shaft is tapped with a metric M2.5 thread so fitting a knob calls for a little ingenuity (the thumbwheel type is normally used in commercial designs). This is a two-gang unit, i.e. two variable capacitors that vary in step with each other, with a common terminal in a plastic case. One section is called the 'aerial' or 'antenna' section (capacity 141.6pF) and the other is known as the 'oscillator' section (capacity 59.2pF). These references relate to its use in superhet receiver circuits. The best way to use it in this case is to connect these two sections in parallel. This still falls short of the specified 300pF but, if you can't pull in your favourite station, it is possible to wind a bit more inductance on the coil, or add some capacitance in parallel with the tuned circuit. Either of these steps will lower the minimum available resonant frequency. However, this will be at the expense of stations at
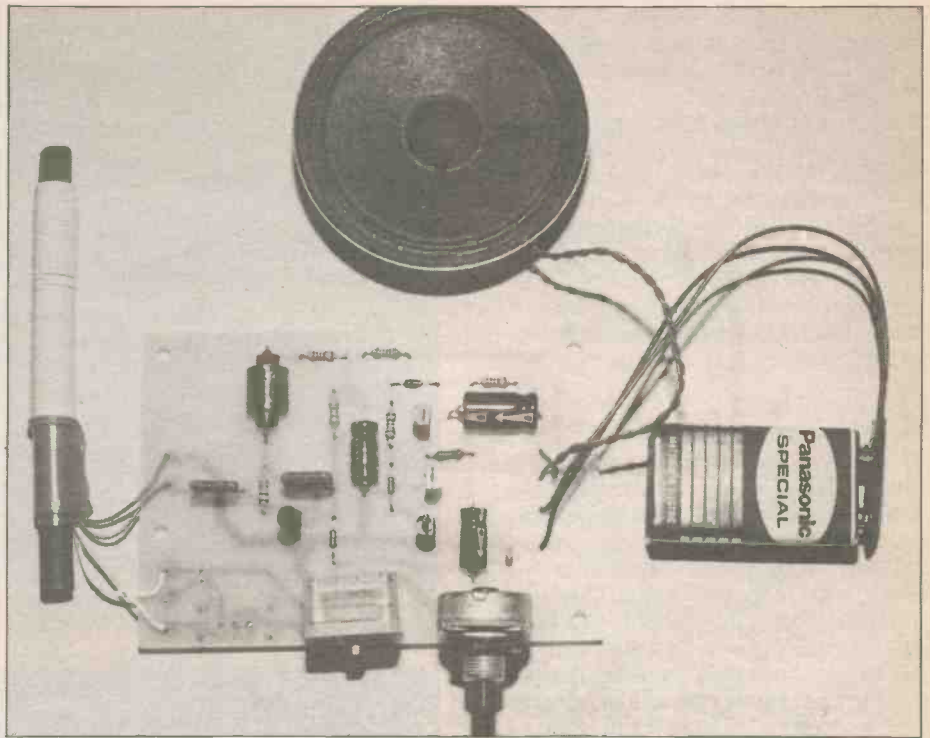
Photo 1. The assembled T.R.F. receiver shows clearly the simplicity of the basic design.

the top end of the medium wave-band.

Now consider the line-up of the receiver of Figure 3. Following the aerial tuned circuit is one stage of RF amplification, whose load comprises a series RL combination of 2.7k and 10mH. The latter is responsible for the high gain of this stage, since its reactance is high at radio frequencies. This high impedance collector load for TR1 is obtained without incurring a large d.c. volt drop, since the 'impedance' to the direct current drawn by the stage is merely that of the 2.7k resistor. The r.f. signal developed across the collector load of TR1 is coupled to the detector

through capacitor C2.

The detector is a diode detector, the diode being D1; its output is developed across the volume control, RV1, the residual r.f. being filtered out by the 820pF capacitor C3. Although a silicon diode has been used, its higher forward turnover voltage has been compensated for by forward bias through the 470k series resistor R3.

The audio section is fairly conventional using a driver TR2 and a complementary output stage, TR3/TR4. The output transistors are not, of course, power types, merely a suitable NPN/PNP combination that gives adequate power for personal
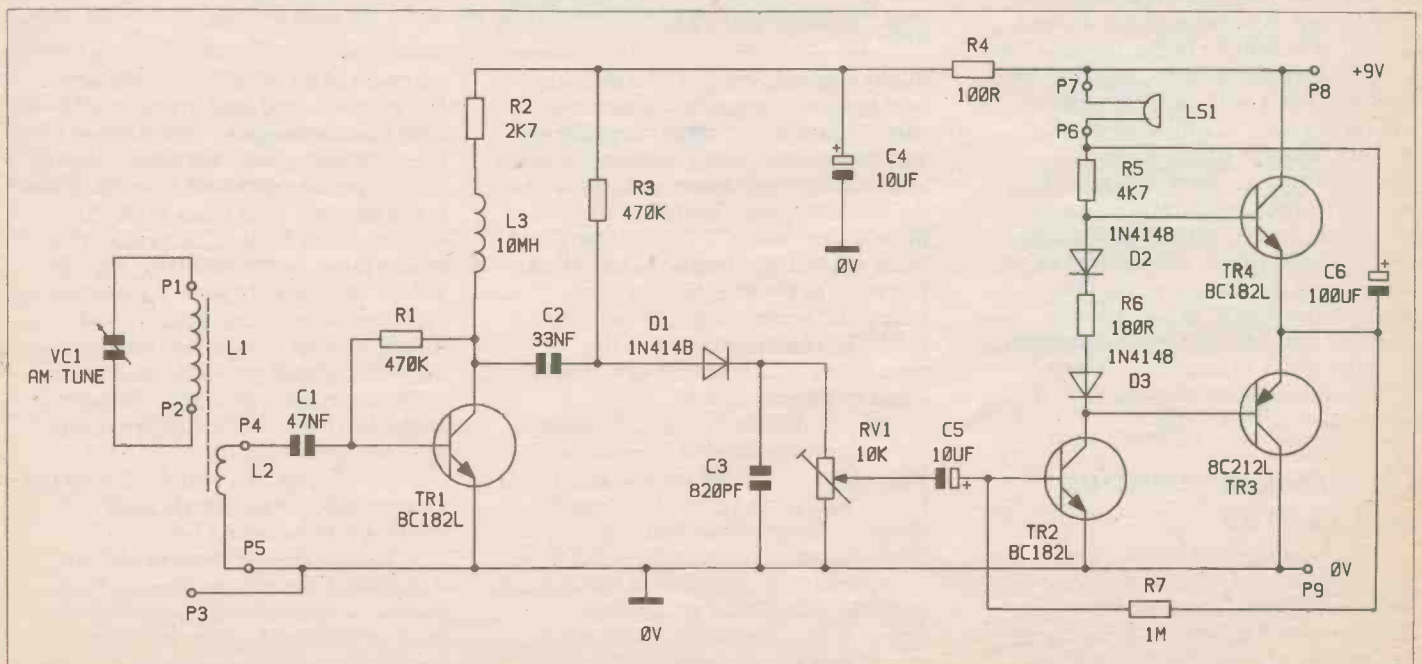
Figure 3. T.R.F. receiver circuit.

listening coupled with economical use of a PP3 battery. This is not to say that the audio output is weak, far from it. It provides a very comfortable listening level. The output impedance of the stage is somewhat higher than usual, so a 64 ohm speaker is used. Temperature compensated bias is provided for the output stage by R6, D2 and D3, these diodes also being given some forward bias by the collector current of TR2.

A Schools Project

That's about all there is to the theory. The receiver was conceived as a simple design that could be guaranteed to work even if the constructor had no previous radio experience, and to work very well at that! The design is due to the sterling efforts of a colleague, Richard Godbolt, who has proved its worth by using it as a class project many times now, always with successful results. It can, therefore, be recommended for use in schools as a suitable project under the G.C.S.E. Electronics syllabus, or in any school where radio and electronics at an introductory level is part of the curriculum. In order to increase the certainty of success, a PCB has been made available for the project and, although, there is no kit of parts as such, all components listed are available from Maplin.

The Ferrite Rod Aerial

A coil of normal equipment wire is close wound onto a length of ferrite rod (see Parts List for details of rod required). If a 300pF tuning capacitor is available, the correct number of turns is 50, with a coupling coil of 2 turns wound over one end of the main winding. With the smaller tuning capacitor specified (both sections wired in parallel as mentioned earlier), it would be better to wind on a larger number of turns, say 70 to 80, although even with only 50 turns it will be possible to pull in several medium wave stations. With the larger number of turns it might be better to wind the aerial coil from enamelled copper wire, say 24 to 30 swg; it's not critical, just as long as you can get the required number of turns on the length of rod. Photographs 2 and 3 show the construction of the original 50 turn coil. The ends of the windings are secured with a turn or two of PVC tape.

General Construction and Testing

Assuming you're using the PCB available from Maplin, it's simply a matter of identifying the components, bending the leads neatly to drop through the holes in the board, soldering them in place quickly and
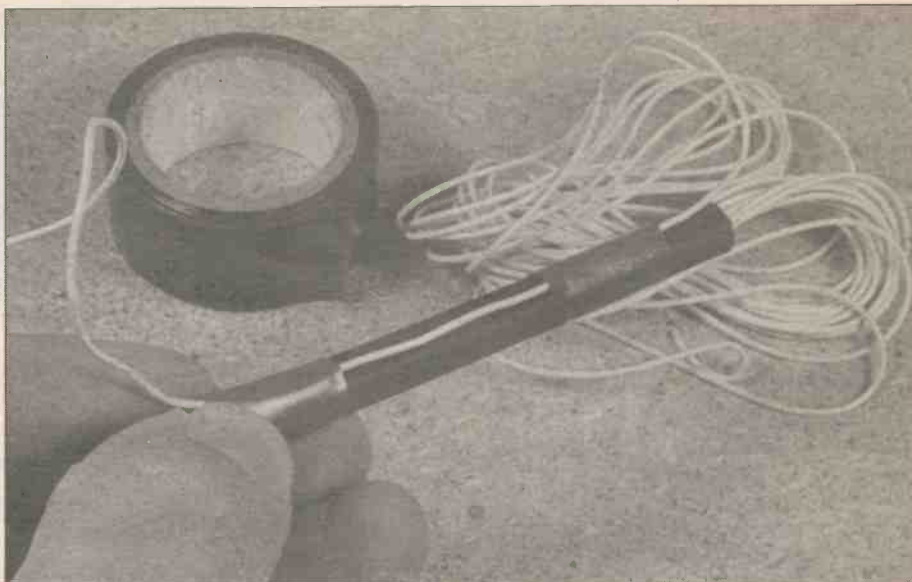
Photo 2. The tuning coil is wound from ordinary equipment wire. To get the connections at the same end, a length of wire is first taped 'along' the length of the rod and the coil wound back over it.
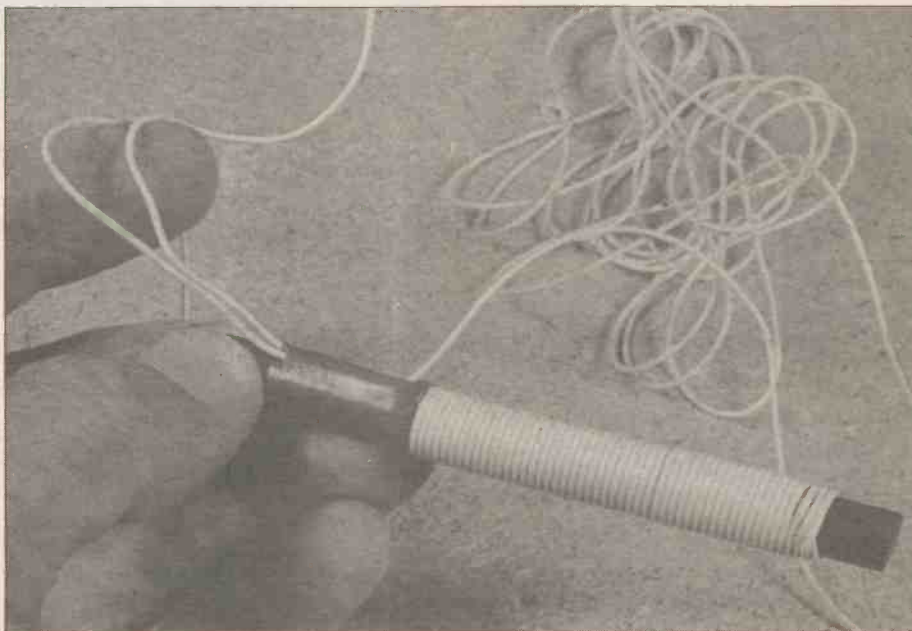
Photo 3. The winding of the main tuning coil completed. The coupling coil would be added next, being just two turns of wire, wound over one end of the main winding and secured with tape.

neatly and snipping off the surplus lead lengths. To quote the obvious, check that the electrolytic capacitors and diodes are the right way round and that the right transistors go into the correct places. There are three BC182s and one BC212. The transistor leads are actually in line as supplied but need to be adjusted to fit the triangular arrangement of holes in the PCB. The orientation of the transistors is clearly shown in Figure 4 and in Photograph 4.

If you decide to build the circuit up without the benefit of a custom PCB, there's nothing critical about the layout. It can follow the circuit diagram more or less, but it would be better to use plain board drilled to take push-through pins for the components rather than stripboard, which is best forgotten about at r.f.

Either way, when the circuit is finished and a visual check has been

carried out on all solder joints, and the position and polarity of components has been given another quick check, then connect up the 9V supply and hear your set burst into life. Even if the receiver's off tune, with the volume fairly well up, you may well hear a faint, but heartening, sign of evidence that all is well. Tuning the receiver should soon find a good, strong station. Ferrite rod aerials are directional so if a station seems weak on first tuning it in, rotate the aerial in the horizontal plane to see if the signal improves.

Assuming that you are one of the rare unlucky ones, a little fault finding will be called for.

Easiest checks to carry out are d.c. measurements, assuming that you can't immediately spot a wiring fault or incorrect component placement. The potentials to expect in the circuit are as follows.
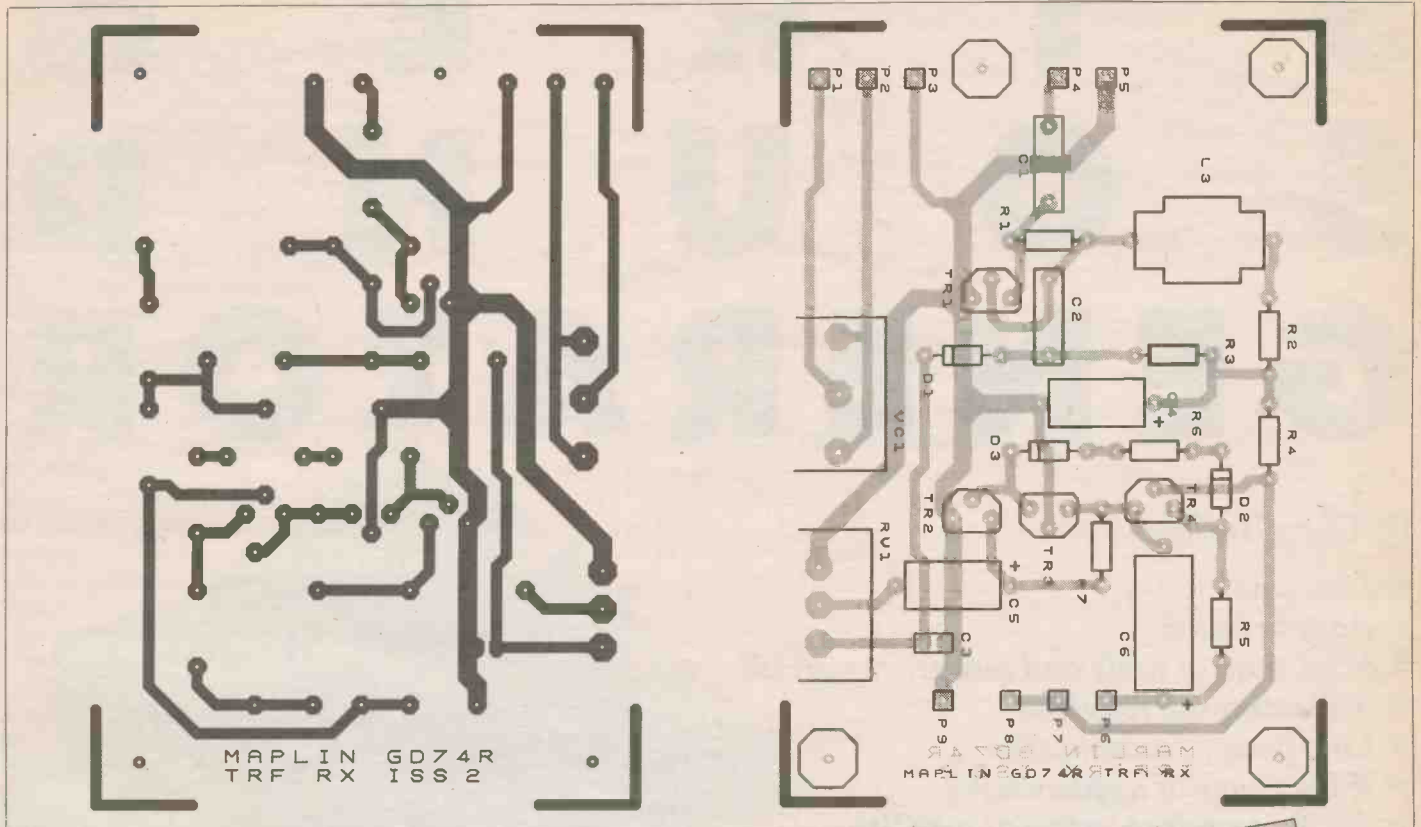
Figure 4. Track and overlay of P.C.B.

Collector of TR1 = 3.8V.
Collector of TR2 = 3.3V.
Common emitter junction of TR3/TR4 (mid-point) = 4.5V.

These are approximate only and some variation should be expected, as long as it is not exceptionally different.

Wildly incorrect values at the mid-point could be due to collector to emitter shorts or open-circuits, R7 of the incorrect value or open circuit, or a fault in the chain of components in TR3's collector circuit.

