Hobby Electronics

SEPTEMBER 1982
ISSN 0142-6192
70p

Project Electronics For Everyone

MODEL PROJECTS
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POPULAR COMPUTING
ZX Interface Project

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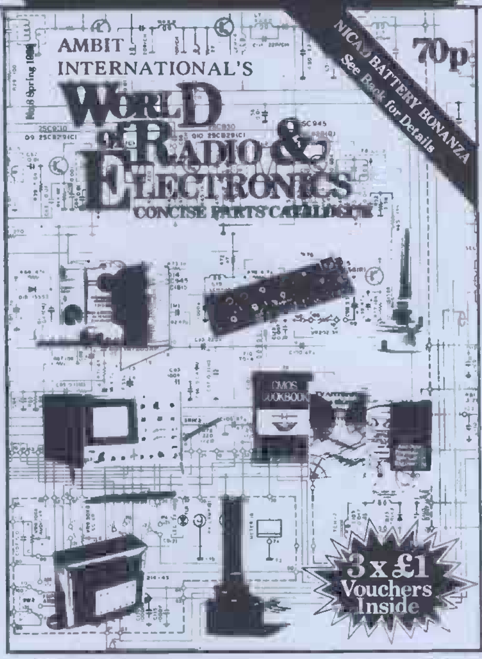
Price on the page



CMOS

4000	0.11
4001	0.11
4002	0.12
4007	0.13
4008	0.50
4008AE	0.80
4009	0.25
4010	0.30
4011AE	0.24
4011	0.11
4013	0.25
4015	0.50
4016	0.22
4017	0.40
4019	0.38
4020	0.55
4021	0.55
4022	0.55
4023	0.15
4024	0.33
4025	0.15
4026	1.05
4027	0.26
4028	0.50
4029	0.55
4030	0.35
4035	0.67
4040	0.50
4042	0.50
4043	0.50
4043AE	0.93
4044	0.60
4046	0.60
4047	0.68
4049	0.24
4050	0.24
4051	0.55
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4053	0.55
4054	1.30
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4056	1.30
4059	5.75
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4066	0.30
4067	4.30
4068	0.16
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4070	0.16
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4073	0.16
4075	0.16
4076	0.55
4077	0.18
4078	0.18
4081	0.12
4082	0.18
4093	0.30
4099	0.80
4175	0.80
4502	0.60
4503	0.50
4506	0.70
4507	0.37
4508	1.50
4510	0.55
4511	0.45
4512	0.55
4514	1.25
4515	1.25
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4521	1.30
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4539	0.80
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4553	2.70
4554	1.20
4555	0.35
4556	0.40
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4580	3.25
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4583	0.80
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4585	0.45
4702	4.50
4703	4.48
4704	4.24
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4706	4.50
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40193	1.08
40194	1.08
40195	1.08

TTL N

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74367N	0.85
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74390N	1.85
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74LS04N	0.14
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74LS670N	1.70

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2114 2	1.49
4027	5.78
4116 2	1 59
4116 3	1 49
4864P	12 50
6116P-3	9.00
6116P-4	11 25
8264	12 50

74CXX

74C00	0.20
74C02	0 20
74C04	0.20
74C08	0.20
74C10	0.20
74C14	0.55
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74C195	1.08
74C200	4.52
74C221	1.06
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74C903	0 38
74C904	0.38
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74C906	0 38
74C907	0.38
74C908	0.84
74C909	1 52
74C910	3 62
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2532	0A
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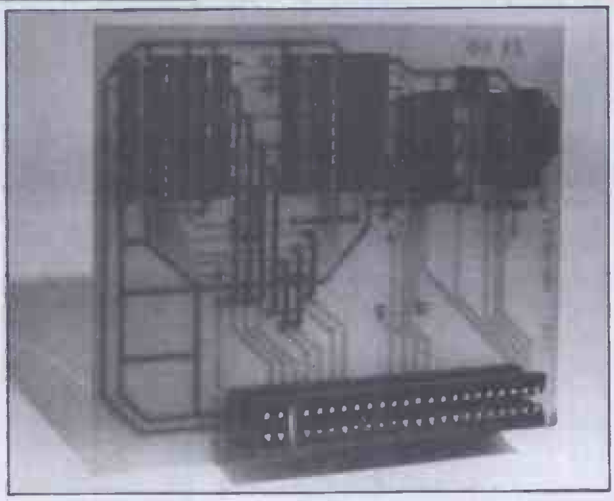
Hobby Electronics

SEPTEMBER 1982
Vol 4 No 9

PROJECTS



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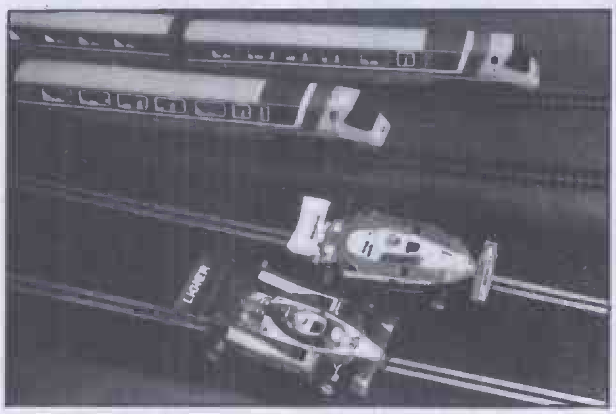

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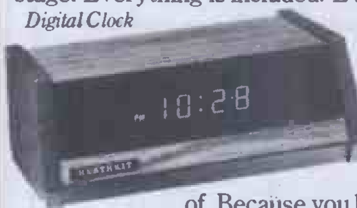

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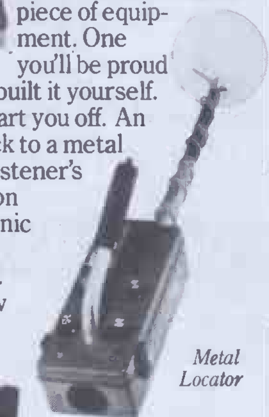
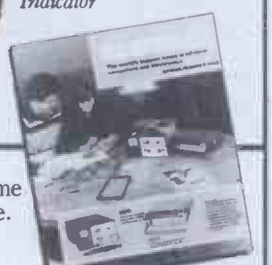


Metal Locator

Windspeed and Direction Indicator



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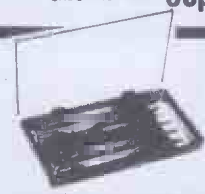

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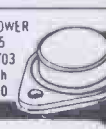

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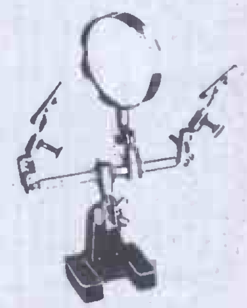

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Adventures with Electronics £2·40. Component pack £17·98 less battery.

ADVENTURES WITH DIGITAL ELECTRONICS

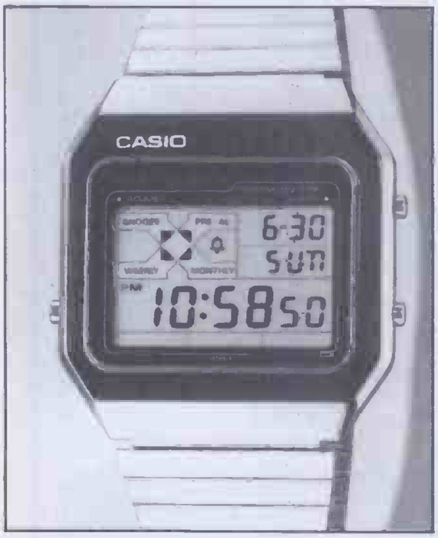
New book by Tom Duncan in the popular 'Adventures' series. This book of entertaining and instructive projects is designed for hobbyists, and students. It provides a stepping stone to the microprocessor.
The first part deals with the properties of some basic ICs used in digital electronics.
The second part gives details of how to build eight devices — shooting gallery, 2 way traffic lights, electronic adder, computer space invaders game etc.
For each project there is an explanation of 'how it works' and also suggestions for 'things to try'.
No soldering — all circuits built on 2 Bimboard 1 breadboards.
Adventures with Digital Electronics book £3.25. Component pack £42.50 ref ETDC. All the components needed including 2 breadboards and hexadecimal keyboard. Available less breadboards £29.98 ref ETDF. Both less battery.

MONITOR

Have A Good Time

The cost of **Casio**'s latest quartz digital watch works out at less than ½p per day, based on a retail price of £5.95 and a five year life from the lithium battery! The timing facilities of the **F10** include continuous hour, minute, second and date display, together with indicators for am/pm and day of the week. The calendar is automatic, but needs adjustment for leap years. The standard F10 has a black resin case and strap though if you fancy something with a little more class, the B815, priced at £9.95, is identical except for the traditional stainless steel case and bracelet.

For something a little different, Casio have come up with the **MM400** watch. It has a normal daily alarm, another which can be set up to a week ahead, and a third with a monthly cycle; each alarm has a different melody! The LCD readout shows hour, minute, second, date and day, plus indicators showing which alarms are set. It also features a stopwatch function accurate to 1/1000th of a second. The MM400 has a stainless steel bracelet and case, and a recommended retail price of £34.95 at any High Street Casio stockist.



Would'n You Like One?

A new range of stabilised power supplies **(right)**, specially designed for the UK market, are being released by **Telecomms**, the exclusive distributors of SHF Electronic products.

The range will be of particular interest to both CB and electronics enthusiast. There are five models, from a 2A unit for standard 40-channel CB rigs up to a 12A heavy duty supply. The prices are very attractive, ranging from £11.90 to £49.95, retail. The cases are made from a toughened nonconductive material and have been designed to be safer and more pleasing to the eye than conventional metal-cased units. Nice picture, too!

SHF Electronic supplies are distributed by **Telecomms**, 189 London Road, North End, Portsmouth; Tel. 0705 660036.

PCB Jig

No, it's not a new dance, simply two additions to the **Carlton Nichol** range of PCB holders/assembly-jigs.

The **CNC 16 (above)** will hold any board of up to 420 x 205 mm. The PCB is clamped between two easily adjustable rails and this also gives it the useful facility for holding a number of smaller boards, rather than one large one. A clip-on foam pad is also available, enabling components to be inserted in the board before soldering.

The **CNC 10** holder is designed to take boards up to 203 x 203 mm, held between two rails and locked in position by means of a single, central clamp. When in position, the PCB may be rotated through 360° and locked at any angle. The holder can be folded flat, for storage, simply by loosening one bolt.

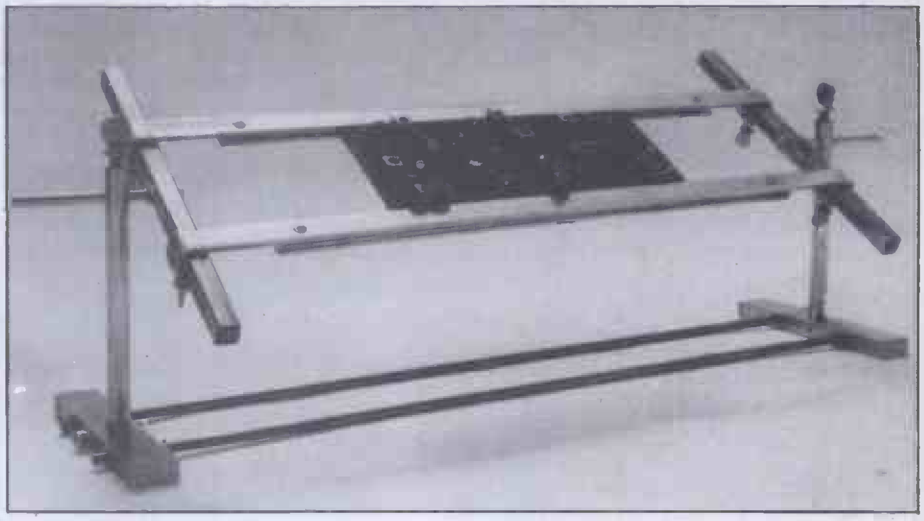
These products are available directly from the manufacturer, **Carlton Nichol and Co. Ltd.**, Goldkey Industrial Estate, Kelveden, Essex. The CNC 16 is priced at £21.75 and the foam pad is £6.90; the CNC 10 costs £16.10 and an optional pad is £5.63. These prices included VAT, but £1.50 should be added to cover postage.

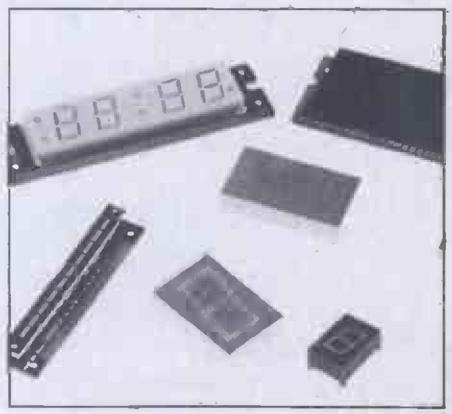
Displays On Show

A new range of high quality, reliable, low cost displays **(below)** from Liton have just been launched by **Stotron Ltd.** They feature high brightness, low power drain and wide angle visibility, and are compatible with ASCII and EBCDIC codes.

The ten-step bar graph is available in either red or green with a bar point size of 1.5 x 5 mm. The clock display has a red colour filter for better contrast.

Further details are available from





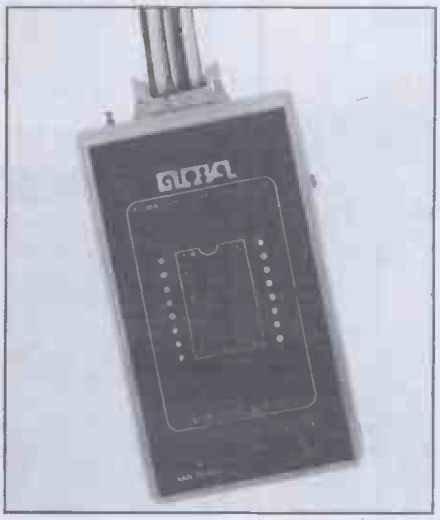
Stotron Ltd, 72 Blackheath Road, Greenwich, London SE10 8DA, or 'phone 01 691 2031.

Call For The Doctor

This one is for serious computer buffs. Normally, faults in memory chips are very difficult to locate as the usual methods, using a 'scope or logic probe, are not well suited to the job. The **Microdoctor**, an intelligent device from **Dataman Designs**, is designed specifically for the purpose.

It is an intelligent device for fault finding on computers or microprocessor based equipment generally, with the capability of performing a series of programmed tests on the memory chips of any computer to which it is attached and printing out the results. In addition, unknown systems can be memory-mapped, with the contents printed out in HEX or in ASCII; any device in the memory or I/O space can be read from or witten to.

The Microdoctor is Z80 based and is supplied with a free Z80 disassembler, allowing it to produce a listing in HEX or ASCII of the contents of any ROM in a Z80 system. As it stands, the Microdoctor is applicable to microprocessor systems, and disassemblers for other popular MPUs will soon be available at low cost.



The Microdoctor costs £339.25, including VAT and carriage, from **Dataman Designs**, Lombard House, Cornwall Road, Dorchester, Dorset DT1 1RX. Tel. 0305 68066.

Logic Logged Here

Fault-finding on digital circuitry is not one of the easier tasks in electronics, and any assistance is generally very welcome. Enter **Global Specialiaties**, with a new 16-pin logic monitor.

The **IM-2A (above)** is specifically designed to monitor dual-in-line packaged integrated logic circuits. It has a built-in LED display which gives rapid, simultaneous readout of the static and dynamic states of eight, 14 and 16-pin ICs. Connection to the circuit under test is via a 610 mm long cable and a 16-pin 'Proto Clip' test probe. Using the LMA-9 optional cable, up to 16 independent points can also be monitored.

The front panel mode switch selects either TTL, CMOS or variable threshold logic levels; the thumb-wheel control selects threshold from +1V to +9V, allowing the LM-2A to monitor practically all non-standard logic levels, and the external voltage sense line used in the CMOS mode ensures that the 70% threshold for CMOS is accurately met. All inputs are 1MO impedance and protected to ±26V.

The LM-2A measures 30 x 81 x 150 mm and weighs in at 0.3 kg. The case is high-impact plastic, and the unit is supplied complete with the 16-way cable terminated in the IC test clip.

The suppliers are **Global Specialities Corporation.** Shire Hill Industrial Estate, Saffron Walden, Essex CB11 3AQ; tel 0799 21682 for further information.

Catalogue News

Finding sources of electronic components and hardware is one of the electronics hobbyist's greatest problems. Of course, our super Electronic Supplies Directory which will appear in the October issue, will help, but beyond that, a good catalogue collection is essential.

A new 28 page release, from specialist suppliers **Roadrunner Electronic Products**, features a wide range of circuit board and enclosure accessories. The Roadrunner 'solder-wrap' wiring system is highlighted, together with their extensive range of prototyping boards, connectors and electronic production accessories.

For further information, contact **Roadrunner Electronic Products Ltd.**, 116 Blackdown Rural Industries, Haste Hill, Haselmere, Surrey GU27 3AY. Tel. 0428 53850.

Another recent arrival was the latest catalogue from **Rapid Electronics**, who have considerably extended their product range. New additions include a wider range of linear devices, with data sheets, more capacitors, PCB transformers and tools. The total stock line now covers over 2000 items at prices that are "the most competitive in the industry", backed by a return post service.

Copies of the catalogue are available free with orders over £10 or by sending 45p to **Rapid Electronics**, Hill Farm Industrial Estate, Boxted, Colchester, Essex CO4 5RD. Tel. 0206 36412.

Calculator With A Difference

The **Hioki 3208**, from **Dorman Smith Instrumentation**, combines the functions of a powerful scientific calculator and a digital multimeter in one compact unit.

The me. v ranges cover AC and DC voltage, ohms, low-power ohms for in-circuit testing, and it has current measuring capability up to 200 mA in two ranges. A single key converts the meter reading into scientific notation, for instant calculations.

The unit is supplied complete with tester probes, and a battery, giving 100 hours of continuous operation. It is available by mail order for £72.50, direct from **Dorman Smith Instrumentation**, Blackpool Road, Preston PR2 2DQ. Tel. 0772 728271.

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TR 80	Toroidal Transformer 80VA	18.00	2.70	20.70	2.00
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CPS 150D	Dual Power Supply	31.65	4.75	36.40	2.60
CPS 250	Power Supply	32.03	4.80	36.83	3.50
CPS 250D	Dual Power Supply	39.43	5.91	45.34	3.65
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REG 1	Regulated Power Supply	8.09	1.21	9.30	0.07
TR 6	6VA Mains Transformer	2.87	0.43	3.30	0.21
XO 2	2 Way Crossover Module	17.39	2.61	20.00	0.07
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CK 1010	Complete Pre-Amplifier Kit	78.26	11.74	90.00	2.50
CK 1040	Complete 40 Watt Power Amplifier Kit	103.48	15.52	119.00	7.30
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HE 'Junior' Slot-Car Controller

Jonathan Scott

Put more zap in your slot-car's zip with our economy model controller

IN their May issue, this year, our cousins at Electronics Today International presented a super, souped-up Slot Car Controller project, providing (amongst other things) fuel tank simulation and controlled overshoot. In the course of developing that project, fierce argument raged around the authors' household, some arguing for the 'no-holds-barred' approach — the method ultimately adopted by ETI — while others argued for 'cost effectiveness'.

If you are a dedicated slot car fanatic, with hundreds of pounds invested in your layout, then you've probably already built the ETI Super Controller. On the other hand, if you're not sure that you are a fanatic, or you have just bought a layout, say, then this cost-effective approach, the HE 'Junior', is the one for you. It is relatively simple to construct, cheap, and easy to get going. It is basically a replacement for whatever you are using to power your set now. It offers operation from AC or DC, car battery, model train transformer, door-bell transformer or a range of typical project transformers or power supplies. It gives independent protected supplies for each lane, adjustable for most car set types available.

In addition, we're giving tips for optimising your set and ideas for layouts. These should be sufficient to turn a simple rig into a first-class slot car racing set-up.

Theory And Practice

In practice, the basic rheostat in series with the track (car) system is not at all a bad compromise. For a given control setting, the car accelerates fairly rapidly towards a final speed. This is because torque is proportional to current (in the permanent magnet motors used) and current is at maximum when the car is standing still; as the engine RPM increase so does the back EMF, or rather the internal EMF of the engine, which represents the mechanical power output in the mathematical model of the engine. As this rises, the voltage drop across the control resistance decreases, and so does the current, the torque and the acceleration (**Figure 1**). This gives a very car-like performance for a minimum of parts. The final speed is fixed by the minimum DC path resistance, the available supply voltage and the amount of friction and other losses in the car. Overall performance includes cornering ability, which is affected by the car weighting and wheel type and condition. Attention to these factors will effectively 'tune' the car.

If you think you have a two-car set with one car better than the other, the chances are that checking the above points will reveal a silly fault in one of them. You can end up, after some tinkering, with two improved cars. Let us go through a typical tuning-up of a small car, such as those in the cheaper sets. We will start at the car and end up at the controller.

Firstly, the wheels. It is important to check that these do not have some wobble or severe out-of-roundness. The tyres should be slightly rough, so that they grip, and fairly flat at the point of contact with the track, so that they do not bounce when the wheel rotates quickly. See that the tyre is fitted straight, if you have removable tyres, and that the wheels are squarely mounted on the axles.

Next, it is worth opening the car up. Check that the axles and cogs are free of dust and carpet fluff. A very small touch of light machine oil on bearings and cogs is a good idea, though not absolutely necessary. Do not oil the tyres or any exposed bit of the car. See that the cogs mesh neatly and fairly silently. On an expensive car, these things should be in order already.

Now let's look at the brushes. These are, in our experience, the most vulnerable point in the car. Brush friction usually accounts for 90% of car performance problems. The brushes should be clean and dust free. There will be some unravelling of the braid, this is good. The ends of the brushes seem to benefit from a bit of 'combing', done with a small jeweller's screwdriver, a scriber or scalpel. About three to five millimetres of combed braid is nice. Finally, the shape of the brushes is important. There are several ways to bend the brush, and you should experiment to see which is better. We used the down-and-then-straight pattern (See **Figure 2**).

Next, the minimum rheostat resistance is important. Some controllers have such high resistive leads that the series resistance never gets below an ohm or two. If you have a protected *voltage* source this is a disadvantage.

Finally, the supply potential is vital. If it is too high, the control becomes too critical and it is too hard to get just the right amount of power. It cannot be too low, of course, as you would not get anywhere near enough power to realise maximum speed without crashing — which takes out all the skill. As well, if the supply is not regulated, one car can interact with the other; an extreme case is when one car suddenly 'shutting down' causes such a surge that the other spins off the track (it can happen!).

One further factor is worth discussing, with respect to the car: weighting, and this is an area where you are going to have to experiment for yourselves. Most cars have spaces inside the plastic shells where nuts or other pieces of metal can be secured with a little Blutac, or similar adhesive, to add weight. Weight will reduce the acceleration for a given power, but it will increase wheel adhesion on the road. It will also change the handling, possibly making spinouts more likely, and reduce the period of time required between brush realignments. In our experience, a couple of 2BA or similar nuts in a small car, near the middle and low down, are quite beneficial if you have adequate power, as with our controller.

The Supply

As we have said, all that is necessary to achieve quite adequate performance is a voltage supply for each car. It needs to be the right voltage, and the cars should not interact with each other via the supply. The HE 'Junior' is a simple supply that meets these standards. It is versatile in that it will operate from whatever source of voltage you have available; it simply needs to deliver at least three volts more than the cars need (average) and to be able to supply the maximum current, typically 0A5 to 1 A per car.

If you think you have a two-car set with one car better than the other, the chances are that checking the above points will reveal a silly fault in one of them. You can end up, after some tinkering, with two improved cars. Let us go through a typical tuning-up of a small car, such as those in the cheaper sets. We will start at the car and end up at the controller.

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Next, the minimum rheostat resistance is important. Some controllers have such high resistive leads that the series resistance never gets below an ohm or two. If you have a protected *voltage* source this is a disadvantage.

The Circuit

The complete circuit is shown in **Figure 3**. It is basically a crude series voltage regulator, based on the 723 variable regulator IC, that supplies power to the rheostat in the hand controller. The rheostat is in series with the motor in the car, via the track connections. The voltage supplied to the controller and car can be preset anywhere between about 3 V and 12 V.

The circuit is designed to be powered from a variety of sources — bell transformer, car battery, plugpack, model train transformer or conventional 240 VAC to 15 V/1-2 A

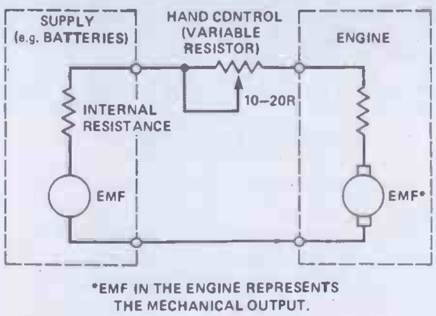

Figure 1. A circuit model of a slot car set-up.

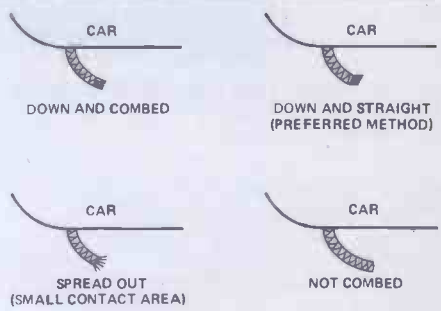

Figure 2. Various brush arrangements.

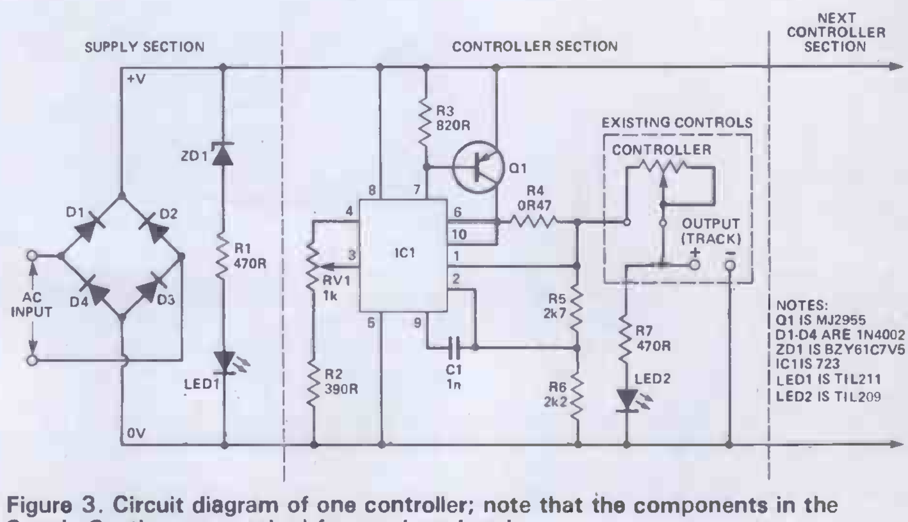

Figure 3. Circuit diagram of one controller; note that the components in the Supply Section are required for one board, only.

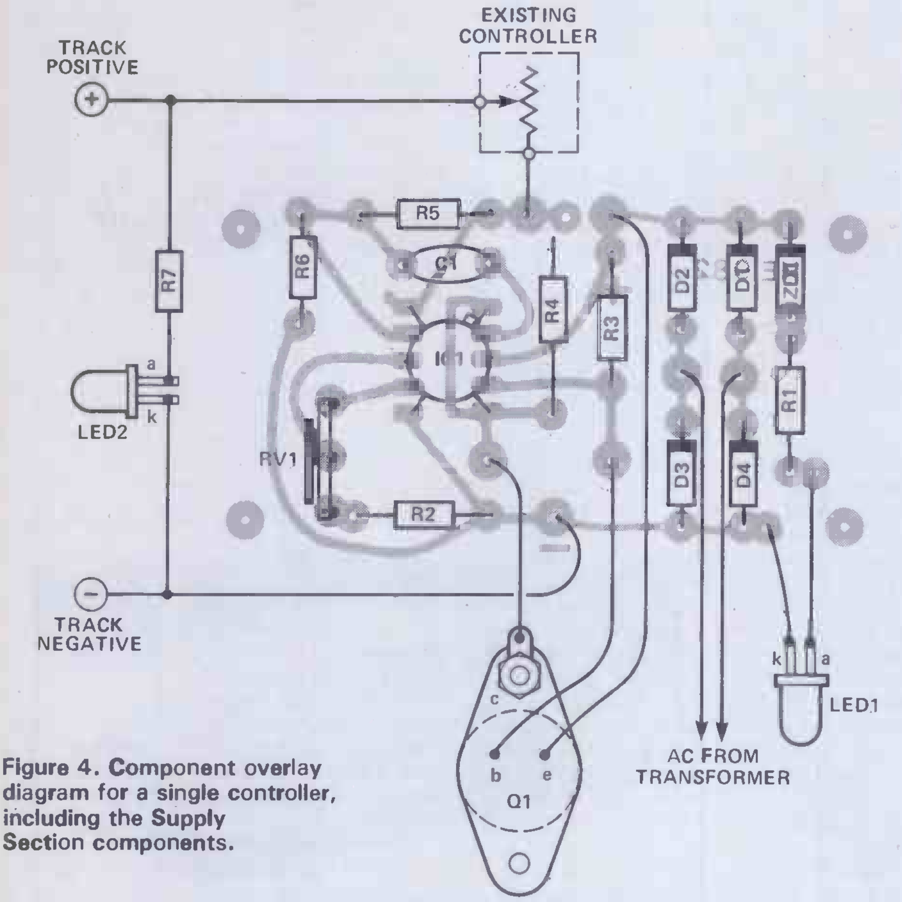

Figure 4. Component overlay diagram for a single controller, including the Supply Section components.

Parts List

RESISTORS

(All ½ watt 5% carbon, unless noted)

R1,7 . . . . 470R
R2 . . . . 390R
R3 . . . . 820R
R4 . . . . 0R47
1 watt
R5 . . . . 2k7
R6 . . . . 2k2

POTENTIOMETERS

RV1 . . . . 1k
miniature vertical preset

CAPACITORS

C1 . . . . 1n
disc ceramic

SEMICONDUCTORS

D1-D4 . . . . 1N4002
rectifier diodes
ZD1 . . . . BZX61C7V5
zener diode
LED1 . . . . TIL211
0.2" green LED
LED2 . . . . TIL209
0.2" red LED
IC1 . . . . LM123
10 pin TO-100 regulator (see **Buylines**)
Q1 . . . . MJ2955
silicon PNP power transistor

MISCELLANEOUS

Case (see **Buylines**); PCB; terminal block; nuts, bolts, wire, solder etc.

BUYLINES . . . . page 33

transformer — whatever is available. If the source is AC, such as that direct from a transformer secondary, the diode bridge rectifier formed by D1-D4 rectifies this, supplying unfiltered DC to the circuit. These four diodes may be deleted if the unit is run from a DC supply, or they may be left in, provided the DC exceeds the voltage required by the car by about four volts. Leaving D1-D4 in place has the advantage that the device can be run off AC at any time, and when running it off a DC supply it can be connected either way round as polarity doesn't matter and no possible damage can be caused by accidental reverse polarity connection.

To indicate that a supply of sufficient voltage is connected to the circuit, ZD1, R1 and LED1 make a simple indicator. When the supply voltage between the +V and 0 V rails is high enough to overcome the zener voltage plus the voltage drop across LED1 and R1 at a current of a few milliamps, LED1 will light. You need to produce a minimum of approximately 10 V between the + V and 0 V rails. Note that, while this is sufficient for the IC regulator circuit to operate, it may not be enough for some slot car sets. For those that require 12 VDC, at least 14 V between the +V and 0 V rails will be required. An AC input of up to 24 VAC (RMS) may be used.

Following the rectifier and indicator sections of the circuit is the regulator, which consists of IC1, Q1 and associated components. Each lane in the slot car set should be supplied with a separate regulator circuit to ensure that one lane does not interfere with the operation of the other, especially in the event of a short circuit due to a crash or a fault, etc. Two regulator sections may be run from a single rectifier section.

The 723, IC1, controls the base current of Q1 to deliver the required voltage to the hand controller, except when the external circuit (controller and car motor, via the track) attempts to draw current above about 1A2. In this case, the 723 reduces the voltage supplied to the external circuit to prevent possible damage.

The output voltage is set by RV1. By adjusting this preset control, the voltage delivered to the controller and external circuit may be varied anywhere between about 3 V and 12 V maximum. This should be adjusted to suit the particular slot car set you are using by setting its position so as to deliver a suitable amount of acceleration to the car when the hand controller is set full on.

LED2 indicates that a voltage is reaching the track. This is useful to check correct operation and for detecting shorts on the track.

Construction

Construction of the HE 'Junior' is relatively straightforward. You will require one PCB for each lane, though some components will not be required on any but the first board. Further lanes will simply demand a larger box and a repeat of the wiring of the first board, less ZD1, R1 and LED1. The component layout for a single-lane board is shown in **Figure 4**.

The first step is to drill the box. We used a cheap metal box, but if you want it to look particularly good, or if it will have to withstand nasty knocks, a diecast aluminium or extruded box of sufficient size can be used, although it will add to the cost. The advantage of a metal box is that the front panel doubles as a heat sink.

Drill the MJ2955 mounting holes and the LED mounting holes first. The only other hardware preparation is for the PCB mounting screw holes and those for the wires and the terminal block.

After drilling, assemble the boards. The first should have *all* components fitted. It is best to include D1 to D4 even if you have a DC supply, as the unit cannot, then, be connected the wrong way round, and can still be used with AC if required. The diodes should only be omitted if the DC supply is too low to tolerate the voltage drop across them, ie below 12 V, on average (omitting the diodes will allow it to run on around 10 V). It

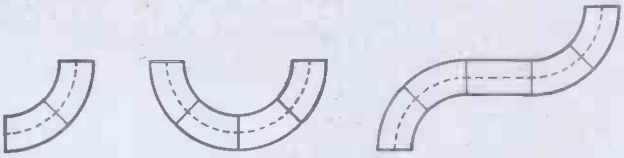

Figure 5. Rational constructs.