But the chances are that all will be well and that you will now have a receiver that is not just a novelty but a practical and useful acquisition, which might get you thinking about a case for it. Next time we shall be looking at a miniature receiver using one of the available r.f. ICs. See you then!
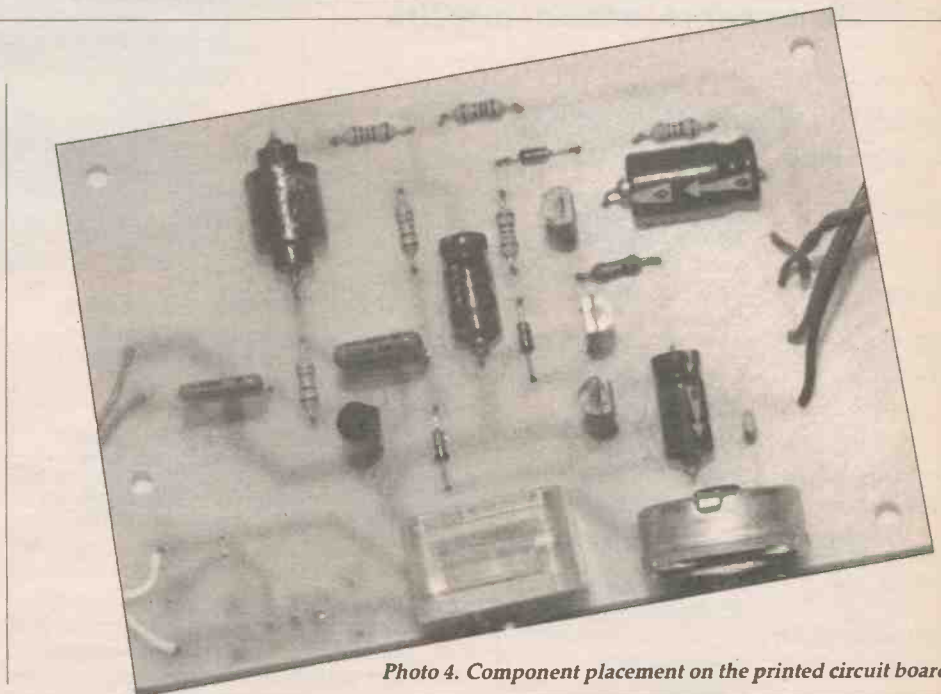
Photo 4. Component placement on the printed circuit board.

TRF RECEIVER PARTS LIST

Resistors: All 0.6W 1% Metal Film

R1,3	470k	2	(M470K)
R2	2k7	1	(M2K7)
R4	100Ω	1	(M100R)
R5	4k7	1	(M4K7)
R6	180Ω	1	(M180R)
R7	1M	1	(M1M)
RV1	10k Lin Pot	1	(FW02C)

Capacitors

C1	47nF Polyester	1	(BX74R)
C2	33nF Polyester	1	(BX73Q)
C3	820pF Ceramic	1	(WX67X)
C4,5	10μF 25V Axial Electrolytic	2	(FB22Y)
C6	100μF 25V Axial Electrolytic	1	(FB48C)
VC1	AM Varitune	1	(FT78K)

Semiconductors

TR1,2,4	BC182L	3	(QB55K)
TR3	BC212L	1	(QB60Q)
D1,2,3	1N4148	3	(QL80B)

Miscellaneous

L1,2	Ferrite Rod 810	1	(YG20W)
L3	10mH Choke	1	(HX19V)
LS1	64 ohm Speaker	1	(WF57M)
	Printed Circuit Board	1	(GD74R)
	PP3 Battery Clip	1	(HF28F)
	EC Wire 28swg	1	(BL39N)
	Bell Wire Black	1	(BL85G)

The following item is available, but is not shown in the 1988 catalogue:
TRF Receiver PCB Order As GD74R Price £2.95

SIREN SOUND GENERATOR

By Chris Barlow

★ *Low cost*
★ *Easy to build*
★ *Minimum of tools and test gear required*
★ *No setting-up required*
★ *Low power consumption*
★ *Wide range of applications*
★ *Audio output to external amplifier*

Specification of Prototype

Integrated circuit	: UM3561 low-power CMOS LSI
Memory	: masked Read Only Memory (ROM) 256 words by 8 bits
Tone generator	: logic controlled divider
Four sound patterns	: 1 Police siren 2 Fire engine siren 3 Ambulance siren 4 Machine gun
Operating voltage	: 2.4V to 15V
Supply current	: 9mA at 9V (Piezo sounder fitted)
Reverse polarity protection	
Output	: Piezo sounder or 8Ω/64Ω loudspeaker
External amplifier output	: 1V square wave at 10kΩ
Operating ambient temperature	: −10°C to 60°C
Storage temperature	: −55°C to 125°C
Printed Circuit Board (PCB)	: single-sided fibre glass
PCB dimensions	: 34 x 31mm

Introduction

The UM3561 is a low-cost, low-power CMOS LSI chip designed for use in toy and model applications. However, the sounds produced could be used as an audio warning signal in security, or environmental monitoring systems. To accommodate this the unit is designed to operate over a wide range of voltage and temperatures. Three siren and one other sound effect are generated and provision has been made for an external amplifier if louder volumes are required. In the following article the operation of the UM3561 chip and the rest of the circuit will be described. In addition, the PCB assembly and testing procedure should ensure the successful completion of the project.
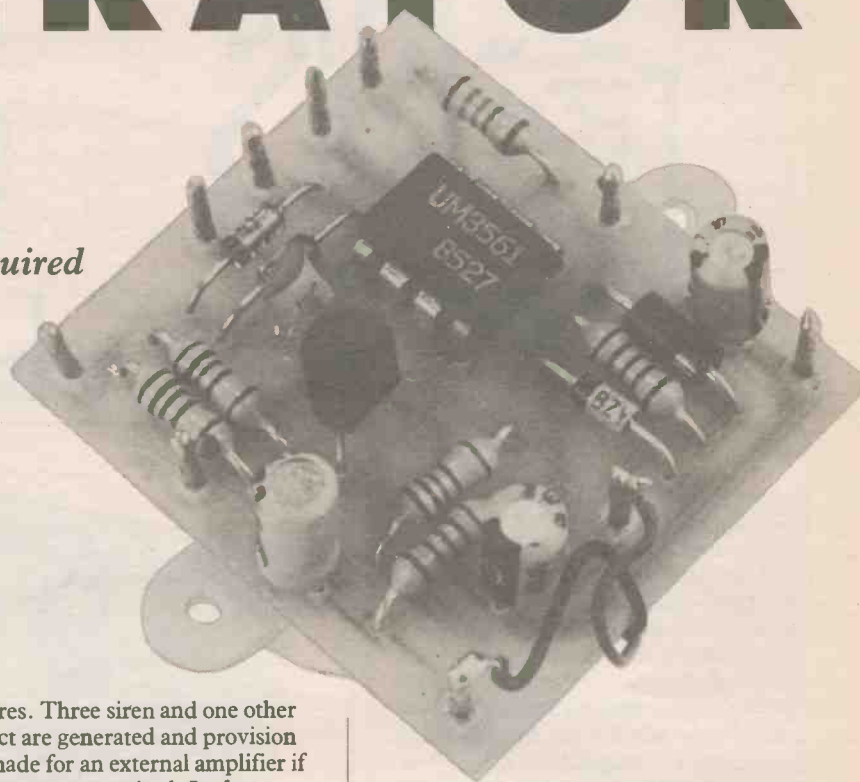
How the chip works

The UM3561 siren sound generator is a compact module containing a logic controlled tone generator, see Figure 1. The oscillator is used as a clock for the control circuit and as the master frequency for the tone generator. To produce the correct tonal range and rate of change for a siren sound the oscillator must run at approximately 106kHz. This frequency is set by an external resistor placed across the OSC1 and OSC2 pins of the chip, see Figure 2. If the value of this resistor is reduced the frequency of the oscillator will increase until a cut off point is reached.

The tone generator is a programmed divider, controlled by the 8 bits of data from the ROM. This binary data gives 256 steps of division of the master frequency. The change in frequency of each step is relatively small, so an incremental count will result in a continuous sweeping sound.
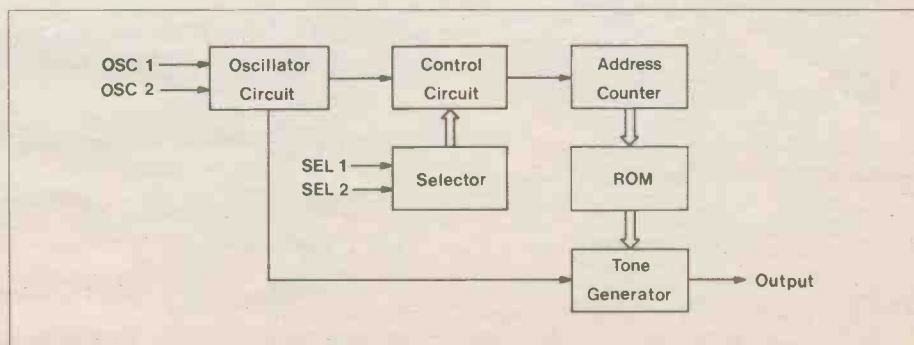
Figure 1. Block diagram.
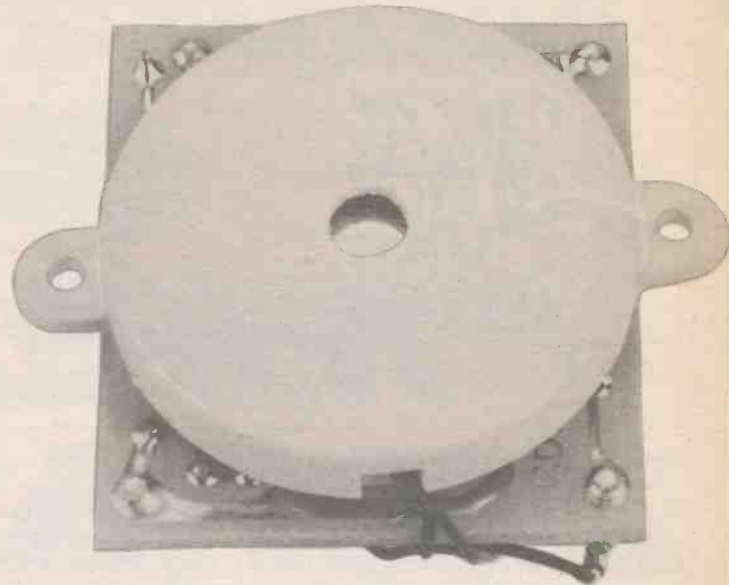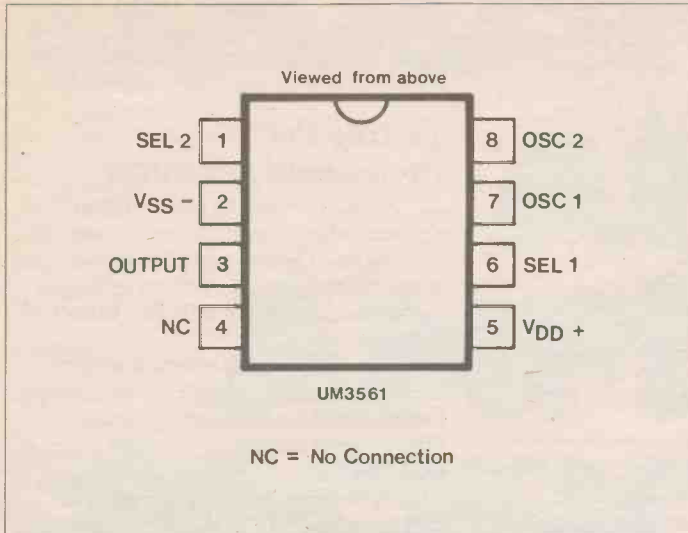
Figure 2. Pin configuration.

This data pattern is just one of the four stored in the chips memory. It is the combined function of the selector, control, and address counter circuits that selects a block of memory and then steps through it.

The selector circuit has two inputs SEL1, SEL2, see Figure 2. SEL1 is a tri-state control pin and can be connected to +V or −V to select the desired block of memory. SEL2 incorporates an internal pull down resistor and it selects a different block when it is taken to +V. However, SEL1 and SEL2 should not be used at the same time. The four following options are possible:

1: No connection to SEL1 or SEL2 the sound effect will be the police siren.
2: SEL1 connected to +V and no connection to SEL2 the sound effect will be the fire engine siren.
3: SEL1 connected to −V and no connection to SEL2 the sound effect will be the ambulance siren.
4: No connection to SEL1 and SEL2 connected to +V the sound effect will be the machine gun sound.

Having selected the desired start address of memory the control and address

counter will step through until the end of that block is reached. At which point the cycle is repeated, thus producing a continuous output. A power on reset circuit ensures that the control and address counter start up at the beginning of the cycle when the supply is connected.

The output waveform of the siren generator is a square wave and its amplitude is close to that of the supply potential. The output can supply 3mA of drive current, sufficient for a piezo sounder but not enough for a loudspeaker. Only a few additional components are required to provide loudspeaker drive, over voltage and reverse polarity protection, see Figure 3.

Circuit description

The DC supply entering the unit must have the correct polarity, otherwise damage will occur to the semiconductors. To prevent this, a diode, D1, has to have the positive supply voltage applied to its anode before the DC power can pass to the rest of the circuit. The maximum operating voltage that should be applied to the supply input pins of the UM3561 is

3.6V. Over voltage protection is provided by ZD1 a 3.3 volt zener diode and R1 a 1kΩ resistor to limit the supply current. Electrical noise on the supply rail is suppressed by the decoupling capacitors, C1 and C4. The square wave output on pin 3 of IC1 is fed to the base of TR1 via R4, a 10kΩ resistor.

An NPN silicon transistor TR1 is used to provide sufficient drive current for a piezo sounder or low impedance loudspeaker. Because of the high impedance of the piezo sounder, a 1kΩ collector load resistor R3 must be included. An amplifier output is provided by taking the signal at the collector of TR1 through C3, a 470nF capacitor, to R4 and R5. C4, a 10nf capacitor, then removes any high frequency signals and D2, D3 limit the output to approximately 1 volt peak to peak. This signal can now be fed to an additional amplifier if higher sound levels are required.

PCB assembly

The PCB is a single-sided fibre glass type and the component overlay and track are shown in Figure 4. Removal of a misplaced component is quite difficult, so please double-check each component type, value and its polarity where appropriate, before soldering! The sequence in which the components are fitted is not critical. However, it is easier to start with the smaller components. When installing the electrolytic capacitors the positive lead must go to the plus sign (+) on the legend. However, on some capacitors the polarity is designated by a negative symbol (−), in which case the lead nearest this symbol goes away from the positive sign on the legend. When fitting the semiconductors you must carefully match the case to the outline shown. The diodes all have a band at one end to identify the cathode connection. Be sure to position them accordingly. For further information on component identification and soldering techniques please refer to the constructors guide included in the kit. This completes the assembly of the PCB and you should now check your work very carefully
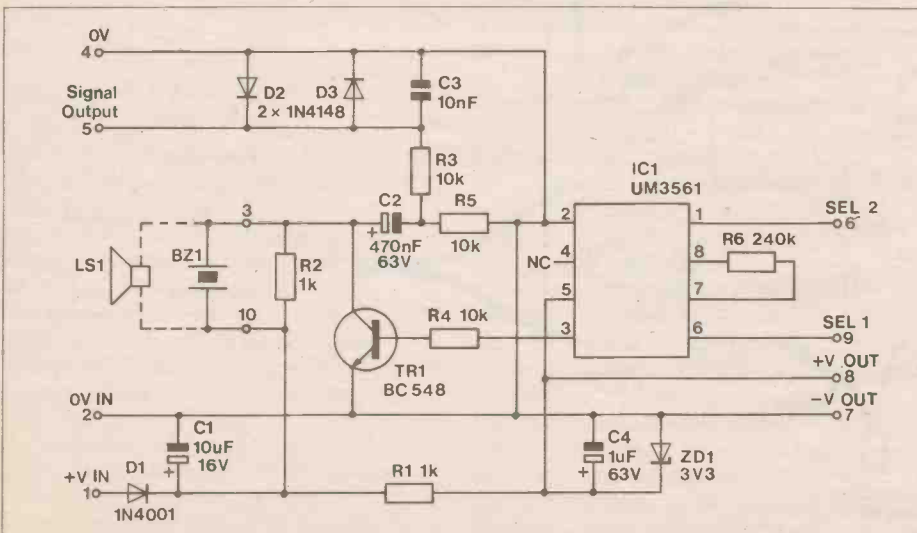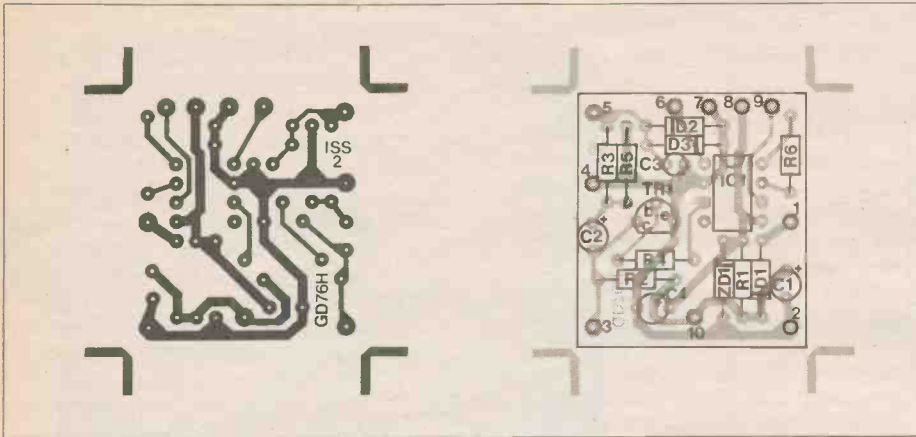

Figure 3. Circuit.

Figure 4. Track and layout of the PCB.

ensuring that all the solder joints are sound. It is also very important that the bottom, track side of the circuit board does not have any trimmed component leads standing proud by more than 1mm.

Wiring

Carefully follow the wiring shown in

Figure 5. Do not fit the sound effect link until it is called for during the testing stage. The piezo sounder BZ1 may have different coloured leads but may be connected either way to the PCB. This completes the wiring of the generator PCB, the amplifier screened cable is optional. Finally a self-adhesive pad is mounted to the back of the sounder. Do
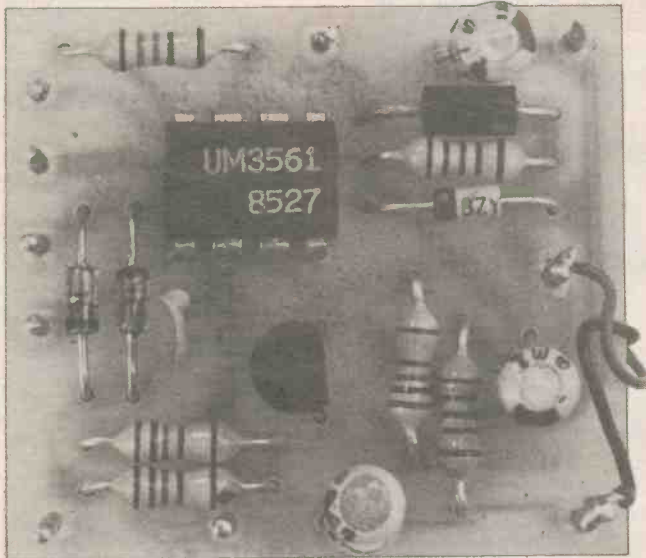
not fit the PCB to the sounder until the testing stage is successfully completed.

Testing the siren sound generator

All the tests can be made with an electronic digital, or analogue moving coil, multimeter. The following test results were obtained from the prototype using a digital multimeter and a 9V PP3 battery as the power supply.

The first test is to ensure that there are no short circuits before you connect the battery. Set your multimeter to read OHMS on its resistance range and connect the probes to the supply cables. The reading obtained with the probes either way round should be greater than 1000Ω (1kΩ). Some multimeters will provide sufficient current to power the siren sound generator during this test.

Next monitor the supply current, set your meter to read DC mA and place it in the positive line to the PCB. When the battery is connected, the unit should produce the police siren sound effect (rapid sweeping tone) and a current reading of approximately 9mA should be seen. If the power supply is reversed then no sound output or current should be observed.

Disconnect the supply before fitting or altering the sound effect link. Select in turn each sound effect using link 1, 2 or 3.

Sound effect 1: Police siren, rapid sweeping tone. No link fitted.
Sound effect 2: Fire engine siren, slow sweeping tone. Link 1 fitted.
Sound effect 3: Ambulance siren, two alternating tones. Link 2 fitted.
Sound effect 4: Machine gun, bursts of pulsed tone. Link 3 fitted.

This completes the testing of the siren sound generator. Finally secure the piezo sounder to the track side of the PCB using the quick stick pad as shown in Figure 6.

Figure 5. Wiring.

Figure 6. Fixing the PCB.

Using the siren sound generator

Having selected the desired sound effect the unit can now be installed into your toy or model. If you have the available space the sound level from the unit can be increased by using a low impedance loudspeaker, such as the 8Ω 768 type (WF57M). When used as an audio warning signal, a high efficiency horn speaker (XQ73Q) will give a further increase in sound level from the basic unit. However, if greater volume levels are required then a power amplifier can be connected to the signal output pins.

SIREN SOUND GENERATOR PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,2	1k	2	(M1K)
R3,4,5	10k	3	(M10K)
R6	240k	1	(M240K)

CAPACITORS

C1	10µF 16V Minelect	1	(YY34M)
C2	470nF 63V Minelect	1	(YY30H)
C3	10nF Ceramic	1	(WX77J)
C4	1µF 63V Minelect	1	(YY31J)

SEMICONDUCTORS

IC1	UM3561	1	(UJ45Y)
TR1	BC548	1	(QB73Q)
D1	1N4001	1	(QL73Q)
D2,3	1N4148	2	(QL80B)
ZD1	BZY88C3V3	1	(QH02C)

MISCELLANEOUS

Siren Sound PCB	1		(GD76H)
Pin 2145	1 Pkt		(FL24B)
Piezo Sounder	1		(FM59P)
Quick Stick Pad	1 Stp		(HB22Y)
Contructors Guide	1		(XH79L)

OPTIONAL

Hi-Z Loudspeaker 64R	1		(WF57M)
5in. Horn Speaker	1		(XQ73Q)

A complete kit, excluding Optional items, is available.
Order As LM42V (Siren Sound Gen Kit) Price £3.50
The following item in the above kit is also available separately, but is not shown in our 1988 catalogue:
Siren Sound PCB **Order As GD76H Price £1.20**

WHICH POWER AMPLIFIER?

by J.K. Hearfield

It is often much cheaper to buy a special-purpose power amplifier IC than to build a similar circuit from individual components. Suppose, for example, that you need something that will deliver 5 watts into an 8 ohm speaker. You would need:

2 medium-power 25 volt 3 amp transistors	@ £1.00
2 small heatsinks	@ £1.00
2 driver transistors	@ 70p
3 amplifier transistors	@ 60p
2 diodes, resistors, small capacitors	@ 50p
1 2200µF electrolytic	@ £1.00

The components alone would cost nearly £5, and the circuit must be built and tested before it could be used. An integrated amplifier would cost perhaps half as much, or even less, and would fit into a much smaller space.

Integrated power amplifier devices currently available can handle power levels from a few hundred milliwatts to more than 20 watts, and as Figure 1 illustrates, they cost only about as much as the output transistors in a discrete-component design.

Power Output, Supply Voltage and Load

The first step in choosing a suitable device is to decide the supply voltage it will need. To deliver an output power of P watts into a load of R ohms, the amplifier output voltage must be:

$V = SQR (P \times R)$ volts rms,

which implies an output voltage swing of:

$V = 2 \times 1.414 \times SQR (P \times R)$ volts peak-to-peak.

For example, to deliver 2 watts into 8 ohms would need a swing of:

$V = 2 \times 1.414 \times SQR (2 \times 8)$

or $V = 11.3$ volts peak-to-peak.

The supply voltage must be greater than this, because the minimum voltage across the output transistors should not be less than a few volts even under maximum drive. A suitable value of supply voltage in this case would therefore be 16 to 18 volts. A higher supply voltage will give lower distortion at maximum output, but at the expense of greater power dissipation.

The graphs of Figure 2 show the minimum value of supply voltage needed to achieve a given power level in a given load. The graphs assume the output transistors are just saturating on signal peaks, so it would be prudent to increase this minimum figure by two or three volts if low distortion is important.

Typical Devices

The LM 380 is a straightforward low-cost power-amplifier-on-a-chip which has been in production now for several years. The circuit shown in Figure 3 is recognisably that of a power amplifier: a differential input stage, with inputs referenced to ground, followed by a driver stage with compensation capacitor, feeding a pair of quasi-complementary output transistors with current-limiting emitter resistors. The circuit's
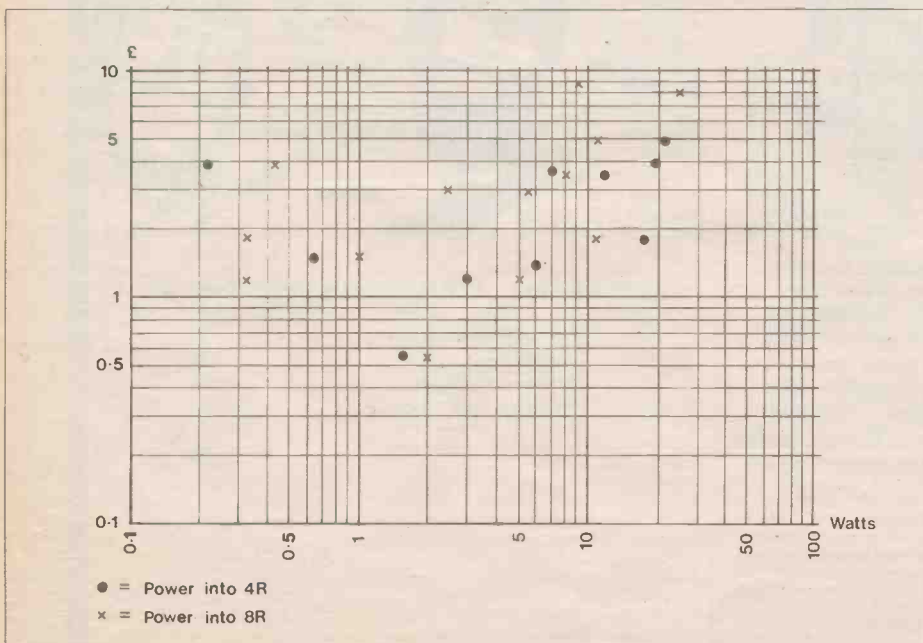
Figure 1. Power amplifier IC's in the Maplin catalogue.

● = Power into 4R
× = Power into 8R
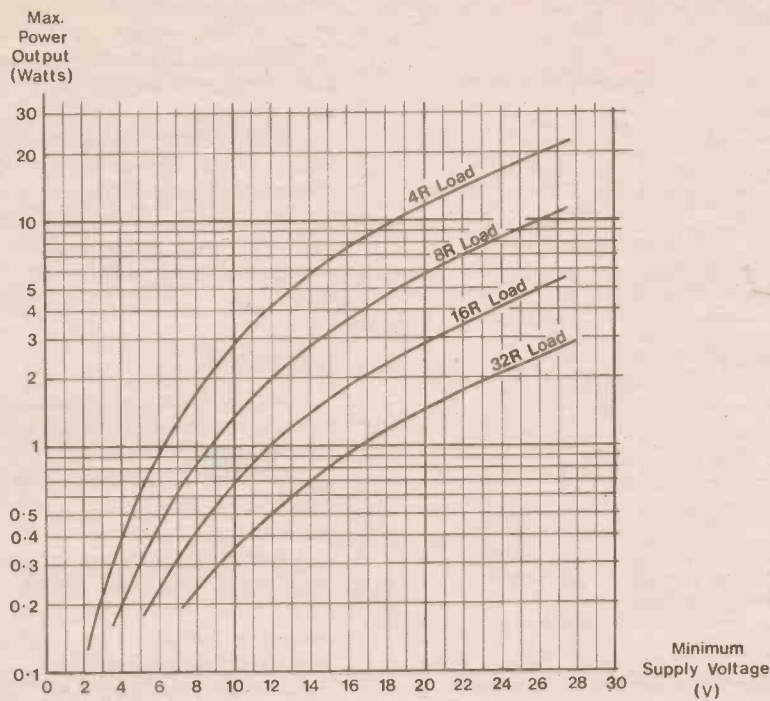
Figure 2. Minimum supply voltage requirements.
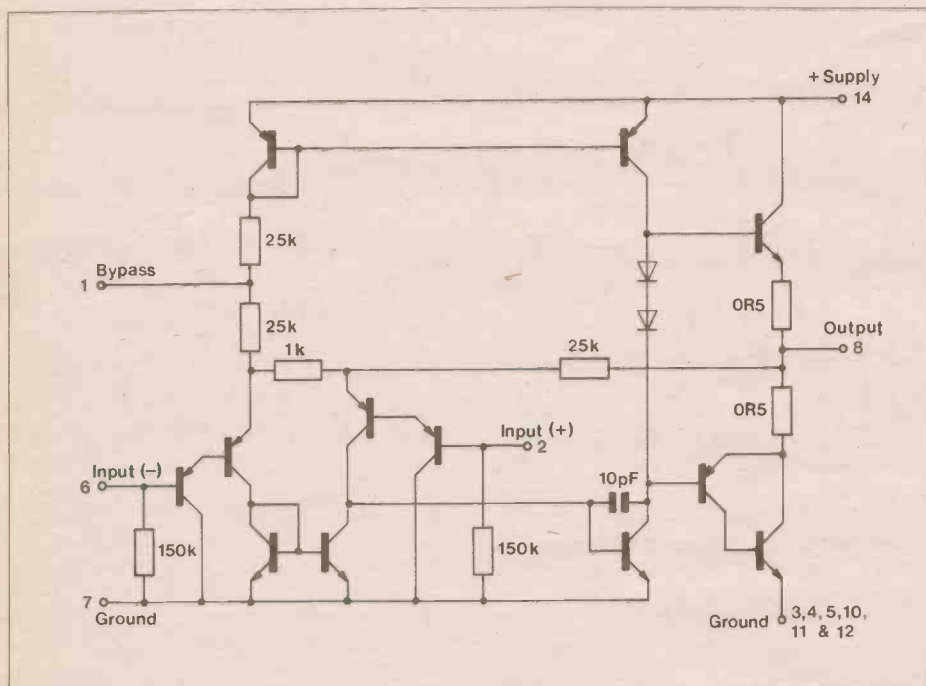
Figure 3. LM380 internal circuit.
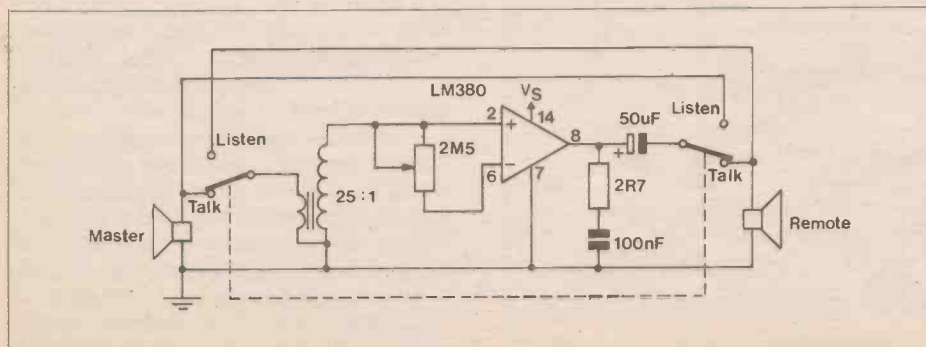
Figure 4. Simple intercom circuit.

voltage gain is set to 50 (34dB) by the internal feedback, which also fixes the quiescent output voltage at half the supply voltage. A simple intercom circuit based on the LM380 is given in Figure 4.

This device is capable of delivering at least 2.5 watts into an 8 ohm load with an 18 volt supply rail. It comes in a standard 14-pin DIL package.

The TDA 1520 is rather more recent. Though similar in concept to the LM380, it includes on-chip protection circuitry to cope with both thermal overload and difficult reactive loads. The device can deliver a power level in excess of 20 watts into a 4 ohm load with very low noise and distortion.

A typical application circuit is shown in Figure 5. Both gain and input resistance are set by external components, as in an operational amplifier circuit; in this case the voltage gain is:

$A = 20k/680 = 29$, or about 30dB.

Some devices include both pre-amplifier and power amplifier within the same package. An example is the TDA 1010, which is designed as a 6 watt car radio amplifier. The internal circuitry (Figure 6) is quite complex, but the application circuit (Figure 7) needs few external components.

Bridge Output Configuration

The quiescent (that is, no-signal) output voltage of a power amplifier is designed to set halfway between the positive supply rail and earth. If the load is then connected between the output and earth, as it usually is, a blocking capacitor must be included in series with it solely to remove this DC offset, see Figure 8.

The capacitor's value must be sufficiently high for its impedance to be small compared to the load at all but the lowest signal frequency. For example, the capacitor needed to allow signals down to 20Hz into a 4 ohm load would have to be at least:

$$C = \frac{1}{(2 \times 3.1416 \times 20 \times 4)}$$

or $C = 2000\mu F$, and a $2200\mu F$ component would be used.

The so-called bridge or BTL (bridge-tied load) configuration removes the need for a blocking capacitor whilst at the same time doubling the voltage swing across the load. Figure 9 illustrates the idea. Instead of returning the load to earth, it is connected to the output of another amplifier. If the quiescent output voltages of both amplifiers are identical, the quiescent voltage across the load is zero. The second amplifier is however fed by a signal which is 180 degrees out of phase with that feeding the first, so as the voltage at one side of the load swings positive, that on the other side swings negative.

This circuit depends critically on the assumption that the quiescent output
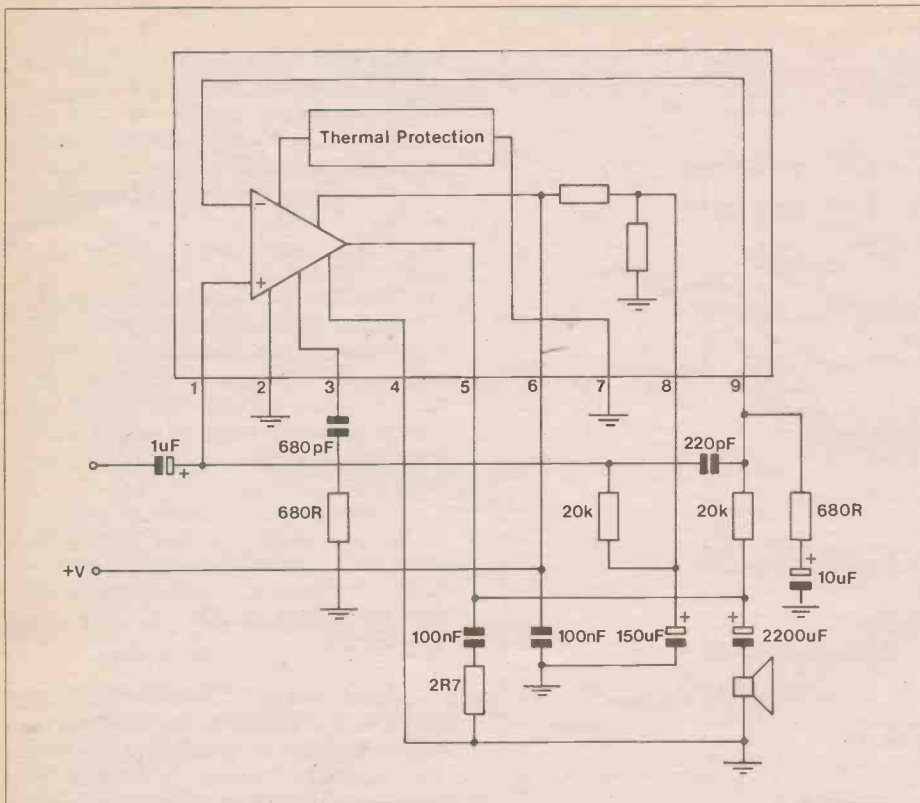
Figure 5. Typical application circuit for TDA1520.

Figure 6. TDA1010 internal circuit.
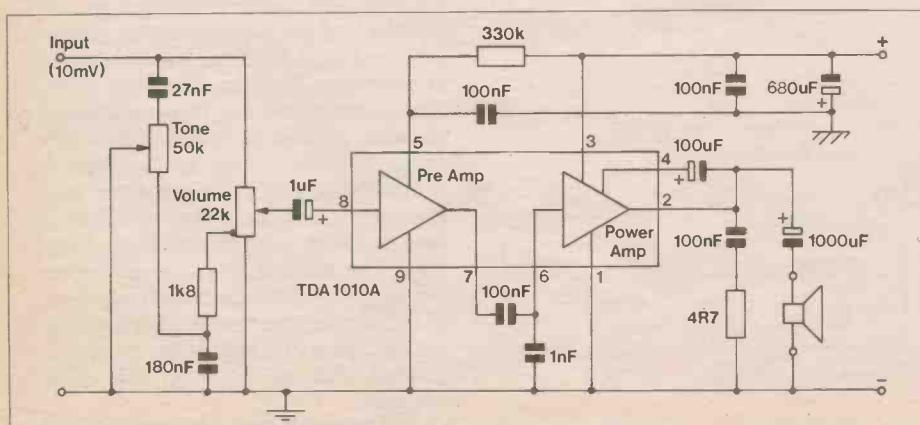
Figure 7. Complete mono audio amplifier of a car radio.

voltage of each amplifier is the same, and remains the same at all operating temperatures. In practice, this means that both amplifiers should be fabricated on the same chip.