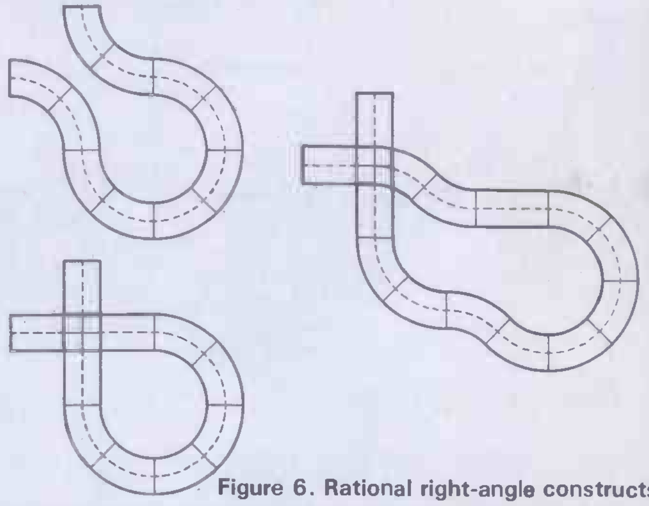

Figure 6. Rational right-angle constructs.

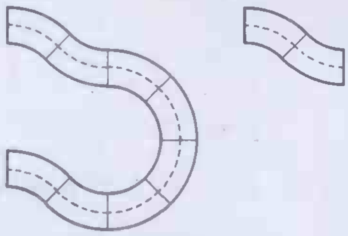

Figure 7. Zig-zags cancel out.

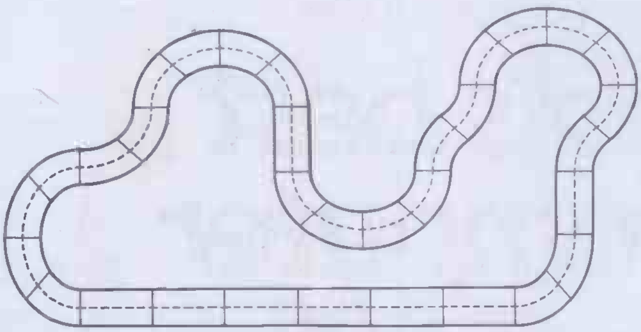

Figure 8. HE's Grand Prix track!

should also be noted that the supply will have to be a bit higher if the car set is a 12 V type — around 15 V at least.

Fit all the components as shown in the overlay, starting with the resistors and finishing with the IC. Take care with the IC orientation. Once the board is assembled, connect the off-board wiring as shown. The current limiting resistors, R1 and R7, are mounted behind the LEDs themselves. For the output leads to the tracks and the controllers, we used an ordinary plastic terminal block, as these are cheap. Once the assembly is complete, label the supply and track LEDs, on the panel.

Testing

The HE 'Junior' is so simple that it does not require much setting up. After completing the assembly and wiring it up to your controllers and to the tracks, you should be 'on the road' immediately. The only adjustment that needs to be made is the setting of RV1, which controls the output voltage as mentioned in the circuit description. For safety, make a trial run with RV1 set for minimum voltage, first!

The Track

When it comes to track, there are three factors worth mentioning which may influence your choice if you have yet to purchase it. These factors are: range of pieces available, flexibility and width. If you are going to buy a cheap set, and let's face it, that is the most economical approach, you will have to accept that the track comes in fixed quantities; probably multiples of what it takes to make up one loop or a small figure-8. However, you can get a good selection of 45° curves and straights, not to mention two cars and controllers, and fences, etc, for under £25 in some places. For this, plus one of our controllers, you can get a really good set-up, and for a bit more you get a really fantastic set.

Laying Out

In designing a layout, the main problem is not to find a shape which is particularly interesting, but one which is fair, or equal, for both lanes, as well as 'rational'.

A layout is said to be *rational* if it fits together *exactly*. For this to happen, there must be no uncancelled irrational constructs. Even if you are lucky enough to have a range of bits, it is quite a challenge to sort out a fair and rational track.

First, let us define some terms. A 'construct' is any group of track section. It does not necessarily meet up to form a closed loop, but is usually a familiar shape which can often be found in layouts. A rational construct is one which replaces a section of an oval track — either a right angle, a single straight section, or a combination of these.

To explain this, consider **Figure 5**. The right angle turn introduces a one-unit displacement along and one unit down. The U-bend introduces a two-unit shift along and no shift down. The S-bend introduces three along, and two down. These are all rational constructs in the system of track used here — that is, one where straights are exactly one radius of curvature long, as is common. The constructs in **Figure 6** are all equivalent to a right angle, and are thus rational.

The zig-zag in **Figure 7**is irrational, but the construct next to it is rational, as the zig-zags clearly cancel out.

Some constructs favour one lane. For instance, in a plain 180° bend, the outside lane is longer, and thus you might expect it to take longer to negotiate. If there are fences it may be faster, as the car can bounce off them and thus allow greater speed without accident.

Experiment will determine how each construct favours lanes. Once you have an idea of each construct and how it favours lanes, you can assemble them into a fair layout. Even though a completely flat layout will inevitably have one lane longer on the outside, it can be made fair by the addition of constructs to favour the worse lane — such as zig-zags at the ends of long straights.

If you are really getting involved, you can devise a catalogue of constructs. We developed a computer program for checking rationality and a layout plotting routine, and here is an optimal layout (**Figure 8**)which uses all the track from two cheap figure-eight sets.

Our thanks to Hornby Hobbies, who supplied the pictures featured in this article. HE

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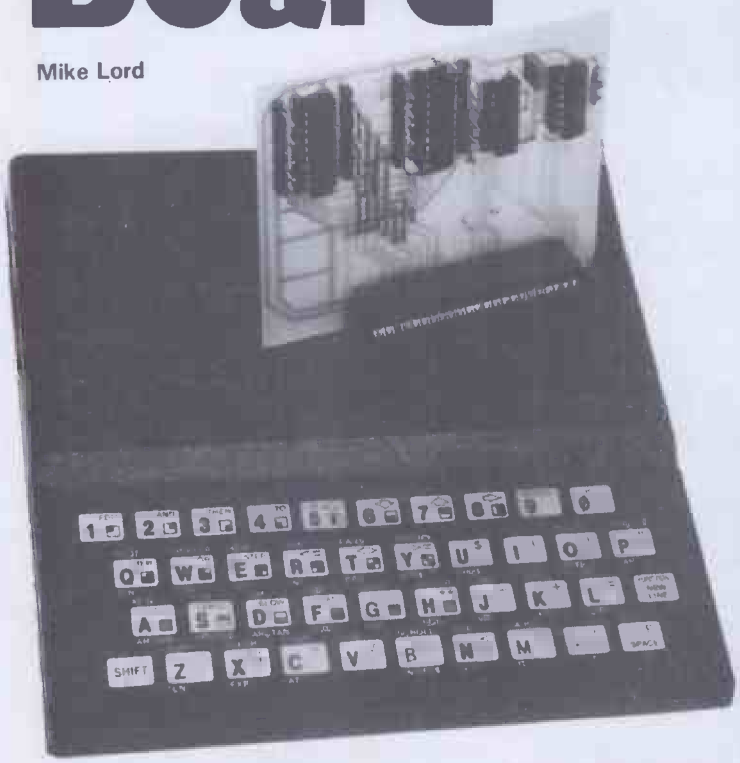
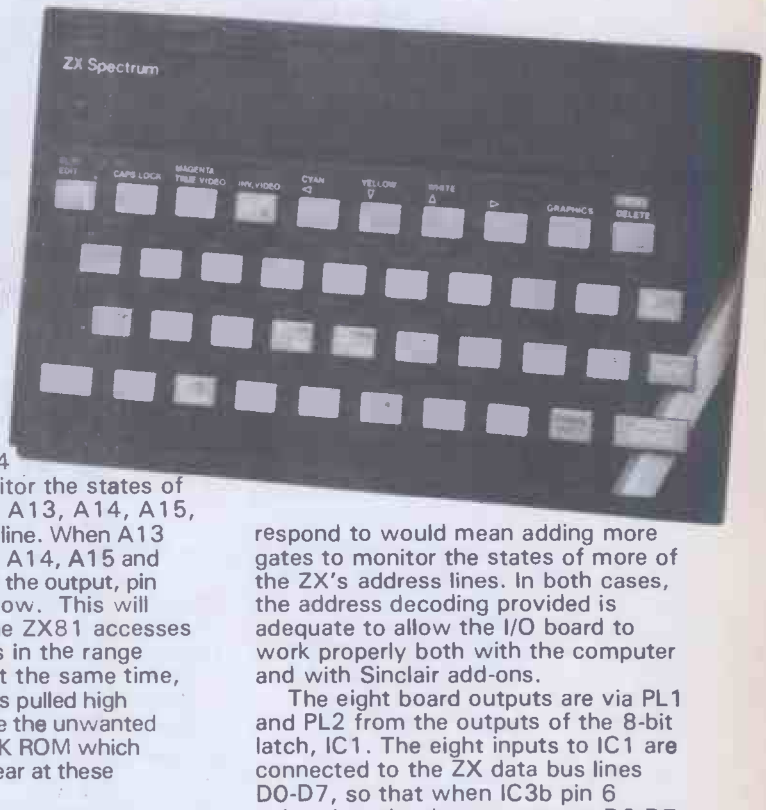
ZX Interface Board

Mike Lord

Last month's article gave a generalised description of techniques for interfacing external circuits to the Sinclair ZX81 and Spectrum. This month we present a practical circuit, an Input / Output interface board which can be built to work with either the ZX81 or the Spectrum.





AS discussed last month, I/O interfaces for the ZX81 are best designed to look like normal memory ('Memory Mapped I/O'). For the Spectrum, on the other hand, it makes more sense to use the Z80's I/O address space ('I/O Mapped'). We have therefore designed the PCB so that the circuit can be constructed as either a Memory Mapped or an I/O mapped interface.

Whichever version is built, it will give you eight separate TTL level outputs, which can be controlled by the ZX, to drive LEDs, relays or whatever you will. There are also eight TTL inputs to the board, and the ZX can examine the states of signals applied to these inputs.

The ZX81 version of the board is designed to work with the basic (1K RAM) ZX81, and also with the ZX printer and the Sinclair 16K RAM pack. It should also be compatible with most ZX81 add-ons offered by other firms except for those which use memory addresses in the range 8192 to 16383.
The Spectrum version will also work with the ZX printer and — as far as we can tell from the limited information available at this time — will be compatible with future Sinclair add-ons such as the Microdrive and RS232 interface.

Circuit Description

The circuit for both versions of the board are shown in **Figure 1.** In the ZX81 (Memory Mapped) version, IC4 and IC3c, IC3d monitor the states of the ZX address lines A13, A14, A15, and also the ZX $\overline{MREQ}$ line. When A13 is high (logic '1'), and A14, A15 and $\overline{MREQ}$ are all low, then the output, pin 11, of IC3d will go low. This will happen whenever the ZX81 accesses any memory address in the range 8192 to 16383. At the same time, the ZX81 $\overline{ROMCS}$ line is pulled high through D1, to disable the unwanted 'echo' of the ZX81 8K ROM which would otherwise appear at these addreses.

For the Spectrum (I/O Mapped) version, IC4, D1 and R1 are not fitted, and IC3d is connected so that its output, pin 11, goes low when address line A5 and the Spectrum $\overline{IORQ}$ lines are both low.

In either case, pin 11 of IC3d going low enables IC3a and IC3b so that during a ZX 'write' operation, when $\overline{WR}$ goes low, the output, pin 6, of IC3b goes low. Similarly, during a ZX 'read', the output of IC3a pin 3, will go low.

Both versions of the board do respond to a wide range of ZX addresses rather than to a single address. This has been done for simplicity, since to reduce the number of addresses that the board would respond to would mean adding more gates to monitor the states of more of the ZX's address lines. In both cases, the address decoding provided is adequate to allow the I/O board to work properly both with the computer and with Sinclair add-ons.

The eight board outputs are via PL1 and PL2 from the outputs of the 8-bit latch, IC1. The eight inputs to IC1 are connected to the ZX data bus lines D0-D7, so that when IC3b pin 6 pulses low the data present on D0-D7 is clocked into the latches. It will be held there until another ZX 'write' operation, to a suitable memory or I/O address, updates it.

IC2 contains 8 'tri-state' buffers. The inputs to these buffers are connected to the I/O board input points on PL3 and PL4. The output of each buffer is connected to one of the ZX data bus lines, but normally has no effect because the IC2 outputs are held open-circuit by a 'high' input to pins 1 and 19. When, however, the ZX does a 'read' operation from a suitable memory or I/O address, so that pin 3 of IC3a goes low, the output circuits of the buffers are enabled, transferring the information present at IC2 inputs to the ZX data bus lines.

Construction

Refer to the component overlay, **Figure 2**. Begin by adding wire links in the positions shown. You should end up with 15 links (including the strap a-b) for the memory mapped version, or 16 (including straps a-c and d-e) for the I/O mapped board. Insulating sleeves should be fitted over the wire for the longer links, which might otherwise be liable to bend and touch each other.

Newcomers to the art of electronic circuit building may be interested to learn an old trick for making neat sleeved-wire links. It involves taking a piece of solid cored (not stranded) plastic insulated tinned copper wire about 18" (457.2 mm) long and carefully — without nicking the conductor — stripping a short length of insulation from each end. You then grip one bare end firmly in a vice or a pair of pliers. Then, holding the other bare end with the pliers, pull firmly until the wire suddenly stretches. Stretching the wire this way straightens it, and removes most of its 'spring'. It also breaks the wire free from the inside of the insulation and reduces its diameter slightly, so that what was insulation now becomes the correct sized sleeving.

Next, solder in D1 and R1 — but only if you are making the ZX81 (Memory Mapped) version of the board. Note that D1 must be fitted the right way round, with the broad coloured band away from the edge of the board. Now fit and solder the IC sockets and then C1. The pins of the IC sockets are fairly close together, so make sure that you don't leave any unwanted solder 'bridges' between adjacent pins.

Parts List

RESISTORS
R1 .... 470R
¼ watt, 5%

CAPACITORS
C1 .... 100n
polycarbonate

SEMICONDUCTORS
IC1 .... 74LS273
TTL octal D type flip-flop
IC2 .... 74LS244
TTL octal tri-state buffer
IC3 .... 74LS32
TTL quad 2-input OR
IC4 .... 74LS00
TTL quad 2-input NAND

MISCELLANEOUS
20-pin DIL socket (2); 14-pin DIL socket (2); 23+23 way ZX edge connector socket, polarising key in position 3; 23+23 way ZX connector, matching socket; 10-pin 0.1" PCB plug (4); 10-way 0.1" socket housing (4); crimp terminal for socket housing (24); PCB, wire, solder, etc.

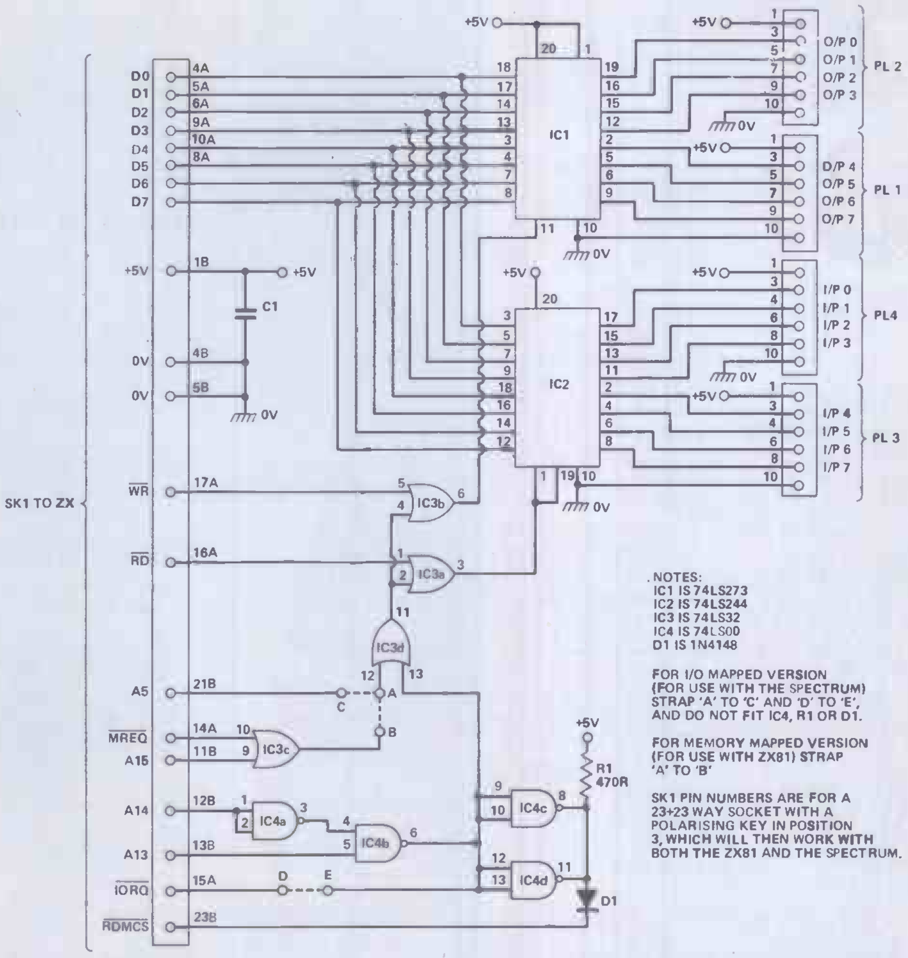


Figure 1. The circuit diagram shows both versions; note the links required to fit the board for one or the other.

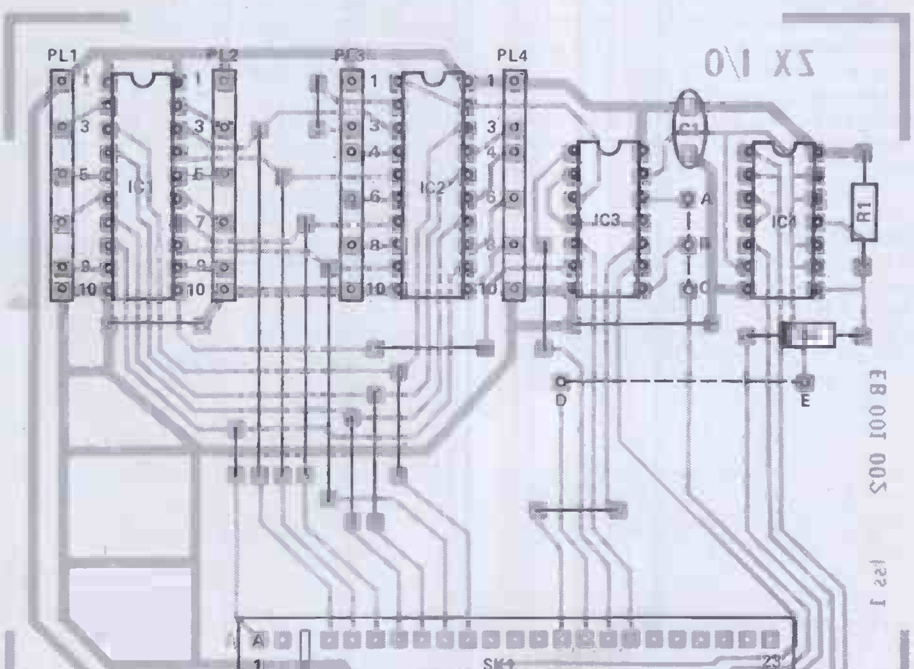


Figure 2. The component overlay diagram.

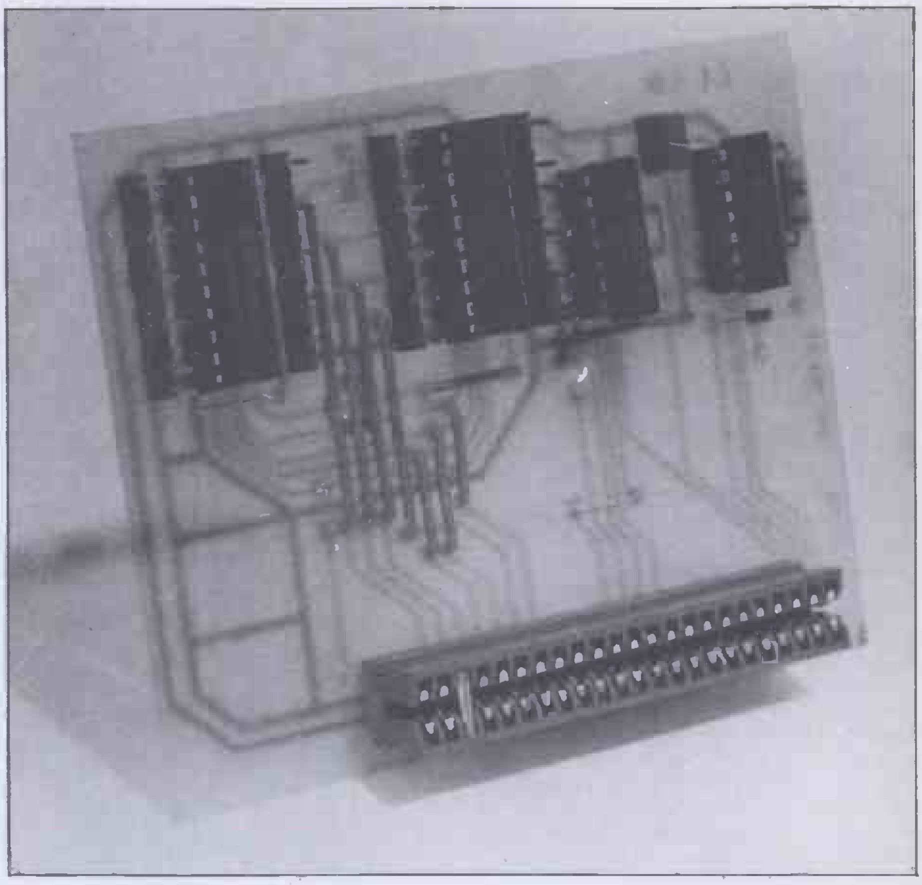
The four Input / Output connectors, PL1-4, can now be soldered in, but before doing so pull out the metal pins from the positions for which there is no corresponding hole in the PCB. The plastic moulding and the long ends of the plug pins should be on the component side of the board, the short ends of the pins should go through the board to be soldered on the track side.

The 23 + 23 way ZX socket can now be fitted so that the body of the connector is on the component side of the board, as close to the board as it will go. Tack-solder a couple of the corner pins first, then make sure that the socket is exactly perpendicular to the board before proceeding. For mechanical soundness, each pin of the socket should be soldered to its PCB pad, even though there may be no track going to that pad. Make sure that no solder bridges are formed between adjacent pads or tracks.

If you want to use other add-ons such as the ZX81 16K RAM pack, then a 23 + 23 way double-sided PCB plug must be fitted, projecting at right-angles from the track side of the I/O board. Each connection pad on this plug must be soldered to the corresponding 'tail' of the 23 + 23 way socket. Again, take care to avoid solder bridges, and make sure that the plug is positioned so that it is exactly perpendicular to the PCB and in line with the 23 + 23 socket.

Note that although the Spectrum actually has a 28 + 28 way plug, the wanted connections lie within the scope of a 23 + 23 way ZX81 connector and — if the polarising key is fitted — in the correct positions to suit both machines.

Finally ICs 1, 2 and 3 (and IC4 for the ZX81 version) may be fitted into their sockets, making sure that they are oriented with the semi-circular depressions in the IC mouldings pointing towards the top edge of the board as shown in **Figure 2**, and that all pins are properly engaged in their sockets.



Testing It

The first, and most important, test is to plug the board onto your computer and check that the computer itself still operates properly! If all is OK, we can test the input side of the board by first keying one of the instructions:

PRINT PEEK 8192
(for the ZX81 version);

PRINT IN 65503
(for the Spectrum board).

The correct answer is 255 (*not* 42!), as all eight inputs to IC2 are, for the moment, open circuit and therefore look to the I/O board as logic '1's.

Repeating the instruction with a temporary connection between 0V (PL3 pin 10 is a suitable point to make connection to the 0V rail) and one of the inputs (PL3 or PL4 pin 3,4,6 or 8) should give the results shown in **Table 1**. Only one input should be connected to 0V at any one time for this test.

Now for the output. Connect a DC voltmeter, switched to its 5 or 10 volt range, between 0V and o/p 0 (PL2 pin 3). Now key in one of these instructions;

POKE 8192,0
(for the ZX81 version);

OUT 65503,0
(for the Spectrum version).

This should result in a voltage reading of between 0V and 0V4. Then input:

POKE 8192, 1 or

OUT 65503,1

which should make the voltage change to between 2V5 and 5V.

The other seven outputs can then be tested, in turn. For each one, POKE 8192,0 or OUT 65503,0 should give less than 0V4, while POKE 8192,n or OUT 65503,n should give between 2V5 and 5V, where n is a number corresponding to a particular output, as shown in **Table 2**.

Programming

Considering the output half first, we have eight separate TTL level outputs which can each be set to give a logic '1' or '0' level by a program command which loads a suitable value into the 8-bit latch, IC1. The value will affect all eight lines simultaneously so, if we want to change just one output, we

TABLE 1

254	IF I/P	0	(PL4 PIN3)	IS CONNECTED TO 0V		
253	,, ,,	1	,, ,, 4	,,	,,	,, ,,
251	,, ,,	2	,, ,, 6	,,	,,	,, ,,
247	,, ,,	3	,, ,, 8	,,	,,	,, ,,
239	,, ,,	4	(PL3 PIN3)	,,	,,	,, ,,
223	,, ,,	5	,, ,, 4	,,	,,	,, ,,
191	,, ,,	6	,, ,, 6	,,	,,	,, ,,
127	,, ,,	7	,, ,, 8	,,	,,	,, ,,

Testing the inputs to the board; the result is '255' if all inputs are logic 1.

TABLE 2

n =	1	FOR O/P	0	(PL2 PIN3)
	2	,, ,,	1	,, ,, 5
	4	,, ,,	2	,, ,, 7
	8	,, ,,	3	,, ,, 9
	16	,, ,,	4	(PL1 PIN3)
	32	,, ,,	5	,, ,, 5
	64	,, ,,	6	,, ,, 7
	128	,, ,,	7	,, ,, 9

Testing the outputs; each will go high (between 2V5 and 5V) when the corresponding value of 'n' is POKEd or OUTput to the latch.

TABLE 3

O/P SET TO '1'	DECIMAL VALUE
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128

Each output is set by loading a decimal value, as shown above.

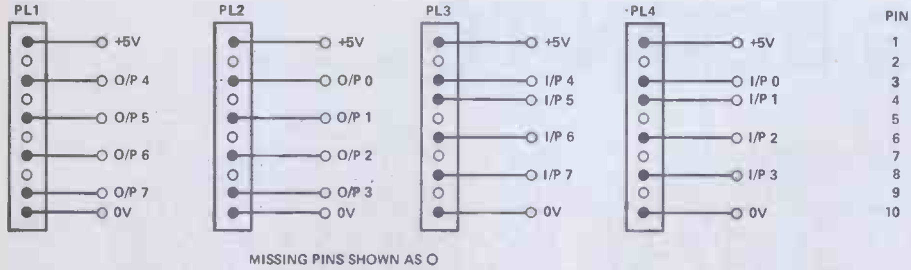


Figure 3. The I/O connectors. PL1 and 2 carry the output lines; PL3 and 4 carry the inputs.

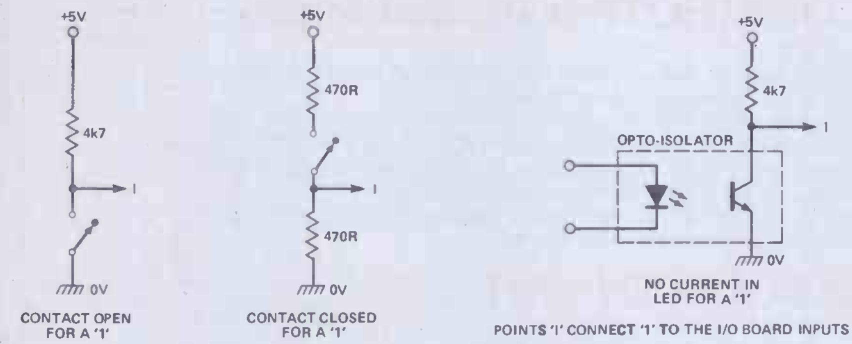


Figure 4. Inputs to the I/O board; points 'I' connect to the board inputs.

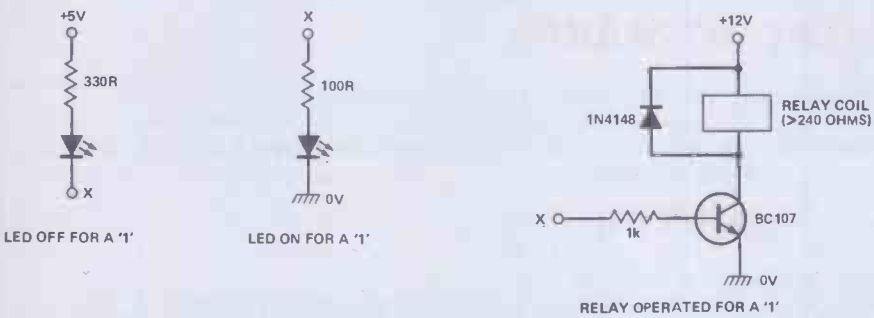


Figure 5. Outputs from the I/O board; points 'X' connect to the output pins.

must remember to load a value which — as well as affecting the output we want to change — will also preserve the previous states of the other seven outputs.

This value can be calculated by considering the eight output lines as individual bits on an 8-bit byte, o/p 0 being the least significant bit and o/p 7 the most significant, and converting the result to decimal. To do this, add together the values from **Table 3** corresponding to the wanted '1' level outputs. For example, if we wanted to set outputs 2 and 5 to '1', and the other 6 lines to '0', the value to be loaded into the latch would be 00100100 binary, or 4 + 32 = 36 decimal, and the correct BASIC instruction would be;

```
POKE 8192,36
(for the ZX81) or

OUT 65503,36
(for the Spectrum).
```

If we wanted to then change output 2 to a '0' without affecting the other lines, then the appropriate instruction would be: POKE 8192,32 or OUT 65503,32.

Alternatively, we could let the computer do the hard work by inserting the following lines near the beginning of our program:

```
LET OP0 = 1
LET OP1 = 2
LET OP2 = 4
LET OP3 = 8
LET OP4 = 16
LET OP5 = 32
LET OP6 = 64
LET OP7 = 128
```

Then, to set, say, o/ps 1, 5 and 7 to '1', use the program line:

```
POKE 8192, (OP1 + OP5 + OP7)

or

OUT 65503, (OP1 + OP5 + OP7)
```

Spectrum programs could use the BIN function, which takes an 8-bit binary number expressed as a string of '1's and '0's and converts it to the decimal equivalent. For example:

```
OUT 65503,BIN 10100010
```

Now for Input. The combined states of the 8 inputs applied to the I/O board are read by the ZX as a single decimal number in the range 0 to 255. For example, if a '1' were applied to inputs 0 and 7, and '0' to the other six inputs, then the variable X would be given the value 129 by a ZX BASIC instruction of the form:

```
LET X = PEEK 8192
(for the ZX81) or

LET X = IN 65503
(for the Spectrum).
```

The following routine can then be used to sort out the states of the eignt individual inputs;

```
DIM I(8)
FOR J = 1 TO 8
LET I(J) = X - 2 * INT (X/2)
LET X = INT (X/2)
NEXT J
```

This routine will give each of the eight array elements I(1) to I(8) the value '1' or '0', depending on the logic level applied to the individual I/O board inputs.

Using It

The whole point of an I/O board is that it will be connected to other equipment, and to this end the board described here has four 10-way plugs (PL1-4) fitted to it. As shown in **Figure 3**, PL1 and PL2 each carry four of the output lines, as well as 0V and +5V rails. PL3 and PL4 each have four of the input lines, and also the 0V and +5V connections. Leads can be soldered to the pins of the plugs or — more professionally — the mating sockets shown in the components list can be used; note that these consist of a shell moulding with separately supplied contacts.

The I/O board inputs can, of course, be connected directly to TTL or 5V CMOS outputs, and switch or relay contacts can be easily interfaced as shown in **Figure 4**, which also shows how a LED-phototransistor opto-isolator could be used to sense signals that it may not be possible to connect to the computer's 0V rail.

LEDs or low power relays can be driven from the board's output lines, as shown in **Figure 5**. In all cases, the total amount of current drawn from the +5V rail on pin 1 of PL1-4 should be not more than about 50 mA, as it is being provided by the regulator in the ZX, which runs hot enough anyway!

Note also that any large or inductive loads such as motors or relay coils should have interference suppressors fitted to cut down the risk of noise pulses upsetting the computer. For this reason it is advisable to isolate any large loads with a relay or opto-isolator, so that high voltage or heavy current circuits are completely separate from the computer. This will also reduce the chance of high voltages getting accidentally connected to your valuable ZX! **HE**

COMING SOON TO . . .

Hobby Electronics

DIRECTORY OF ELECTRONIC SUPPLIES

Hobby Electronic's October issue features the largest, most comprehensive survey of electronic components and hardware ever published.

The Directory consists of three large pull – out wall charts showing 40 categories of components, hardware and information for the electronics constructor. More than 60 company names and addresses are listed separately, with comments on product lines, specialities and services, and mentioning any items not covered in the charts.

With all this information presented so efficiently, the October issue of Hobby Electronics is a *must* for *all* electronic enthusiasts.

CB SQUELCH UNIT

Stamp out noise!

This device is the companion to our Stereo Noise Gate, also under preparation for October, but designed to eliminate CB receiver noise when the channel is open. If you find noise annoying, this easy-to-build and economical unit will sooth your nerves!

CIRCUIT MAKER

A complete kit for making PCBs at home, using the photographic process, has recently been released by Electrolube Limited. In October, Owen Bishop reports on his experiences with the photo-resists, the light frames and the bags of ferric chloride. His conclusions? See for yourself in the October issue of Hobby Electronics!

HEBOT II

Remember the HEBOT?

Way back in November 1979 we published one of the first ever mobile robot projects, which we christened HEBOT. It proved to be enormously popular and, judging by the mail we still receive, reader's enthusiasm for simple robotics has not decreased over the years!

HEBOT has long since 'passed on' but now, in conjunction with Powertran Ltd., we are proud to present its successor.

HEBOT II is a very similar animal — er, robot — but using today's more sophisticated circuitry and operating under the control of a microcomputer. Like the original, it is a 'turtle' robot, propelled by two large, independently controlled rubber wheels which enable it to perform a wide variety of movements. Obstacle-sensors allow it to explore its environment, discovering the limits of movement or the shape of a room, or it can draw patterns or graphs using a pen, which presses down on command. Its blinking eyes and on-board beeper can be programmed to communicate with the operator, eg to indicate that it has finished a task.

The projected cost of this educational and inspirational robot is under £100, and it is initially intended to be controlled via a Sinclair ZX81 microcomputer — though future developments will open still greater possibilities. Look out for HEBOT II in the November issue of Hobby Electronics.

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Although these articles are being prepared for the next issue, circumstances may alter the final content.

RADIO RULES

Ian Sinclair

Radio Frequency Power Amplifiers.

THE SAMPLE examination papers for the Radio Amateur's exam don't mention valves — though they do mention a number of topics that aren't covered to any great extent in the manual! Yet the fact is that the output power permitted to be used on the most popular amateur bands cannot easily be achieved using transistors. The good ol' fashioned valve is still the only way of ensuring that you have a beefy signal, without spending your whole income on the output stage! Unless you have some understanding of valve operation, then, the higher power stages of transmitters are going to be a bit of a mystery to you, and that doesn't sound like a good idea to me. So, for the benefit of those whose hair has not yet turned gray, let's look at the low-down on high-vacuum devices.

A valve relies for its action on electrons moving across a vacuum. Only electrons are involved, because holes can't exist outside a solid crystal, so the action of the valve resembles that of the N-channel MOSFET rather than that of a bipolar transistor, and there is no valve-type device which corresponds to the P-channel MOSFET. The electrons are emitted from a hot material, the cathode, which is cylindrical in shape and is heated by a wire filament, the heater (**Figure 1**). The cathodes of the smaller valves use a non-conducting (at room temperature) white material (the oxide cathode) which becomes an electron-emitting conductor when it is heated to a temperature of around 700°C, when it glows a dull red. Larger transmitting valves work with large currents and voltages, enough to damage a coating of this type, so that a filament of tungsten, either pure or coated with thorium, is used and carries out the tasks of both heater and cathode.

Electrons released into the vacuum of the valve from a hot cathode will, obeying the law that unlike-charges-attract, move to anything that is at a more positive voltage than the cathode. Surrounding the cathode, then, is a metal cylinder, called the anode, which is maintained at a positive voltage of anything from 100 V to 25kV, depending on valve size and power, so as to pull electrons away from the cathode at high speed. This electrode corresponds to the drain of the MOSFET.

A valve with only a cathode and an anode is a diode and can be used for rectification, though nowadays we use valves as rectifiers only for very high voltages, like the 100 kV supplies used in X-ray work. But if we add a third electrode, called a grid, between the cathode and the anode, it can control the flow of electrons and make the valve a useful amplifier or oscillator. The grid is usually a coil of wire held on metal posts between the cathode and the anode, but very much closer to the cathode (**Figure 3**). When the voltage on the grid is the same as the cathode voltage, electrons will pass through between the wires, practically unaffected by the grid, and will reach the anode. If the grid voltage is made negative, however, the electrons will be repelled from the grid wires and the space immediately around the wires, reducing the number of electrons that can reach the anode. At some particular negative voltage on the grid, this repulsion effect will be so strong that no more electrons will reach the anode and in this state, the valve is said to be 'cut off'. Therefore, a varying voltage on the grid, which must be biased so that its starting voltage (with no signal) is suitable (usually negative), will cause a varying anode current, just as a varying gate voltage on a FET causes a varying drain current.

The important difference is that the valve can operate at much higher power levels. If we try to operate semiconductors at high power, we have a problem conducting away the heat which is generated inside the material, as electrons and holes flow through it. Heat is also generated in a valve, of course, but most of it is released at the anode and the anode is made of a metal which can withstand much higher temperatures than a semiconductor junction made of silicon. In addition, the valve can dissipate heat by radiation through its glass envelope (as used in the smaller valves) or even by making the anode part of the outside of the valve and 'finning' it, so that it can be air-cooled, or by forming a water-jacket

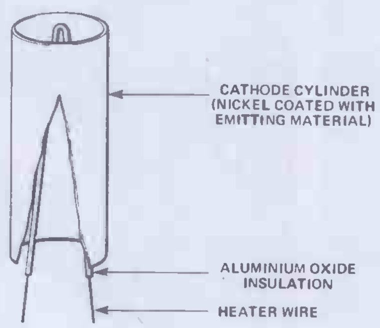


Figure 1. The cathode and heater of a valve. The heater is insulated from this type of cathode.

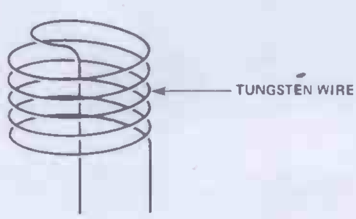


Figure 2. A tungsten filament, acting as combined heater and cathode, for the larger types of transmitting valve.

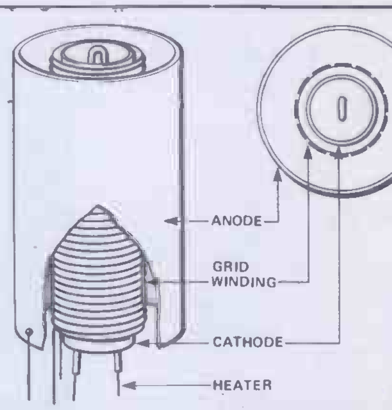


Figure 3. Arrangement of cathode, grid and anode in a small transmitting valve.

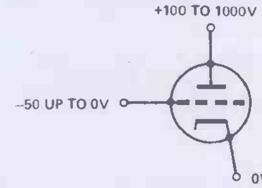


Figure 4. Valve symbol (triode) with typical voltage ranges (heater not shown).

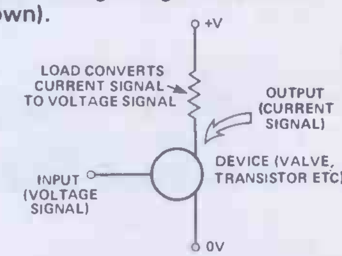


Figure 5. The principle of using a load to convert current signals to voltage signals.

around the anode so that it can be cooled like the cylinder-block of a car.

For powers of more than 100W, then valves are simpler and more reliable than transistors and in countries where high powers (several kilowatts) are permitted and used, valves are unchallenged.

Classes

No, it's not like the Post — first-class or pigeon. Class of operation means the way that we use a device, valve or transistor, to amplify signals; and it's important. There are three main classes of operation, termed (imaginatively) A,B and C, and you need to understand them thoroughly because all three are used in radio circuits.

Before we start, let's clear the way by making sure that we know what's involved in an amplifier. What it does is straightforward enough — create a high-power signal under the control of a low-power signal. An amplifier is an 'enlarger' of signals, using electrons instead of light.

The electronic devices, valves or semiconductors, that we used for constructing amplifiers do not, by themselves, amplify signal *voltage*. Rather, they create a *current* signal at the output, from a voltage signal (low current) at the input. What we usually need, however, is a voltage signal at the output, and to convert current signals into voltage signals we need a load — something that obeys Ohm's law so that the voltage across the load is proportional to the current through it. Audio amplifiers use a resistor or loud speaker as load, but radio frequency amplifiers use a tuned circuit which, at the frequency of resonance, behaves like a resistor for AC signals, but as a resistor of a very different and lower value for DC bias currents. We've looked at this point previously, when we dealt with tuned circuits and their dynamic resistance. Now: what distinguishes one class of operation from another is the way in which the load and the amplifying device work together.

Class A

Class A is the most familiar operating class because it's used so extensively for audio amplifier circuits — the ones that most of us cut our teeth on. In a Class A circuit, the transistor or valve never cuts off and is never saturated. In other words, the biasing and the signal amplitude will be arranged so that a change in the voltage of the input will *always* cause a change in the current at the output. For a silicon transistor, this means that the bias voltage between base and emitter must never fall much below 0V6 and the collector voltage must not fall much below the base voltage; a typical audio Class A amplifier is shown in **Figure 6**. With no signal input, the collector voltage is around half the supply voltage and the signal amplitude, when a signal is applied, must never cause the output voltage to reach either the supply voltage or earth level.

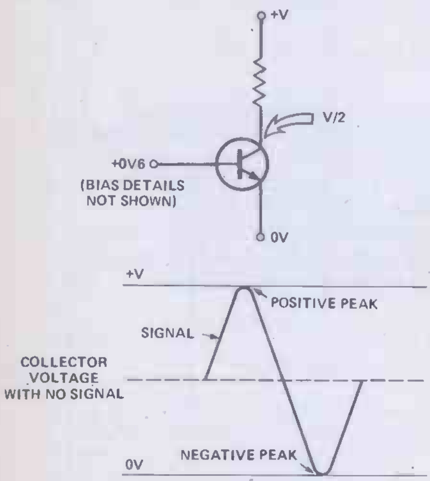


Figure 6. Class A bias — the collector voltage, when there is no signal input is at around half of supply voltage.

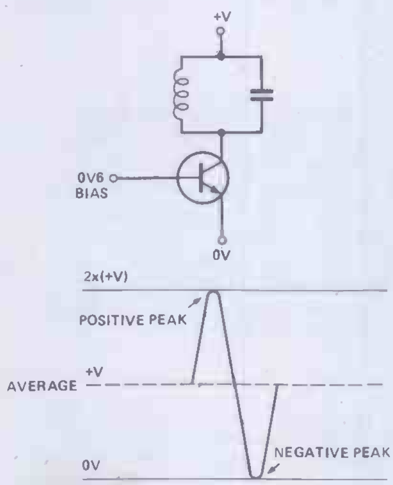


Figure 7. Adapting Class A to radio frequencies. The load is tuned circuit, and the no-signal collector voltage is equal to supply voltage.

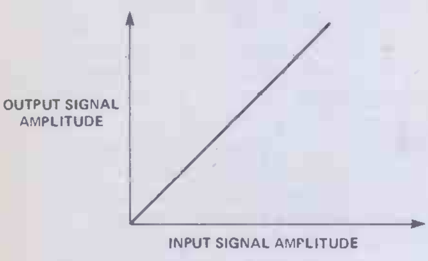


Figure 8. Linear amplification — the graph of output plotted against input is a straight line.

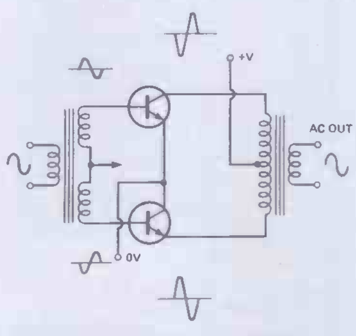


Figure 9. An old-fashioned audio push-pull stage, which can use Class B bias because the two output transistors each use half of the signal wave.

Radio frequency amplifiers working in Class A are similar — but different. To start with (**Figure 7**) the load will be a tuned circuit or a choke (inductor) rather than a resistor. Since the DC resistance of such a load is small, the normal no-signal voltage on the collector will be equal to the supply voltage and when a signal is applied, the voltage at the collector will be below supply voltage on one half of the cycle and above it on the other half. The restrictions are the same though — the current must never cut off and the collector voltage must never go as low as the base voltage, give or take a fraction. Using Class A for a radio-frequency amplifier produces what is called 'linear amplification', meaning that a graph of the amplifier signal current output plotted against the signal voltage at the input is a straight line. This is the type of amplifier that is needed for FM or single-sideband (SSB) signals, as we shall see later. One very important feature of a linear amplifier stage like this is that the DC current is constant — the amplifier takes the same amount of current from the supply when a signal is being amplified as it does when there is no signal and this makes decoupling and supply filtering a lot easier.

The trouble with the Class A amplifier is its low efficiency. Like the horse which is eating its head off even when it is not working, the Class A amplifier is taking current from the supply even when there is no signal, so that the ratio of power output from the amplifier to the DC power taken from the supply (confusingly called the power input) is low — always less than 50%. This ratio implies that a Class A stage will always run hot if it is handling more than a few milliwatts.

Class B

The Class B amplifier operates rather differently. To start with, the amplifying device is biased back, almost to cut off. This means that current flows mainly for the positive half-cycles of the signal (assuming a NPN transistor or valve) only. This type of stage can be usefully employed in audio amplifiers only in the form of balanced pairs (the push-pull circuit) so that one transistor handles the positive half-cycles and the other transistor handles the negative half-cycles. This is the basis of push-pull Class B circuits which, at one time, used transformers for splitting the signal into two opposite phases and recombined the phases later, but which now always deal with the two half-cycles directly by using a PNP and NPN transistor in series combination (**Figure 10**).

Radio frequency amplifiers can make more effective use of Class B amplifiers because they can use a load which is a tuned circuit. A tuned circuit reacts to short duration electrical pulses as a bell reacts when it's struck — it rings! A suddenly applied voltage across a parallel tuned circuit (**Figure 11**) will charge the capacitor, which will then discharge through the inductor, which re-charges the capacitors . . . and so on, with the cycle continuing until the energy of the original pulse has been dissipated in the resistance of the circuit. A tuned circuit will, in fact, produce a continuous signal at its resonant frequency with only a little help — it needs just enough signal at the right frequency to compensate for what is being lost in the resistance. It's like a swing — once you get it going, it needs only a very small amount of effort to keep it going.

A Class B tuned amplifier depends on this; the transistor or valve needs to conduct only for part of a cycle to keep a complete cycle going. Providing that the Q-factor of the tuned circuit is not too low, this works well and the Class B amplifier can be used for near-linear amplification. In many cases, however, the tuned circuit is loaded by other amplifier stages and has a low Q, so that the bias current has to be increased to obtain more linear operation. This need not necessarily be to the extent that is used in a Class A stage, and such arrangements are called Class A-B amplifiers.

The Class B amplifier has much higher efficiency than the Class A amplifier, meaning that a greater proportion of the power taken from the supply is converted into signal power (up to 80%), but it also means that the current is taken from the power supply in pulses, making smoothing difficult and requiring very good decoupling if these pulses are not to affect other stages in the circuit.

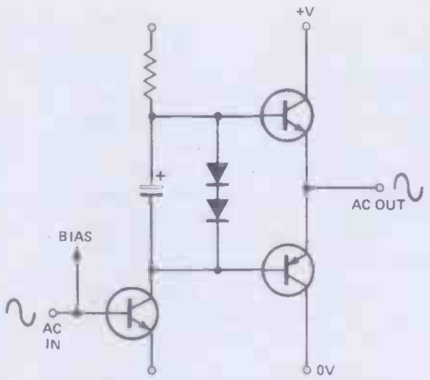


Figure 10. The more modern type of series Class B audio circuit — each transistor conducts alternately.

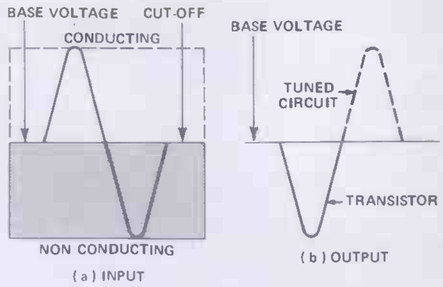


Figure 12. Using Class B for radio frequency — the tuned circuit contributes half of the output; this is possible only if the Q is fairly high.

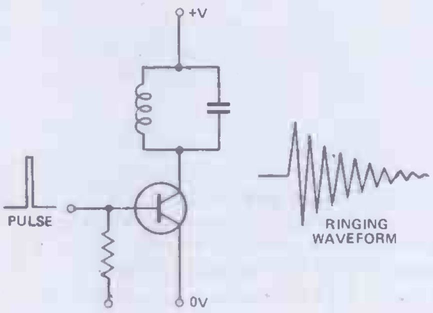


Figure 11. A ringing circuit. The pulse causes the transistor to conduct briefly — but the tuned circuit continues to oscillate even after the transistor has cut off. By feeding a small portion of the output back to the base of the transistor, this circuit can be made to oscillate, as described in an earlier part of this series, or it can be used as the basis of a Class C radio frequency amplifier.

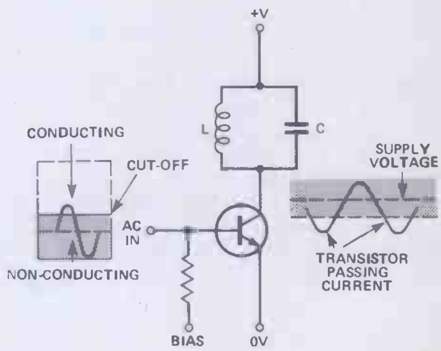


Figure 13. Class C radio frequency amplification. The transistor conducts for only a small portion of the input cycle and the tuned circuit contributes the remainder. Class C amplifiers are the most efficient, but the distortion they introduce means they can only be used for radio frequency amplification.

Class C

Class C amplification carries the "ringing" principle to its logical conclusion by biasing the transistor or valve so far into cut-off that the device conducts only on signal peaks (**Figure 13**). Unless the load has a high-Q, this will distort the signal considerably and so Class C amplification is used mainly for power stages of conventional AM transmitters. The fraction of the signal wave for which the transistor or valve conducts is called the 'conduction angle', and is given in degrees. If we imagine a complete cycle as being 360°, then the fraction of the wave for which the Class C stage conducts is given by the conduction angle divided by 360° so that a 30° conduction angle would mean that the transistor or valve was passing current for only one twelfth of the cycle, a lot less than the half cycle (180° conduction angle) of the Class B amplifier. The main advantage of Class C is its very high efficiency — the DC power that is taken from the supply is only slightly more than the AC signal power at the output, so that Class C is particularly useful for high-power stages which do not need linear amplification. Such power amplifiers need to be carefully designed, however, because the large pulse currents which flow for very short times will cause feedback to other parts of the circuit, and radiate from the supply leads! It is good practice to feed a Class C stage from a separate supply and to have a large decoupling capacitor across the Class C stage, between the 'cold' end of the load and earth. Large capacitance, in this respect, means about 100nF or less, depending on the frequency at which the stage is being operated. Electrolytics, which usually have rather large RF resistance, are quite definitely unsuitable.

Frequency Multipliers.

Up till now, we've been considering the best ways of obtaining, from an amplifier, a reasonable copy of the input signal but with higher power. Another problem that is tackled by surprisingly similar methods is that of obtaining a signal which is *not* a good copy but is, in fact, a different frequency! A frequency multiplier is an amplifier which is deliberately made to distort the shape of the sinewave so that harmonics appear. These harmonics are at multiples of the input frequency (twice, three times, and so on) and any one of them can be selected by using a tuned circuit so that it is amplified to a much greater extent than the others. By using an amplifier with low bias, such as a Class C stage, and with a load which is tuned to a multiple of the input frequency, we can produce an output which is a signal at the frequency to which the load is tuned. (**Figure 15**).

This circuit is useful because we can use crystal oscillators operating at comparatively low frequencies to generate outputs at VHF. We can, for example, multiply the frequency of an

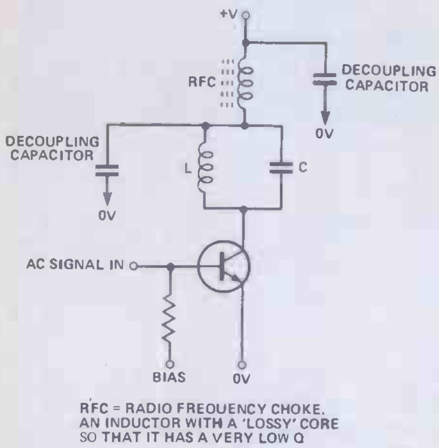


Figure 14. Decoupling a Class C circuit.

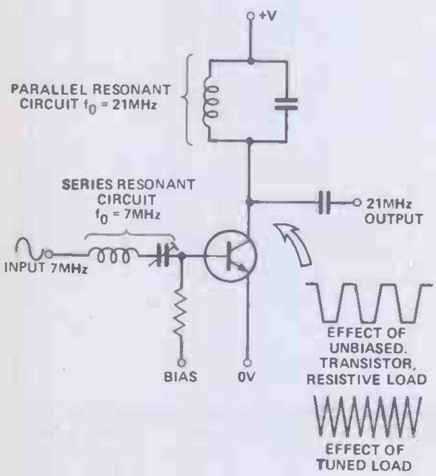


Figure 15. Frequency multiplication – the transistor output would be a square wave but for the tuned circuit, which rings at a harmonic of the input frequency so that, each time the transistor conducts, the result is in the correct phase to maintain oscillation.

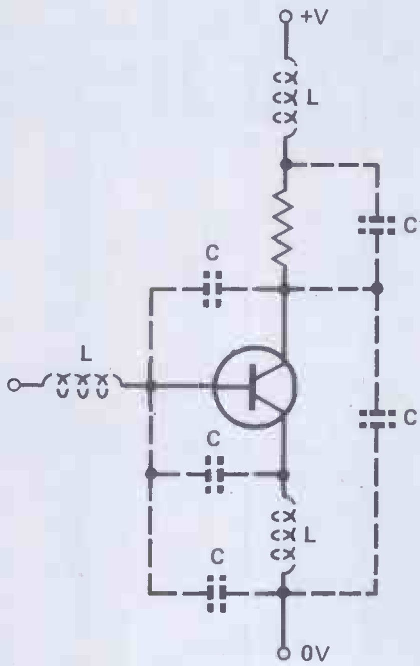


Figure 16. Stray capacitance and inductance around an amplifying stage. Each length of wire has some inductance, and there will be stray capacitance between any two points at different voltage.

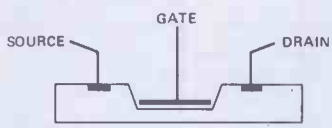


Figure 17. A FET, illustrating why transit time of electrons is important.

8 MHz crystal to 144 MHz, using several stages of multipliers. The amounts of multiplication that are used are mainly x2 and x3, though x4 is possible for low-power stages.

Frequency Limitations

An ideal amplifier stage design would be one that could be used at all frequencies — but there's no such animal. What we do in practice is to use different designs for different parts of the frequency range. Just to complicate matters, there are several effects which combine to restrict the highest frequency that an amplifier can operate at and we have to be aware of all of them, if we are to make wise choices for components and circuits.

One of the most important limiting effects is stray capacitance. Any two points in a circuit which are not directly connected will have some stray capacitance betwen them and this invisible capacitance is as real in its effect as a capacitor soldered in place. Stray capacitance can even exist between two bits of metal that are connected together because, when a radio frequency wave moves along a strip of metal, some points will be at high voltage and some at low voltage, so there can be capacitance between them.

The second effect is stray inductance. Any length of wire has an inductance and, though the inductance of a few centimetres of wire is very small, even this will be significant if we are using UHF signals. Finally, the transistors and valves that we use as amplifying devices can't operate at frequencies above the limit set by the speed of their current carriers (eg electrons).

That last one needs some explanation; suppose you imagine a FET in which electrons move from the source to the drain and are controlled by a gate (**Figure 17**). Suppose, also, that the voltage on the gate is a sinewave at a high frequency, perhaps 10 MHz. Now a 10 MHz signal means that one complete cycle takes 100 nS and one quarter of a cycle takes 25 nS. What's the significance of this? Think of the movement of the electrons; if an electron starts moving from the source when the wave on the gate is at its positive peak, then it has to get past the gate before 25 nS has elapsed. If it doesn't, it will be slowed down or even repelled because the gate voltage will, by that time, have reversed. As it happens, we can make the gate and the source very close to each other, so that even with the slow speed of electrons in semiconductors, it's possible to operate FETs at fairly high frequencies, certainly more than 10 MHz — but only if the FET has been designed with its gate very close to the source. A similar effect occurs in valves and is called 'transit time'. The limitation here is that it's impossible to get the grid really close to the cathode without risking them touching, particularly when the electrodes expand due to heat. Transistors suffer from another effect, 'charge storage', meaning that the base of a NPN transistor, which conducts because of hole movement, will fill up with electrons while the transistor is switched on and it takes some time to clear these electrons when the transistor is switched off.

Whatever the cause, we have to choose amplifying devices that will cope with the frequencies that we want to use. This may, for example, mean using transistors in common-base circuits rather than in common-emitter circuits.

For audio amplifiers, there are no serious frequency limitations. Even power amplifier transistors now have good frequency responses, provided we use modern transistor designs. The limitations caused by the effects of stray capacitance, along with the use of resistor loads have very little effect at audio frequencies.

In tuned-load amplifiers, the stray capacitance can actually be made part of the tuned circuit and becomes a problem only when we use such high frequencies that the stray capacitance is larger than the total capacitance that we need! At such frequenices, we are also up against the frequency limitations of the device itself and the effects of stray inductance, so that specialised constructional techniques are needed when we work at 400 MHz or above. Ultimately, if we want to use frequencies above 1 GHz (1000 MHz), we have to use pulsed devices such as klystrons and magnetrons to generate signals, and linear amplification eventually becomes out of the question.

We've now dealt with a lot of pieces of circuitry — oscillators, amplifiers and basic component theory — so we're ready to start putting the bits together to see how they are used in radio receivers and transmitters. We'll kick off next month, then, with the AM superhet receiver. Out. **HE**

MicroTraining

Paul Kelly

Concluding the main part of our MicroTrainer project.

In the first article of this series we described the general principles of microprocessor operation, using the 1802 as a particular example. In this issue, we continue with a detailed description of the 1802 instruction set, and a discussion of simple programming techniques using these instructions. Then we should have laid the foundations for aspiring designers of control systems, so that in future articles we may concentrate on the applications aspects of microprocessing. We also said, at the outset of the Microtrainer series, that we were not aiming to produce experts in machine code programming, but rather to encourage the use of microprocessors in a wide range of hobbyist applications, and we believe the average hobbyist will be well able to produce his own useful designs with only a basic understanding of machine code software.

Instructions Executed

A microprocessor operates by sequentially fetching data bytes from an external random access memory (this includes ROM) and interpreting each one as an instruction to perform specific operations on data stored in either internal registers or in external memory. The task that a micro-rocessor system performs is determined almost entirely by the particular sequence of instructions held in the memory, know as software or, more simply, a program. A particular microprocessor, such as the 1802, is distinguished by the set of instructions available, and by the functions of a closely related set of internal registers, as well as its peculiar hardware features.

We have already given a table of 1802 instructions and a representation of the register set (June '82 issue) and to supplement this, the internal architechture of the 1802 has been drawn in **Figure 1** and the instruction set is reproduced here as **Table 1**. This information is also available in the RCA programming manual. The architechture of the 1802 reveals some of the 'hidden' registers (eg the instruction holding registers I and N) as well as the user accessible registers, but a description of the MPU's operation at this level is beyond the scope of this article.

The instruction set can be subdivided into broad categories, which we will look at in turn. The categories are: register operations, memory references, logical operations, arithmetic operations, branch and skip instructions, control instructions and input/output instructions.

Register Instructions

The 1802 register set includes a bank of 16, 16-bit registers, each of which can hold 2 bytes of data or one 16-bit address. The instructions that operate on these registers show that they are primarily intended for use as memory address pointers for subsequent instructions. Here are the register instructions:

INC	R(N)	Increment register N.
DEC	R(N)	Decrement register N.
IRX		Increment register X.
GLO	R(N)	get low byte of register N and place in accumulator.
PLO	R(N)	put accumulator in low byte of register N.
GHI	R(N)	get high byte of register N, place in accumulator .
PHI	R(N)	put accumulator in high byte of register N.

These are the only instructions which specifically alter the contents of the 16-bit registers (some instructions have a 'register auto-increment/ decrement' addressing mode, however). In order to set-up a sixteen bit address in any of the registers, data must be fetched from memory via the accumulator, one byte at a time. An example will best illustrate this (the prefix '$' and suffix 'H' both denote hexadecimal):

```
LDI $40   ;load accumulator with
           40H
PHI R5    ;R5.1 = 40H
LDI $E0   ;load accumulator with
           E0H
PLO R5    ;R5.0 = E0H
```

At the end of this sequence of instructions, register 5 will hold the address 40E0H. The LDI instruction has been described earlier in the series. Two other instructions, INC & DEC, provide a quick means of changing this address to adjacent or nearby memory locations, eg two INC instructions will advance R5 to address 40E2H.

Each of the register instructions is a single-byte op-code which can be found in the instruction table. Clearly, since these instructions can be applied to any of sixteen registers, there must be sixteen possible codes in each case. Happily, these codes can easily be worked out by, firstly, looking up the first digit of the hex op-code and then using the register number as the second hex digit. For example, the instruction 'DEC' has a quoted op-code of '2N' where 'N' is the register number, so that 'DEC R9' has the op-code '29H'. In fact, any of the 1802 instructions which make use of the 16-bit registers can be worked out in this way.

Memory Reference

These instructions allow transfers of data bytes between the accumulator and memory locations. You have already met the two-byte instruction LDI (Load Immediate), wherein the byte stored after the op-code is copied into the accumulator. There are four other instructions that will also load data from memory into accumulator, and which illustrate the different addressing modes of the MPU:

Memory Immediate mode (LDI): has been described already.
Register Indirect (LDN): the memory byte pointed to by register N is loaded into the accumulator.
Indexed Addressing mode (LDX): the memory byte pointed to by the index register R(X) is loaded into the accumulator.
Register Indirect with auto-increment (LDA): as Register Indirect but the register is automatically incremented by one after loading the data byte.
Indexed Addressing with auto-increment (LDXA) — as with Indexed Addressing but the index register is automatically incremented after the load operation.
All but the LDI instruction are a single byte.

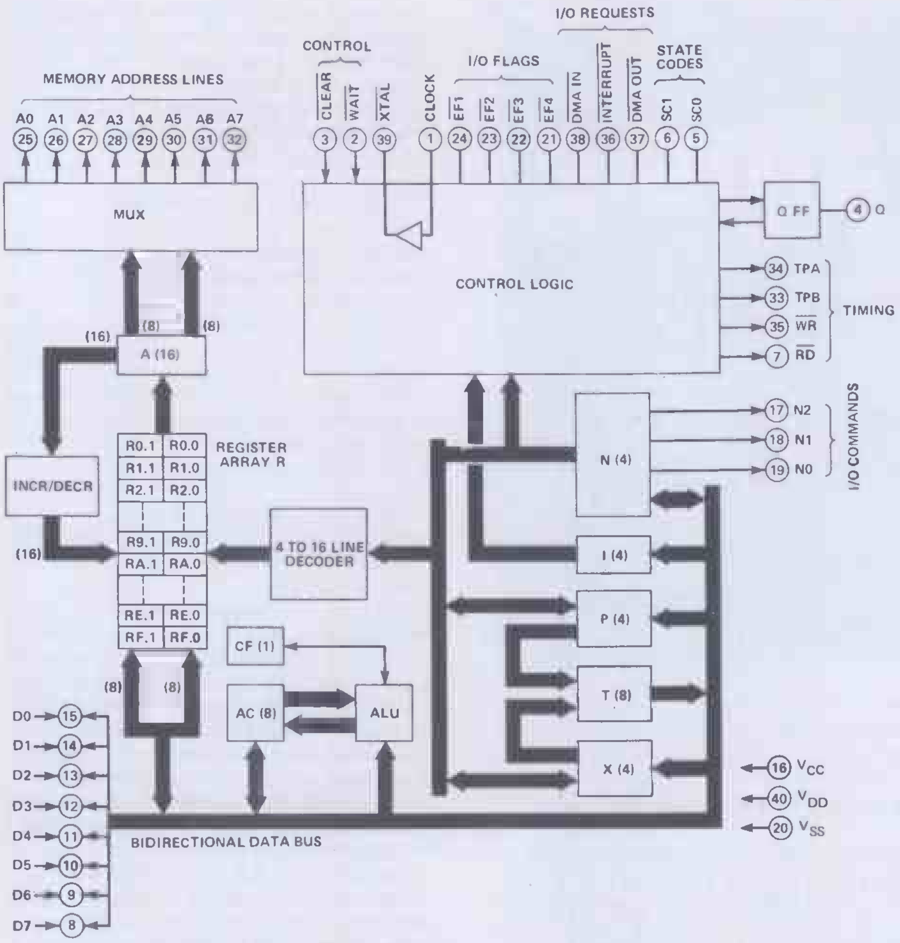


Figure 1. The 'internal architecture' of the 1802 microprocessor.

The immediate mode of addressing allows data to be placed in the program during writing, as an alternative to setting up an address pointer and then loading the data byte from elsewhere in memory. Register Indirect and the very similar Indexed Addressing modes are the most powerful and often used; they permit several data blocks within memory to be speedily accessed, using the large number of address registers available. The auto-increment addressing modes are useful when a program is operating on a large array of data stored successively in memory, where the improved execution time is a virtue.

There are two instructions which allow storage of the accumulator in memory; STR uses Register Indirect addressing and STXD is Index Addressed with auto-decrement.

The instructions described so far provide a flexible system for transferring data between memory locations and the main 1802 registers. A few of these instructions (eg STXD) may, for the moment, seem obscure, however they come into play in more advanced programming techniques.