Bridge-type amplifiers find particular application in areas where the maximum supply voltage is restricted - for example, in battery-powered equipment. A 4 watt car radio audio amplifier circuit using an LM377 is shown in Figure 10.

Layout

All high-gain wideband amplifiers must be constructed in such a way that as little as possible of the output signal finds its way back to the input. The unwanted coupling may be by any of several paths, and each one must be broken.

Keep the input as far as possible from the output, and screen the input wiring if necessary. The risk of unwanted pickup is higher if the input leads are long or if the amplifier has a high input impedance. High-frequency pickup can usually be cured by adding a small capacitor (of say 220pF) directly across the amplifier input pins.

Keep the power supply wires well away from the input, to prevent the large and spiky power supply currents from being inductively coupled back. Twist the power supply wires together, and run them away from the board at right angles to it for at least an inch or so.

Arrange the tracking so that all currents flowing to the circuit earth point do so via separate paths. In particular, it is most important to ensure that the load current does not share a track with the input current. Remember that just 100mA of load current flowing in 0.1 ohm of track represents 10mV. If this unwanted 'signal' appears in series with your input signal the effect on the output will be unpredict-
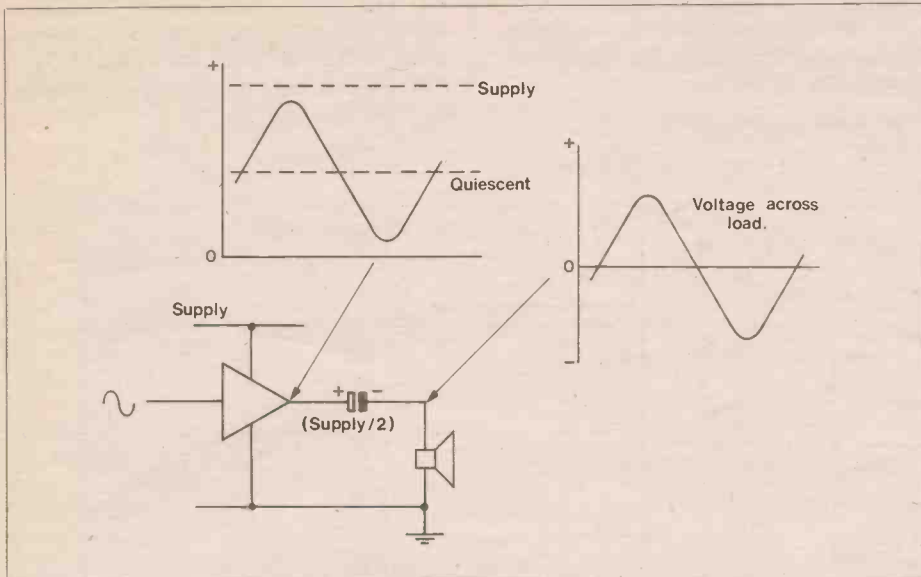
Figure 8. Blocking capacitor.
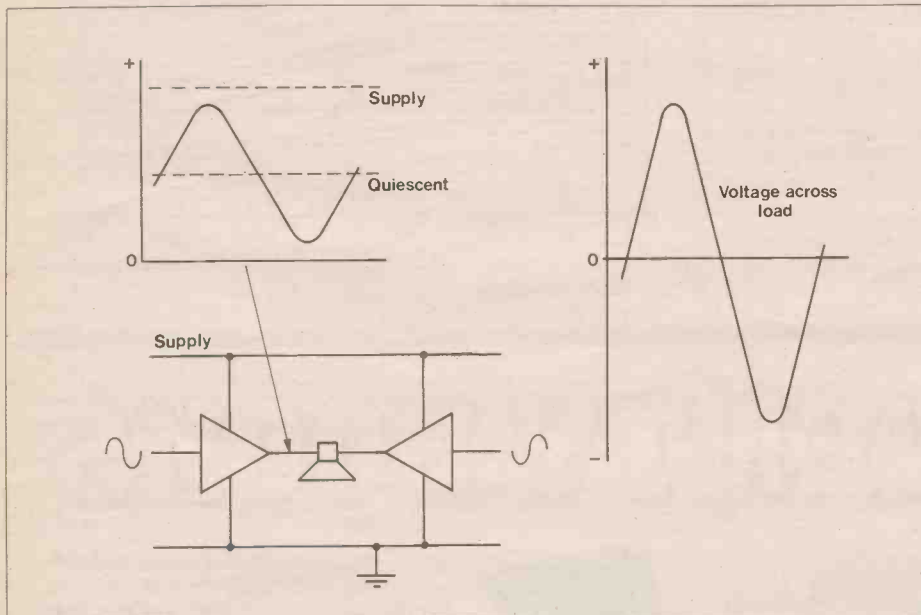
Figure 9. Bridge-tied load.
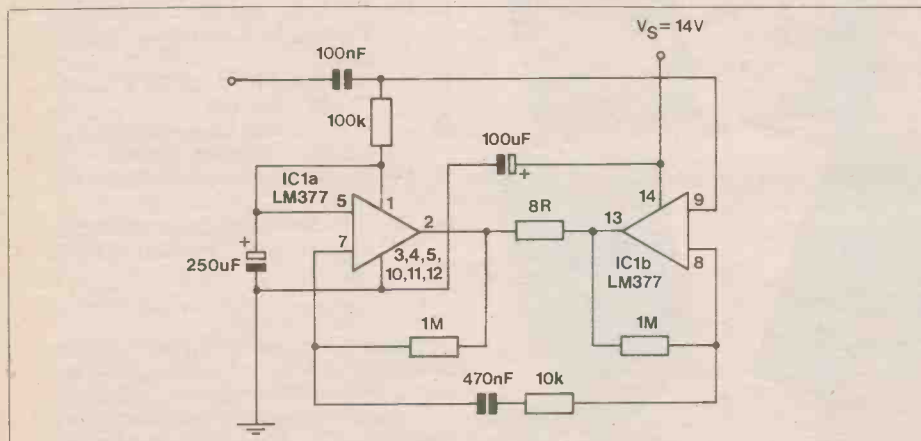
Figure 10. 4W bridge amplifier.

able. Often, the output signal is just noisier and more distorted than it should be, leading to the false conclusion that the amplifier device is sub-standard. Sometimes the whole circuit oscillates at a high frequency, perhaps in bursts, perhaps only when a load is connected.

Decouple the power supply ade-

quately. A large electrolytic is needed to act as an energy store for the large current peaks delivered to the load, but this is not enough by itself. Don't forget that power supply track has inductance as well as resistance, so mount suitable decoupling capacitors physically close to the device pins. The same argument

applies to the output compensation components.

Capacitive Loads

Most power amplifiers do not like driving capacitive loads, mainly because of the very low impedance such loads present at high frequencies. A load capacitance of up to $0.1\mu F$ or so should not cause problems in practice, but if the amplifier is required to deliver energy into a much larger capacitance the amplifier must be at least partially isolated from this load. The usual technique is to add a small resistor (of a few ohms) in series with the amplifier output. The resistor may have a small inductor (of a few μH) connected across it.

Output Transistor Protection

Like any other power transistors, those in a power amplifier IC can be damaged by excessive voltage, current, or power. In most applications it is enough to follow the manufacturer's recommendations regarding supply voltage, load impedance and heatsinking, but some types of load do cause problems. Reactive loads such as motors (or transformers) may draw large currents at the same time as high voltages appear across the output transistors. Worse, the load may attempt to swing the output voltage beyond the power supply limits. Many modern amplifier devices automatically limit the output current to a safe value, but an excessive output voltage will usually degrade or destroy the device. The solution in this case is to limit the output voltage variation by means of diodes connected between the output and the supply rails.

Heatsinking

Power amplifiers tend not to be very efficient. For example, when an LM380 running from an 18 volt supply is delivering 2 watts into an 8 ohm load, the LM380 itself is dissipating more than 2 watts of heat (Figure 11). The heatsink used must be big enough to maintain the device junction temperature at something less than the manufacturer's quoted maximum figure of 150 degrees C: as usual, the lower the operating temperature, the longer the device life. In this case, Figure 12 shows that 2 square inches of PCB copper will be adequte at ambient temperatures of 60 degrees C and below.

Amplifiers designed for higher-power applications are usually housed in packages of inherently low thermal resistance which can easily be bolted to standard heatsinks. The size and type of heatsink needed for a particular job can be calculated as follows:

Total thermal resistance =

$$\frac{\text{Max junction temp} - \text{Max ambient temp}}{\text{Device power dissipation}}$$

Heatsink thermal resistance =

$$\text{Total thermal resistance} - \text{Package thermal resistance}$$

For example, if a power amplifier device in a TO-220 package must dissipate 10 watts in ambient temperatures up to 60 degrees C, the maximum thermal resistance from the junction to the ambient air can be:

$$\frac{150 - 60}{10} = 9°C/watt$$

The thermal resistance of the package is about 4 degC/w, so the heatsink must be 5 degC/w or less. The Maplin EHP TO-220 heatsink (4 degC/w) would be quite suitable.
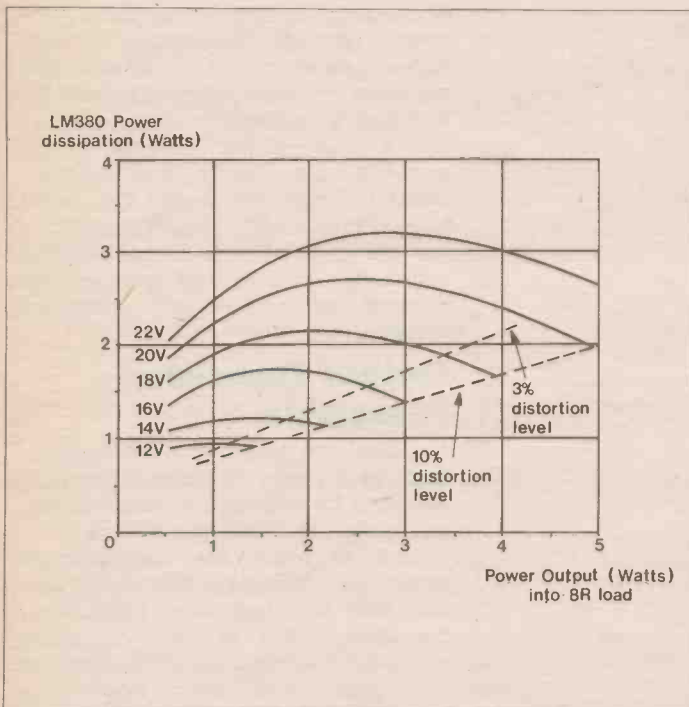
Figure 11. LM380 power dissipation.
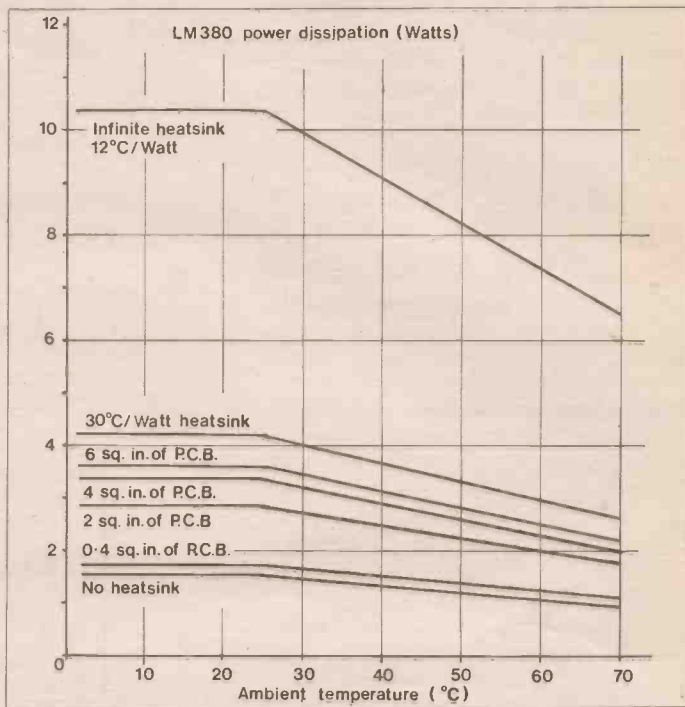
Figure 12. Heatsinking.

TOP TWENTY BOOKS

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3. (3) Power Supply Projects, by R.A. Penfold. (XW52G) Cat. P78.
4. (7) IC555 Projects, by E.A. Parr. (LY04E) Cat. P80.
5. (–) 30 Solderless Breadboard Projects Book 1, by R.A. Penfold. (WA51F) Cat. P77.
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19. (–) Popular Electronic Projects, by R.A. Penfold. (RQ29G) Cat. P77.
20. (6) More Advanced Electronic Music Projects, by R.A. Penfold (WP44X) Cat. P83.

These are our top twenty best selling books based on mail order and shop sales during October, November and December 1987. Our own magazines and publications are not included. The Maplin order code of each book is shown together with page numbers for our 1988 catalogue. We stock over 250 different titles, covering a wide range of electronics and computing topics.

PROGRAMMABLE

Metronomes are commonly used in music, to help musicians keep time. The traditional metronome is based on an oscillating arm that swings from side to side and ticks as it goes. The speed (or tempo) of movement is adjusted by sliding a small counter balance weight up the arm, to slow the tempo, or down the arm to speed up the tempo. Various electronic metronomes use LED's and sounders to indicate the tempo, as indeed does this design. They have the advantage of being robustly transportable, compact, and in this version the facility to set time signatures with an appropriate note duration indication.

The module is housed in a small plastic box, with enough room for a small 9V battery, and a self adhesive front panel to finish.

Circuit Description

With reference to Figures 1 & 2, the clock oscillator determines the tempo or speed by varying RV2. Note generator IC2 is a 4017 positive edge triggered decade counter with ten decoded, active high outputs. Each output is active in turn for one clock pulse and the first pulse in a sequence, Q0 sets the latch IC1, via D3, and LD1 illuminates via TR3 turning on. The remaining nine outputs, Q1-9, are individually selected by the note length multiplexer IC3, which resets the latch (see Figure 3) and extinguishes LD1. In this way, ten different pulse lengths (0 to 9), corresponding to note periods, can be selected by a 4 bit binary code from IC4 display and multiplex selector. IC4 is a dual BCD counter clocked by the divide by 10 output pulse from IC2, via push switch S2. With S2 held operated, a BCD code advances one count on the A-D bus, for every clock pulse, and steps the note period display driver IC7 and the note length multiplexer IC3. With S1 operated, the beat display driver and beat multiplexer codes are advanced over a separate A-D bus, in similar fashion. Beat counter IC5 & IC9 are connected together in cascade, and clocked from the latch/beat pulse to produce 15 sequential pulses although only nine are used, the selected pulse output to D9 resets IC5 and pin 3 goes high for the duration of the latch/beat pulse. LD2 illuminates signifying the first beat – or accent – in the sequence, or bar. For every note beat the tone oscillator is enabled from D1 and produces a tone, determined by the position of preset RV1, which drives the piezo buzzer via TR1. As the accent pulse is
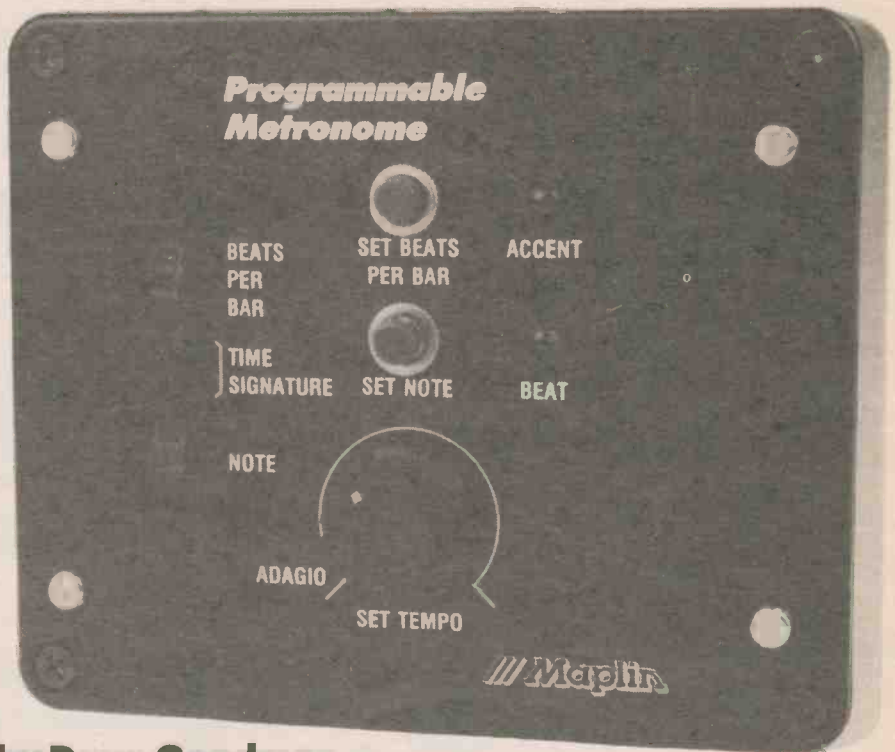
by Dave Goodman