Logic Operations

Most readers will be familiar with the logic functions 'OR', 'AND' and 'Exclusive OR' (EX-OR) which operate on two single-bit operands to produce a single bit result. The 1802 has logic instructions, of this form, which opeate on a memory byte and the

IDL	00	Wait for interrupt or DMA request
LDN	0N	Load accumulator, via register N
INC	1N	Increment register N
DEC	2N	Decrement register N
BR	30	Branch always
BQ	31	Branch if Q = 1
BZ	32	Branch if accumulator is zero
BPZ	33	Branch if positive or zero
B1	34	Branch if EF1 = 0
B2	35	Branch if EF2 = 0
B3	36	Branch if EF3 = 0
B4	37	Branch if EF4 = 0
BRN	38	Branch never
BNQ	39	Branch if Q = 0
BNZ	3A	Branch if accumulator not zero
BM	3B	Branch if minus
BN1	3C	Branch if EF1 = 1
BN2	3D	Branch if EF2 = 1
BN3	3E	Branch if EF3 = 1
BN4	3F	Branch if EF4 = 1
LDA	4N	Load accumulator, via register N, then increment register N
STR	5N	Store accumulator in memory, via register N
IRX	60	Increment index register
OUT	6N	(N = 1,7) Transfer via index register to output device N, then increment index register
• • •	68	Illegal instruction
INP	6N	(N = 9,F) Transfer to accumulator from input device (N-8), then store via index register
SHLC	7E	Shift left with carry (accumulator)
SMBI	7F	Subtract with borrow, immediate data from accumulator
GLO	8N	Load accumulator with low order byte of register N
GHI	9N	Load accumulator with high order byte of register N
PLO	AN	Store accumulator in low order byte of register N
PHI	BN	Store accumulator in high order byte of register N
LBR	C0	Long branch always
LBQ	C1	Long branch if Q = 1
LBZ	C2	Long branch if accumulator is zero
LBPZ	C3	Long branch if positive or zero
NOP	C4	No operation (long skip never)
LSNQ	C5	Long skip if Q = 0
LSNZ	C6	Long skip if accumulator not zero
LSMI	C7	Long skip if minus
LSKP	C8	Long skip always
LBNQ	C9	Long branch if Q = 0
LBNZ	CA	Long branch if accumulator not zero
LBMI	CB	Long branch if minus
LSIE	CC	Long skip if IE = 1
LSQ	CD	Long skip if Q = 1
LSZ	CE	Long skip if accumulator zero
LSPZ	CF	Long skip if positive or zero
SEP	DN	Set program counter to register N
SEX	EN	Set index register to register N
RET	70	Return from interrupt or subroutine
DIS	71	Return from interrupt with interrupts disabled
LDXA	72	Load accumulator, via index register, and increment index register
STXD	73	Store accumulator in memory, via index register, and decrement index register
ADC	74	Add with carry, via index register, to accumulator
SDB	75	Subtract with borrow, accumulator from memory, via index register
SHRC	76	Shift right with carry (accumulator)
SMB	77	Subtract with borrow, memory from accumulator, via index register
SAV	78	Save T register in memory, via index register
MARK	79	Push X, P registers on stack, via index register
REQ	7A	Reset Q flag to zero
SEQ	7B	Set Q flag to one
ADCI	7C	Add with carry, immediate data to accumulator
SDBI	7D	Subtract with borrow, accumulator from immediate data
LDX	F0	Load accumulator via index register
OR	F1	Logic OR, memory with accumulator, via index register
AND	F2	Logic AND, memory with accumulator, via index register
XOR	F3	Logic XOR, memory with accumulator, via index register
ADD	F4	Add memory to accumulator, via index register
SD	F5	Subtract accumulator from memory, via index register
SHR	F6	Shift right accumulator
SM	F7	Subtract memory from accumulator, via index register
LDI	F8	Load accumulator with immediate data
ORI	F9	Logic OR, accumulator with immediate data
ANI	FA	Logic AND, accumulator with immediate data
XRI	FB	Logic XOR, accumulator with immediate data
ADI	FC	Add to accumulator, immediate data
SDI	FD	Subtract accumulator from immediate data
SHL	FE	Shift left accumulator
SMI	FF	Subtract from accumulator, immediate data

Table 1. The instruction set of the 1802.

A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

TRUTH TABLE
A AND B

A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

TRUTH TABLE
A OR B

A	B	A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

TRUTH TABLE
A EX-OR B

0	0	1	0	1	1	1	1	2FH
0	0	0	0	0	1	0	0	04H
0	0	0	0	0	1	0	0	

(2FH) AND (04H) = 04H

0	0	0	0	0	0	0	0	00H
0	0	0	0	0	1	0	0	04H
0	0	0	0	0	1	0	0	

(2FH) OR (04H) = 2FH

0	0	1	0	1	1	1	1	2FH
1	1	1	1	1	1	1	1	FFH
1	1	0	1	0	0	0	0	

(2FH) EX-OR (FFH) = E0H

Table 2. Above, the truth tables for AND, OR and Exclusive-OR functions. Below; AND, OR and Exclusive-OR operations performed on a data byte.

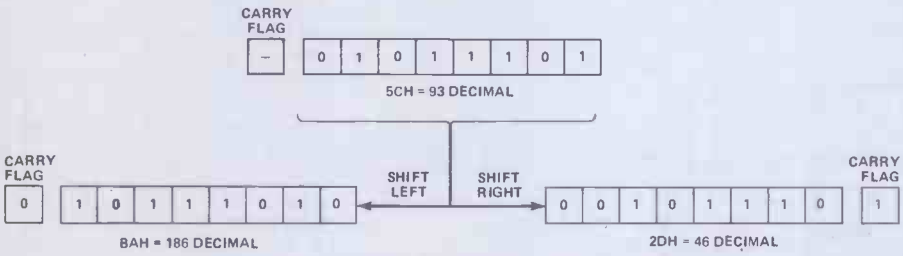


Table 3. A shift left is equivalent to 'multiply by two' and shift right performs 'divide by two'.

accumulator byte to produce a result in the accumulator, doing so on a bit-by-bit basis. For each of these functions, there is an instruction (to fetch the memory byte) in Immediate Addressing mode and an instruction in Indexed Addressing mode. The need for these instructions in a control system is obvious, however they have an important but not so apparent second use, that of 'bit manipulation'. For example, suppose the accumulator had the initial value of B7H and then we executed the instruction ANI $0F (AND Immediate) the result would be 07H, in the accumulator. The effect has been to mask the first four bits of the data byte. Looking at the 'AND' function analytically, we can say that the effect of a logic zero in a particular bit of one operand has the effect of resetting, to logic zero, the state of the corresponding bit in the other operand. This can be used for testing the state of an individual bit within a byte (you shall see what is meant by this later). For example, ANI $04 will mask out all but bit 2 of the accumulator data (04H = 00000100 binary). **Table 2** shows that the 'OR' function has a bit-setting capability, whilst the 'Exclusive Or' function may logically invert bits.

The remaining logical operations fall in to the category of Shifts and Rotates, and are single operand functions operating on the accumulator. 'SHL' (Shift Left), for example, causes all the bits of accumulator data to move one place left (bit 0 becomes bit 1 etc); for example, after SHL, 01011101 becomes 10111010. A few calculations should convince you that this operation is equivalent to a 'multiply by two' (but see **Table 3**, if in doubt), and the primary use of such an instruction is to permit arbitrary multiplications and divisions, in conjunction with the arithmetic functions (Subtract and Add). Similarly, the Shift Right instruction, 'SHR', is, in effect, a 'divide by two'. Note that the MSB, in the case of SHL, and LSB in the case of SHR, are shifted out of the accumulator into the one-bit carry-flag, CF. The setting of the carry-flag indicates that the division or multiplication by two is not quite right; it may be looked upon as a arithmetic carry (multiplication) or as a remainder (division). At the other end of the accumulator, a zero is copied in during shift operations.

There are two other instructions (RSHL, RSHR), 'ring shifts' or 'rotates', in which the previous state of CF, rather than a zero, is shifted into the 'trailing' end of the accumulator. In conjunction with ordinary shifts, these instructions allow the shift operation to be extended to multiple byte words.

Arithmetic Operations

The 1802 has only two basic arithmetic operations, Add and Subtract, and they are as simple as you might guess. The only difficulty is when the result goes above FFH or below 00H. A useful model, here, is to consider the accumulator a 'binary' bicycle mileometer. For example, when adding 07 to FD the accumulator counts up to FF then cycles back through 00, finally arriving at the value of 04 after seven counts. Similarly during subtraction, the accumulator counts down to 00 then switches back to FF and continues to decrement. In both cases, the carry flag indicates that the result has 'overflowed' or 'underflowed'. If you look at the other Add and Subtract instructions in **Table 1** you will find that there are instructions for 'accumulator substracted from memory' as well as 'memory subtracted from accumulator' (the result always falls in accumulator) together with Add and Subtract with Carry/Borrow instructions (again, to cope with multiple-length arithmetic) all of these instructions use the two basic addressing modes of memory, Immediate and Indexed.

Branch instructions

Theoretically, any program could be written with a sequential string of arithmetic, logic and transfer instructions. However, if you consider programs that require operations to be performed many thousands of times over, this prospect becomes plainly ridiculous. Branch instructions allow program control to be transferred to a new address by directly altering the program counter, rather than the usual increment after each instruction. The simplest branch instruction is 'BR$XX' where 'XX' is the byte following the op-code. In executing this instruction, the byte 'XX' is copied into the low-order byte of the program counter, so that execution continues with the instruction found at that address. The exampled below shows how a repetitive loop can be set-up using this branch instruction.

```
0000H  1F      INC   RF
               ;increment register 'F'
0001H  30 00   BR    $00
               ;branch back to 0000H
```

Normally, loops are constructed to terminate when certain conditions are set, and so a number of Conditional Branch instructions are provided. Conditions, such as the state of the carry flag or whether the accumulator is zero, are tested by the Branch instruction and a branch takes place only if the condition is met, otherwise execution continues with the next instruction. Suppose, for example, we wished to increment the 'F' register 100 times:

```
0000   F8  64  LDI    $64
   ;100 = 64H

0002   A1      PLO    R1
   ;initialise counter with one hundred

0003   1F      INC    RF
   ;increment RF

0004   21      DEC    R1
   ;decrement counter
0005   81      GLO    R1
   ;bring count into accumulator for
   testing
```

```
0000  F8  20        LDI  $20   ;load 20H in accumulator
0002  B2            PHI  R2    ;put in high byte of R2
0003  F8  77        LDI  $77   ;load 77H
0005  A2            PLO  R2    ;put in low byte of R2
                               ;2077H is centre screen address
0006  F8  00        LDI  $00   ;"0"
0008  52            STR  R2    ;store in memory pointed to by R2
0009  12            INC  R2    ;R2 = 2078H
000A  F8  00        LDI  $00   ;"0"
000C  52            STR  R2    ;
000D  12            INC  R2    ;R2 = 2079H
000E  F8  3A        LDI  $3A   ;":"
0010  52            STR  R2    ;
0011  12            INC  R2    ;R2 = 207AH
0012  F8  00        LDI  $00   ;"0"
0014  52            STR  R2    ;
0015  12            INC  R2    ;R2 = 207BH
0016  F8  00        LDI  $00   ;"0"
0018  52            STR  R2    ;display now shows "00:00"
0019  F8  7B   P0   LDI  $7B   ;start of delay loop
001B  A2            PLO  R2    ;sets R2 to point to last digit of display
001C  F8  00        LDI  $00   ;
001E  A5            PLO  R5    ;
001F  F8  0F        LDI  $0F   ;
0021  B5            PHI  R5    ;0F00H sets the delay period
0022  25       L0   DEC  R5    ;start of loop L0
0023  95            GHI  R5    ;load accumulator with high byte of R5
0024  3A  25        BNZ  L0    ;go back if not zero
0026  02            LDN  R2    ;fetch last digit
0027  FC  01        ADI  $01   ;add 1
0029  52            STR  R2    ;put in display
002A  FF  0A        SMI  $0A   ;subtract 10 to test if greater then 9
002C  3A  19        BNZ  P0    ;go back if not zero
002E  52            STR  R2    ;set last digit to zero
002F  22            DEC  R2    ;R2 = 207AH
0030  02            LDN  R2    ;load third digit (tens of minutes)
0031  FC  01        ADI  $01   ;add 1
0033  52            STR  R2    ;put back in display
0034  FF  06        SMI  $06   ;subtract 6 to test if greater than 5
0036  3A  19        BNZ  P0    ;go to delay loop if less than 60 minutes
0038  52            STR  R2    ;set to zero if 6
0039  22            DEC  R2    ;R2 = 2079H; ":"
003A  22            DEC  R2    ;R2 = 2078H
003B  02            LDN  R2    ;fetch second digit (hours)
003C  FC  01        ADI  $01   ;add 1
003E  52            STR  R2    ;put in display
003F  FF  0A        SMI  $0A   ;subtract 10 to test for 9 hours
0041  32  52        BZ   P1    ;goto to P1 if hours greater than 9
0043  02            LDN  R2    ;if not, load hours digit again
0044  FF  03        SMI  $03   ;subtract to test if 3 hours
0046  3A  19        BNZ  P0    ;if not, go back to delay loop
0048  22            DEC  R2    ;R2 = 2077H
0049  02            LDN  R2    ;load first digit (tens of hours)
004A  FF  02        SMI  $02   ;subtract to test if 20 hours
004C  3A  19        BNZ  P0    ;if not go to delay loop
004E  52            STR  R2    ;if 23 hours, set tens to zero
004F  12            INC  R2    ;R2 = 2078H
0050  02            STR  R2    ;set hours to zero
0051  30            BR   P0    ;goto to delay loop
0052  52       P1   STR  R2    ;set hours to zero
0053  22            DEC  R2    ;R2 = 2077H
0054  02            LDN  R2    ;fetch first digit (tens of hours)
0055  FC  01        ADI  $01   ;add 1
0057  52            STR  R2    ;put in display
0058  30            BR   P0    ;go to delay loop
```

Table 4. A simple program to simulate a 24-hour clock. The timing is set by the data byte loaded in lines 001CH to 0021H; 0F00H gives a delay of approximately one minute, and may be adjusted for more accurate timing.

```
0006   3A   03 BNZ       $03
   ;branch to 0003 if count not yet
   zero
0008 . . . . . . . . . . . . . . . . . . . .
   next instruction
```

Notice that loop counters are usually decremented to zero rather than incremented from zero, because it is easier to test a zero condition than a content of 64H. Besides loops, conditional branches are used to transfer control to different sections of a program, according to certain conditions. If, for example, a control system required the illumination of an LED in the event of an 'underflow' following the subtraction of two variables, then a conditional branch 'BM' (Branch if Minus) immediately following the Subtract instruction could transfer control to a section of code designed to light the LED.

There are other Branch and Conditional Branch instructions that permit a program counter jump to anywhere within the memory system. These are 'long branches' and have a two-byte address, following the op-code, which is copied into the accumulator, eg LBR $A007. Obviously these take longer to execute, and take up more memory space.

The Skip instructions of the 1802 may be considered a luxury, in that they can always be replaced by one or more Branch instructions simply by writing the program in a slightly different way. An example of the skip instructions is:

```
0005   CE    LSZ
   ;long skip if zero (skip 2 bytes)
0006   . . .               . . .
0007   FC    01      ADI     01
   ;add 1
0009   C4            NOP
   ;continue
000A   . . .               . . . .
```

The instruction to add one to the accumulator is executed only if the accumulator was non-zero.

Control Instructions

There are two instructions, in this group, that we are particularly concerned with, namely SEP and SEX (no comments, please!). As described in earlier issues, these two instructions define a particular 16-bit register as program counter and index register, respectively.

Often, large programs will contain sections of code which occurrs many times, and it is useful to be able to condense this code into one routine or 'subroutine' to which control can be transfered from various points in the program. The greatest difficulty with this scheme is finding a method of storing the address of the program counter before control is transfered to the subroutine so that, when the subroutine has completed, control can be returned to the correct point in the main program. How this is achieved with the 1802 is outlined below:

```
0000        F8      10    LDI $10
   ;load immediate, 10H.

0001        B1            PHI R1
   ;store in high byte of register 1.

0002        F8      00    LDI $00
   ;load immediate, 00H

0003        A1            PLO R1
   ;store in low;byte of R1; R1 now
   points to subroutine.
. . . .     . . . .       . . . . . .
0030        D 1           SEP R1
   ;go to subroutine; program counter
   is now R1.
. . . .     . . . .       . . . . . .

0050        D 1           SEP R1
   ;go to subroutine.
. . . .     . . . .       . . . . . .
0FFF        D 0           SEP R0
   ;return to main program; program
   counter is now R0; R1 increments
   to 1000H.
1000        . . . .       . . . .
   ;start of subroutine
. . . .     . . . .       . . . . . .
. . . . .   . . . .       . . . . .
100F        C 0           LBR 0FFF
   ;long branch to 0FFF;
```

Note that it is necessary to reset the subroutine pointer (register R1) to the subroutine address (1000H) before returning to the main program because, since it is the program counter, R1 is automatically incremented after each instruction. A return at, say, 100FH would leave R1 pointing to 1010H. Instead, a jump is made to the address just before the start of the subroutine; control is returned to R0 and R1 automatically increments to 1000H. The other catch is that the subroutine must not use R0, else the return address will be lost!

It is possible to have many subroutines, each with a different pointer register, for as many registers as you can spare; it is also possible to nest subroutines (call a subroutine from a subroutine) provided that careful track is kept of the registers used. Often, each subroutine will have its own data space in memory, and this can be quickly accessed by a subroutine by reserving a register to point to this data area and defining it as the index register (SEX), on call.

Much of this may seem very academic, but it is a necessary requirement before useful programs can be written. We'll finish, however, by listing a quite complex practical program (Table 4). The comments should prove a sufficient explanation.

Next time we will look at the largely hardware-orientated instruction, so far ommitted, when we discuss I/O interfaces. **HE**

POINTS OF VIEW

Feel like sounding off? Then write to the Editor stating your Point Of View!

The most interesting Point of View, this month is from Mr. A.G. Meakins, who comments on writing style of certain points mentioned in "Scaling the HiFi Heights" (HE January issue).

Unimpressed

Dear Sir,
Your cover puts H.E. as having "a down to earth approach to electronics", but it's a pity you don't impress this on your writers, who use long words like "parameters" when "limits" would do.

In Scaling the HiFi Heights, your writer should come down to earth. When he states that £400 is the lowest starting point, he is way off target. I would suggest that, for most HE readers, that would be the extreme top limit.

Another piece of pie in the sky that comes from his pen is the wattage of the amplifier. I have a room of 1200 cubic feet, my amplifier is 14 W per channel and with the volume control at 30%, I can comfortably fill my room with ample power left to take the peaks. Perhaps your writer destroyed his hearing in a disco, when young.
A.G. Meakins
Richmond,
Surrey.

First, this letter was attached to a late return of our Reader Survey, also from the January issue. We have since changed our masthead slogan but not, we hope, our approach.

Every article which appears in HE is carefully edited to ensure that it can easily be understood. However, this must not be overdone; an article consisting entirely of words of one syllable would not only be an insult to our readers, it would also be boring and, most likely, inaccurate because it is not always possible to find a 'short word' to substitute for a long one. Remember that electronics is a technical subject, that certain words have very precise meanings and, therefore, cannot be changed.

In fact, the word 'parameter' is one for which there is no suitable substitute. It means ". . . a constant in the case considered but varying in different cases." (C.O.D.). In general usage, a parameter is a factor by which a device or property is defined or measured, for example the small-signal parameters which define transistor operation under certain conditions. A limit is a border or boundary line or point, and not the same thing at all.

The suggestion that £400 is the top limit of spending for HE readers is an example of a limit that is somewhat arbitrary. True, it is a lot of money, but a system costing this much or more is not out of the question. It is possible to build up a very expensive hifi over a period of years buying units one at a time. Also, the figure was mentioned as the lowest total ". . . for serious sound pursuit." and considering that it is possible to spend over £1000 on audio gear, a £400 system only just qualifies as hifi!

For example, a 14 W per channel amplifier, while adequate for normal listening, would not satisfy a dedicated hifi fanatic. It has to be said that opinions on listening levels are extremely subjective (one man's pleasure is another's pain), nevertheless, all other factors (type of programme material, the size of the room and acoustic treatment, the efficiency of the speakers etc) being equal, a large amplifier will come closer to reproducing the original dynamic range of music, at comfortable levels, than a small amp. This, after all, is the goal of hifi — accurate reproduction of the original music.

Finally, it's worth pointing out that concert musicians, sitting in the middle of an orchestra which can produce sound peaks of up to 100 dB SPL, do not usually destroy their hearing. There is no reason why these levels, accurately reproduced, should destroy the hearing of a listener in the middle of his lounge room. What the neighbours think is another question!

No Kitting

Dear Sir,
I have been trying to get you by phone to ask about the LED VU Meter project from the November '81 issue. I was wondering if the kit you did for it included the integrated circuit U267B Bargraph Driver.

If so, could you please send a full kit for the VU Meter and when I receive it I will send on the money.
S. Harvey,
Cleethorpes,
South Humberside.

Sorry, but we do not sell kits or component parts for HE projects except, of course, the printed circuit boards which are advertised in each issue. However, there are companies who supply kits for our projects and they usually advertise in the magazine. One of them should be able to help you.

This reply should also answer S.N. Heider of Dedridge, Livingstone, West Lothian, who wrote with a similar enquiry.

Trying to 'phone us is not a good idea — we cannot, unfortunately, accept telephone enquiries because of the time involved. There simply aren't enough hours in a day! One other thing; most companies would want to see the colour of your money before sending the goods.

'Diana' Hunted

Dear Sir,
Please will you let me have a copy of your article, from the September 1981 issue of Hobby Electronics, on the Diana Metal Detector. I work at Plessey Radio at Cowes, here on the Isle of Wight, as a test engineer. Our librarian has contacted on my behalf our local libraries, Portsmouth and Southampton libraries and, finally, the British Museum, for a copy of the issue but all without success.

I hope you will be able to assist me.
G.M. Store,
Ryde,
Isle of Wight.

The quickest and easiest method for obtaining most back issues of HE is to write to our Backnumbers Department — see the advertisement in this or any recent issue. It certainly beats chasing around libraries and museums.

Meanwhile, interested readers might like to know that the add-on VCO for 'Diana' has been finalised and will appear in the near future.

Into Electronics Lost

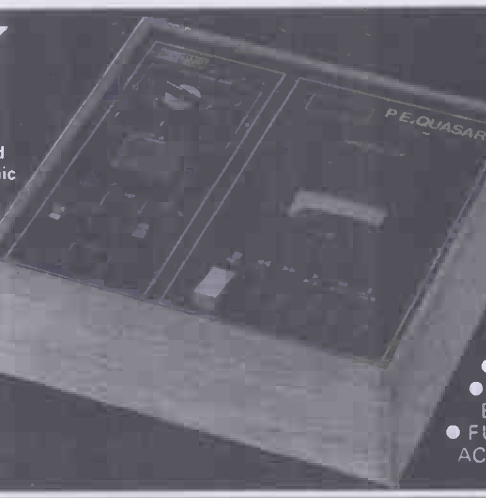
Dear Sir,
Recently a friend loaned me one of your books, 'Into Electronics Plus', published in 1979. I found it of great interest and wondered if you could advise whether it is still possible to obtain a copy, and the price.

Three years since publication is a long time, I realise, but if a copy could be located I would very much appreciate it.
D. C. Holmes,
Bury St. Edmunds,
Suffolk.

Regretably, this book is no longer available. It has been 'out of print' for some time. However, you might find 'Electronics — It's Easy' a suitable alternative; it provides a slightly less detailed, broader introduction to electronics. It is available from our Specials Department, 513, London Road, Thornton Heath, Surrey CR4 6AR, for £4.95 including p&p; don't forget to ask for it by name! **HE**

LOOK

HI-FI STEREO CASSETTE RECORDER KIT



Kit includes tape transport mechanism, ready punched and back printed quality circuit board and all electronic parts. i.e. semiconductors, resistors, capacitors, hardware, top cover, printed scale and mains transformer. You only supply solder and hook-up wire.

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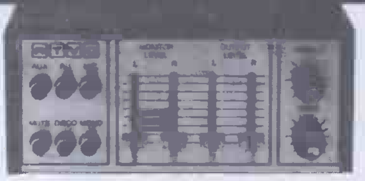

- Featuring latest SGS/ATES TDA 2006 10 watt output IC's with in-built thermal and short circuit protection.
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SPECIFICATIONS:	Suitable for 4 to 8 ohm speakers
Frequency response	40Hz – 20KHz
Input sensitivity	P.U. 150mV. Aux. 200mV. Mic. 1.5mV.
Tone controls	Bass ±12db @ 60Hz Treble ±12db @ 10KHz
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ACCESSORIES: Suitable mains power supply kit with transformer: £7.50 plus £3.15 p&p. Suitable LS coupling electrolytic: £1.00 plus 25p p&p.

SPECIFICATIONS:
Max. output power (RMS): 125W.
Operating voltage (DC): 50 - 80 max.
Loads: 4 - 16 ohms.
Frequency response measured @ 100 watts: 25Hz - 20KHz.
Sensitivity for 100 watts: 400mV @ 47K.
Typical T.H.D. @ 50 watts, 4 ohms: 0.1%.
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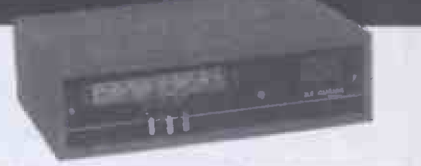

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Suitable stainless steel fully retractable aerial (locking) and speaker (6"x4"app.) available as a complete kit. £2.50/pack + £1.50 p&p.

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As featured in E.T.I. December '81 issue. Kit of parts including PCB, UHF tuner and selector switch with all components excluding case.

- Transformer £1.50 + £1.50 p&p (p&p free on transformer if ordered with kit).
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50 WATT Six individually mixed inputs for two pick ups (Cer. or mag.), two moving coil microphones and two auxiliary for tape, tuner, organs, etc. Eight slider controls – six for level and two for master bass and treble, four extra treble controls for mic. and aux inputs. Size: 13¼"x 6½"x3¾"app. Power output 50 watts R.M.S. for use with 4 to 8phm spkrs. Attractive black vinyl case with matching fascia & knobs. Ready built.

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RTVC

BUYLINES

IN THE constant search for new ways to ensure Hobby readers get the best deal when buying components, we are in the process of re-thinking Buylines. Next month, we will be presenting a comprehensive survey of component suppliers and hope to provide a special ordering service to supplement this page. For this month, though, we are introducing an improved system for finding sources of hard-to-get items, as well as attempting to produce more accurate estimates of building costs. We would be interested to know what you think of the changes.

Signal Lights

Not much here to trouble the constructor. The TTL ICs can all be obtained from **Watford** or **Technomatic**. Remember, it's a good idea to use sockets just in case you have to replace any faulty chips; most companies sell the complete DIL socket range at a reasonable price, so why not buy a few as spares?

The three differently coloured LEDs — red, amber (yellow) and green — can be bought from **Rapid** and **TK**, or for a wide range of shapes try **Ace Mailtronix**.

The only source we can find for one-off ⅛ watt resistors is **Maplin**, though most suppliers sell ¼ watt types that will do just as well.

Cost is **£2.60** for the junction module and **£3.50** for the main module (inclusive of PCBs).

'Junior' Slot Car

It was quite difficult finding a source for the low value (OR47) 1 watt resistor. This was due to the fact that most companies sell these values in 2½ watt packages only. However, **Greenweld** came to the rescue and they can also supply the unusual 10 pin metal can 723 regulator IC (LM123). An altemative source for this IC is **ElectroValue**.

The MJ2955 is stocked by most people, but the cheapest source we found was **Ambit**, whose quoted price is 25% lower than their nearest competitor!

The best case for your controller will depend on your particular slot-car set-up. However, **Newrad** do a range of high quality low – cost cases, should you find no room on your present layout. Cost excluding the case, should be about **£5** for each board with rectifiers and indicators.

ZX PCB

Quite a useful little board, this, though you may be unfamiliar with a couple of the components. The low-power Schottky ('LS') TTL integrated circuits are stocked by both **Technomatic** and **Watford**, though most other retailers sell them at widely differing prices. The appropriate DIL sockets can be bought from either **Bi – Pak** or **Greenweld**.

The only supplier of the exact SIL plug-pin strip was **Ambit**, though **Maplin** do a 6-way and 4-way version making up the required 10-way strip.

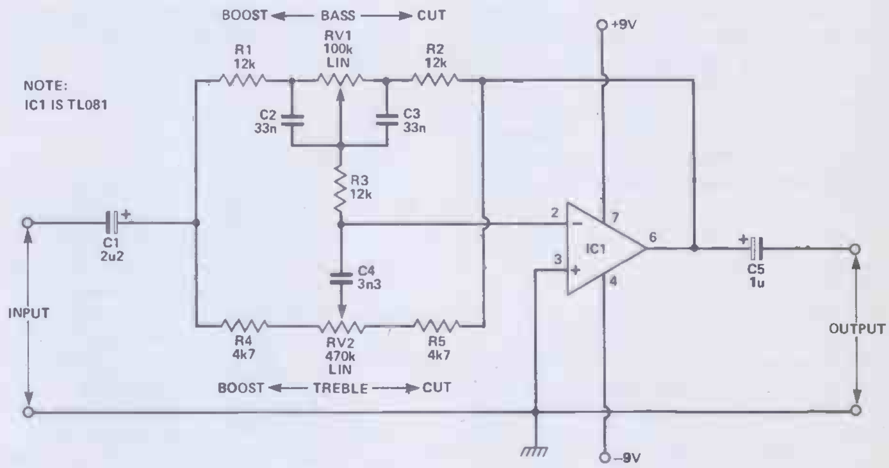
Finally, the edge plug and matching connector (double sided) are to be found in the RS range (codes 468-709 and 467-021 respectively) and must be ordered from your supplier. These are 43-way connectors with the polarising pin at position 7, and must be carefully sawn to convert them to 23-way, with the polarising pin at position 3. You may be able to find other sources for the edge connector, probably not with the matching plug, but it's worth looking around. Cost of the board, using the specified components, will be **£8** — plus the edge connector/plug combination of your choice.

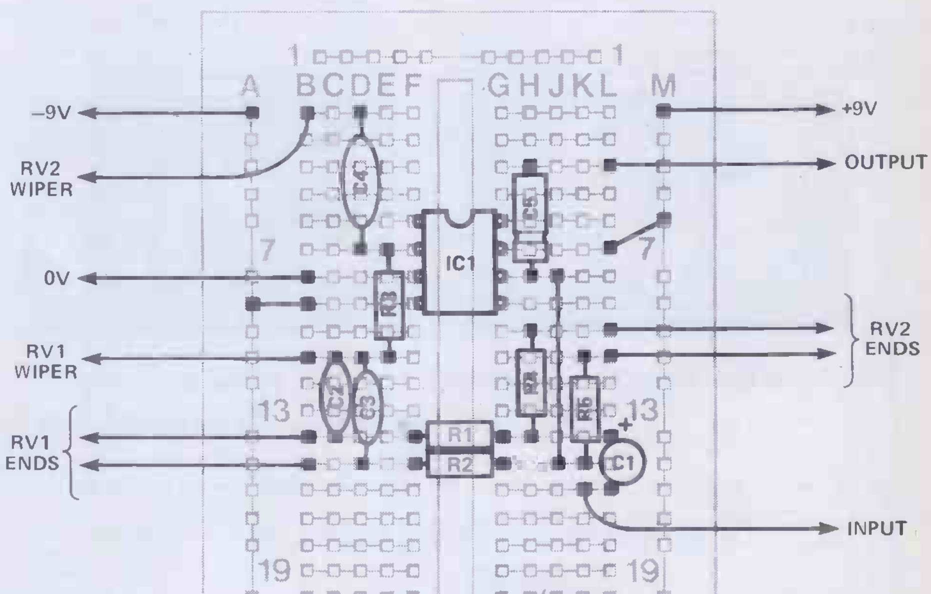
Breadboards

Design and build your own tone controls.

JUST one project for this month's Breadboard, but it's a winner — high performance tone controls in a simple arrangement that you can modify for any application. The controls are based on a standard op-amp circuit, using the TL081. This has high impedance FET inputs and a high slew rate, enabling it to operate over a wide band of frequiencies. The circuit also allows you to experiment with different component values.

Talking of experimenting, we are offering £5 to any reader whose design is original and/or ingenious enough for publication. All you need to supply is a circuit diagram, a breadboard layout and a brief description of how the circuit works plus any ideas for modifications or experiment. Put them all in an envelope marked 'Breadboards' and addressed to us — remember to enclose an SAE if you'd like the contents returned.





Gain Controlled

It is just about thirty years since the publication of the first practical circuit for varying bass and treble independently within a single network, without using switches. It is known as a Baxandall circuit, after its inventor, and is still used, more or less modified, in most audio equipment.

The simplest way to understand how the circuit **(Figure 1)** operates is to look at what's happening to the gain of the op-amp at different frequencies. The gain is controlled by the feedback resistance from pin 6 to pin 2 of IC1, via the tone control network consisting of RV1, R2, R3, C3 and RV2, R5, C4, and R3 again.

At very low frequencies, capacitors C2, 3 and 4 may be compared to very large resistances. To all intents and purposes, they are open circuit and the gain is dependent on the values of the resistors only, and mainly on RV1. At low frequencies, the gain will be maximum (boost) when RV1 is maximum, and minimum (cut) when RV1 is minimum, as indicated in **Figure 1**. At higher frequencies, however, the impedence of C3 decreases, so that the effective value of RV1 is reduced and at mid-frequencies, the gain is about one (unity gain).

At stil higher frequencies, the impedance of the capacitors decreases further until, at some frequency, RV1 is effectively shorted out by C3. The gain, then, will depend on the setting of RV2, as indicated in the circuit diagram.

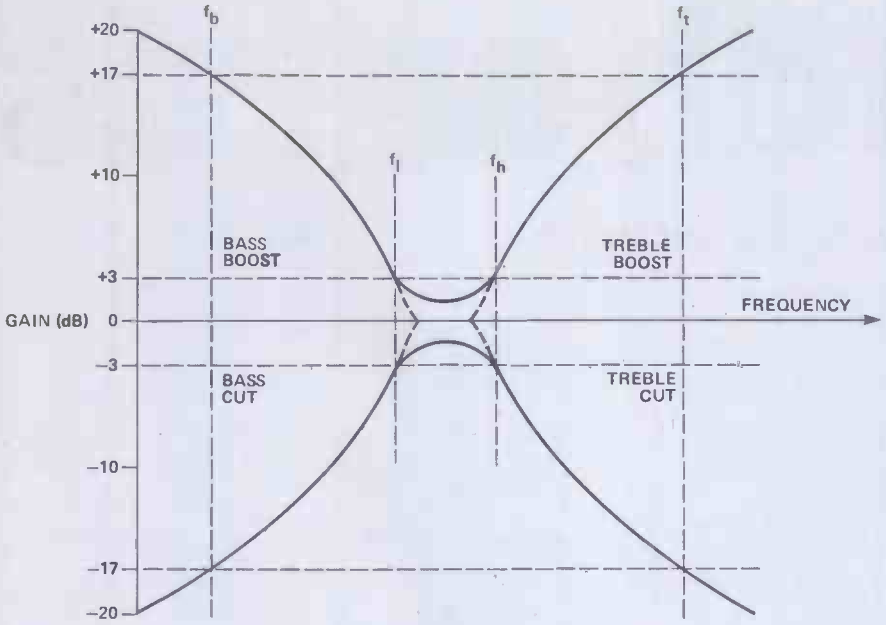


Table 1

1. Choose the upper and lower corner frequencies, f_h and f_l, and the maximum boost/cut (gain, A_v) required.

2. Select values for RV1 and R3.

3. $R1 = R2 = \frac{RV1}{A_v}$

4. $C2 = C3 = \frac{1}{(2\pi)(f_l)(R2)}$

5. $R4 = R5 = \frac{R2 + 2R3}{A_v}$

6. $C4 = \frac{1}{(2\pi)(10)(f_h)(R5)}$

7. $RV2 \geqslant 10(R2 + R5 + 2R3)$

Alternatively, to set the maximum boost/cut at frequencies f_b and f_t, use:

4. $C2 = C3 = \frac{1}{(2\pi)(10)(f_b)(R2)}$

6. $C4 = \frac{1}{(2\pi)(f_t)(R5)}$

Example:

1. Design a bass and treble tone control with a gain of 10 (± 20 dB) and corner points at 500 Hz and 2 kHz.

2. Let RV1 = 50k, let R3 = 10k.

3. $R1 = R2 = \frac{RV1}{A_v} = \frac{50k}{10} = 5k$

4. $C2 = C3 = \frac{1}{(2\pi)(f_l)(R2)}$

$= \frac{1}{(2\pi)(500)(5k)} = 63n$

5. $R4 = R5 = \frac{R2 + 2R3}{A_v}$

$= \frac{5k + 20k}{10} = 2k5$

Preferred value = 2k7

6. $C4 = \frac{1}{(2\pi)(10)(f_h)(R5)}$

$= \frac{1}{(2\pi)(10)(2k)(2k7)} = 2n9$

Preferred value = 2n7

7. $RV2 \geqslant 10(R2 + R5 + 2R3)$

$\geqslant 10(5k + 2k7 + 20k) \geqslant 277k$

Therefore, choose RV2 = 500k.

Alternatively, to set the maximum boost/cut at f_b = 60 Hz and f_t = 12 kHz:

4. $C2 = C3 = \frac{1}{(2\pi)(10)(f_b)(R2)}$

$= \frac{1}{(2\pi)(10)(60)(5k)} = 53n$

Preferred value = 56n.

6. $C4 = \frac{1}{(2\pi)(f_t)(R5)}$

$= \frac{1}{(2\pi)(12k)(2k7)} = 4n9$

Preferred value = 4n7

Shaping Up

The three factors which determine the response curve of a tone control (**Figure 3**) are the slope of the curve, the maximum boost/cut, and the frequencies at which the curve breaks away from the flat — the 3 dB or 'corner' points. These parameters are all set by selecting the appropriate values for the tone control network. The full design procedure is quite complicated but, as is usually the case, a simplified 'rule-of-thumb' method gives the right results! One of the most important simplications is that, in the circuit, R1 = R2, R4 = R5 and C2 = C3.

At low frequencies, with all capacitors effectively open circuit, the gain is more or less equal to RV1/R2; a value for RV1 is simply selected and R2 calculated to give the required boost/cut. The values used here give a maximum gain of approximately 8 (18 dB) at low frequencies.

At high frequencies, the capacitors are all effectively short circuits and the gain is set by RV2, provided it is higher than 10 times (R2 + R5 + 2R3), but the maximum gain is approximately equal to (R2 + 2R3)/R5. Here, the value of R2 has already been found, R3 is merely selected and R5 calculated for the required amount of gain. Again, the values have been chosen to give a maximum gain, at treble frequencies, of 18dB.

All that remains is to set the low and high frequency corner points, which we will refer to as f_l and f_h; these are determined by the values of C3 and C4, respectively.

The value of C3, for any desired f_l, is equal to $1/(2\pi)(f_l)(R2)$. Another useful characteristic of this circuit is that the bass corner frequency is always about ten times the frequency, f_b, at which the boost/cut is maximum; the value of C3 in our circuit puts the bass corner at 400 Hz, so the maximum effect is at 40 Hz. To select a value of C3 to give maximum boost/cut at a desired frequency, simply multiply the selected f_b by ten to find the corner frequency which is used in the equation.

Similarly, the point at which the treble boost/cut is maximum, f_t, is ten times the treble corner frequency, and the value of C4 which will give a particular corner frequency is $1/(2\pi)(10f_h)(R5)$. To find the value of C4 which gives a desired f_t, simply substitute for $10f_h$ in the formula. The values in our circuit place the treble corner at 1 kHz and give maximum effect at around 10 kHz.

Finally, remember that RV2 must be chosen to be greater than 10(R2 + R5 + 2R3). The values of RV1 and R3 are then chosen; any close to those used in our circuit will do. Remember also that R1 = R2, C2 = C3 and R4 = R5.

These rule-of-thumb formulas are summarised in **Table 1**; using them, the tone controls can be re-designed to give a selected amount of boost and cut at any desired frequency. **HE**

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330n 42p; 470n 52p; 680n 60p; 1μF 68p; 2μ2 82p; 4μ7 85p.
160V: 10nF, 12n, 100n 11p; 150n, 220n 17p; 330n, 470n 30p; 680n, 38p; 1μF 42p; 1μ5 45p; 2μ2 48p.
1000V: 1nF 17p; 10nF 30p; 15n 40p; 22n 36p; 33n 42p; 47n 48p; 100n 50p; 470n 99p.

POLYESTER RADIAL LEAD CAPACITORS: 250V:
10nF, 15n, 22n, 27n 6p; 33n, 47n, 68n, 100n 7p; 150n. 220n 10p. 330n, 470n 13p; 680n 19p; 1μF 23p; 1μ5 40p; 2μ2 46p; 4μ7 60p.

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20p; 220 24p; 470 32p; 2200 90p. 40V: 4.7, 15, 22 9p; 3300, 90p; 4700, 120p; 25V: 1.5, 6.8, 10, 22 8p; 33 9p; 47 8p; 100 11p; 150 12p; 220, 15p; 330 22p; 470 25p; 680. 1000, 34p; 2200, 50p; 3300, 76p; 4700 92p; 16V: 40,
47, 100 9p; 125, 12p; 220 13p; 470, 20p; 680 34p; 1000 27p; 1500, 31p; 2200 36p; 3300 74p; 4700 79p.
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10μF 28p; 16V: 2.2, 3.3 16p; 4.7μF, 6.8, 10 18p; 15, 36p; 22 30p; 33, 47 40p; 100 75p; 220 88p; 10V: 15, 22, 26p; 33, 47 35p; 100 56p; 6V: 100 42p.

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		74132	28		
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LS10	13	LS145	70
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4013	20	4066	24
4014	46	4067	245
4015	40	4068	14
4016	20	4069	13
4017	32	4070	13
4018	45	4071	13
4019	25	4072	13
4020	42	4073	13
4021	40	4075	13
4022	40	4076	50
4023	13	4077	13
4024	32	4078	15
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4026	80	4082	13
4027	20	4085	50
4028	39	4086	60
4029	45	4089	125
4030	15	4093	20
4031	125	4094	70
4032	80	4095	75
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4034	140	4095	290
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4040	40	4162	99
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4042	40	4175	105
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4046	40	4410	725
4047	40	4411	690
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4049	25	4415	480
4050	25	4419	280
4051	45	4422	770
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CA3046	70	MC3360P	120
CA3048	220	MC3401	65
CA3059	285	MC3403	75
CA3075	213	MC3403	110
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CA3081	190	MK50398	635
CA3085	95	ML924	250
CA3089E	200	MM5303	635
CA3090AQ	375	MM5307	1275
CA3123E	150	MM5387	47
CA3130	90	NE529	225
CA3140	40	NE531	14
CA3160	95	NE543	225
CA3161	160	NE544	210
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HA1336W	240	NE556	45
ICL7106E	750	NE560	325
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ICM7216A	1950	NE566	155
ICM7217A	790	NE567	140
ICM7224	785	NE570	410
ICM7555	80	NE571	400
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LF356	90	SL490	350
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LM339	47	TBA120	70
LM348	64	TBA641	290
LM349	115	TBA800	80
LM358	60	TBA810	95
LM377	175	TBA820	80
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LM380	75	TDA1004	290
LM381	145	TAD1008	310
LM382	115	TDA1022	499
LM384	140	TDA1024	150
LM386	90	TDA1490	325
LM387	120	TDA2004	495
LM389	95	TDA2020	320
LM393	100	TL061	40
LM394	290	TL063	80
LM733	100	TL071CP	24
LM1458	40	TL072	45
LM2917	195	TL074	100
LM3900	50	TL081	24
LM3302	50	TL082	45
LM3900	50	TL083	75
LM3909	85	TL084	90
LM3911	125	UAA170	170
LM3914	210	UAA180	170
LM3915	220	UA2240	120
LM3916	220	XR2206	300
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MC1455	150	Z80APIO	275
MC1458	55	ZN414	80
MC1488	55	ZN424E	130
MC1458	100	ZN425E	345
MC1469	300	ZN426E	300
MC1488	100	ZN427	590
MC1489	55	ZN428	410
MC1495	350	ZN429	210
MC1496	70	ZN1034E	200
MC1596	225	ZN1040E	675

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AC128	30	BC338	15	BSX20	20	TIP36A	130	2N2160	95	2N5459	30
AC141/2	30	BC441	34	BSY65	35	TIP36C	140	2N2219A	28	2N5485	30
AC176/87	30	BC461	34	BSY95A	25	TIP41A	50	2N2220A	23	2N5777	45
AC188	30	BC477	40	BU105	170	TIP41B	52	2N2222	25	2N6027	32
ACY17/18	70	BC516/7	40	BU205	190	TIP42A	55	2N2369A	18	2SA636	250
ACY20/1	75	BC547/8	12	BU208	200	TIP42B	58	2N2476	50	2SA671	250
ACY22	60	BC549	14	E113	45	TIP120	70	2N2483	27	2SA715	60
AD140	120	BC556/7	15	E176	50	TIP121/2	73	2N2497	63	2SC495	70
AD149	79	BC558/9	15	E421	250	TIP141	105	2N2646	45	2SC496	70
AD161/2	42	BCY70	16	MJ2955	70	TIP142	105	2N2894	30	2SC1061	250
AF115	60	BCY71	18	MJE340	54	TIP147	120	2N2904	28	2SC1096	85
AF139	40	BCY72	20	MJE370	100	TIP2955	60	2N2905A	26	2SC1173	125
AF178	75	BD131/2	48	MJE371	100	TIP3055	60	2N2906/7	26	2SC1306	100
AF180/6	70	BD133	60	MJE520/1	95	TIS43	32	2N2926G	10	2SC1307	150
AF239	55	BD135	45	MJE2955	70	TIS44	45	2N3053	26	2SC1449	85
BC107/8	10	BD136/7	40	MJE3055	70	TIS88A	50	2N3054	58	2SC1923	50
BC108B	12	BD138/9	40	MPF102	40	TIS90	30	2N3055	48	2SC1945	225
BC108C	12	BD140	40	MPF103	30	TIS91	32	2N3121	30	2SC1953	90
BC109	10	BD695A	99	MPF104	30	VK1010	80	2N3133	45	2SC1957	90
BC109B	12	BD696A	99	MPF105	30	VN10K	55	2N3135	30	2SC1969	140
BC109C	12	BDY17	195	MPF106	40	VN46AF	78	2N3252	46	2SC2028	85
BC117/8	20	BDY60	160	MPSA05/6	25	VN66AF	80	2N3442	140	2SC2029	210
BC119	38	BDY61	160	MPSA12	30	VN88AF	94	2N3568	25	2SC2078	170
BC137	40	BF115	35	MPSA55	30	ZTX107/8	11	2N3663	15	2SC2091	85
BC140/3	30	BF167	29	MPSA56	30	ZTX109	12	2N3702/3	10	2SC2314	85
BC147/8	9	BF173	27	MPSU06	55	ZTX300	13	2N3704/5	10	2SC2166	165
BC149	9	BF177	25	MRSU56	60	ZTX301/2	16	2N3706/7	10	2SC1679	190
BC153/4	27	BF178	35	OC35	125	ZTX303	25	2N3708/9	10	3N128	112
BC157/8	10	BF179	35	OC36	120	ZTX304	17	2N3710/11	10	3N140	112
BC159	11	BF180	38	OC41/2	75	ZTX314	25	2N3713	140	40311	50
BC160	45	BF194/5	12	OC44	75	ZTX326	30	2N3771	179	40313	130
BC167A	10	BF196/7	12	OC45/70	40	ZTX341	30	2N3772	195	40316	95
BC168C	10	BF198	18	OC71/2	40	ZTX500	14	2N3773	210	40317	80
BC169C	10	BF200	30	OC76	50	ZTX501/2	15	2N3819	22	40324	100
BC170	15	BF224A	25	OC81/2	50	ZTX503	18	2N3820	38	40326	60
BC171/2	11	BF244	28	OC83/4	40	ZTX504	25	2N3822/3	45	40327	70
BC177/8	16	BF256	35	OC170/1	50	ZTX531	25	2N3866	90	40347	90
BC179	20	BF257/8	32	TIP29A	32	ZTX550	25	2N3903/4	15	40348	120
BC182/2L	10	BF259	35	TIP29C	38	2N526	58	2N3905/6	15	40360	60
BC813/L	10	BF594/5	40	TIP30	48	2N696	30	2N4037	46	40361/2	70
BC184	10	BFR39/40	23	TIP30A	35	2N697	23	2N4058	10	40407	60
BC186/7	26	BFR41/79	23	TIP30C	37	2N698	40	2N4061/2	10	40408	70
BC212	10	BFR80/81	25	TIP31A	38	2N699	48	2N4069	45	40411	285
BC212L	10	BFX29	28	TIP31C	37	2N706	19	2N4859	78	40412	90
BC213	10	BFX81	45	TIP32A	38	2N918	35	2N4871	55	40467	130
BC213L	10	BFX84	28	TIP32C	42	2N930	20	2N5135/6	20	40468	85
BC214	10	BFX85/6	28	TIP33A	65	2N961	65	2N5138	18	40594	105
BC214L	10	BFX87/8	28	TIP33C	78	2N1132/2	24	2N5179	45	40595	110
		BFY50/1	23	TIP34A	74	2N1304	65	2N5180	45	40603	110
				TIP34C	88	2N1305	60	2N5191	75	40636	175
										40673	85

Sir Edward Appleton

Ian Sinclair

A pioneer of radio and radar who won a Nobel prize for his work on the ionosphere.

You don't have to be a student of radio history to have heard of the Appleton layer — but the fact remains that a lot of people who ought to know the name, just don't. Edward Appleton was born in Bradford in 1892, and started his academic career, after conventional schooling, at St. John's College, Cambridge. In 1920 he became assistant demonstrator in Experimental Physics in that most famous of all laboratories, the Cavendish, where his own particular interest was in the propagation of radio waves, following the work of Heaviside and Kennelly in 1901. The situation at that time was that everyone knew that radio waves could be used to send messages over very large distances, but no-one could show, with any real proof, why this should be so.

By the end of the 18th Century, Oliver Heaviside had put forward the theory that the intense radiation from the Sun, which is a nuclear furnace that no-one protests about, was splitting atoms in the low-pressure air at the outer fringes of our atmosphere. These split atoms are electrically charged and can move fairly freely (they get the name 'ions' from an ancient Greek word meaning "wanderer" but even at the low pressures a hundred miles or so above the Earth, these ions are still sufficiently close to each other to affect a radio wave.

Ionic Effects

The effect depends on the radio wavelength. A radio wave will pass fairly easily between metal objects which are spaced by a distance equal to several wavelengths, but when the objects are closer than a wavelength apart, they act to reflect the wave. Heaviside's theory was that the spacing between the charged particles would be close enough to act as reflectors of radio waves, certainly for wavelengths down to 10 metres.

The idea had been strongly supported by the American physicist, Kennelly, but few other people took very much notice until Marconi succeeded in doing what so many had said was impossible — transmitting a radio signal across the Atlantic. This made many engineers and phyicists, who had scoffed at Heaviside, pay rather more attention to his ideas, and it started a rush to find and measure these reflecting layers.

Appleton had the idea of using a method which was direct, elegant, and which used what nowadays would be called "state-of-the-art" technology. In doing so, he devised the essential principle of radar and the principle was simple! A burst of radio waves could be beamed directly upwards, and the time for it to be reflected back could be measured. Since radio waves travel in space at the same speed as light (around 300 million metres per second) the distance that the waves had travelled to the reflecting layer and back could be precisely measured.

Trouble With Time

The trouble with direct, simple and elegant methods is that they are usually extremely difficult to carry out! The snag, in this particular example, was how to measure the time which, from rough calculations, looked as if it would be about 300 microseconds. Measuring a time period as short as that wasn't exactly a routine matter in 1923, and Appleton solved it by turning to new technology — the cathode-ray tube.

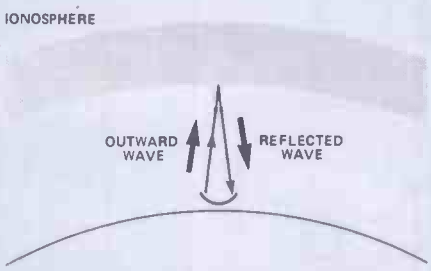

Figure 1. The Appleton experiment. This was an early use of the principle of radar to measure the distance of the Appleton and other layers from the surface of the earth.

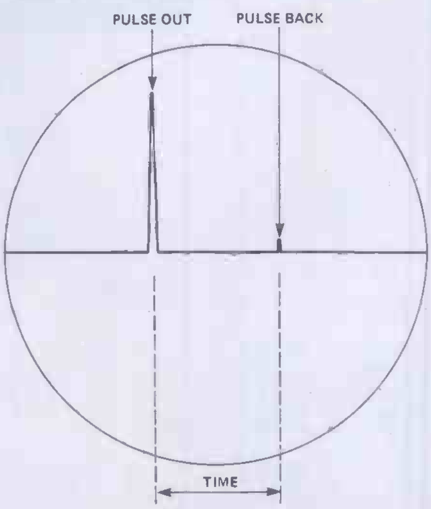

Figure 2. An oscilloscope display used to measure the distance. With a constant speed timebase, distance along the screen represents time, which in turn represents distance travelled by the wave.

He saw that the electron beam could be moved rapidly across the screen by using changing voltages on the deflection plates, and if the deflecting voltage is a sawtooth shape, then the speed of the spot across the screen is practically constant. Even better, its value can be calculated from the size of the deflection plates and their distance from the screen, thus the position of a spot can be used to represent time from some starting position.

Appleton's Layers

Appleton's classic 1923 measurements showed that there were several layers of reflecting particles, labelled D,E, and F, above the atmosphere, at heights ranging from 50 to 400 km. The shorter wavelengths that penetrated the lower layers of this "ionosphere", as it was called, were reflected higher up in the F-layer, which from then onwards was called the Appleton layer. The F-layer is about 100 miles above the surface of the Earth and, during the day, actually consists of two layers; a thin F1 layer, and a higher, more strongly ionised F2 layer. At night, the F1 layer rises to the F2 level and reflects wavelengths down to 10 m (around 30 MHz), so providing the excellent short-wave conditions that we experience at night. These days, the heights of the layers are monitored continually — using methods very similar to Appletons — by weather research stations all over the world, and ionospheric predictions are available for anyone who is occupied with short-wave transmission. The main UK ionospheric station is at Slough.

Appleton's brilliant research work eventually led him to London, where he became Wheatstone Professor of Physics, and subsequently back to Cambridge as Jacksonian Professor of Natural Philosophy (Physics). At the outbreak of war in 1939, he was attached to the Department of Science and Industry (they associated the two, in those days!) to work on radar research, along with the pioneers of television, from EMI, and of shortwave transmission, from Marconi. He was awarded the Nobel prize in 1947, for his work on the ionosphere, and became Vice-chancellor of Edinburgh University in 1949, a post which he held for several years. He died in 1965 after a brilliant career which covered some of the most exciting developments in electronics, and with his name immortalised in the Appleton layer. **HE**

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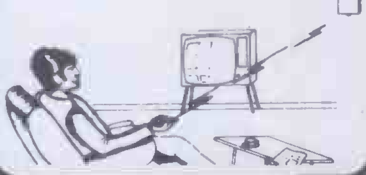

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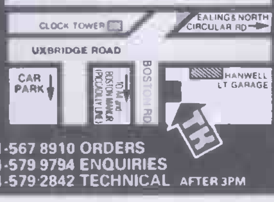

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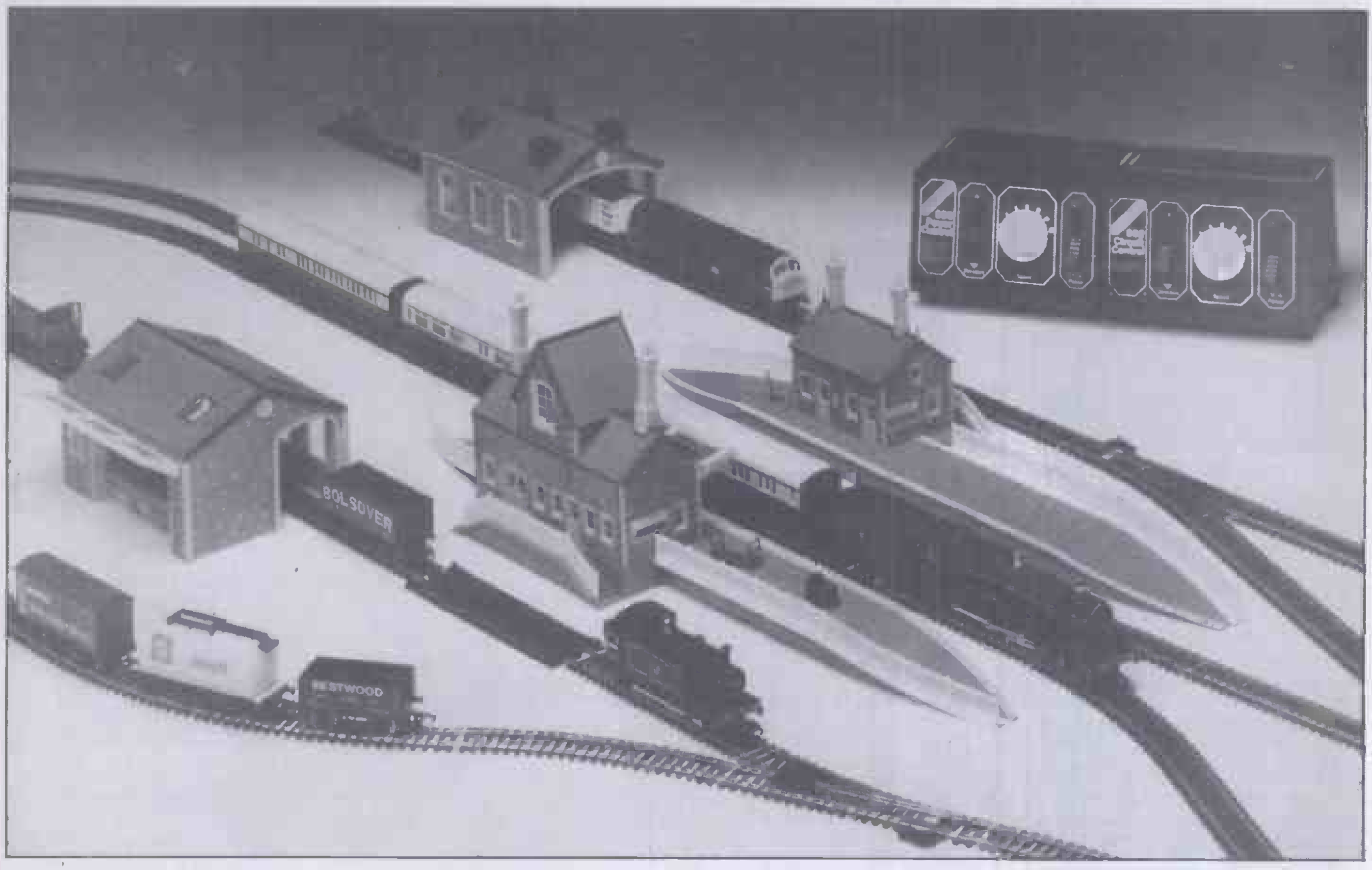


Three-Aspect Signal Lights

Just the right lights for a realistic model rail set-up.

RAILWAY signal lights are intended to indicate whether or not the way ahead is clear. In the simplest case a colour signal, either a red or a green light, shows if it is safe for a train to proceed into the next section of track. As soon as the train passes a green signal, the light changes to red.

This was the first type of signal system to replace the older semaphore signals; today, they are used only in a few isolated cases. With three-aspect signalling, an additional amber light indicates that the line ahead is clear but that the *next signal* is set to red — danger ahead! More common still, these days, is the four-aspect system, where a second amber light is used. A display of two amber lights indicates two clear sections before the next red signal, allowing the driver to adjust his speed accordingly (regular commuters can observe the system from almost any British Rail platform — if the trains are running!).

Signalling a simple junction, where a branch line leaves the main line, requires an extra arm to the signal; this is positioned on the signal stand, on the same side as the branch and shows a row of four or five white lights, together with a green or an amber light, when the points are set for the branch line. A green or amber signal alone indicates that the points are set for a straight-through run.

In the real world, these signals are controlled by track circuits which detect the position of a train on the line. The axles span electrically isolated sections of rail, thereby completing a circuit to indicate its location. Of course, the settings of points and level crossings also control the signals.

Prototypes and Models

In the prototype, failsafe requirements lead to considerable circuit redundancy — backup units in case one should fail — but for model railways, the basic functions of a three-aspect signalling system can be provided quite simply.

The electronics of the system consist of two circuit modules. The basic Track Module controls one set of signal lights for one section of track; it responds to the location of the train and the settings of any points, level crossings etc in that section of track. The second module is a Junction Module, required to drive the white lights of a branch line indicator and to control the Track Modules either side of the junction.

For the signal lights, it is easy to use Light Emitting Diodes (LEDs) which, conveniently, are available in red, yellow (amber) and green. There are several methods that can be used to detect the position of a train; one of the simplest and most reliable is to use small bar magnets attached under the locomotives at axle height, and magnetically operated reed switches positioned on the track between the rails. Model points do not usually provide a signal suitable for driving the circuits but, with a little ingenuity,

INPUTS		OUTPUT
A	B	$\overline{A \cdot B}$
0	0	1
1	0	1
0	1	1
1	1	0

NAND
OUTPUT = NOT (A AND B)

INPUTS		OUTPUT
A	B	$\overline{A+B}$
0	0	1
1	0	0
0	1	0
1	1	0

NOR
OUTPUT = NOT (A OR B)

Table 1. Truth tables for NAND and NOR gates.

microswitches can be attached to the points to give suitable inputs to the modules.

The Track Module

The circuit diagram of **Figure 1** is for a single Track Module; a model layout will need one of these for each set of lights. The circuit itself is quite simple (though as we shall see, the interaction of two or more modules becomes slightly more complicated!). The 'brain' of the circuit is the bistable flip-flop consisting of NAND gates IC1c and IC1d (truth tables for both NAND and NOR gates are shown in **Table 1**). Switches SW2 and SW3 are the magnetic reed switches which close momentarily when the locomotive passes over them.

When SW2 closes, pin 5 of IC1c is taken to 0V (logic 0 or 'low') for just a moment, so that the output at pin 6 goes high (logic 1, +5V). This high is coupled to pin 2 of IC1d and, since its pin 1 input is already held high through R6 and R7, pin 3 goes low. This is coupled back to the other input of IC1c at pin 4, ensuring that output stays high. Thus the momentary low on pin 5 is 'latched' by the flip-flop and it will maintain this state, which indicates that there is a train in the section controlled by the module.

When the train leaves the section of track, SW3 closes and pin 1 of IC1d goes low for a moment; this is coupled to pin 4 of IC1c and, since pin 5 in being held high through R4, R5, the output at pin 6 goes low. This is fed back to the pin 2 input, maintaining the high output on pin 3. So, the new state is latched in and this indicates to the following circuitry that the train has cleared the section.

Resistors R4 and R6 provide the +5V to ensure that the inputs are normally high. The other components, R5, C1 and R7, C2, provide interference suppression which works satisfactorily even in the presence of high frequency track cleaning systems. The value of R6 has been chosen to provide a 'power-on-reset'.

When the power is first switched on, both C1 and C2 conduct heavily so that both plates of the capacitors are momentarily at 0V. They soon begin to charge up but, because R6 is more than twice the resistance of R4, C2 will take more than twice as long to reach full charge. In fact, the voltage on C2 will still be at logic 0 level when C1 is fully charged. Thus at power-on, a low pulse is effectively applied to pin 1 of IC1d and a high pulse to pin 5 of IC1c. As previously described, these are the conditions for the flip-flop to be reset to 'track clear', thus making sure that all

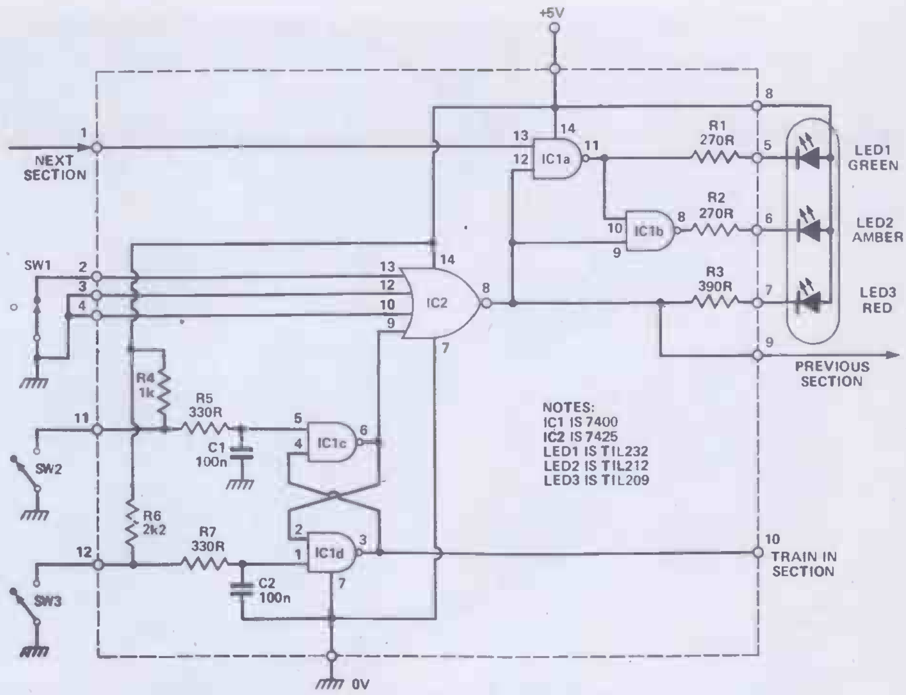


Figure 1. Circuit diagram of the Track Module.