★ Audio & visual beat and accent indication
★ Variable tempo from slow (adagio) to fast (presto)
★ Programmable time signature on 7 segment displays
★ Powered from 5V to 12VDC
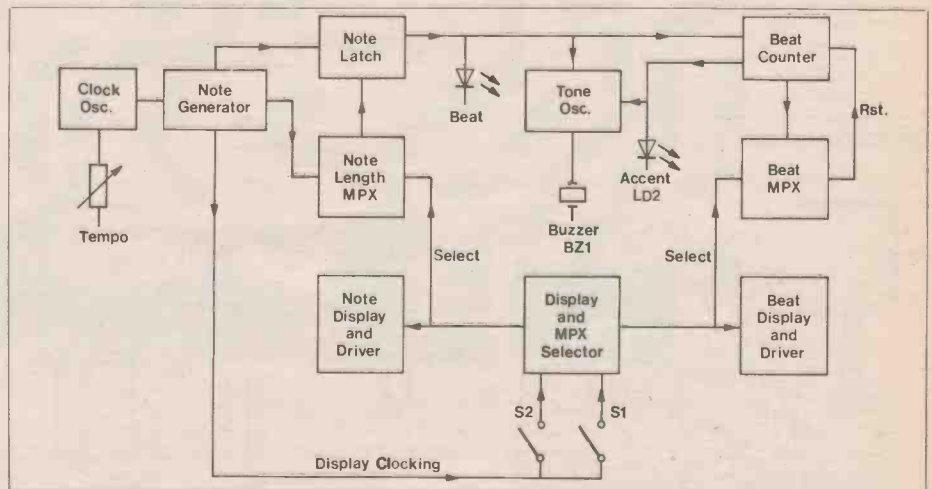
Figure 1. Block diagram.
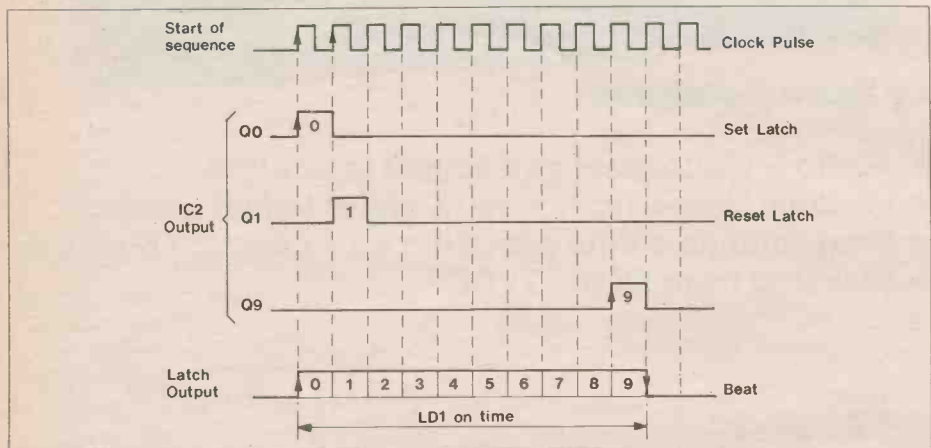
METRONOME
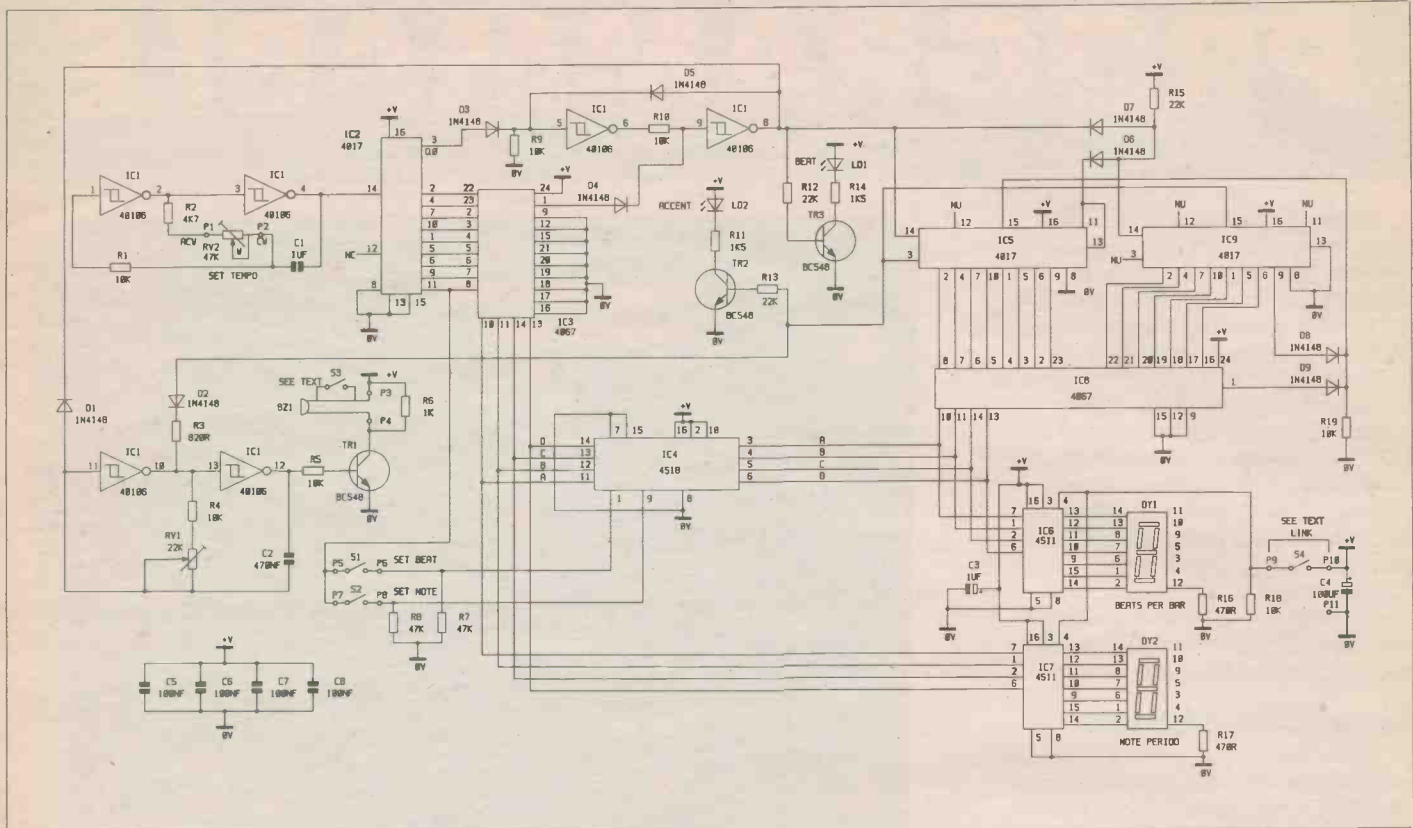
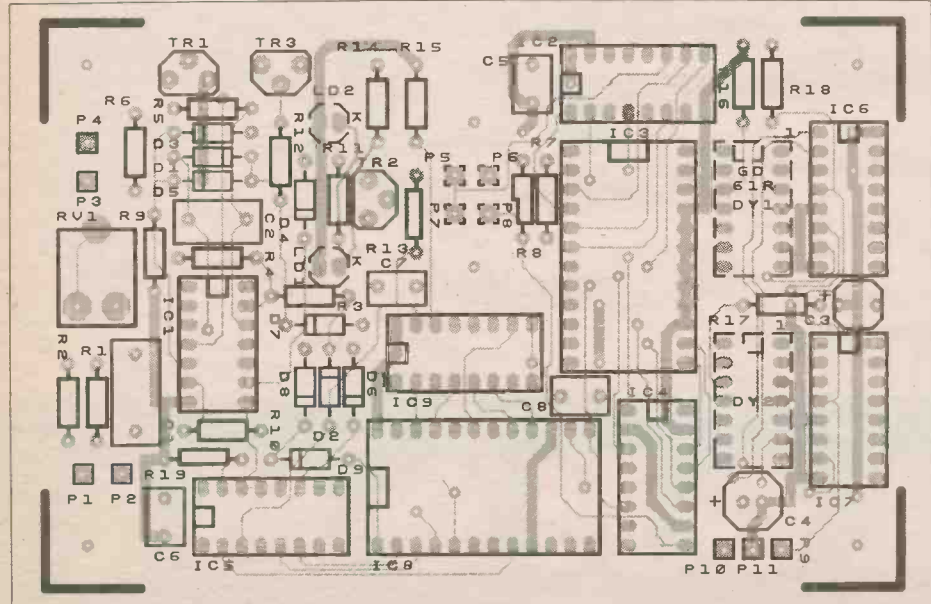Figure 2. Circuit diagram.

Figure 3. Note period timing.

Figure 4. Layout of PCB.

sequential with the beat pulse, the oscillator frequency drops by D2 conducting through R3, which changes the C2/RV1 charging characteristic. Thus the audible effect is one of a regular beep of the same pitch for each beat and a beep at a lower pitch on the down beat to accentuate a new bar.

Construction

Refer to Figure 4, the parts list and constructors guide. Identify and insert resistors R1 to R19, and diodes D1 to D9. Fit the 22k preset RV1 and capacitors C1 to C8 noting lead orientation on polarised types C3 & C4. Next, insert BC548 transistors TR1 to TR3 and solder all components fitted at this time. Cut off the excess wire leads and insert nine IC sockets, bend a few terminals on each socket over the track pad to prevent the socket from falling out and solder all remaining components. Clean any flux from the track areas and inspect for short circuits and dry joints before continuing.

Two sockets for DY1 & DY2 are mounted on the solder side of the PCB, as shown in Figures 5 & 6, and the socket terminals are soldered on the component side of the PCB. LED's LD1 & LD2 are also inserted from this side and positioned 10mm above the board (Figure 5) and soldered on the component side of the PCB. Insert the two seven segment displays, decimal points to the bottom, into their sockets on the PCB solder side, ensuring all 10 leads enter the socket correctly.

Solder both piezo buzzer leads to pins 3 & 4 and stick BZ1 to the solder side of the PCB, beneath LD1, using the adhesive quick-stick pad. Cut seven lengths of hook up wire 100mm long and connect the tempo control RV2 to pins 1 & 2 as shown. Connect 2 wires to each of switches S1 & S2, insert the wires through each hole in the PCB on the solder side and solder S1 to pins 5 & 6, S2 to
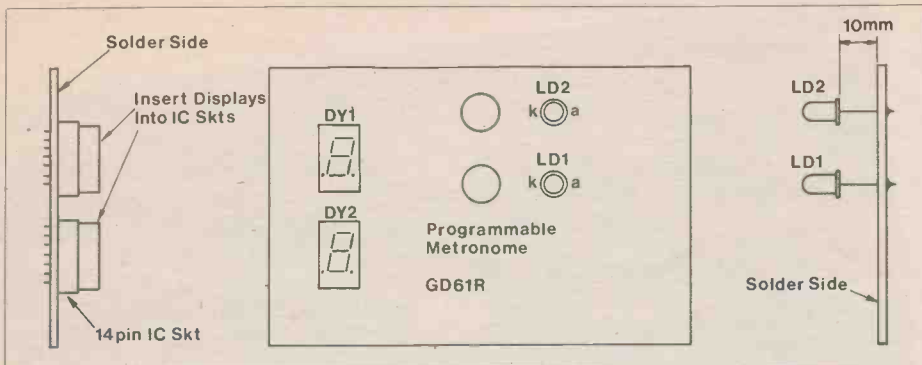
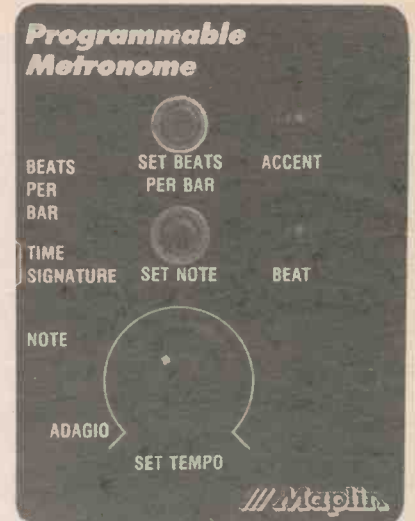**Figure 5. Mounting LED's and displays.**
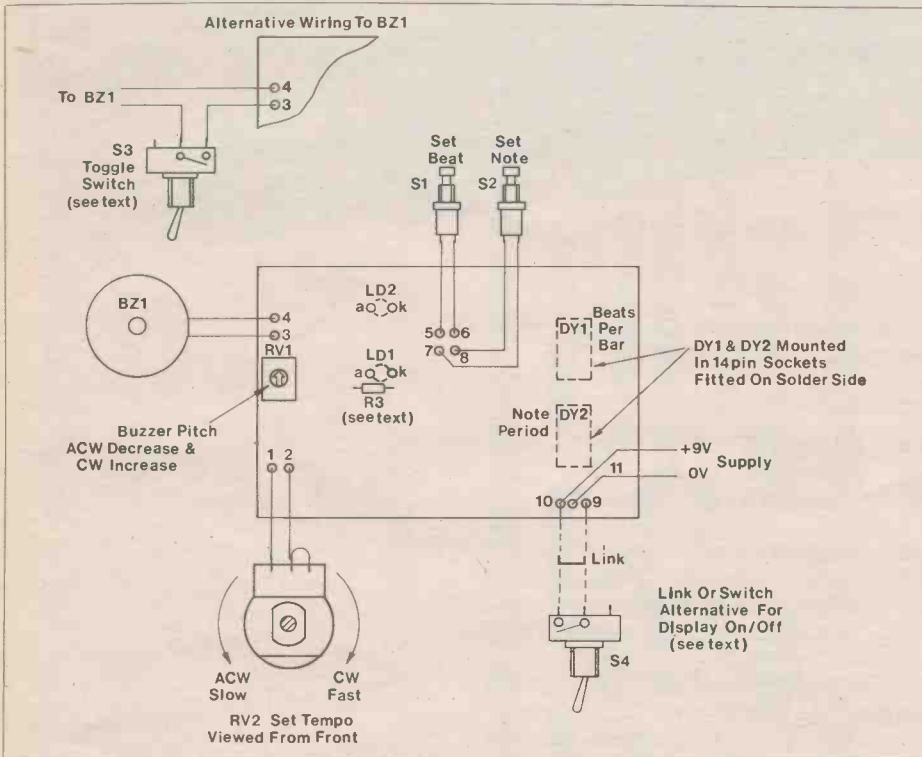
Figure 6. PCB wiring.
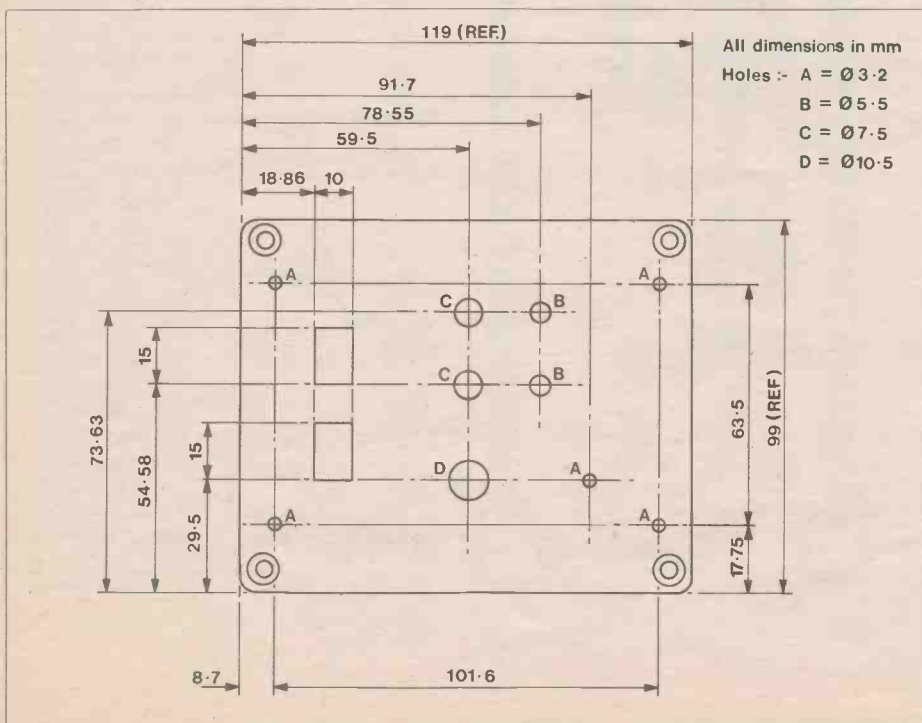
Figure 7. Box lid drilling.

Front Panel.

pins 7 & 8. The final length of wire is connected between the positive supply, pin 10, and display enable pin 9, shown as a link in Figure 6. If the link is omitted, the metronome still functions, but the seven segment displays will not be on.

Box Drilling Details

Figure 7 details the dimensions for drilling the box lid. The lid is shown from the front (outside) view and two 7·5mm holes are drilled for S1/2, two 5·5mm holes for LD1/2, a 10·5mm hole for RV2 and a 3·2mm hole to let the audio out. Four 3·2mm holes are required for mounting the PCB pillars onto, and two rectangular slots are required for the displays. Measure, mark off and drill the lid from the outside, drill the display slots 10mm diameter and file both holes out to 15mm x 10mm. The adhesive panel is now fixed in position over the centre of the lid and a piece of red filter can be cut and glued over the display cut outs as required.

No provision has been made for fitting the two switches, S3 & S4, on the lid as both are optional items and may not be used. The same applies to a power on/off switch. This too is optional and should be fitted as required.

Testing

Connect a 9VDC supply with positive to pin 10 and negative to pin 11. Link display pins 9 & 10, if not done previously, and apply power. The supply could be between 5 and 12VDC, but nominally 9V at 15mA with displays disabled or 9V at 50mA with displays enabled. A PP3 type battery could be used, but if the time signature displays are left on continuously, then a PP3 will not last very long: a few hours at most! Alternatively, a mains battery eliminator could be used instead of a battery and unregulated versions are best used with the 6VDC option selected. Set the tempo control RV2 at half travel and check the two displays. Numbers displayed are random at first power up and could be 0, 1 or 2 in both displays at this time. Press beats per bar switch S1 and hold operated; the beats per bar display count advances with each beat/flash of LD1. Release S1 and press S2; the note period display advances with each beat. Press both S1 & S2 at the same time and both displays advance together.

55

When the tempo is increased, or decreased by RV2, the display advance rate increases or decreases to suit. Set both displays to 0 and beat LED LD1 illuminates continuously while the buzzer sounds continuously. Press the set note switch S2 for 1 on the note display DY2. The buzzer should pulse, as should LD1, with a long 'on' to short 'off' ratio. Eventually, LD2 will flash and the buzzer pitch will drop. Start counting each beat now, from '1', and on the '17' count the pitch should drop again, with LD2 pulsing. Step the note display from 1 to 2, observe the beat LED and listen to the tone again. This time the 'on' to 'off' ratio is slightly less than before. Check each note length setting from 2 to 9 and the note length becomes shorter at each setting, as does the tone length. Leave the note length display set to 9 and adjust the beats per bar display for 1. After the previous sequence has finished, the tone drops, the accent LED flashes and the beat LED stays on permanently. Step the beats per bar display from 1 to 2 (both display 2 over 9), the beat LED flashes on the higher pitch and both the accent & beat LED's flash on the lower pitch. Step the beats per bar display from 3 to 9 checking the count from the first accent pulse up to (but not including) the next accent pulse, corresponds to this display.

The continuous pulsing tone may wear on the nerves after a while. Try adjusting preset RV1 for a different tone and/or change R3. Removing this resistor results in the beat and accent tones being the same, whereas the accent tone only can be altered by changing R3 for values between 220Ω and 2k2. A toggle switch, shown as S3 in Figure 6, could be fitted in series with one lead of BZ1, to switch it in or out of service when required.

Final Assembly

Fix four threaded pillars onto each hole at each corner of the PCB. The pillar is mounted on the solder side of the board and fixed with a 6BA x ¼in bolt as detailed in Figure 8. Insert the previously wired RV2 into the lid, from the inside, and also, S1 & S2; secure in place with the nuts and washers supplied. Offer the module up to the lid and place four 6BA x ¼in counter sunk screws into the lid and PCB pillars and tighten gently, see Figure 9. Fit any extra switches to either the lid or box and insert the module/lid assembly into the box. Secure with four box lid screws.

Time Signatures

As can be appreciated, time signatures do not have a 0 value which can be displayed on this metronome. To give a brief explanation of the signature, the bottom number relates to the type of note, or note length/duration, and the top number tells how many of these note types are in a bar.

A musician has to appreciate timing and 'counting time' becomes relative to the tempo and note. Each note type has a name and a count time, examples of some of these are:

Semibreve	(whole note	1)
Minim	(half note	2)
Crotchet	(quarter note	4)
Quaver	(eighth note	8)
Semiquaver	(sixteenth note	16)
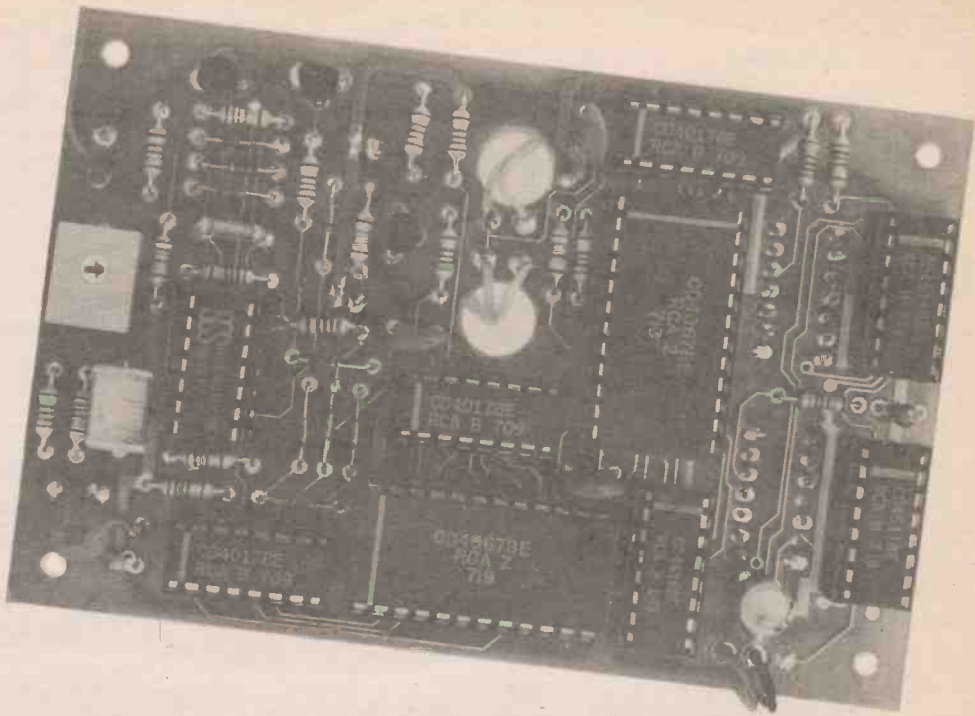
Relating these notes to more usual time signatures, we have:

2/2	2 minims in a bar
2/4	2 crotchets in a bar
3/4	3 crotchets in a bar
4/4	4 crotchets in a bar (common time)
3/8	3 quavers in a bar
6/8	2 dotted crotchets (6 quavers) in a bar
9/8	3 dotted crotchets (9 quavers) in a bar
12/8	4 dotted crotchets (12 quavers) in a bar

There are also music terms to describe the tempo of a piece of music. The term tempo does not only refer to the speed or pace that a piece of music should be played at, but introduces certain qualities such as: maestoso (majestically), brioso (vigorous) and scherzando (playfully). The metronome does not reflect these qualities in use, instead such terms as: adagio (slow), allegro (fast) and presto (very fast) apply and the qualities are left to the user!
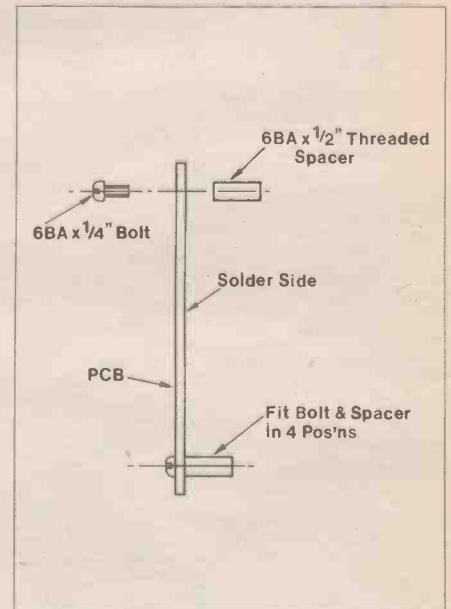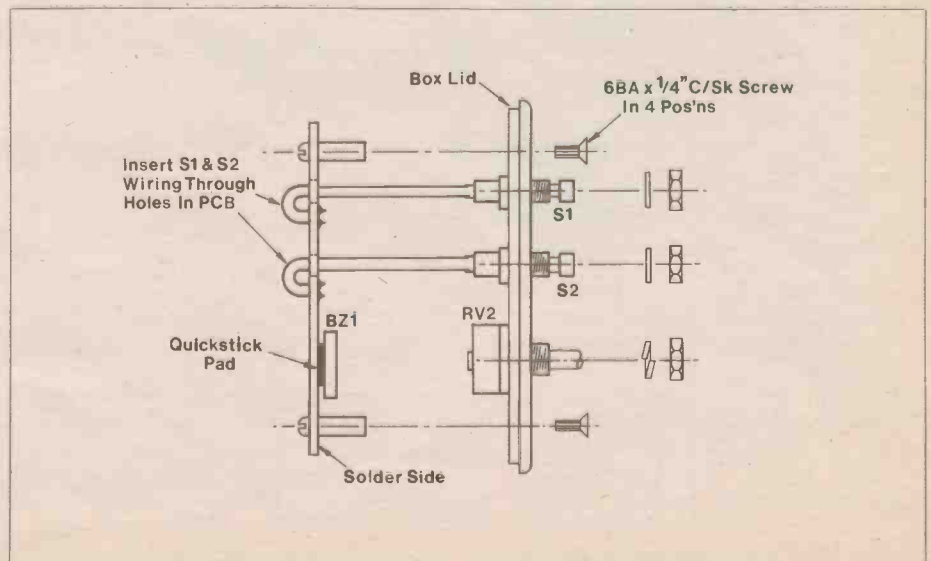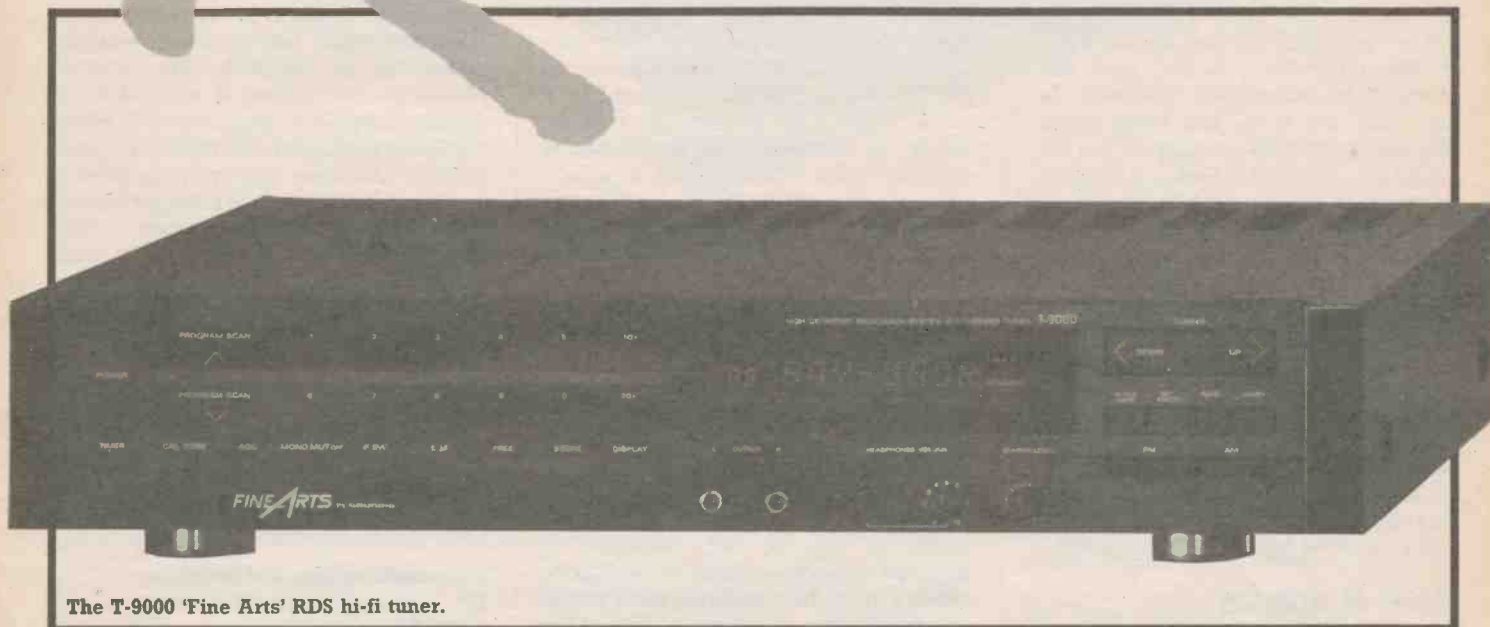
Figure 8. Fitting spacers to PCB.

Figure 9. Mounting PCB to lid.

Radio WITH BRAINS

The T-9000 'Fine Arts' RDS hi-fi tuner.

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

In 1968 I attended a liaison meeting between Working Party A of the European Broadcasting Union (EBU) and European receiver manufacturers. We discussed, among other things, the increasing problems (even then) of tuning radios; how you find the station you want and how, when you have tuned in a station, you know which one it is. I ended my report of the meeting (to the British radio industry) with the conclusion that we would continue to have problems finding the programmes we want 'unless the broadcasters would code them'. Nineteen years later, after 10 years of basic development work, such a system is being introduced, not only in Britain but also in other countries.

The Radio Data System and its forerunners

Some years ago, both the BBC and the German broadcasters developed analogue systems for broadcasting to car radios. The German 'ARI' (Auto Rundfunk Information – Broadcast information for motorists) system, which works on the VHF/FM band, has been introduced in some parts of Germany. The information capacity is rather limited and all the information is not available simultaneously. The BBC system, called 'CARFAX', would have operated on a special frequency at the low end of the MF band, but agreement could not be reached on making such a frequency available, so the service was not introduced. It would have operated on a similar principle to cellular radio, with a series of 'cells' of synchronised transmitters. Some IBA stations experimented with ARI, but there were then not so many FM car radios in Britain, and the siting of transmitters is far from ideal for broadcasting to cars. For example, there is a long stretch of the M20 which receives a very high field strength from the Wrotham transmitter, and a very high-performance receiver is required in order to receive any other station in this area.

Even while these systems were being developed, it was becoming clear that in due course a digital system could be introduced, because with LSI circuits, receivers could be made at a realistic cost to sell in sufficient volume. Most of the development work on the new system was carried out by the BBC and the Swedish broadcasting authority (Televerket), with a very great deal of evaluation and testing by other members of the EBU. The EBU published a technical specification of an agreed European system (EBU Tech. 3244) in 1984, and international agreement was reached on the system in 1986, through the CCIR (Comite Consultatif International de Radio), resulting in CCIR Recommendation 643. So your RDS receiver will work in any country in the world that has an RDS service, won't it? Well, yes, except, of course, Japan and Australia, where VHF/FM broadcasting is on different bands! But do you plan to take your car there?

RDS at home and away

While broadcasting to cars is a major application of RDS, it is very useful in the home radio, too. The only way to find your way through the maze of local radio stations is with one of those little books of frequencies available (free!) from the BBC and IBA and an accurately calibrated receiver, preferably with a digital fre-
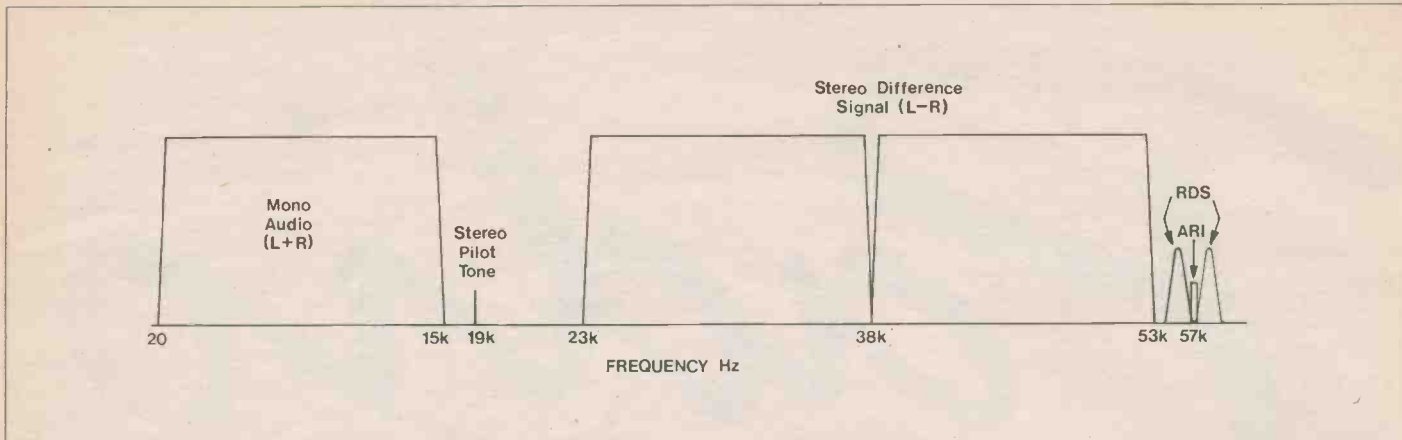
Figure 1. Spectrum of f.m. stereo signals with RDS and ARI added.

quency display. With the average portable it is a hopeless task. Not only this; you need to know about traffic hold-ups and incidents BEFORE you start on a car journey; otherwise you may pick the wrong route immediately you start. In fact, RDS can give you much more information about the programme you are listening to, and what is available on other stations, than you are ever likely to need in a car. There is so much data capacity that about half is simply 'reserved for future expansion'. As experience is gained with the system, the best uses of this spare capacity will become clear.

RDS is not the same as the closed user-group text transmission systems being introduced on the London IBA transmissions. These operate on a different principle, and a transmitter may not be able to carry RDS as well as these data channels; RDS and ARI are, however, with care at the transmitter, compatible.

How it works

The data is carried on a 57kHz sub-carrier which is inherently suppressed by the system of modulation employed. The sub-carrier is phase-locked to the 19kHz stereo pilot-tone, and may be in quadrature or in-phase, depending on whether ARI is also in use or not. On mono broadcasts the sub-carrier free-runs, but with only a 6Hz tolerance on frequency. The spectrum of a stereo broadcast signal with RDS and ARI added is shown in Figure 1. The injection level of the unmodulated sub-carrier is set to correspond to 2kHz deviation of the main carrier, but receivers should accept values from 1kHz to 7.5kHz. When ARI is in use, the RDS deviation should be 1.2kHz.

The modulation system is quadrature phase-shift keying, which can also be described as suppressed-carrier amplitude modulation of differential biphase-coded, band-limited data signals. We can break this condensed description down into its component parts to see more clearly what is happening.

Data rate, format and processing

The basic binary data rate is 1187.5 bit/s, obtained by dividing the sub-carrier

frequency by 48. This relationship is helpful in receiver design, not least because it eliminates the possibility of asynchronous interference between parts of the circuit. The data is made up of 16 bit words, each accompanied by a 10 bit checkword, making up a 26 bit 'block'. In this way, each block can be decoded quite independently, in principle, of any other. Four blocks are combined in to 104 bit 'groups'. In all cases, the most significant bit is transmitted first.

The 10 bit checkword consists of a 10 bit cyclic redundancy check (CRC), added to which is a 10 bit offset word to provide synchronisation at the receiver. The CRC allows the receiver to detect and possibly correct most of the errors which occur due to reception difficulties. The error-checking in the receiver is designed so that in one of its possible modes it can be very sensitive to slippage of block synchronisation. Blocks within a group have different offset words for identification. The first five bits of the second block of each group are reserved for specifying the application of the group. Because each block can, in principle, be decoded independently, data for which access time is critical can be transmitted very often, in the same place in each group, and decoded directly whereas that which is only required occasionally can be sent less often, and its application determined by reference to the five application bits in the second block of the group. This is clearly a most efficient way of using the channel capacity.

Before applying the data stream to the modulator, it is differentially encoded. This means that the coder output changes state only when the input bit is 1:

Input (at time t)	Output
0	$Q (t-1)$
1	$\overline{Q} (t-1)$

This truth table can be implemented simply with a D type flip-flop and an exclusive OR gate, which is quite easy to do.

The differentially coded data still consists of a stream of 1's and 0's. These are converted into biphase symbols by means of a double-frequency clock, some logic and a lowpass filter. The

result is a '1' symbol which consists of a positive-going, rounded pulse followed by a similar negative-going pulse, and a '0' symbol which has the negative-going pulse first, see Figure 2. When a data stream of this nature is applied to a double sideband suppressed carrier amplitude modulator, the resultant signal spectrum has zero energy at the carrier frequency, and very little energy close to that frequency. This is the part of the spectrum occupied by ARI signals, and the low RDS energy in this region allows compatible, simultaneous operation of both services.