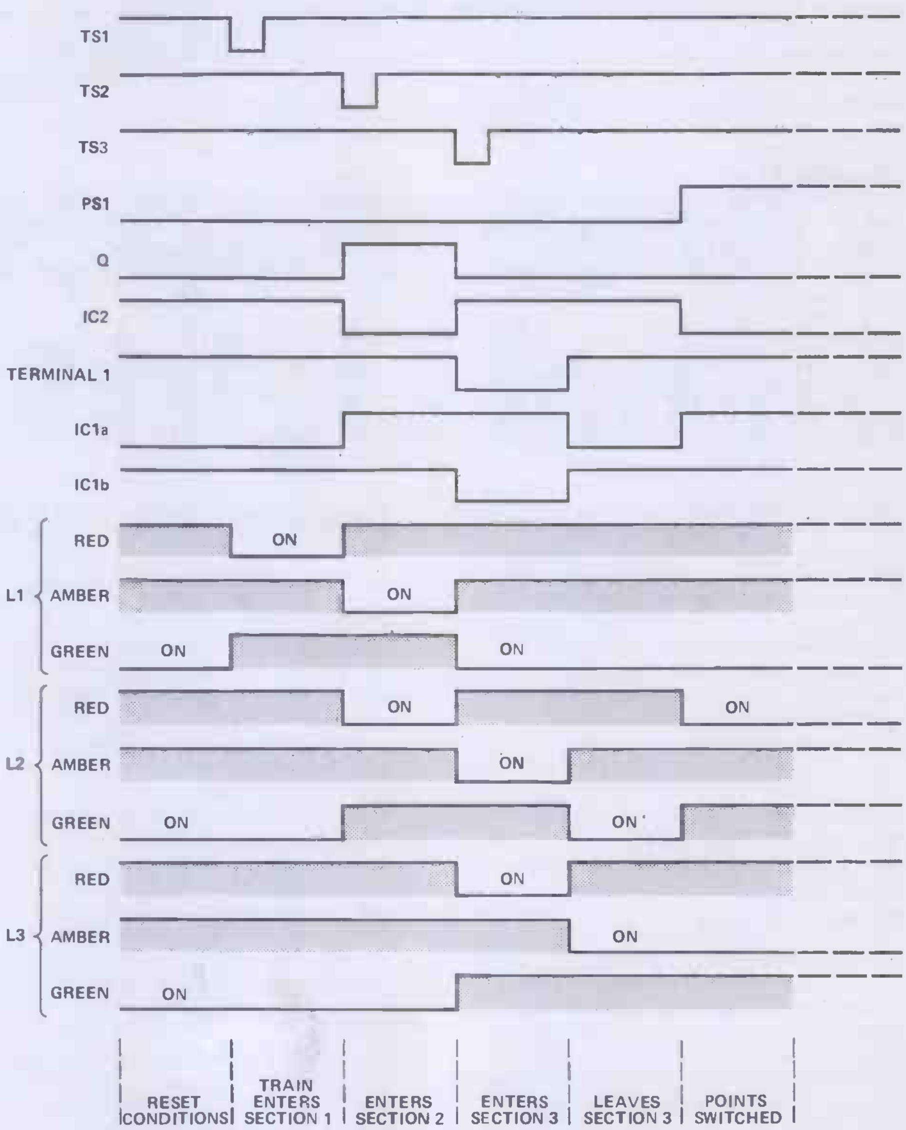


Figure 3. Timing diagram for "Keeping Track".

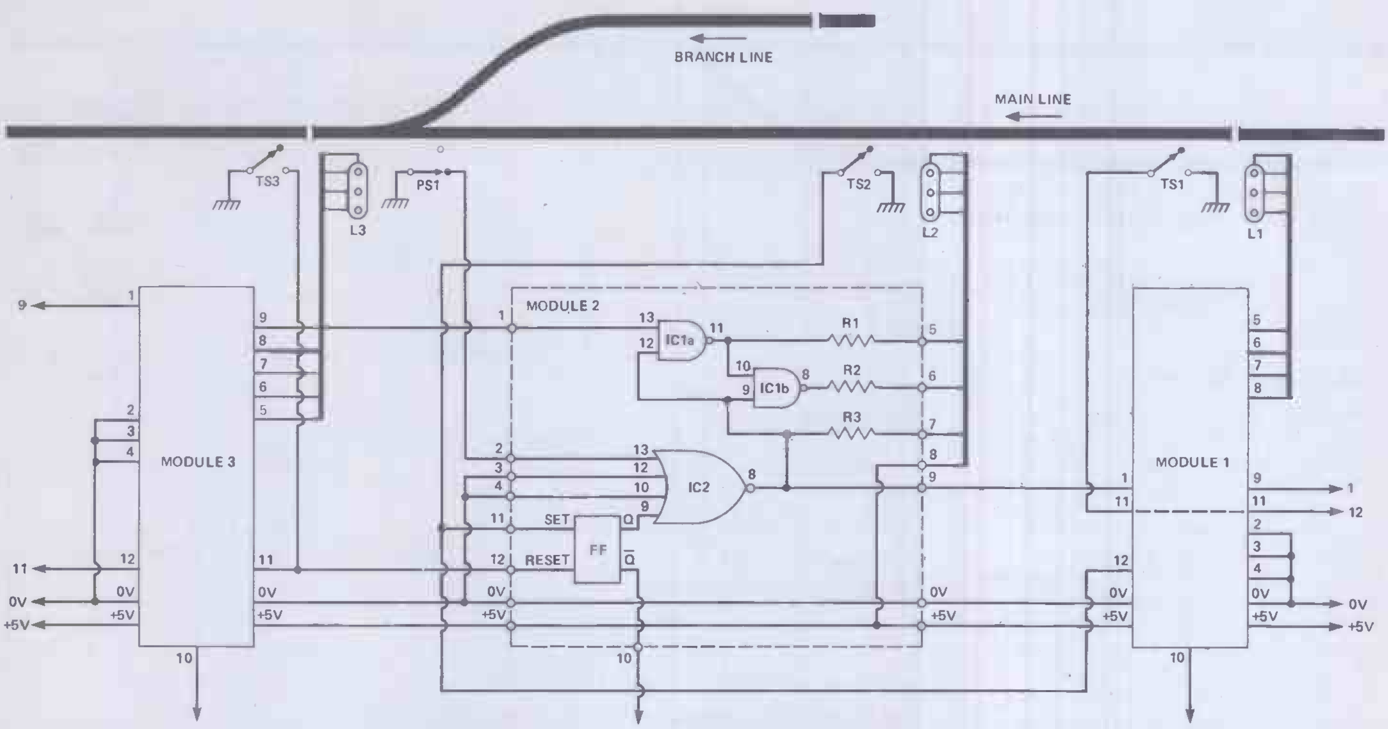


Figure 2. Combines Module circuit and track layout diagram; note that the flip-flop has been drawn here in standard 'block' form.

signal lights are green when the system is first turned on. It will probably be necessary to adjust the value of R6 to suit a particular layout and power supply; a little experimenting should soon determine the correct value.

If the flip-flop is the brain of the circuit, the quad-input NOR gate IC2 is its 'heart'. Its output at pin 8 directly drives the red signal light, LED3, and indirectly controls the other two lights. As shown in **Figure 1**, two of the inputs are wired directly to 0V, one to 0V via the normally closed points switch SW1, and the fourth is connected to the pin 6 output of the flip-flop. When all four inputs are low, the output will be high and the LED is biased off, with + 5V on both the anode and cathode. However, when the flip-flop is triggered by a train entering the section, pin 9 of IC2 goes high, pin 8 goes low and LED3 turns on. The result is the same if SW1 is opened (indicating that the points are set against an oncoming train), since the internal circuit of the TTL gate puts a high on any open circuit input.

If the section of track monitored by a module does not contain a set of points, then terminal 2 should also be wired to 0V. The other two inputs, at module terminals 3 and 4, are available for other switch functions within a section of track, eg for level crossing indication, etc.

Keeping Track

To understand how the remainder of the circuit works, it is easier to look at the interaction between several modules, controlling two or more sections of line, and to trace the logic sequence as a train passes through. The composite circuit diagram of **Figure 2** shows the internal circuit of the module controlling Section 2 of a length of line, together with the outlines and terminals of the adjacent modules. The internal circuit has been simplified by drawing the flip-flop as a block with SET and RESET inputs, and Q and $\overline{Q}$ outputs, in standard notation; however, its operation is exactly as described earlier. The timing diagram, **Figure 3**, will be helpful in tracing the action of the sequential logic.

First, though, we should establish the starting conditions. After a power-on reset, all inputs to IC2 are low and the red LED is turned off. The output from Module 2 terminal 9 is a high, indicating that the section is clear. Similarly, the terminal 9 output from Module 3 is high. Therefore, the inputs to NAND gate IC1a are both high; its output will be a low and the green light, LED1, turned on. The gate IC1b has a high input from IC2 and a low from IC1a so its output will be high and the amber light, LED2, is turned off. The logic conditions are the same for Modules 1 and 3.

What happens, then, when a train leaves Section 1 and enters Section 2? First, Track Switch one (TS1) closes for a moment and the Q output of the flip-flop goes high. This forces the output of IC2 to a low and the red LED of L1 comes on. This low is also applied to the terminal 1 input of Module 1, indicating that there is a train in Section 2. At the same time, the $\overline{Q}$ output of the flip-flop goes low, and this point (terminal 10) can be wired back to a current limiting resistor and LED on a track layout panel near the controller, to indicate train movements.

At this point the inputs to IC1a are: a high from IC2 and a low from the terminal 1 input (because Section 3 is still clear). Therefore, the output of IC1a goes high, turning off the green LED. The inputs to IC1b are: a high from IC1a and the low from IC2. The output stays high and the amber stays off.

The lights change again as the train leaves Section 2; now L3 will show red and the terminal 9 output of Module 3 will go low. However, TS3 is also connected to the terminal 12 input of Module 2 so when it closes, as the locomotive passes, it resets the flip-flop with the Q output low and the $\overline{Q}$ output high. With all inputs low, IC2 goes high, turning off the red LED. The inputs to IC1a, now, are a high from IC2 and the low from terminal 1, so its output will stay high and the green LED, off. However, the inputs to IC1b are both high, its output is low and the amber LED is turned on — indicating that Section 2 is clear but that L3 is showing red.

When the train clears Section 3, eventually, the same sequence takes place within Module 3; its terminal 9 output goes low so that IC1a now goes low, turning on the green light.

The low input from IC1a forces IC1b output to a high, turning off the amber light; LED3 simply remains, off.

The only other operation is when the points are set for the branch to join the main line. Points switch PS2 is normally closed, maintaining the low on that input to IC2. When it is opened, the internal TTL circuitry take the input high, forcing the output to a low and turning on the red LED. The low to the inputs of ICs 1a and 1b forces their outputs high, so that both the green and amber lights are held off until the points are reset.

Junction Module

The function of the second circuit module is to control the signal lights indicating a branch leaving the main line, and to connect the Track Modules on either side of the junction, according to the setting of the points. The composite diagram, **Figure 4**, shows the internal circuit of a junction module and

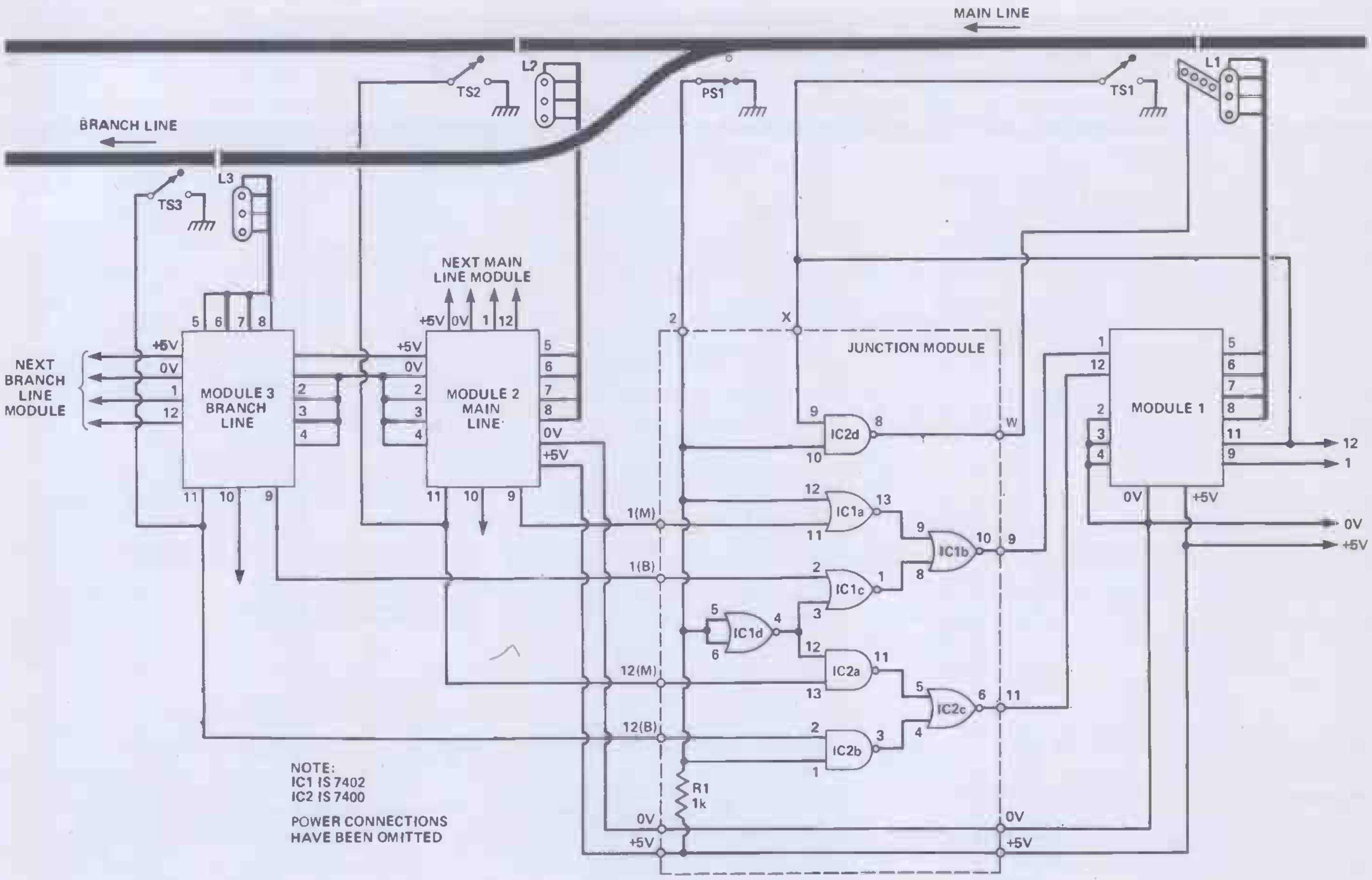


Figure 4. Combined Junction Module circuit and track layout diagram.

its connections to the Track Modules. It is most easily understood with the aid of the timing diagram **Figure 5**, which traces the logic sequence of trains passing through the junction, and with the truth tables of the NAND and NOR gates.

We can assume, at the start, that all signals are showing green, ie, all Track Modules are in their reset condition, and that the points are set for a straight-through run. The inputs and outputs of the Junction Module are as follows: the inputs to IC2d are a high (since TS1 is open) and a low (from PS1, which is closed); therefore its output is high and the branch lights are turned off.

Both terminal 9 outputs from Modules 2 and 3 are high (tracks clear) and these force the outputs of ICs 1a and 1c to low: IC1b output, therefore, will be high, sending a 'track clear' signal to Module 1. Similarly tracing the logic levels through ICs 1d, 2a, b and 2c will show that the input to the reset terminal of Module 1 is high, as it should be.

Now, a train moving along the track will momentarily close TS1, triggering the Module 1 flip-flop and switching L1 to red. The input to IC2d from TS1 also goes low, but this has no effect.

Normally, in a straight section of track, Module 1 is reset by the train passing over TS2; in this case, however, it is reset via the Junction Module. When TS2 closes, it takes one input of IC2a low for a moment, forcing

the output to go high. With both its inputs high, IC2c will go low, providing the reset pulse to terminal 12 of Module 1 and turning off the red LED of L1.

At the same time, terminal 9 on Module 2 has gone low, taking one input of IC1a with it; the other input is a low from PS1, so the output will go high, forcing IC1b output low; this turns on the amber LED of signal L1. Finally, when the train clears Section 2, terminal 9 goes high, IC1a goes high and IC1b goes high, turning off the amber light in L1 and turning on the green.

Now let's see what happens when a train takes the branch line. First, the points must be set, opening PS1; both inputs to IC2d go high, so its output goes low, turning on the branch line indicator. At the same time, all inputs connected to PS1 will change state (including those to ICs 1c and 2a, which are via inverter IC2d). These changes switch the logic to accept inputs from Module 3, rather than from Module 2.

As a train passes over TS1, signal L1 will turn to red, as before. A side-effect of TS1 closing is that the branch line indicator lights turn off for an instant.

The train now moves through Section 1 and takes the branch line, which we have called Section 3. As it does, TS3 closes, turning L3 to red and putting a low on one input of IC2b, so that its output is forced high. The other input of IC2c is being held high by PS1, via ICs 1d and 2a, therefore IC2c will go low, putting a reset pulse on terminal 12 of Module 1 and turning off its red LED. Simultaneously, terminal 9 of Module 3 has gone low; IC1c now has two low inputs (the other is held low by PS1 via IC1d), so its output goes high, forcing IC1b high and thus turning on the amber LED in L1 via

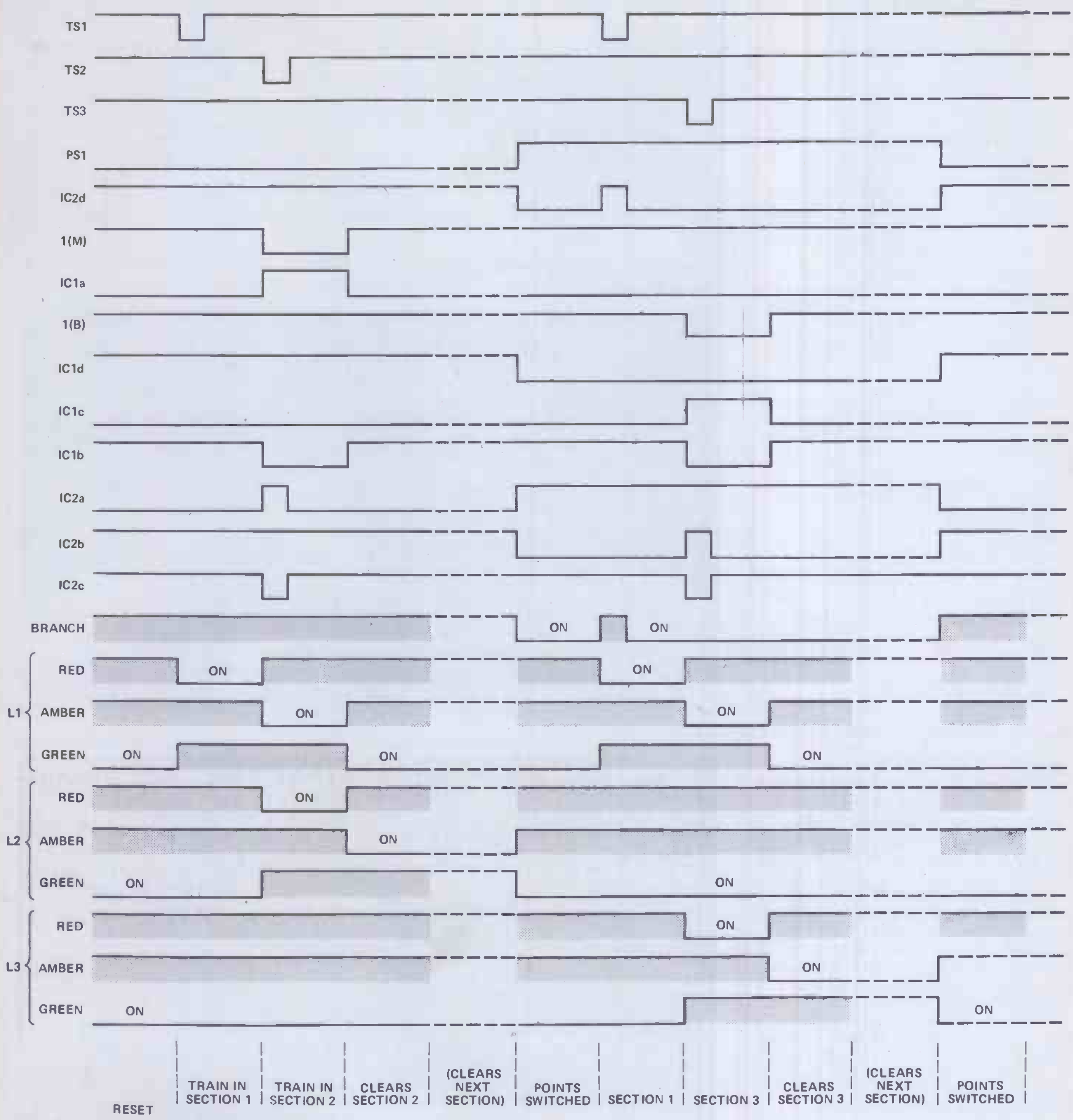


Figure 5. Timing diagram for tracing the Junction Module operation.

Module 1.

A similar sequence of logic will set L1 to green when the train finally clears Section 3. The timing diagram, **Figure 5**, shows this sequence as well as that which results when the points are reset.

These circuits, although very simple by themselves, can be quite complicated in their interactions, as we have just seen! Everthing depends on the timing of the various switch closures, together with the conditions which resulted from the last operation. Timing diagrams are essential for understanding circuits of this kind.

In fact, if the timing of the switch closures (which trigger the logic changes resulting in the appropriate signal lights) are not correct, the system will not produce the right results. The track switches must be positioned very carefully, at the start of each section of line, to produce the desired signals. Another small trap, which should not normally be of any bother, is that a set of points cannot be changed until the train has cleared the section controlled by the branch indicator. In other words, the points cannot be set for the branch line, in our example, until the train has cleared Section 2. Otherwise the amber light on L1 will not clear.

Construction and Layout

The component overlay diagrams for a Track Module and for a Junction Module are shown in **Figures 6 and 7**, respectively. Full sized PCB patterns are reproduced on the PCB Printout page.

The construction is quite straightforward and should not give any difficulty. The ICs are all TTL, so no special handling procedures are needed except for normal care not to overheat them or bend the pins. The composite circuit diagrams, **Figures 2 and 4**,

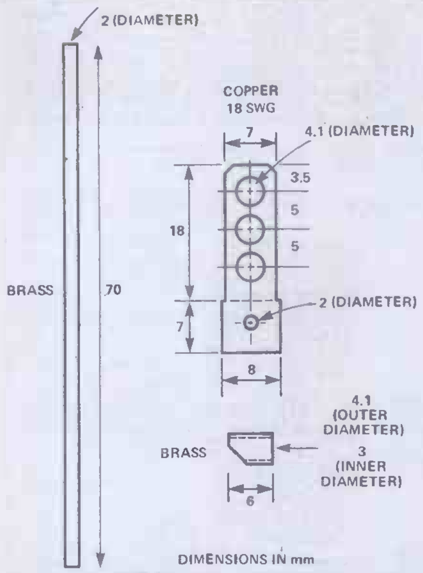


Figure 8. Mechanical details of a simple signal stand.

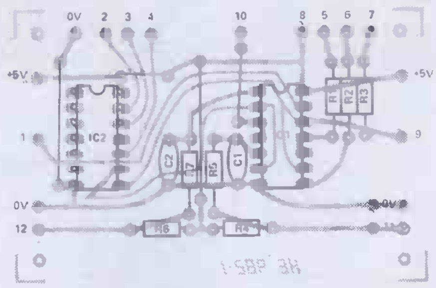


Figure 6. Component overlay for the Track Module.

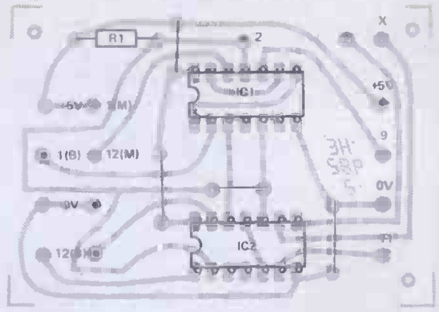
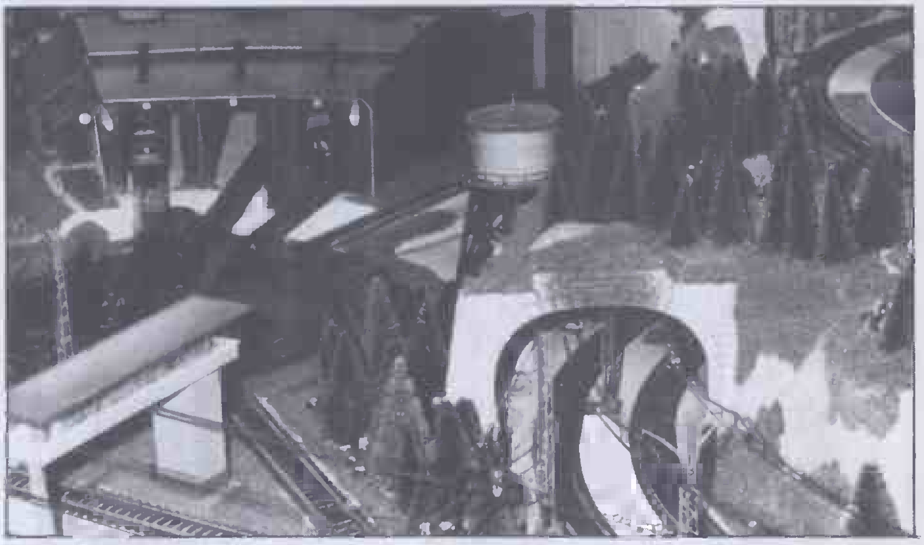


Figure 7. Component overlay for the Junction Module.



Parts List

Track Module

RESISTORS
(All ¼ watt 5% carbon)
R1,2 . . . . 270R
R3 . . . . 390R
R4 . . . . 1k
R6 . . . . 2k2
R5,7 . . . . 330R

CAPACITORS
C1,2 . . . . 100n
C280 polyester

SEMICONDUCTORS
IC1 7400
TTL quad 2-input NAND
IC2 7425
TTL dual 4-input NOR
LED1 . . . . TIL232
green 0.2" LED
LED2 . . . . TIL212
orange 0.2" LED
LED3 . . . . TIL209
red 0.2" LED

MISCELLANEOUS
SW1 . . . . SPST switch
track switch - see text
SW2 . . . . SPST switch
points switch - see text

PCB; signal stands (see text); wire, solder etc.

Junction Module

RESISTORS
(All ¼ watt 5% carbon)
R1 . . . . 1k

SEMICONDUCTORS
IC1 7402
TTL quad 2-input NOR
IC2 7400
TTL quad 2-input NAND

MISCELLANEOUS
SW1 . . . . SPST switch
points switch - see text

BUYLINES page33

should be used as a guide to positioning the track switches and signal stands. The modules are most conveniently mounted under the track layout and connected together, as shown in Figures 2 and 4, by lengths of four-way ribbon or multicore cable. The connections to the signal lights can also be made with four-way cable.

In a track layout as shown in **Figure 2**, there would normally be another signal stand on the branch line, near its junction with the main line. To connect another control module into the system at this point, simply wire it in parallel with the four-way module bus. However, point switch PS2 must now be a two-way type, with the change-over terminal connected so that terminal 2 of the new module is connected to 0V when the points are set for the branch line to join.

Power Supply

All the circuit modules are powered from +5V, which can easily be derived using a three-terminal 5V regulator; a suitable circuit to operate from a smoothed DC supply of 12-15V appeared in the June issue of Hobby Electronics, this year. Each module will draw approximately 50 mA, so the source must have the capability to supply this current, times as many modules are there are in the layout.

Signal Stands Alone

Many model signals currently available use miniature coloured incandescent bulbs, but these are rather expensive and draw considerable current. Dedicted modellers might, therefore, be interested in **Figure 8**, which shows the details of a signal stand especially designed for 3mm LEDs.

The bracket holding the LEDs is cut from 18SWG copper, bent at right angles and soldered to the post. The light shields are formed from brass tubing with an inside diameter of 3mm to take the LEDs, and the post is cut from 2mm tubing. These parts are all available from model shops and you can, if you wish, add to the construction with a ladder and safety rails made from tinned copper wire.

The connections to the LEDs should be made with appropriately colour coded wire-wrap wire (!), which is thin enough so that four or more leads can be fed up the post and through a small hole in the bracket. The connections can be covered by a cowling made from thin card, lightly glued in place.

The only other question which remains to be answered is: what to use for the branch line indicator lights? Unfortunately, white LEDs are not available! Well, one suggestion is to use low current miniature light bulb and fibre optic filaments to simulate the line of lights. However, the solution to this problem, as with many other practical problems in modelling, depend on particular set-ups and individual ingenuity. That, after all, is half the fun!

Photo Credits. Our thanks to: Hornby Hobbies for the photo on page 39 and C.J. Freezer (Editor, Model Railways) for the picture on page 42.

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Hands Off!

Paul Coster

Hobby's hardworking editorial assistant was happy to come to grips with this handy auto-ranging multimeter. Read on for his hard-hitting comments . . .

ABOUT the most surprising feature of the Teston LCD multimeter is its size. For a meter that auto-ranges, measures AC and DC *and* has a continuity checker (with tone generator), to fit into your hand, is pretty impressive. The complete package, available from Stotron, is supplied with test leads, carrying strap, test clip, current shunt and soft case. There is also a small folded sheet — entitled (optimistically) 'Instruction Manual' — which describes each range and how to use it. However, despite this lack of a decent manual, the meter was easy to use and very good value for the facilities offered.

Its full title is the ISI-Teston DM 2350 and it is an auto-ranging digital multimeter with only three scale-select buttons; current, voltage and resistance. A small switch, — push-to-changeover, selects AC/DC or ohms/lo ohms (more about this later). The meter is powered from two AAA batteries and protected against overload by a 200 mA fuse. It is cased in grey plastic with a clear 10mm display. Input impedance was a creditable 10 megohms on both AC and DC voltage ranges; rising to 100 M on the 200 mV DC range. Accuracy on all ranges was also good, at better than 1% (the highest resistance range is quoted at 2%, but our unit was well within this). Overload protection is provided by an external fuse and special FET circutry — the meter also 'bleeps' to warn of a dangerously high input.

Wide Ranging

The DM2350 has five DC and four AC voltage ranges. The DC scale extends down to 200 mV FSD, which makes possible measurements as low as 100uV. Maximum DC input is 1000 volts, accurate to better than 1% of the reading. The AC scale is not quite as sensitive but is adequate for most purposes. The range is 2-600 volts, with a resolution on the lower range down to 1mV. This would have been excellent for audio measurements, except for the narrow frequency response — 40 to 500 Hz (though, in fairness, this is common to just about all comparable meters) — and the inductive pick-up which results from using non-screened test leads; its easy enough to make your own screened lead's, however.

Both the AC and DC ranges worked well — it was possible to switch between AC and DC without plugging the test leads into different sockets — and the AC frequency limitations were not a major drawback (just use 440 Hz instead of 1 kHz as a test frequency).

There are two resistance scales, one for normal measurements and one for taking readings with components 'in circuit'. This latter facility is extremely useful for measurements around silicon junction components — silicon diodes and transistors etc — since the low output (0V4) is not sufficient to activate them. Both scales read up to 2 M, with the out-of-circuit range going down to 1 ohm resolution. Accuracy was found to be better than 1% on all ranges. An additional feature on both these ranges is that the tone generator can be used to indicate continuity. By connecting the leads between any two points in a circuit (power off!), and switching to resistance, the meter will bleep if a direct path is 'made' (a DC resistance of less than 1 ohm).

The two current scales are the only ones that do not auto-range, simply because both have a single limit of 200mA. This meant the sensitivity suffered (only 100 uA resolution) and very low current readings — quiescent supply in CMOS circuits etc — were not possible. However, this did not seem too important in the tests carried out and with the 10 A shunt fitted, the extended range made up for the deficit. The current scales were slightly less accurate at just over 1%, but, since most current readings will vary from device to device, higher accuracies are not so important. More significantly, the DM2350 compares favourably with its competitors in this particular respect.

Getting To Grips

Using this multimeter was a sheer delight, with the push-button controls and auto-ranging capability enabling one-handed operation — you can twiddle knobs *and* take readings simultaneously! In fact, the only aspect I found slightly annoying (as did the editor!) was the bleep every time a range was automatically switched. It's a good idea for continuity testing — indeed, vital — and as an overload warning signal, but does get a bit irritating after a while. Perhaps something less piercing is called for?

So, bearing in mind the comments on frequency response and current sensitivity, I found this meter had a lot to recommend it. The simple operation and auto-ranging facility made it a real pleasure to use and, for anyone thinking about buying professional test gear — hobbyists and engineers alike — it's worth including on your shortlist.

The price for the complete package of meter, test leads and case etc is £56.93 (all inclusive). Further details can be obtained from Stotron Limited, Haywood Way, Ivyhouse Lane, Hastings, East Sussex.

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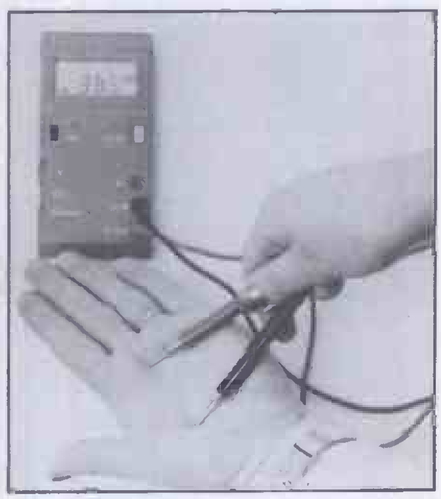


Planning on Success

Vivian Capel

First-time success with a project depends on careful planning and execution. Here's how to go about it ...

WE'VE ALL done it; spent long hours with a hot soldering iron and bags of components, seeing a once bare PCB gradually filling up, mounting switches and controls, lettering the control panel, wiring up, and finally coming to the moment of truth, the switch-on.

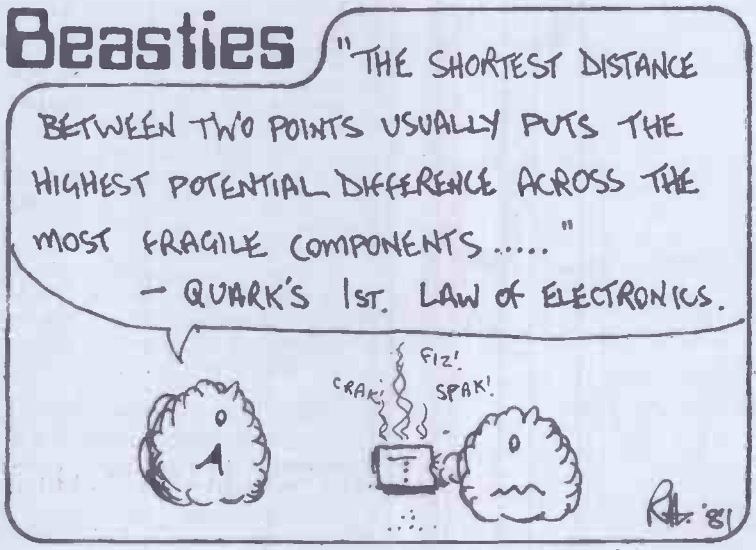
Perhaps for the first time, a moment's anxiety — will it work? What will happen if it doesn't? With an accelerating pulse rate, we turn the switch. Our worst fears are realised, nothing happens, or perhaps there is some sign of activity but nothing like what it should be. Worst still, maybe a tiny curl of smoke drifts upward from some undetermined component on the board!