What can RDS do?

The services that the full RDS system can provide are very comprehensive: indeed, some of them have not been fully worked out yet. The services which have been standardised are as follows:

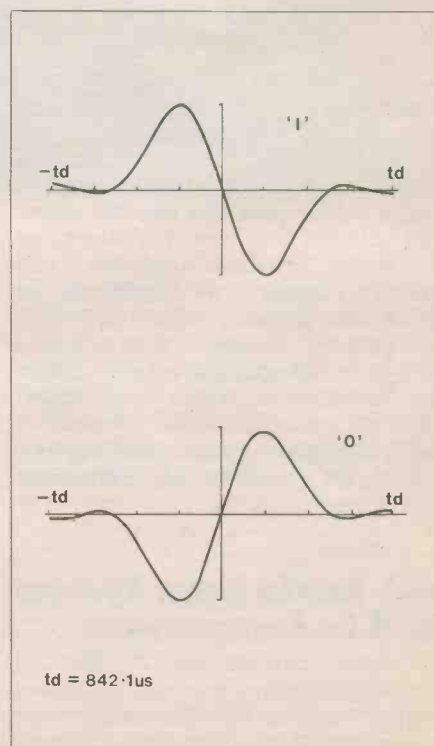**Automatic tuning and re-tuning**
PI: programme identification.

Figure 2. Biphase coded symbols.

PS: programme service name.
AF: alternative frequencies carrying the same programme.
TP: traffic programme identification.
PTY: programme type.

General functions
TA: traffic announcement identifier.
DI: decoder identification.
M/S: music/speech switch.
PIN: programme item number.
RT: radio teletext.
ON: other networks.
TDC: transparent data channel.
IH: in-house applications.
CT: data and time.

It is not necessary for each RDS station to include all of these services in its transmissions, and receivers must be designed not to misbehave when any service is absent.

PI: Programme identification

This is a 16 bit word, the first four being a code for the country of origin of the broadcast, then 4 bits indicating the service area (local, regional or national) and 8 bits for individual station identification, allowing up to 255 stations in a network. This word is for the receiver to use to find a specified programme.

PS: Programme service name

This consists of eight ISO646 characters giving the programme name in user-friendly form (such as 'BBC R 1'). ISO646 is an international standard, embracing ASCII codes for Roman letters and Arabic numerals, but extended to include accented letters, Greek and Cyrillic characters. The PS can be displayed on the receiver panel.

AF: Alternative frequencies

In order to ensure that the receiver is tuned to the strongest available signal carrying the wanted programme (without having it continuously search the band), alternative frequencies may be stored in RAM in the receiver, so that they can be looked up quickly by the control processor. These frequencies may be outside the VHF band, because automatic band-switching in the receiver is perfectly feasible if the VHF receiver is kept operating to update the RDS information while a programme on another band is being listened to.

TP: Traffic programme identification

This flag allows car or household receivers to be retuned automatically to the local traffic information station.

PTY: Programme type

This word allows the user to select programmes by general type ('News' or 'Jazz'), rather than specifically. This information could also be displayed on the receiver.

TA: Traffic announcement identifier

This single bit flag indicates that a traffic announcement is being broadcast, and allows automatic over-ride of another programme to reproduce it.

DI: Decoder identification

This is a 4 bit word which allows the automatic insertion in the receiver of a specified standard decoder for noise reduction, surround-sound or whatever. It remains to be seen whether non-technical issues will hinder the development of this very desirable feature, but previous history is not encouraging! Still, at least the possibility has been acknowledged, and the bits are there.

M/S: Music/speech switch

In spite of all the Peak Programme Meters, dynamic compressors and pre-emphasis, it is still not possible to satisfy all listeners in respect of subjective loudness balance between music and speech. I doubt whether this feature will solve the problem, but it does allow the receiver to have two volume controls, one for music and one for speech. My pessimism is founded on the belief that the listener's preferred balance is strongly subjective, and varies from time to time. For instance, I quite like Sosa marches, and react positively to one following, at a clearly higher sound level, a continuity announcement. But not at 7.00 on Monday morning! In fact, I want 3dB less output from the radio in the morning, irrespective of programme.

PIN: Programme item number

This can be used to tell how far the programme has gone, and for educational broadcasting it allows programme-controlled automatic recording.

RT: Radio teletext

This is the most glamorous feature: a 64 character display of text on the radio. This could show newsflashes, sports results, emergency messages (using a speech synthesiser rather than a visual display for in-car use) and titles of musical items. However, it is unlikely that a full text service will be introduced until there are a considerable number of receivers in the field.

ON: Other networks

These data allow retuning for news broadcasts, or to preserve the type of programme that one wants to listen to.

TDC: Transparent data channel

Transparent means that the user of the receiver can be unaware of the existence of this feature unless he needs it. Data, such as telesoftware, could be downloaded through a connector on the receiver to a computer or other DP unit. Steps are already in hand to standardise such a connector and the signal characteristics internationally.

IH: In-house applications

This is data for the broadcasters' own use. I wonder what they will do with it.

CT: Clock time and data

The radio can display either UTC (formerly GMT) or local time/zone time, and the date. All leap year days and leap seconds can be automatically included.

Group type codes

The 5 bits allocated for the group type code are split into a 4 bit 'A-word' and a 'B-flag'. This flag allows two different versions of each group to be sent. Only seven of the sixteen A-words have their meaning defined at present, the others being reserved for future expansion. In terms of the decimal values of the A-words, code 0 means basic tuning information, code 2 means Radiotext and code 15 means fast tuning information.

The CCIR recommends repetition rates for the data ranging from 11 times a second for PI, PTY and TP to once every 5 seconds for RT. AF data should be transmitted serially every 4 seconds: there may be up to 25 alternative frequencies listed, so the list may take 100 seconds to send.

Receiver design

Receiver manufacturers have been working with IC designers to develop suitable low-priced devices for decoding and processing RDS signals. The achievement of low prices, of course, depends on making enough sales to pay for the vast costs of developing l.s.i. devices. Some of the techniques used in experimental receivers are described below: commercial receivers may well use different techniques.

The stages of signal processing in the RDS section of a receiver are:

Demodulation of the 57kHz (suppressed) carrier.
Decoding the biphase symbols.
Regenerating the bit-rate clock.
Group and block synchronisation.
Error detection and correction.
Decoding address and message codes.
Implementing instructions for automated operation.
Storing and/or displaying data.

Demodulating the sub-carrier

There are several ways of doing this, but one of the simplest is called a 'differential demodulator'. Effectively this multiplies the received signal with a delayed version of itself. In order to do this, any ARI or other signals close to 57kHz have to be filtered out. This filter can be made with another delay device, as shown in Figure 3.

Symbol decoder

The biphase symbols may be decoded by means of an integrate-and-dump circuit, as shown in Figure 4. The inverting amplifier and switch convert the skew-symmetrical (pure AC) biphase signals into two positive pulses for a '1', or two negative pulses for a '0'. The result is integrated over one bit-period, and the integrator is reset after the voltage at its output has been measured. This voltage represents the differentially-encoded data, which can be converted to normal data by means of a D type flip-flop, just as it was encoded at the transmitter. This circuit, and the following sections, re-
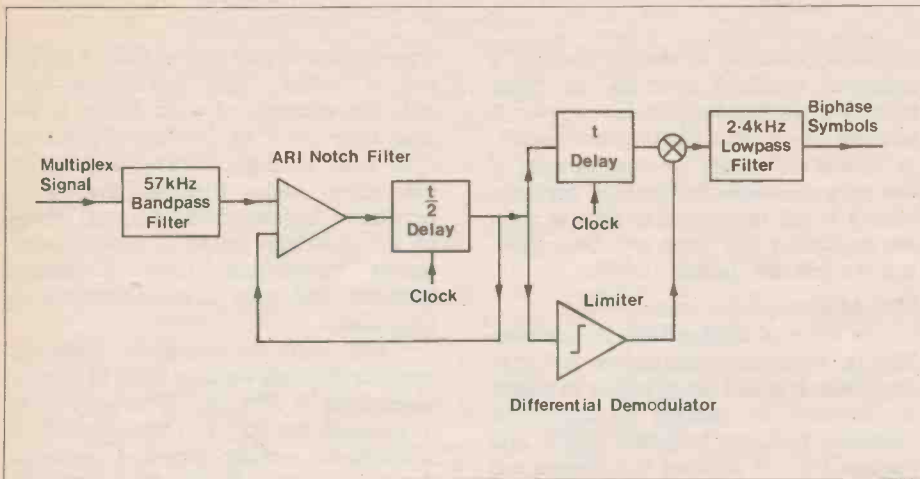
Figure 3. Differential demodulator with delay line filter for ARI rejection.
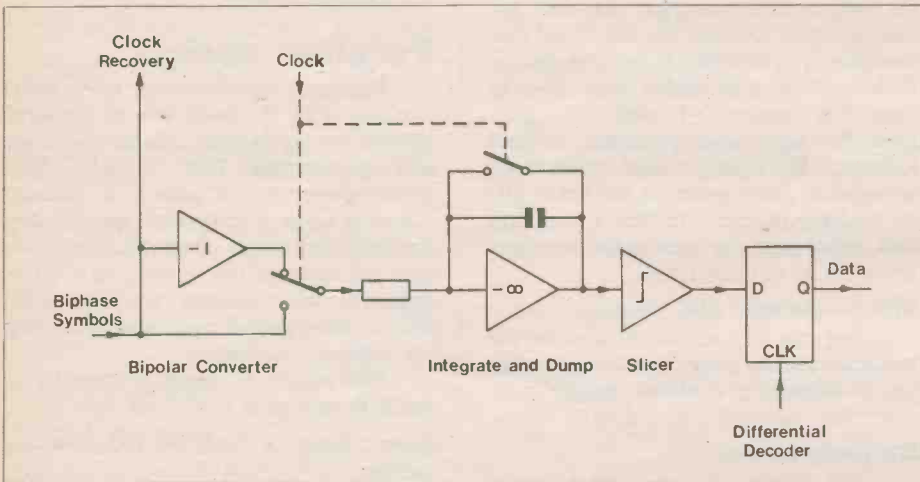

Figure 4. Biphase symbol decoder.

quire a bit-rate clock to be recovered from the data signal.

Regenerating the bit-rate clock

There is always a zero-crossing at the centre of every biphase symbol, but there is a zero-crossing at the start of a symbol only if the previous data symbol and the current one are the same. It is possible to use this property of the signal to control a variable-ratio digital divider operating on the 57kHz recovered sub-carrier signal. This allows a certain flexibility in the ratio of the sub-carrier frequency and the bit-rate, which can be helpful at the transmitter.

Group and block synchronisation

It is possible, and very practical, to do this, and all the subsequent processing, by means of a standard 8 bit microprocessor. In fact, using one of the faster devices, all processing except the initial demodulation can be carried out in this way.

The synchronisation is carried out using the checkwords and the error-correction procedure: in synch mode error-correction itself does not take place, instead the error-correction is used only to synchronise the processor with the data. This process is very difficult to describe, but basically the offset words are chosen so that for each
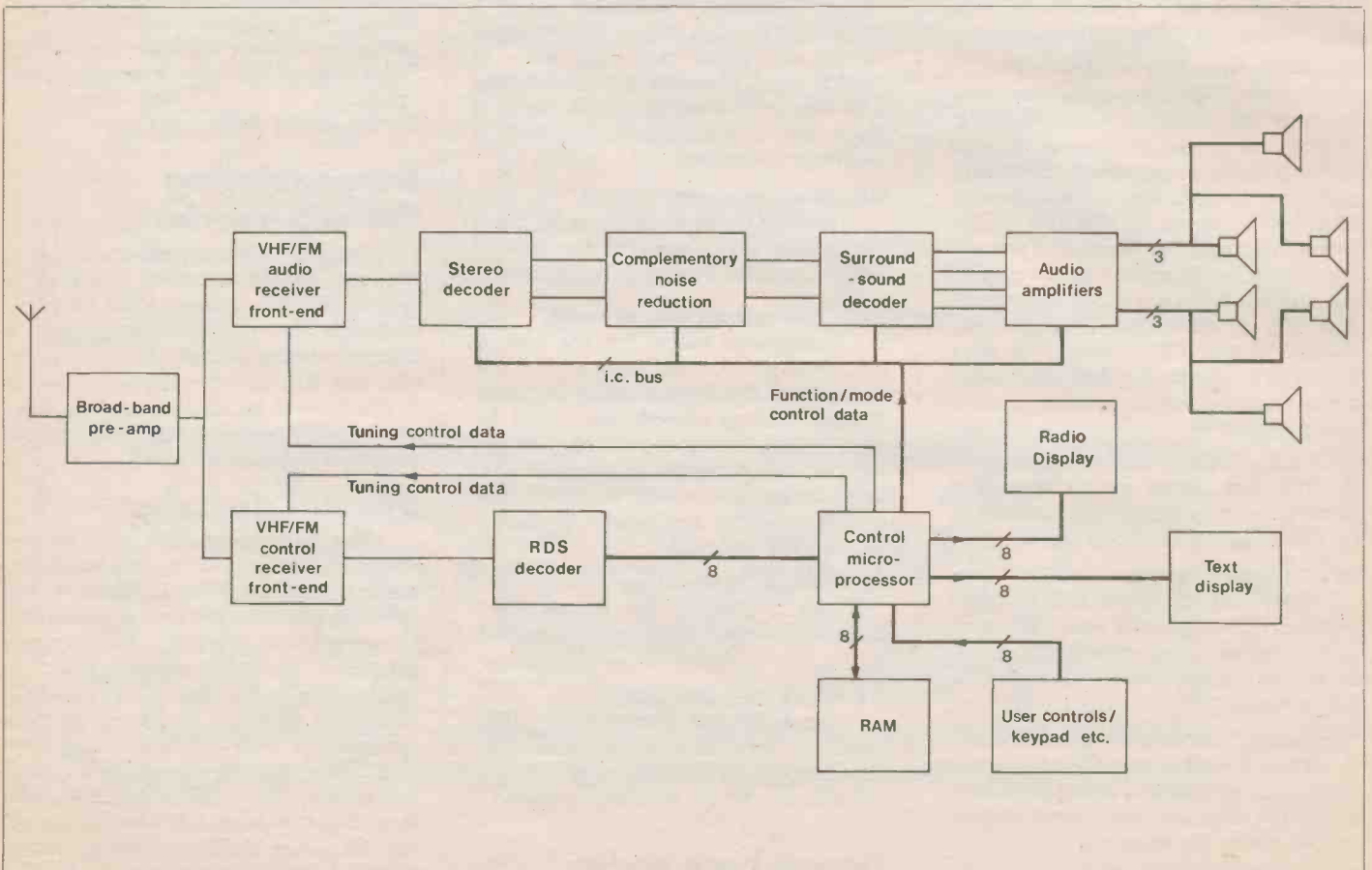

Figure 5. Block diagram of a possible future design of RDS receiver.

number of bit-periods of synch slippage a unique bit-sequence ('syndrome') is produced by the error-correction: it is thus easy to use this data to drive the data decoder into synchronism quickly.

If the full 5 bit burst error-correction capability of the system were employed (after synchronisation had been achieved), too many undetected errors could occur, so it is normally arranged that 1 or 2 bit errors are corrected, and blocks containing more errors are simply discarded.

Implementing commands, storing and displaying data

A block diagram of a complete stereo receiver is shown in Figure 5. This receiver has two tuners, one to produce the audio signals and one to look for better (usually stronger) signals and traffic broadcasts. The majority of RDS processing uses an 8 bit microprocessor, and AF, ON and user data are stored in RAM. User input to the RDS system is by means of a keypad. The display is split into two parts: that for the radio functions being separated from the Radiotext display so that it does not distract the person reading the latter.

Where can you buy one?

The RDS service is now operating on all the FM transmitters serving England, and will be extended north and west during 1988. Many receivers, however, are not scheduled for release until late next year in this country, although, like the Grundig hi-fi tuner, they are on sale in Germany now. While the BBC are doing their best to provide information on the service and on receivers, the information from manufacturers is sparse: Philips, for instance, suggested that only the head office in Eindhoven could answer questions on RDS! It was hoped that a sample receiver could be made available so that this article could have included a 'mini-review' and some practical results, but none of the manufacturers contacted could oblige.

Conclusions

RDS is the first sign to the general public of the impact of information technology on the second oldest means of true mass communication. While the British public has traditionally been regarded, with justification, as conservative and suspicious of new technology, it

seems likely that the computer-literate generation will respond very positively to RDS, and will demand it, not on up-market radios but on ghetto and yuppie-blasters not too different in price from the present offerings, and will demand it sooner than the industry is geared to provide.

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Continued from Page 56.

PROGRAMMABLE METRONOME PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,4,5,9,10, 18,19	10k	7	(M10K)
R2	4k7	1	(M4K7)
R3	820Ω	1	(M820R)
R6	1k	1	(M1K)
R7,8	47k	2	(M47K)
R11,14	1k5	2	(M1K5)
R12,13,15	22k	3	(M22K)
R16,17	470Ω	2	(M470R)
RV1	22k Hor Preset	1	(UH04E)

CAPACITORS

C1	1μF Polylayer	1	(WW53H)
C2	470nF Polylayer	1	(WW49D)
C3	1μF 35V Tantalum	1	(WW60Q)
C4	100μF 16V Minelect	1	(RA55K)
C5,6,7,8	100nF Minidisc	4	(YR75S)

SEMICONDUCTORS

IC1	40106	1	(QW64U)
IC2,5,9	4017	3	(QX09K)
IC3,8	4067	2	(QW42V)
IC4	4518	1	(QX32K)
IC6,7	4511	2	(QX31J)
TR1,2,3	BC548	3	(QB73Q)
D1-9	1N4148	9	(QL80B)
LD1,2	LED Red Hi Bright	2	(WL84F)
DY1,2	Display 7 Seg Red Type 4	2	(FR38R)

MISCELLANEOUS

S1,2	HQ Push Switch	2	(YR67X)
BZ1	Min Piezo Sounder	1	(FM59P)
	DIL Socket 14 Pin	3	(BL18U)
	DIL Socket 16 Pin	6	(BL19V)
	DIL Socket 24 Pin	2	(BL20W)
	Metronome PCB	1	(GD61R)
	Spacer Threaded 6BA x ½in.	1 Pk	(LR72P)
	Bolt 6BA ¼in.	1 Pk	(BF05F)
	Bolt 6BA ¼in. Csk	1 Pk	(LR56L)
RV2	47k Pot Lin	1	(FW04E)
	Box ABS MB3	1	(LH22Y)
	Front Panel Stick on	1	(JG23A)
	Filter Red	1	(FR34M)
	Knob K7A	1	(YX01B)
	Constructors Guide	1	(XH79L)
	Quickstick Pad	1 Stp	(HB22Y)
	7/02 Wire 10m White	1	(BL09K)

OPTIONAL

S3,4	SPST Ultra-Min Toggle	2	(FH97F)

A complete kit of parts, excluding Optional items, is available:
Order As LM49D (Metronome Kit) Price £29.95
The following items are also available separately, but are not shown in our 1988 catalogue:
Metronome PCB **Order As GD61R Price £7.95**
Metronome Front Panel **Order As JG23A Price £1.50**

Practical Digital Electronics Handbook

by *Mike Tooley*

This 'handy' book is a practically based introduction to digital electronics for enthusiasts, technicians and students alike. It contains constructional details on nine test gear projects including a logic probe, current tracer, digital IC tester, pulse generator, RS232 breakout box and a bench PSU. All of the projects are fully explained with circuit descriptions and testing procedures, in addition a circuit diagram, stripboard layout, front panel wiring and full parts list are shown for each.