From satisfaction at having completed the project, we are plunged into gloom and despondency. With growing despair we make haphazard checks on this and that, but can find no cause. Sooner or later we switch off, wishing we had taken up pigeon fancying instead of electronics. Of course, with or without help, we may get the thing going eventually but, even if not, it isn't long before some new circuit fires our imagination and we are making out our shopping list of components. This one will be different — it's bound to work first time. Hope springs eternal . . !

If you have ever built a project and that, or something like it, has never happened to you, you are either fortunate or careful — or both. Sometimes, getting a project working satisfactorily can take as long if not longer than building it in the first place. So what can be done about it?

Prevention vs Cure

As the old saying has it, "prevention is better than cure" and that is certainly true with project-building. The foundations for a "work-first-time" are laid from the start. First of all, we must have a sound design and layout, and if the project is one that is published by a reputable electronics magazine there should be no worries on that score. If it is one of your own designs then obviously you are well qualified to handle any problems that may turn up. However, most projects are built from published circuits by constructors who differ in technical competance. Some may have only a hazy idea of how the circuit works, in which case fault-finding, should it be necessary, could pose problems. Careful building of a good design is the only sure guarantee of success.



Sometimes a constructor will modify some part of the published design in order to improve its performance or to add or change some feature or facility; this is where caution *must* be exercised. In most cases, performance will have been optimised by the original designer and further improvements are unlikely, other than by going beyond the original framework of design. Almost any circuit *can* be improved, but only if one is prepared to make it a lot more complex and expensive!

Modifications to change some facility to one more in keeping with one's own requirements are legitimate, but you need to be sure of what you are doing. It is often better to construct it as designed, get it working, then modify it afterward. At least you know then, where you are and where the trouble lies if problems should arise. The section it is planned to modify can be built on a temporary basis, with components not permanently fixed and soldered into place.

Construction

In the majority of cases, the design is constructed as published, without alteration, and success then depends on the quality of construction, and the components.

There are a number of common construction errors which are frequently responsible for many faults and which we will now discuss. Most published designs include a PCB pattern that can be copied and etched, but some use a Veroboard layout.

With the custom-designed PCB, care must obviously be taken in copying, masking and etching and, especially where fine circuit tracks and/or spacings are involved, a careful examination with a magnifying glass should be made to see that all the copper has been etched away between tracks and that no etching solution has encroached on to a track due to faulty masking. The larger areas of spacing or conductor are usually fault-free, unless something has gone radically wrong with the etching.

Veroboard has its drawbacks, but can be very useful for many small applications where high currents are not involved. However, although the constructor is spared the task of copying and etching, rather more care is needed in the actual construction. For example, cuts are required in certain places along the tracks and all these should be inspected through a magnifying glass, however clean they appear to the naked eye. Another pitfall in making track cuts is their position. Errors can easily occur and the wrong track or position cut. To avoid this, count the number of holes along the track from the nearest end and place the cutting tool on the hole while you count back again to the edge. Then, select the right track by counting in from the edge, moving the tool to the track so counted and, as before, count back to the edge to double check. The tool should thus finish up on the correct hole. Now make the cut without removing the tool or, if for some reason it must be taken off, at least make a definite mark with it so that the position can be identified.

Components

A problem that frequently arises is that components of the specified type or value are not available. The choice is, therefore, between waiting an idefinite period in the hope that the required part will be obtained, or substituting something else. Substitutions can be made providing they are of a type which is equal or superior to that specified.

In the case of resistors, carbon composition types are the cheapest and used for general applications where nothing else is required. Other types have particular characteristics which may be important in the particular circuit. High stability carbon film resistors generally have improved characteristics, with about double the value-stability when not in use and some four times the stability of composition resistors when operated at full power rating; generated noise is about a third, the maximum operating voltage is higher and the temperature coefficient is less, but amount depends on the value.

Metal oxide resistors have even better characteristics than the carbon high-stab types, with particularly low self-noise generation — about a tenth of the high-stab value — and a lower temperature coefficient; value-stability is some four times better at full rating, but the voltage rating is lower than either composition or film resistors.

Metal-film resistors generate about three times as much noise as the oxide types, but are still better than the carbons. They excel in temperature stability, being some two-and-a-half times lower than the oxides, but they have the lowest maximum voltage rating. Another type is the thick-film metal glaze resistor. This combines the low noise properties of metal-oxide with the stability of metal-film and is also the smallest, for a given wattage; it is also the most expensive!

Thus, the choice depends on the use, and the designer has taken this into consideration when specifying a certain component. However, if a substitute must be made, then another type with similar characteristics can be chosen.

The wattage rating of resistors should not be lower than that specified but can, with advantage, be higher. This will improve reliability but will take up more room,so where close packed components are involved, larger sizes could be difficult to accomodate.

Resistance values are always given in the preferred E12 range, which advances in 20% increments. There is also an E24 range which increases in 10% steps; these are less common but may occasionally be specified (see Understanding Component Values, in HE June '82 issue). Usually, if a particular *type* of resistor is stocked by a supplier, all the values in the range will be held. Sometimes particular values may go out of stock, but the value can usually be made up by connecting two others in series or parallel, using Ohm's Law to calculate the values.

The same is true of capacitors, where the type of dielectric is determined by the application. Polyester is a good general purpose material; polycarbonate has a low temperature coefficient and so is desirable when stability at temperature extremes is required; polystyrene has a very high insulation resistance, of the order of a hundred times greater than most others, while polypropylene is best for pulsed voltages and AC operation. Large values require electrolytics, but these have a high leakage factor, so where this is important, tantalum capacitors, with about a third of the leakage, should be used. They are smaller, and also nearly three times the price of electrolytics.

The voltage rating of all capacitors should exceed the voltage across them, under all operating conditions, by a comfortable margin. Reliability is improved if higher voltage ratings than specified are used, but this usually means larger components.

At the low capacitance end of the scale there are polystyrene, silver-mica and ceramic capacitors. Ceramics are commonly used, but silver-mica types have better temperature stability in circuits where the value must be constant. As they have a positive temperature coefficient (whereas ceramics are negative), the required value is sometimes made up by paralleling one of each type in critical circuits, to improve the temperature stability.

With diodes and transistors, there are often equivalents of another make which can be satisfactorily used, but not if the circuit is designed to take advantage of some particular property possessed by a certain device. There will be some cases where a listed equivalent may not work as well! If a transistor is specified with a suffix letter, A, B, or C, this should not be ignored. The suffix refers to the gain grouping — lowest for the A types and highest for the Cs. Many circuits are designed for a specific gain, and will not function correctly with any other.

Although seemingly simple, diodes cannot be substituted without consideration of the characteristics. If a germanium type is called for, do not think that a silicon diode will do. Germanium has a lower forward voltage drop, and this may be needed in a circuit involving low voltages. Also, a point-contact diode has a low capacitance which makes it suitable for high-frequency circuits, and so could not be successfully changed for a junction diode.

Integrated circuits are more specialized and substitutions cannot usually be made without circuit modification, unless the replacement is a direct equivalent of another make. The only room for manoeuvre, here, is that some ICs come in differently packaged versions, and one may be available while another is not. Of course this could upset the PCB connections!

Mounting Components

Assuming all the components, or suitable alternatives, are to hand, and the PCB is prepared, the next stage is to mount them. Some constructors like to mount the parts one at a time and solder

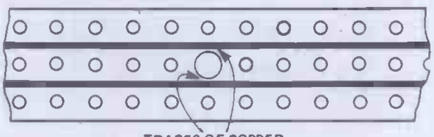


Figure 1. When cutting Veroboard tracks, ensure that no fine copper bridges are left at the edge of the cut.

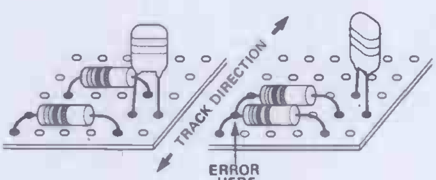


Figure 2. Check that component wires are all going to the right holes. It is easy to make mistakes, as can be seen by comparing (a) and (b).

Figure 3. When a component straddles several holes on a matrix board count the number as it is fitted. It is not so easy to check when the part is in place.

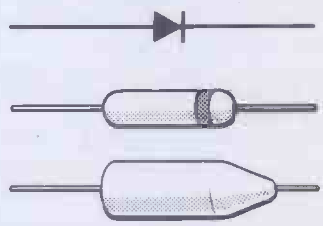


Figure 4. The easy way to remember the connections to a diode; the band marks the straight line of the symbol (the cathode) and with power diodes, the taper points in the same direction as the arrow.

Figure 5. Transistors can be fitted more easily, and errors reduced, by cutting the wires to unequal lengths. The emitter wire is left full length, the base is cut shorter and the collector the shortest. They are inserted in the same order.

each one, while others prefer to mount them all, retain them by bending the wires, then solder all at once. The latter method has some advantages in that any mistake can be rectified without unsoldering, and it is usually quicker to do all the soldering operations together.

Whichever method is followed, it is a good practice to leave all the semiconductors to last, mounting and soldering the passive components first. Thus, the transistors or ICs will not be repeatedly subjected to conducted heat from the iron as associated components are soldered in. In the case of ICs, it is wise to use sockets rather than solder the device directly in to the circuit. Not only does this remove any possibility of damage by heat but it facilitates changing the device, should it prove faulty. Furthermore, suppliers are more inclined to change a faulty IC if the pins are unsoldered.

There is always the likelihood of component wires being inserted in the wrong holes — even in a PCB, but especially with Veroboard, where all holes are in rows. Take special care with this, and where the component straddles several holes, count them! After getting the first hole right, it is easy to put the other wire in, say, the second instead of the third hole along.

Watch that you have the correct resistor values, because some colours are difficult to distinguish on small components; red and orange, for example, can easily be mistaken. In particular, make sure that you are reading the colour code from the right end! There are four values, especially, that can be easily mistaken. A 270k, (red-violet-yellow) can be mistaken for a 4k7, (yellow-violet-red), while a 1k2, (brown-red-red) could be thought to be a 220 ohm (red-red-brown) and, of course, vice-versa in both cases.

When mounting capacitors, it is a good practice to fit them with their values uppermost, or where they can be read. While not affecting the working of the circuit, it will help with component identification should the circuit need servicing later. Ensure that all electrolytics and tantalum capacitors are wired in with the correct polarity; this is another very easy error to make, so check when fitting and also afterward.

The same is true of diodes; some constructors find difficulty in remembering which way diodes are marked. An easy method is to regard the band, at one end, as the straight line used to depict the cathode in the diagram. In the case of power diodes, the tapered end is also the cathode and can be remembered as the end to which the 'arrow' in the diagram is pointing.

Care is likewise necessary in fitting transistors, and double-checking is necessary to make sure they are wired correctly. Difficulty is sometimes experienced in getting all three of the wires in their holes at the same time without any slipping out, so here is a tip which aids this operation and also reduces the possibility of incorrect fitting. Cut the wires to unequal lengths by leaving the emitter as it is, cutting the base somewhat shorter and the collector the shorter still. Now fit the longest wire in its hole first, followed by the next and finally the shortest; Each one being longer than the next, it stays put in its hole, without coming out. When all are in place, bend, solder and crop off the excess. If the habit is established of fitting the emitter first and collector last, correct insertion is almost guaranteed!

In the case of ICs we have the problem of being able to insert them, in the PCB or in their holders, the wrong way round. Not only are there two ways of plugging in an IC, but the identification is not at all clear. A dot at one end marks 'pin one', but it is often no more than a shallow depression, so watch out for this; it is all too easy, when turning the board over and working on both sides, to get it wrong. It is a good idea, when preparing the board initially, to put a mark either with paint or a marking pen, at the site of all ICs on the 'pin one' end. Then, when assembling or changing them later, the chance of a mistake is reduced.

As to the actual mounting, fit components fairly close to the board so that surplus wire is minimised. Shorts can occur between wires of adjacent vertically mounted components, so make sure that these are well spaced. Also ensure that vertical components are seated firmly on the board, otherwise they man lean over and touch. Transistors should have short leads — but not too short, they man be damaged by heat, when soldering, and future servicing may be hampered.

Checking Components

Is it necessary to test components before they are fitted? With many, this should not be necessary; resistors, for example, are very rarely faulty from new, other than obvious physical defects such as loose end-caps or wires. Also, it is most unusual for a value to be outside the rated tolerance. Wire-wound resistors could be checked, as occasionally one is found to be open circuit.

Electrolytic capacitors should be tested for leakage, as any held in stock by the suppliers for any length of time can develop high leakage currents. Resistance, when measured with an ohmeter, should be well above a megohm, although it will be lower if measured reverse-connected (note that the positive lead of the meter is actually of negative polarity when switched to ohms).

Diodes should be tested before fitting. Cases of new diodes being open circuit are certainly not unknown, and in at least one case a power diode was found with reversed polarity! This could have been disastrous had it not been checked before fitting. To test, connect the ohmeter across the diode with the positive lead to a cathode (band or rounded end) whereupon a reading of from a few hundred to a thousand ohms should be obtained. Then reverse the meter leads to obtain a very high or infinite reading.

It is prudent to check transistors, and this can also be done with an ohmeter and a resistor. For NPN devices, connect the positive-marked meter lead (which is actually negative) to the

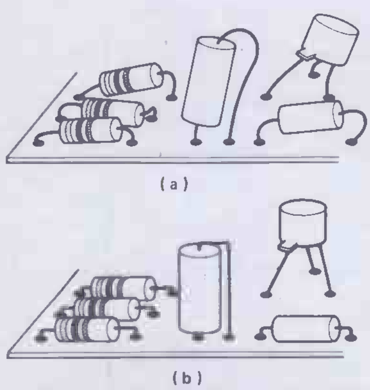


Figure 6 (a). Untidy fitting with wires left too long, leading to possible shorts; (b) the same layout wired neatly, as it should be.

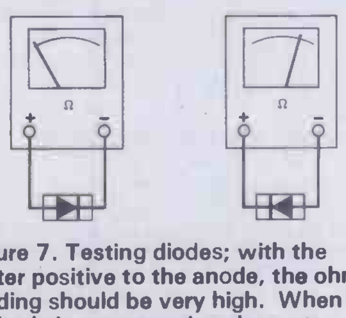


Figure 7. Testing diodes; with the meter positive to the anode, the ohms reading should be very high. When the cathode is connected to the meter positive, the reading should be around 1,000 ohms.

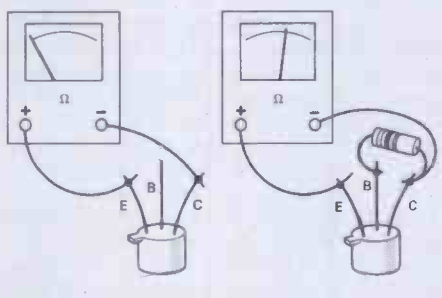


Figure 8. Checking a NPN transistor with a meter; with positive to emitter and negative to collector, there should be very high or infinite reading. Connecting a 10k resistor between base and collector should give a reading much less than 10k. Reverse the polarity for PNP device.

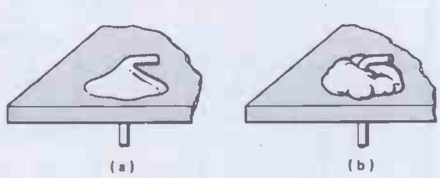


Figure 9 (a). A good soldered joint is smooth and rises gradually from the track; (b) a bad joint is lumpy, curls under at the base and dips inward toward the wire, but not all bad joints have all these features.

emitter and the negative-marked lead to the collector; there should be no reading. Now connect a resistor of about 10k from the base to collector. A reading of around 10k should be obtained; the actual reading depends on the gain of the transistor and the value of the resistor, which can be any value from 10k to 33k. If the reading is a little higher than the value of the resistor, you are looking at the base/emitter junction, through the resistor, which means that the collector is open circuit. If you get no reading at all, the emitter is open circuit; a low reading before connecting the resistor means either the device is short circuit or is reversed polarity. Try reversing the meter leads; if the reading is still low, it is definitely shorted, but if it now gives normal results, the polarity is wrong and you actually have a PNP transistor! For testing PNP transistors, connect the positive meter lead to the emitter. As new transistors have been found to be shorted, open, and with wrong polarity, it is by no means a waste of time to do this!

If constructing is your hobby, and you regularly build circuits, it is recommended that you equip yourself with a transistor tester such as the Eagle TT 145 or similar instrument, as well as the obligatory multimeter. You will then be able to measure gain, leakage, polarity, and be able to match up transistors for complementary circuits.

Soldering

Quite a number of faults are due to soldering defects so take care; the symptoms they produce can be quite baffling. Firstly, always ensure the work is clean; handling the board can leave greasy deposits that resist the solder but a clean-off with a spot of meths will get rid of most of the grease. Apply the iron to the work with a little solder on the bit to facilitate the flow of heat and, after a second or two, introduce the solder, which should melt on the joint itself. Wait another couple of seconds until the solder can be seen to be flowing freely, then remove the iron. Do not carry the solder to the work on the iron, and do not try to 'paste' it on like applying putty.

After the board (or the section you are working on, if it is a large one) is completed, examine every joint with a magnifying glass, scanning across the board in strips to ensure none are missed. With Veroboard this is easy, as you only have to run along each track in turn. Every joint should be smooth with a gradual rise from the copper and a smooth taper to the component wire. Any sudden rises, hollows around the wire, or blobby looking lumps of solder spell bad joints. Re-heating with the iron for a few seconds will, in most cases, put things right.

Another possibility is the presence of tiny whiskers of solder between tracks. So, when scanning the board for doubtful joints, examine the spaces between close running tracks; with the Vero, examine every space! A further potential cause of trouble is the wire cropped off from components; pieces can lodge in all sorts of places and escape detection so, when cutting the surplus wire, hold the board so that it falls away onto the bench, then gather them up and dispose of them before they find their way into trouble. Likewise screws, washers or other items of hardware that may be dropped into the works when assembling. If it seems to have disappeard, don't take the easy way out and fit another; search for the truant, even if it means upending the project and shaking it. Wandering screws can be responsible for all kinds of future problems.

Fault-finding

If all the above suggestions are carried out during the building, the chances of non-operation at first switch-on are greatly reduced. However, it can still happen, so what do we do then? The most likely causes in order of probability are: soldering faults, including damage to components by soldering; PCB faults; incorrect assembly or use of wrong components; defective transistors or ICs; defective passive components.

As can be seen from this list, construction faults are still the most likely in spite of your precautions, so a careful visual check over the whole thing is the best first step. It is surprising how obvious errors can be sitting there, looking right at you, yet pass unobserved. So do not take anything for granted; check everything again.

If this fails to reveal the cause of the trouble, use the multimeter to check voltages. The absence of a voltage will, in many cases, indicate where the fault lies. Sometimes a voltage will be present but incorrect, such as a full supply voltage on a transistor collector. This suggests zero current due to no forward bias on the base, an open circuit emitter junction or transistor.

Actual voltage readings depend entirely on the type of circuit, but a few basic rules are: the collector of a NPN device must be positive when measured from the emitter, usually by several volts; if the emitter does not go directly to chassis or earth, it will be slightly positive, usually by less than one volt; the base should be 0V6 more positive than the emitter, in the case of silicon transistors. If the device is used as a gate or switch it may be biased off, normally, in which case the voltage would be high on the collector and low or zero elsewhere.

Check all the supply points to the ICs, measuring on the actual pins, but be careful! Use fine pointed meter prods to avoid bridging two adjacent pins, as this might put supply voltage where it shouldn't be, with disastrous effects. Measure the voltages on the circuit side of stabilizers and across zener diodes, to ensure that they are working properly.

With PNP devices, the collector voltage will be negative and the base 0V6 negative with respect to emitter. For germanium transistors, the voltage difference will be 0V15.

If voltage readings fail to show up the cause of the trouble, we will have to delve deeper. Try to establish what parts of the circuits are working. How this can be done depends on the function of the circuit and what it is supposed to do. Usually, the circuit is intended to operate on some sort of signal, whether audio, RF, DC control or digital pulses, and respond in some way by amplifying, triggering, controlling another circuit or an electro-mechanical device.

It may be possible to determine whether the input signals are present or, if this is uncertain, suitable signals may be produced by other means. Disturbance testing has long been used by professional engineers as a quick check; this can be as simple as scratching a test prod on the input pin, thereby producing pulses that extend into the RF spectrum. If this produces some response at the output, even if not the required result, it shows that the circuit is working to some extent.

The main thing is to work systematically, not hopping from one point to another, hoping to alight on the trouble by chance. Establish the area of the fault by eliminating those parts of the circuit that appear to be working, and concentrate on the doubtful ones. It is not unlikely that more than one fault exists and that possibility must always be considered.

Resistance readings with, of course, the equipment switched off, can often be illuminating. Measurements to earth from points that normally carry no voltage sometimes show up short-circuits that would not otherwise be revealed.

The IC will probably come under suspicion, at some point. Unlike transistors, it cannot be tested out of the circuit before fitting, so when the other components in the affected part of the circuit have been absolved, attention naturally turns to the IC. Many circuits use several of the same type in which case, if they have been fitted by means of sockets, a swop can easily be made to see if that makes any difference. If faulty, it means that, now, some other part of the circuit will not work.

It is a good idea to keep a few spares of the cheap, commonly used ICs, as it is with general-purpose transistors and a selection of resistors and capacitors. All told, the cost of a small stock is very little but can be well worth while when chasing faults or experimenting.

Although publishers of the original circuit will, in most cases, offer what suggestions they can in response to a letter for help(*and provided an SAE is enclosed! — Ed.*), servicing at a distance, without being able to make tests and observe results is rarely satisfactory; they will often suggest things you will have already tried.

However, if care is taken in the initial construction, and systematic tests made in the event of trouble arising, the fault should eventually be localised. Although it may be irritating at the time, it will add to your experience — and make the next project that much easier! **HE**

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Clever Dick

Nostalgia is a wonderful thing ... why, it seems like only yesterday when I first had the chance to parade my journalistic talents before an unsuspecting public. Since that epic day, way back in August 79, I've stood firm against overwhelming odds (and editors!) to continue to answer your questions. I hope you appreciate it! But now for this month's offerings, the first of which had me working overtime!

Dear CD,
How good is your memory? Can you remember if any faults appeared in the Envelope Generator project published in the June '81 issue of Hobby?

I'm at the point of filing the project for future reference (ie finishing it!) so I'd be grateful for any advice.

Also, am I right in assuming that if I use a BC183L in place of a BC183, then the leadout wire configuration is changed?

Your replies will a) cure my insomnia and b) prevent hair loss (due to me tearing it out!)
Kevin McKeourn,
Cirencester,
Gloucs.

PS Have you ever thought of publishing an auto – wah project?
PPS The sounds I can get with your effects hooked up to my penny whistle and chime bar set-up are amazing!

I hope you realise that my memory is very good ... in fact, it's excellent! So, I can tell you, categorically, that the Envelope Generator was without errors — check your unit again. As you say, changing the BC183 for a BC183L will mean wiring the leads differently. However, this is not the only component that must be correctly oriented, so make sure all the others are right.

Can't say I've ever thought of publishing anything (not even my memoirs), but the editor tells me that HE did an Auto-Wah in June 82, though it was designed with guitarists in mind. Maybe it's time for you to move onto something a little more musically adventurous — dustbin lids perhaps?

Dear CD,
I like playing with TV games and hand held electronic games but I haven't got one of my own. I'm sure that your team could come up with an idea. I mostly like playing with TV games, please please I am only 10 and am not trying to scrounge a binder.
David Ovington,
Camberley,
Surrey.

PS Is the Digi-Die in the January 80 issue a Digital Dice?

Surprising how many young HE-men seem to spend most of their time playing games. In my day ... ah, but that's another story. Anyway, "our team", as you call them, is working on such a project at this very moment — after their tea-break of course — so you should see it within this noble tome in the near future.

As for the Digi-Die, it displays the numbers on seven LEDs arranged like the spots on a standard die and it is digital since it deals with logic signals or binary digits.

Dear CD,
Re: HE OCTOBER 1981 — BABY ALARM

Unfortunately you have neglected to print the track breaks in the Veroboard layout for this project. Please can you either send me a diagram of the breaks or print them in the next issue.
Paul Brade,
Herne Bay,
Kent.

Unfortunately you have neglected to enclose a SAE, which must accompany letters enquiring about Hobby projects. Of course, if you were a regular reader you'd know that already. You'd also know that we published the answer to your question in 'Your Letters' March 82. So now you know ... eh? I still haven't told you where the breaks are supposed to be — well, since you did say 'please': the breaks were merely to prevent the mounting bolts shorting any of the tracks. Omit the bolts (use double sided adhesive pads) and you've solved the problem. Happy now? Good.

Stop me if you've heard this one — letters to Hobby Electronics must include a SAE if they require a personal reply. You're right, it's not a joke and you've probably heard it before, but if it means one less letter using up the precious time of our back-room boys (as some of you like to call them), then it's worth repeating. So, I will: letters needing written replies must include a SAE. However, just to be awkward, letters to my own honourable personage don't need a SAE because questions will usually be answered through the magazine. Indeed, in an effort to allow others to share the limelight, letters I receive WITH a SAE are usually passed to the Technical Queries department, leaving me to concentrate on giving my all for readers of this page. Aren't I good to you?

Dear CD,
I am writing in the hope that you may be able to answer the following question:

Is it possible to receive an electric shock from a 12V car battery?

I have asked several people the same question and they all said yes. This leaves me puzzled however, as I wouldn't have thought it possible, since 12V doesn't seem to be a harmful voltage level.

I would be most grateful for any information on this matter as I would prefer to use a battery for low voltage equipment thus eliminating the need for mains connections to power supplies etc.
Wm. Lumsden,
Glasgow.

Interesting one, this, because it really boils down to 'What is an electric shock?' The truth of the matter is that reactions to a shock vary greatly between individuals. Some are almost unshockable, while others jump at the smallest things (small rodents included!). However, I diverge, the answer to your question is no — unless the voltage has been stepped up. In fact as the potential gets higher, assuming the current is not limited, the more dangerous the possible shock.

More to the point, though, if you build a proper PSU then the whole issue becomes irrelevant. They're a lot easier to carry around and a lot cheaper!

Dear CD,
Please, Please, Please, Please, Please, Please, Please can I have a binder. The pages of my March '82 issue have already fallen out. You'd better, or you'll have my mum to deal with (my, you should see her). Secondly, how about a digital, I repeat digital voltmeter (DC). I've looked in many magazines and haven't seen one. I think that ones with meters in are useless! As your loyal and faithful servant would indeed love a binder.
Yours sincerely, loyaly (or loyally?),
F. Woodroffe.

PPS Where can I get a book about building experimental circuits on Verobloc?

PPPS Sorry about the punktchewayshun but I came 28th out of 31 in Inglish.

Faced with all that, what can a peace-loving man (or woman) do but send a binder — so, that's where this month's blue and gold delight is going. Regarding the question about a DC digital voltmeter, you'll be happy to hear that one was printed last month. Also, you need look no further than our 'Breadboards' page, for a source of circuits to experiment with. Oh, and, incidently, you're punctuation wasn't that bad, just your spelig! **HE**

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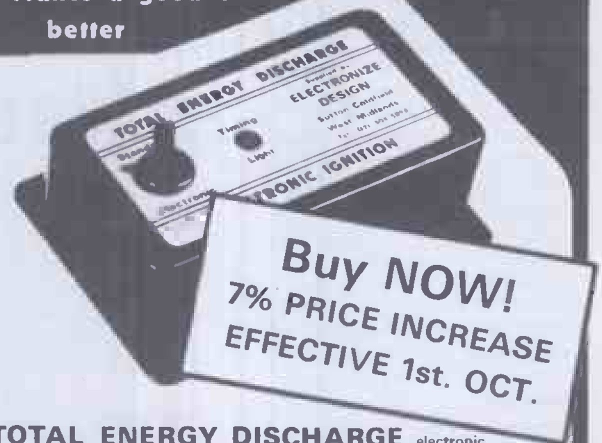

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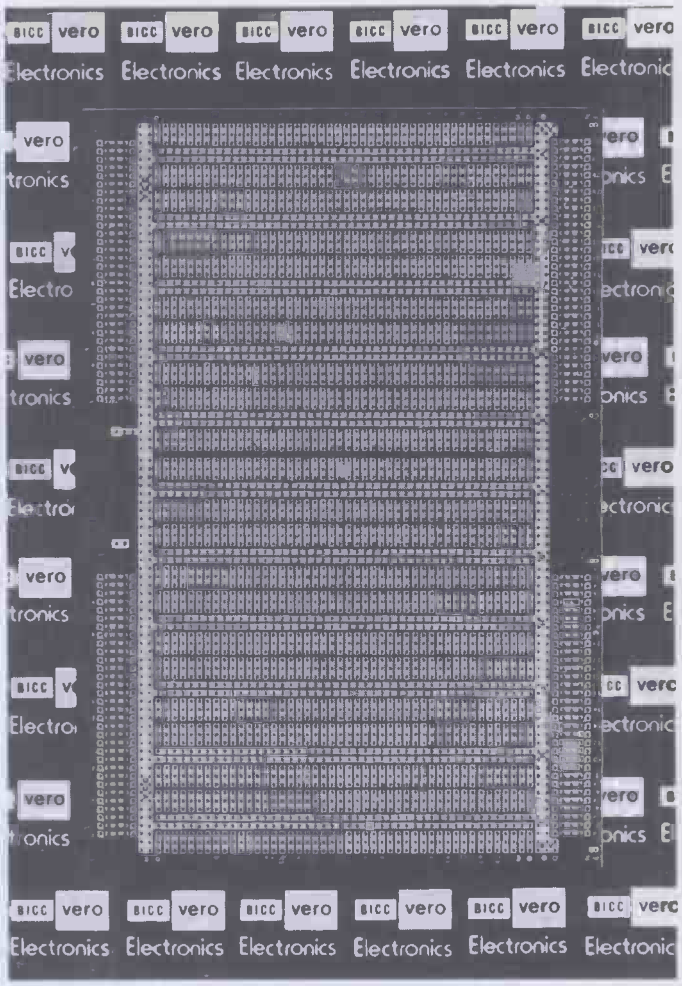

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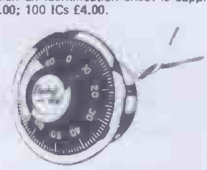

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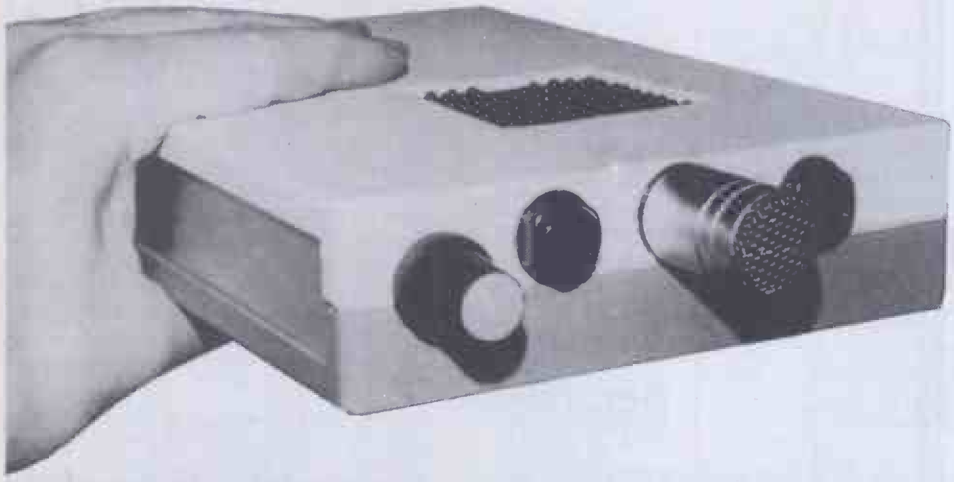
Audio Analyser



Concluding the Audio Spectrum Analyser project with the method of construction and setting up.

CONSTRUCTION of this project is not for the faint-hearted! To make this project handheld has meant using two fairly dense PCBs. so you can put away your gas-fired soldering irons and pliers; delicacy, finesse and a steady hand are required. Use an iron with a small bit and make sure you don't leave huge blobs of solder that bridge the PCB tracks. IC sockets are not just recommended; we insist upon them. Fit the components to the boards in the usual way, filter board first, taking great care to observe component polarity where this is important. Don't miss out any of the wire links; and *don't* try to finish it all in one evening — or two. Time 'saved' during contruction will be wasted on fault-finding, later!

The nice men who designed the 4017 didn't put its sequential outputs 'sequentially' on the IC pins and this often leads to tricky PCB layouts when using the IC. Fortunately we can cheat, because all we need in this project is to look at each of the 10 channels separately — so long as they appear on the right display columns it doesn't matter what the actual order is. This is why the filters don't run in sequence down the PCB — it's purely for convenience.

To avoid the use of a double-sided PCB for the display matrix, a rather cunning technique has been adopted. Solder in one row of LEDs only and cut off one pin only — the ones whose solder pads are linked by copper tracks. Now solder a length of tinned copper wire to the pad indicated, bend it over so it touches the other LED pins about ¼" away from the board, then solder all the pins to it and trim them off. Then do the next row, and so on. Mistakes made here will be almost impossible to correct later, so check that every LED in every row is the right way round before you solder it. The most certain method is to use Figure 2; flats, dots and 'one leg is shorter than the other' can all lead you astray.