The constructional projects however are not the main part of the book, they are presented in the form of appendix two. Appendix one is also very useful as it contains pin-outs for the most popular TTL 74 series and CMOS 4000 series integrated circuit packages, and also a decimal to binary to hex to ASCII conversion chart. The main part of the book covers basic logic gates, monostable and bistable devices, timers, microprocessors, memories, input and output devices and interfaces, this includes RS232 and IEEE-488 information. The text is liberally sprinkled with diagrams, tables and charts, and is easy to read and doesn't get bogged down with too much technical trivia.

All in all a very useful introductory book with the added bonus of practical projects to build.

208 pages, 216 x 138mm, illustrated.
Order As WP86T (Pract Dig Elec Handbook) Price £6.95 NV

Audio Amplifier Fault-Finding Chart

by *Chas. E. Miller*

This chart has been designed to help the reader approach fault rectification and repair of audio amplifiers in a systematic and logical way. The author has developed the chart by drawing on many years of experience in repairing audio and hi-fi systems and used properly, should enable the reader to trace many common faults reasonably quickly.

All the reader has to do is select one of the faults shown at the top of the chart, then follow the arrows carrying out the suggested checks in sequence until the fault is cleared. With the aid of this inexpensive chart you will be able to improve your skills at the work bench and increase the working life of your equipment.

Fold out sheet 640 x 450mm
Cover size 178 x 120mm
Order As WP83E (Audio Amp Fault Chart) Price 95p NV

Radio Amateurs Examination Manual

by *G. L. Benbow G3HB*

This highly informative manual published by the RSGB is aimed at supplying all the knowledge required to become a 'radio amateur'. The book covers all the technical subjects that an amateur needs to know to pass the RAE examination, as well as general information about being an amateur and some example examination papers (with answers).

The subjects covered include electrical theory, semiconductors, radio receivers and transmitters, measurements, propagation and antennas. Also included is a large section on operating practices and procedures. Other sections cover mathematics, transmitter interference and licence conditions.

As one would expect from the RSGB, the book is crammed with their accumulated knowledge and is ideal for anyone contemplating taking the RAE and joining the ranks of the 'radio enthusiast'.

156 pages, 244 x 180mm, illustrated.
Order As WP87U (Radio Ams Exam Manual) Price £4.94 NV

Amplifier Fault-Finding Chart

CHAS. E. MILLER

A Guide to Amateur Radio

by Pat Hawker G3VA

This book is intended to assist the newcomer to learn more about the hobby, and to help him/her to obtain a transmitting licence. The guide also contains technical information of interest to all radio amateurs and listeners.

The conditions for the UK amateur licences and the syllabus for the Radio Amateurs' Examination are incorporated together with a set of specimen questions, and there is a separate chapter devoted to the principles of electronics. Both newcomers and those seeking basic information on the very large range of equipment that has been produced for amateurs will find the enlarged chapter on factory-built equipment, popular receivers, transceivers and transmitters, particularly valuable. Other useful chapters include one on workshop practice, i.e. how to make your own equipment, one on safety pointers and one on the RSGB itself. In fact this book is an indispensable aid to all who want to learn about this unique and fascinating pastime.

154 pages, 246 x 184mm, illustrated.

Order As WP88V (Guide to Ams Radio)   Price £3.62 NV

Pat Hawker, G3VA

a guide to amateur radio

Nineteenth Edition

Electronic Hobbyists Handbook

by R. A. Penfold

This book provides an inexpensive single source of easily located information that the amateur electronics enthusiast is likely to need for the day to day pursuance of this fascinating hobby.

The characteristics and pin-outs of many popular semiconductor devices are given, including various types of logic ICs, operational amplifiers, transistors, FETs, unijunctions, diodes, rectifiers, SCRs, diacs, triacs, regulators and SMDs, etc.

The handbook illustrates many useful types of circuit, such as timers, oscillators, audio amplifiers and filters, as well as a separate section on power supplies. A multitude of other useful data including circuit symbols, common colour codes, interface details, amateur and CB frequency allocations have been included which will be useful to professional engineers, designers, and students alike.

88 pages 265 x 195mm, illustrated.

Order As WP84F (Elec Hobby Handbk)   Price £4.95 NV

A Practical Approach to Systems Electronics

by J.M. Gregory, R.Q. Hackett and C. Vincent-Smith

This book provides a complete experiment-based course in digital and analogue electronics, combining detailed instructions for practical work with theory and questions to aid understanding. It has been written for A level physics students, but would also be useful to those preparing for O, AO and A level examinations in electronics and as a source of useful circuits for project work.

The emphasis is on the systems approach - concentrating on using currently available devices as building blocks, rather than on how the devices themselves work. In line with this approach, integrated circuits are introduced before discrete components such as the transistor.

By working through the experiments and questions, students will quickly gain confidence in constructing circuits and in interpreting data sheets and other electronics literature. Answers or guides to practical solutions are provided for all the questions.

88 pages, 215 x 275mm, illustrated.

Order As WP85G (Prct App Syst Elec)   Price £4.95 NV

How to Pass the RAE

by George Benbow G3HB

The RAE is now a multiple choice examination and this book explains the implications of multiple choice and recommends an approach to studying for it. Mathematical questions in the RAE often present difficulties to the mature student and hence a revision course is included in chapter 3. The student is then taken through all the stages of preparing for the examination, from finding a college course to the preliminary formalities in the examination room and how to fill in the answer sheet.

A number of sample examination papers having the form of the RAE are included. It is, of course, not possible for these sample questions to have been pre-tested and validated in the same way as those set by the City and Guilds of London Institute, but they have been carefully vetted by a panel of members of the Education Committee of the RSGB.

If you are intending to take the RAE, this book will be invaluable in your preparation and a useful aid in testing your knowledge.

90 pages, 246 x 184mm, illustrated.

Order As WP89W (Pass the RAE)   Price £3.15 NV

A PRACTICAL APPROACH TO SYSTEMS ELECTRONICS

JM Gregory, RQ Hackett, C Vincent Smith

CLASSIFIED

VARIOUS FOR SALE

Heathkit laboratory oscilloscope, 5in. screen, single beam, 10MHz 10mW, excellent condition. Tel: 01 748 1410.
Components for sale! Capacitors, semiconductors, opto-electrical, connectors, switches, fuses, cable, etc. Send an S.A.E. to Adrian Bhagat, 10 Meynell Walk, Peterborough, Cambs PE3 6RR. Also send your list of components please.
Woodworker magazines 1920 - 1985, various for sale or exchange for oscilloscope, or similar. Please send an S.A.E. for details. D. Hine, Glenrue, 6 Butt Lane Close, Hinckley, Leicestershire LE10 1LF.
Datong Morse Tutor, model D70. Good condition, £35. Morse key, £1.50. Please Tel: 0823 432909 (Somerset) before 9.30pm.
Heathkit AO-1U A.F. Generator, £27. Nombrex C/R bridge, £22. Tech grid dip meter, £18. Range doubler 50k ohm/volt multimeter, £12. Phonosonics spring line reverb unit, £17. Eagle FF11 graphic equaliser, £29. Tel: 0502 66026.
Teletext: Texas XM11 module £12. Mullard VM6101 module, plus local keyboard chip and data, £30. S100 Tarbell blank cards £15 each, 4 available. Highest quality. Prices include postage. Porthtowan 890688.
300 copies (approx) of Practical Electronics and Electronics Today, plus odd copies wireless magazines. Any reasonable offers? N. Mitchell, 9 Castleton Road, Nottingham SE9 4BY.
Collector's Items: Early Siemens signal generator (c. 1930); WW2 receiver R1155; Old Solartron oscilloscope (1950's). Details on request (SAE). M. A. Priestley, 32 Bankpark Grove, Tranent, E. Lothian EH33 1AU.
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Radio control pick-up, scratch built with Maplin's receiver and speed controller with working side, head, reversing and indicator lights (all bulbs). Sell to best offer. Phone for details: 01 593 8522.
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Maplin 15W Amplifier Kit built, tested & mounted in aluminium chassis, £7 inc. p & p. Also copper clad board at giveaway prices; Mike, Portsmouth (0705) 694637.

COMPUTERS FOR SALE

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Neos Mouse for Commodore. Brand new, unwanted gift with 'cheese' art program disk, for Commodore 64/128, £15. Also music maker keyboard for C64, £5. Fareham (0329) 235370.

BBC 'B' software on tape. Music, peeko computer, membership manager, £4.50 each. Welcome £3.99. Games: Airline, mined out, £2.99 each. Starship command £3.99. Tel: Hatfield (07072) 60791.
Spectrum 48K computer plus interface, Maplin speech synth, 18 programs and joystick, £78. Fidelity sensory 8 chess challenger, £39. Tel: 0502 66026.
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Amstrad CPC464 with monitor, colour modulator, books and magazines, speech synthesiser, £140. 70 software titles, games and serious (worth £260), £80. Both for £200. Tel: 0293 518104.
Commodore printer/disk drive. MPS-801 printer with Z4 typestyles, C1541 disk drive. Suits any Commodore computer. With disks, paper, etc. 1 year old, as new. £180 the lot! Will split. Fareham (0329) 235370.
First Byte switched joystick interface for Electron, boxed with conversion tape. Used twice, excellent condition. Contact Peter Davey, 10 Westleigh Drive, Sonning Common, Reading, Berks RG4 9LB. Tel: 0734 722457.

CLUBS

Radiation monitors? Will Sellafield, Trawsfynnydd, Hinkley, blow again? Will they tell you? Have you got a monitor and a Class A licence? Do you want a Downwinders' Doomwatch? NOT Raynet. Contact Box No. 7, Electronics, The Maplin Magazine, P.O. Box 3, Rayleigh, Essex, SS6 8LR.

MUSICAL FOR SALE

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MIDItations is a cassette of easy-listening synthesiser music performed and arranged by David Howard using MIDI. Available for £3.50 (inc. P & P) from: MIDItations, 9 Cavendish Drive, Leytonstone, London E11 1DN.

Maplin organ complete to MES55. 50W amplifier and speakers. Solid wood console. Full working order with diagrams and springline. Cost in excess of £750. Serious offers? Must sell, need space. Tel: 0277 821534.
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1982 Matinee Organ plus stool, little used, as new. Original component book etc. Two adjustments needed. £300 o.n.o. Tel: 0272 694599.

WANTED

Pioneer SX525, amp/tuner or printed boards with components, working or not, any condition considered. Write to Alex Palfrey, Commerce House, Brockdish, Diss, Norfolk, IP21 4JY.
Beginner wants copies of Television magazine: 1970 onwards, must be consecutive. Also radio and television servicing books, the red hardbacks, state price. Contact 44A Caersalem Terrace, Llanelli, SA15 1AY.
Wanted 12V to 240V AC inverter up to 800W intermittent rating. Alternatively inverter transformer to this rating. D. Lillington, Farm Cottage, Merstone, I.O.W. Ring 0983 529347.
Wanted service manual and/or circuit diagram for Heathkit oscilloscope model 10-18U. Please phone 0732 359376 or write to D. Terry, 4 Hadlow Road, Tonbridge, Kent TN9 1NU.
Wanted circuit diagram for high gain 5 S.S.B. AM/FM CB radio. Contact Alec, 898 Middleton Road, Chadderton, Oldham, OL9 9SB.
Wanted oscilloscope, cheap, good working order. Also 'Electronics' issues 1 to 5. V. Thornley, 10 Greenbank, Ulverston, Cumbria. Tel: 0229 54280.
Wanted IBM 'golfball' printer mechanism, etc., suitable for Maplin driver and ASCII centronics facility. Phone (091) 2525355.
Wanted dead or alive, barograph and temperature recorders, G2LV. South Molton (07695) 2495.
Information required on initialising a Brother EP44 printer with a 48K Spectrum using a transform ZXLPRINT III interface. McAllister, 48 Daneswell Drive, Moreton, Wirral, Merseyside.
Wanted Heathkit COA-2600/4 timing light with built in advance meter, for connecting to Heathkit CO-2600 ignition analyser. Contact M. Mills, 34 Girton Road, Sydenham, London, SE26 5DH or Tel: 01 676 9005.
Wanted Oric Atmos microdrive and Oric printer. Preferably with data. Also any information on user groups still in existence. Tel: Tom on 0772 617305 after 6pm.

DID YOU MISS THESE ISSUES!

Project Book 1 Universal Timer. Programmable mains controller. **Combo-Amplifier.** 120W MOSFET power amp. **Temperature Gauge.** 10°C - 100°C, LED readout. **Pass The Bomb!** Pass-The-Parcel with a difference. **Six easy-to-build Projects on Veroboard.** Car batt. monitor; Colour snap game; CMOS Logic Probe; Peak Level meter; Games timer; Multi-colour pendant.
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Project Book 18 Weather Satellite Receiver. Display regional weather systems on your TV or monitor. **Mixing It Part 2.** Mono/stereo Hi–Z mic

input, mixer and line amplifiers; VU/headphone driver. **Stepper Motor Driver.** How to build and start using the Stepper Motor Kit featured in the Catalogue. **Amstrad Expansion System.** The Maplin Amstrad External ROM Card System for the CPC 464, CPC 664 and 6128. **Sealed Lead Acid Battery Charger.** Special high stability output with automatic trickle charge mode for sealed lead acid batteries. **Fantastic Five.** Veroboard projects comprising HF tremelo unit, crystal checker, clap switch, low–Z ohmmeter, snooze timer.
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Electronics Issue 19 Active Aerial and Aerial Tuning Unit. Get more from SW. **Amstrad Expansion System.** 6 x 8-bit parallel I/O card and PSU. **ADA Digital Echo.** RAM based low cost echo machine. **Mixing It.** Mixer Modules' PSU.
Order As XA19V (Maplin Magazine Volume 5 Issue 19) Price 75p *NV.*

Project Book 20 Weather Satellite Decoder. Displays output from Satellite Receiver on TV or monitor. **Infra Red Proximity Detector.** Short range heat or movement detector. **Fibre-Optic Link.** Sends AF signals over up to 20m of fibre-optic cable. **Low-Z Microphone Pre-amp.** For 200-600Ω mics plus gain adjustment.
Order As XA20W (Maplin Project Book 20) Price 85p *NV.*

Electronics Issue 21 6 Channel Burglar Alarm. Develop a complete security system. **Six Circuits.** Bass Fuzz, Voice-Over Unit, Noise Gate, Envelope Tremolo, RTTY Decoder and Scratch & Rumble Filter on veroboard. **Notch Filter.** AF processor for communications receivers. **12V Public Address System.** 10W per channel from car battery. **Tungsten Lamp Controller.** AC phase control for mains lamps.
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Electronics Issue 22 MIDI Interfacing Techniques. Connect MIDI instruments to the VIC20 or CBM64. **Hi-Fi Speakers & Enclosures.** Two high quality loudspeaker cabinet designs. **Keypad for Z80 CPU.** At last a keypad I/F & ROM for the Z80 CPU kit. **4½ Digit Counter.** Versatile basic counter module to 4½ digits. **Weather Satellite Down Converter Part 1.** Aerial & freq. converter for MAPSAT Receiver to tune into the Meteosat satellite. **Mini Circuits.** Veroboard Audio Level Tester, Sound Triggered Flash, In-Circuit Resistance Meter, I/R Audio Isolator.
Order As XA22Y (Maplin Magazine Volume 6 Issue 22) Price 85p *NV.*

Electronics Issue 23 MAPSAT Frame Store #1. Z80B CPU controller. **Servo Tester.** Proportional servo tester. **Weather Satellite Down Converter Part 2.** Channel Switching Unit. **Capacitance Tester.** 5 ranges, 3 digit display. **More Mini Circuits.** Movement alarm, Stepper Motor Driver, Pink Noise Generator, Optical Port Data Link, 'Metal Pedal'.
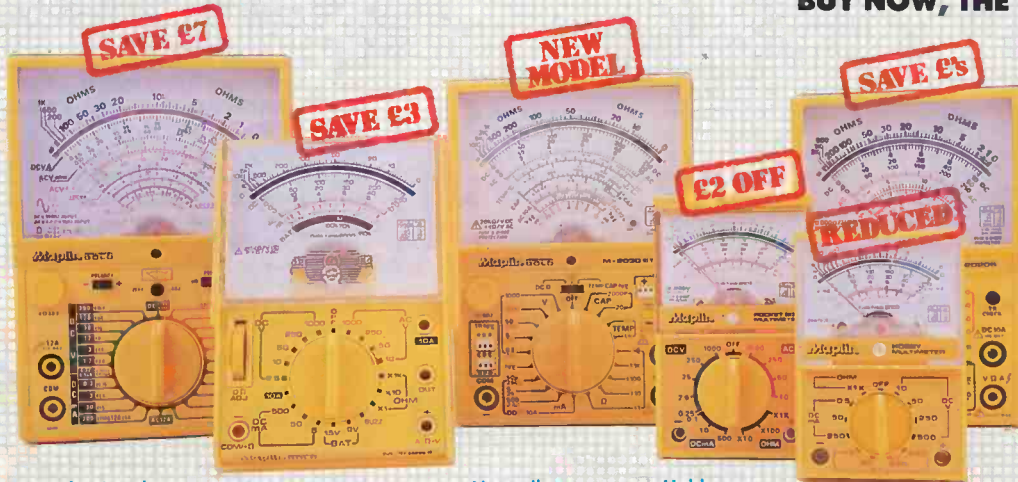**Order As XA23A (Maplin Magazine Volume 6 Issue 23) Price 85p** *NV.*

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