The case used was a Vero type 1 (reference number 202-21034), external size 205 x 140 x 40 mm; a fair bit of work with a sharp chisel is required to make everything fit, though. The vertical slot guides at both ends of both case halves should be removed, plus all the PCB mounting pillars in the grey (bottom) half and the outer set of four pillars in the white (top) half. Everything mounts on the top half except the on/off switch, which is fitted in the side aluminium panel.

The two PCBs are bolted together with stand-off pillars and have a number of wire links between them. The easiest way to do this is to solder lengths of tinned copper wire to the relevent pads of the display board and cut them down slightly to different lengths, gradually increasing as you move down the board (Figure 3). Then you can insert the longest link onto the filter board, move the two closer together, insert the second and so on, until they're all through.

Assembly starts by test-fitting the display board and making a hole for the display. It's a good idea to glue a piece of red plastic or polarising filter behind it to improve the contrast of the LEDs. Fix the pillars to the display board and screw into the case — the transistors and tantalum capacitors will probably have to be bent over to give clearance. Now slide the main board over the wires, as described above, solder all the links and trim them. Now the wiring for the off-board components can be completed.

We found the cheapest way of getting an electret mic element was to buy a cheap electret cassette recorder mic (about £3) and cut the end off it. Do this very carefully as you musn't damage the insulation on the internal wiring; you'll need it to link the mic to

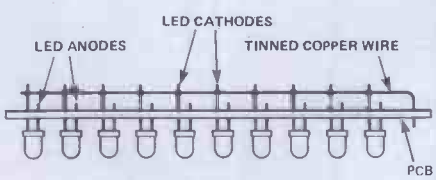


Figure 1. Wiring the LED matrix; it is best to check all the LEDs before soldering them in, because replacing one will be very difficult once the boards are assembled.

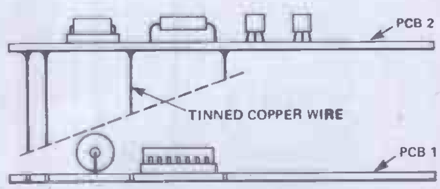


Figure 3. Fitting the links between the two boards.

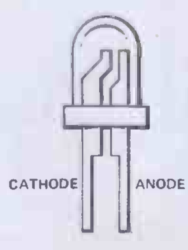


Figure 2. Pin connections of a LED.

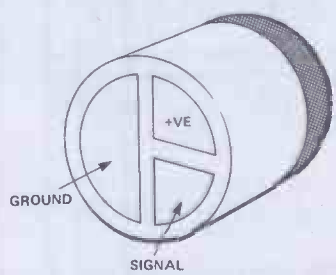


Figure 4. Connections to an electret microphone.

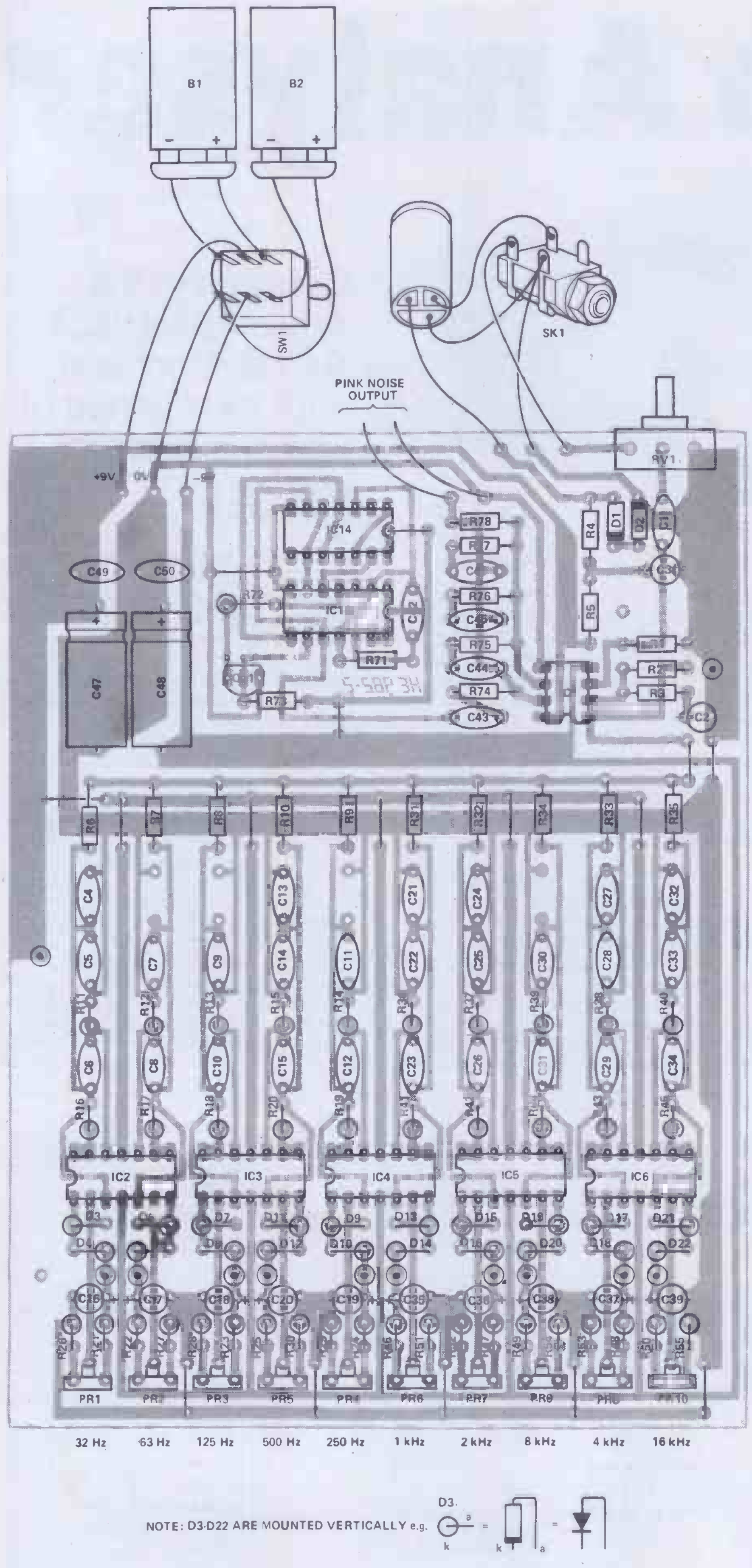


Figure 7. The filter board component overlay.

the PCB. Glue the mic into a suitable-sized hole cut in the end of your case and connect it to the PCB as shown on the overlay; the existing battery terminals of the mic will tell you which are the positive and negative supplies, while the third wire is the signal connection (probably screened by the earth wire). If you don't feel your constructional abilities are up to this, just plug a mic into the external jack socket; not as compact but much easier.

If choosing an alternative case, bear in mind that you'll want easy access to the batteries; the current consumption of the unit is quite high and you'll either have to replace your alkalines regularly or, if you've been sensible, recharge the Nicads.

Anyone who attempts to improve on our PCB design is on his own. Anyone who attempts to build the circuit on Veroboard will be recommended for committal to a mental institution.

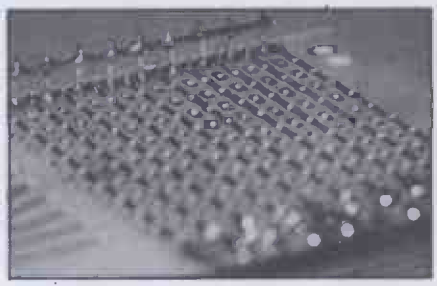


Figure 5. View of the LED display from the foil side.

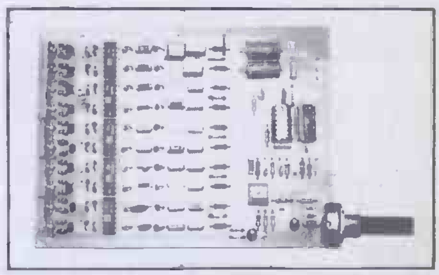


Figure 6. The completed display board.

Setting up and Use

The unit can be set up using either the built-in pink noise generator or, better still, with a sine wave oscillator. Adjust PR10 to about 75% of its travel (wiper towards the clockwise direction). With the unit switched on and the sine wave oscillator connected to the external input, by sweeping the oscillator frequency, each column should come up in sequence. Adjust the sine wave frequency and the analyser level control until the 16 kHz column is peaking at a column height of about eight LEDs.

Now, using the same amplitude and without touching the level control, adjust the signal generator frequency until the 8 kHz column peaks and adjust PR9 to give the same height. Repeat this adjustment for each of the filters. Due to component tolerances the actual peak of a filter may not

Parts List

NOTE: The parts list published last month contained several errors and these are corrected here.

RESISTORS (All ¼ watt 5% carbon)
R1,2 . . . . . 220k
R3 . . . . . 2k2
R4,5,69 . . . . . 15k
R6-10,31-35,72 . . . . . 10k
R11-15,21-25,
36-40,46-50,78 . . . . . 1M
R16-20,41-45 . . . . . 220R
R26-30,51-55,,6876 . . . . . 100k
R56 . . . . . 680k
R57 . . . . . 6k8
R58-67 . . . . . 47k
R68 . . . . . 100k
R69 . . . . . 15k
R70 . . . . . 430R
R71 . . . . . 27k
R73 . . . . . 4k7
R74 . . . . . 180k
R75 . . . . . 18k
R77 . . . . . 390k

POTENTIOMETERS
RV1 . . . . . 47k log carbon
PR1-10 . . . . . 220k min horiz preset

CAPACITORS (All metallised Polycarbonate unless noted)
C1,13,43,49,50 . . . . . 100n
C2,3,41 . . . . . 10u 16V tantalum bead
C4,5,7 . . . . . 1u0
C6 . . . . . 56n
C8,10 . . . . . 27n
C9,11 . . . . . 270n
C16-20,35-39 . . . . . 2u2 35V tantalum bead
C12 . . . . . 6n8
C14 . . . . . 18n
C15 . . . . . 3n9
C21,22 . . . . . 39n
C23 . . . . . 1n5
C24 . . . . . 33n
C25,32,33 . . . . . 2n2
C26,44 . . . . . 820p ceramic disc
C27 . . . . . 12n
C28 . . . . . 3n3
C29 . . . . . 470p ceramic disc
C30 . . . . . 10n
C31 . . . . . 180p ceramic disc
C34 . . . . . 100p ceramic disc
C40 . . . . . 22n
C42 . . . . . 1n
C45 . . . . . 2n7
C46 . . . . . 5n6
C47,48 . . . . . 220u 16V axial electrolytic

SEMICONDUCTORS
IC1 . . . . . LF353 dual BIFET op-amp
IC2-6 . . . . . TL064 quad lo-power op-amp
IC7 . . . . . 4011 CMOS quad 2-input NAND
IC8,9,10 . . . . . 4016 CMOS quad analogue switch
IC11 . . . . . LM3915 bargraph driver
IC12 . . . . . 4017 CMOS decade counter/divider
IC13 . . . . . 4070 CMOS quad EX-OR
IC14 . . . . . 4006 CMOS 18-stage shift register
Q1-11 . . . . . BC184L silicon NPN transistor
D1-22 . . . . . 1N4148 signal diode
LED1-100 . high efficiency red LED (see **Buylines**)

MISCELLANEOUS
SK1 . . . . . ¼" jack socket with break contacts
MIC1 . . . . . electret microphone (see **Buylines**)
PP3 battery clips (2 off); IC sockets (13 off); case; wire; solder; PCBs, etc.
Buylines . . . . . page 33

correspond exactly to its nominal centre frequency. The 16 kHz filter has the greatest loss which is the reason for starting with it near its maximum gain.

If a sine wave oscillator isn't available, connect the pink noise output to the external input and adjust the presets to give an even response across the 10 channels. Each column should be approximately the same height; due to the nature of noise, the top of the columns may jump up and down slightly and this should be averaged out by eye. If one of the columns appears dimmer than the rest, replace the transistor that drives that column; if only a single LED appears dim then it must be replaced but as we've pointed out, the method of contruction make this a bit tricky. It's a good idea to either buy good quality LEDs or test them individually for duds before commencing construction.

To measure a room set-up, feed the pink noise into the hi-fi or PA system via a cable from the listening position and adjust the graphic equaliser controls until a flat response is indicated.

A final point; the microphone used must be fairly flat or its frequency response will affect the measurements you're making. If you use one with a limited bandwidth it's possible to use the presets to compensate; however, to do this properly you'll need to play the pink noise into the mike via a sound system/location you already know to be flat.

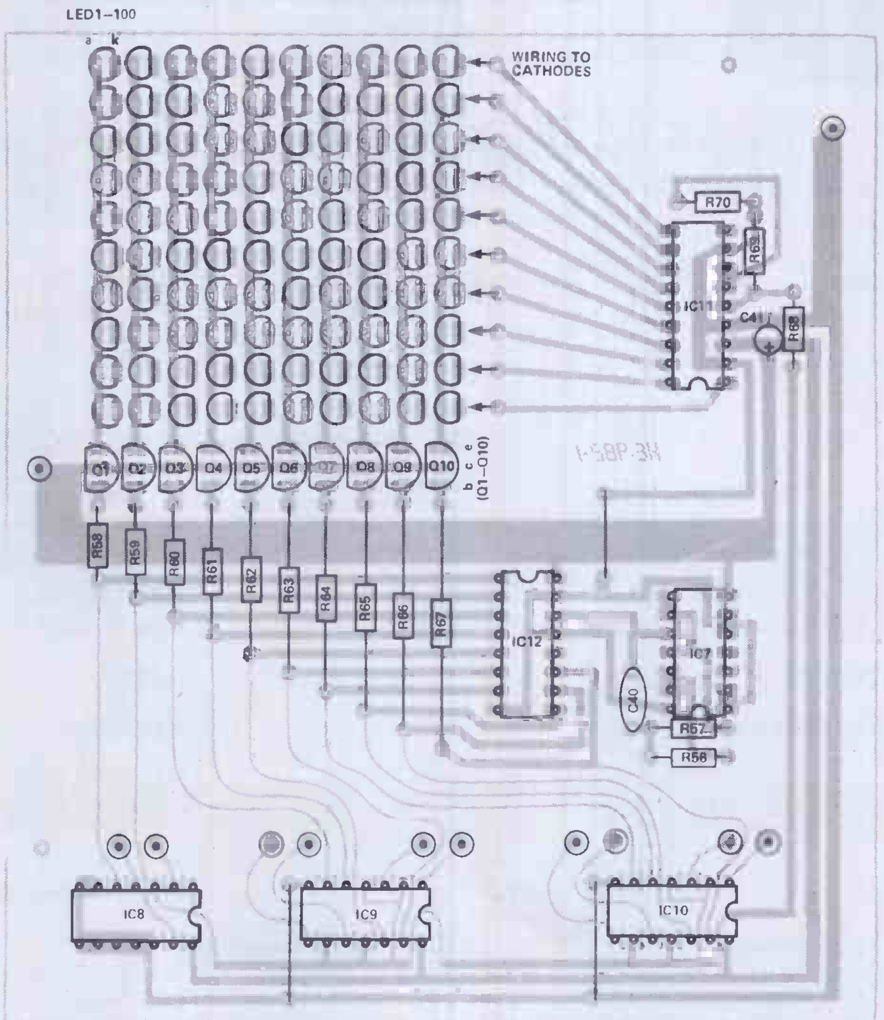
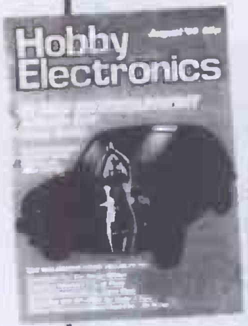


Figure 8. Display board component overlay.

NOTE: CIRCLED PADS INDICATE LINK-WIRES BETWEEN THE PCBs (SEE TEXT)



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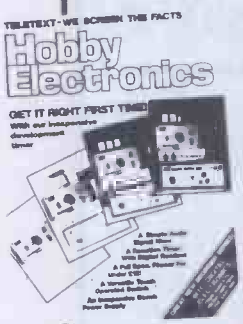

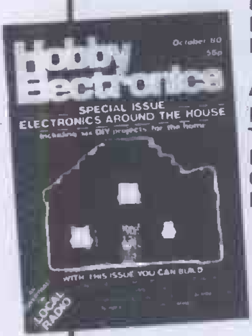

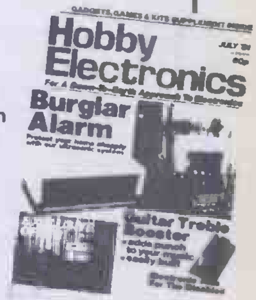

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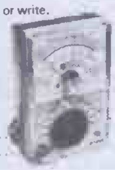

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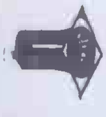

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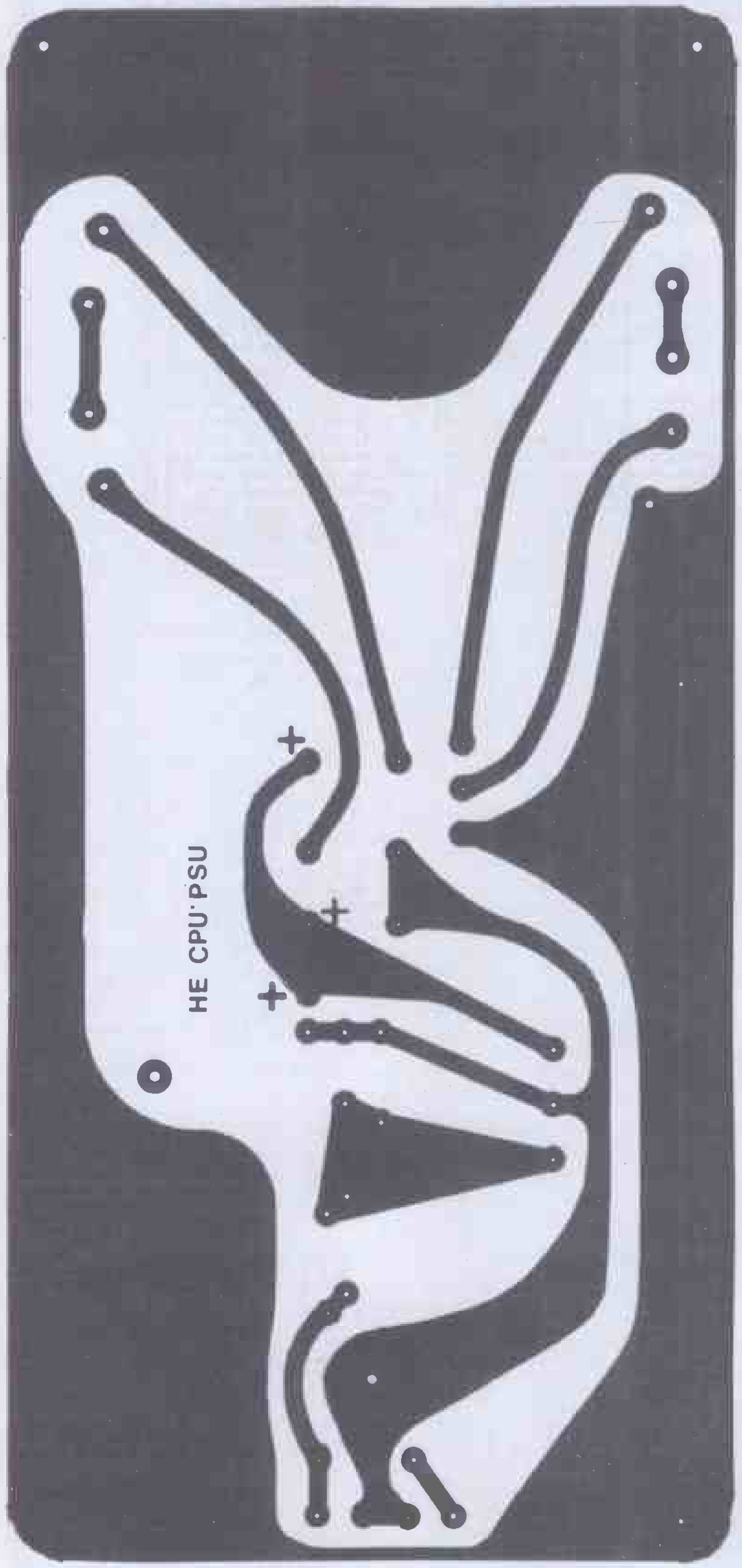
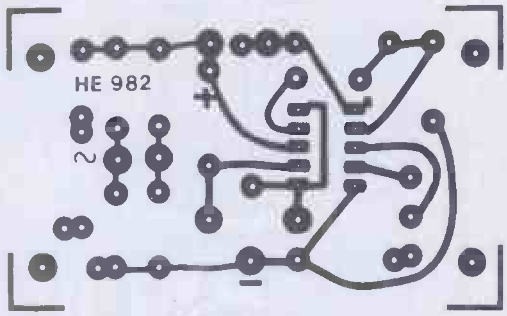
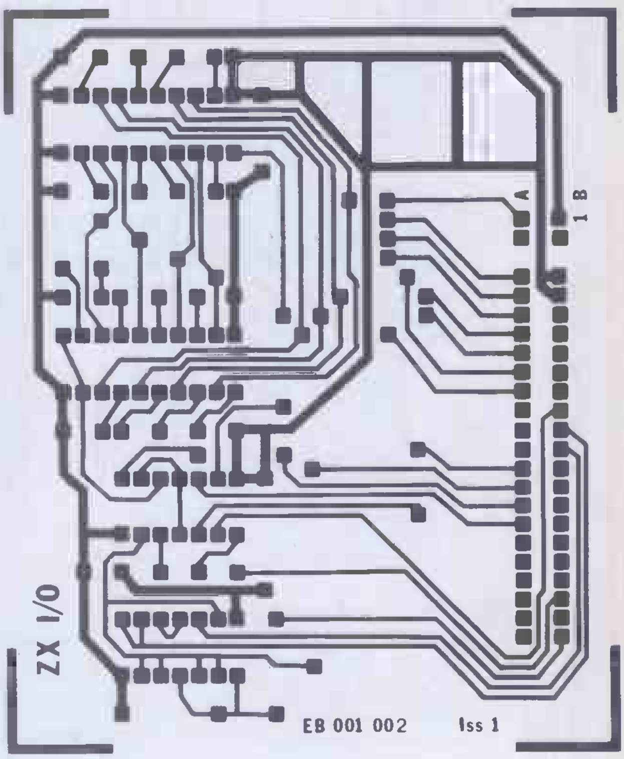


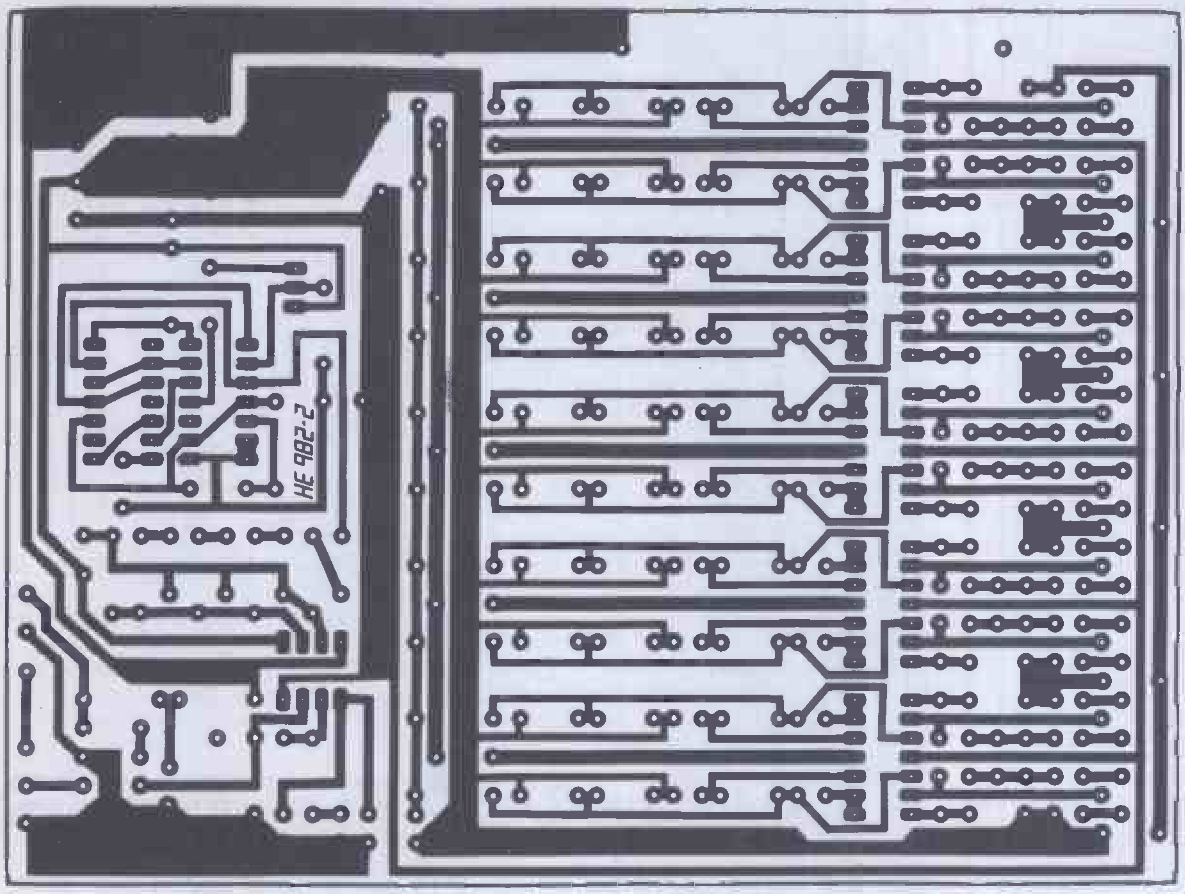


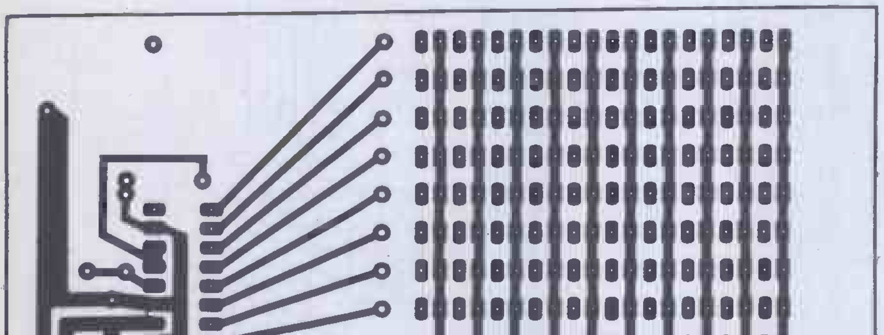
Above: The PCB pattern for the 'Junior' Slot Car and (below) the foilside pattern for the ZX PCB.



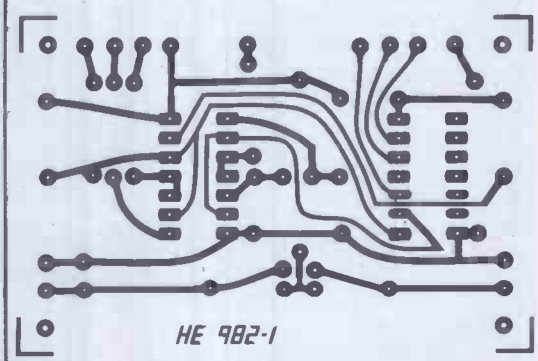
Computer PSU

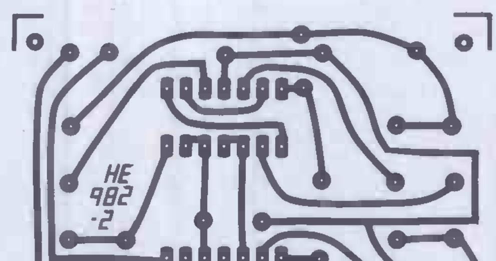
We apologise to all those readers who attempted to build the Computer PSU featured in the July issue. As you probably realised, the PCB pattern was shown half size but we omitted to say this in the caption – sorry! The full size foil pattern is shown on the left.





The two PCB foil patterns for the Audio Analyser. The display board (left) is fixed on top of the filtèr board (above).





Above: The two foil patterns for the Signal Lights; uppermost is the signal module and below that the junction module board.

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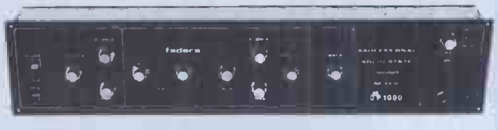

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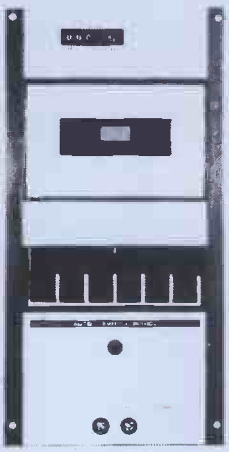

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8" 50 watt R.M.S. Impedance 8 ohms, 20 oz. 1½" aluminium voice coil, Resonant Frequency 40Hz, Frequency Response to 6KHz, Sensitivity 92dB. Also available with black cone fitted with black metal protective grill. **Price: White cone £8.90 each. Black cone/grill £9.50 each.** P & P £1.25 each.

OMP POWER AMPLIFIER MODULES

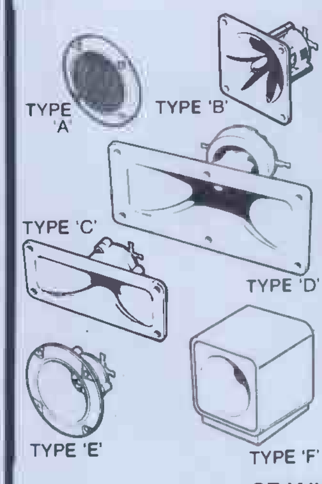
100 WATT R.M.S. AND 300 WATT R.M.S. MODULES

Power Amplifier Modules with integral toroidal transformer power supply, and heat sink. Supplied as one complete built and tested unit. Can be fitted in minutes. An LED Vu meter is available as an optional extra.

SPECIFICATION:
Max Output Power: 110 watts R.M.S. (OMP 100)
310 watts R.M.S. (OMP 300)
Loads: Open and short circuit proof. 4-16 ohms.
Frequency Response: 20Hz – 25KHz ±3dB.
Sensitivity for Max. Output:
500mV at 10K (OMP 100) 1V at 10K (OMP 300)
T.H.D.: Less than 0.1%
Supply: 240V 50Hz
Sizes: OMP 100 360 x 115 x 72mm
OMP 300 460 x 153 x 66mm
Prices: OMP 100 £29.99 each + £2.00 P&P
OMP 300 £89.00 each + £3.00 P&P
Vu Meter £6.50 each + 50p P&P

PIEZO ELECTRIC TWEETERS – MOTOROLA

Join the Piezo revolution. The low dynamic mass (no voice coil) of a Piezo tweeter produces an improved transient response with a lower distortion level than ordinary dynamic tweeters. As a crossover is not required these units can be added to existing speaker systems of up to 100 watts (more if 2 put in series). **FREE EXPLANATORY LEAFLETS SUPPLIED WITH EACH TWEETER.**



TYPE 'A' (KSN2036A) 3" round with protective wire mesh, ideal for bookshelf and medium sized Hi-fi speakers. **Price £3.45 each.**

TYPE 'B' (KSN1005A) 3½" super horn. For general purpose speakers, disco and P.A. systems etc. **Price £4.35 each.**

TYPE 'C' (KSN6016A) 2" x 5" wide dispersion horn. For quality Hi-fi systems and quality discos etc. **Price £5.45 each.**

TYPE 'D' (KSN1025A) 2" x 6" wide dispersion horn. Upper frequency response retained extending down to mid range (2KHz). Suitable for high quality Hi-fi systems and quality discos. **Price £6.90 each.**

TYPE 'E' (KSN1038A) 3¾" horn tweeter with attractive silver finish trim. Suitable for Hi-fi monitor systems etc. **Price £4.35 each.**

TYPE 'F' (KSN1057A) Cased version of type 'E'. Free standing satellite tweeter. Perfect add on tweeter for conventional loudspeaker systems. **Price £10.75 each.**
U.K. post free (or SAE for Piezo leaflets).

Matching 3-way loudspeakers and crossover

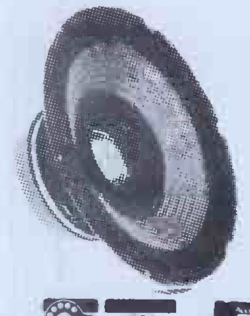
Build a quality 60watt RMS system 8ohms

Build a quality 60 watt R.M.S. system.

★ 10" Woofer 35Hz-4.5KHz
★ 3" Tweeter 2.5KHz-19KHz
★ 5" Mid Range 600Hz-8KHz
★ 3-way crossover 6dB/oct 1.3 and 6KHz
Recommended Cab-size 26" x 13" x 13"

Fitted with attractive cast aluminium fixing escutcheons and mesh protective grills which are removable enabling a unique choice of cabinet styling. Can be mounted directly on to baffle with or without conventional speaker fabrics. All three units have aluminium centre domes and rolled foam surround. Crossover combines spring-loaded loudspeaker terminals and recessed mounting panel.
Price £22.00 per kit + £2.50 postage and packing. Available separately, prices on request.

12" 80 watt R.M.S. loudspeaker.
A superb general purpose twin cone loudspeaker. 50 oz. magnet. 2" aluminium voice coil. Rolled surround. Resonant frequency 25Hz. Frequency response to 13KHz. Sensitivity 95dB. Impedance 8ohm. **Attractive blue cone with aluminium centre dome.**
Price £17.99 each + £2.50 P&P.



B.K. ELECTRONICS

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