EVERYDAY ELECTRONICS

APRIL 1987

INCORPORATING ELECTRONICS MONTHLY

£1·20

FREE 16 PAGE BOOKLET INSIDE
GUIDE TO PRINTED CIRCUIT BOARDS
Design · Layout · Construction

EXPERIMENTAL SPEECH RECOGNITION UNIT

BULB LIFE EXTENDER

CURRENT TRACER

The Magazine for Electronic & Computer Projects

£1 BAKERS DOZEN PACKS

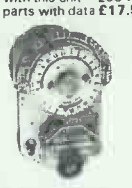
Price per pack is **£1.00.*** Order 12 you may choose another free. Items marked (sh) are not new but guaranteed ok.

1. 5 – 13 amp ring main junction boxes
2. 5 – 13 amp ring main spur boxes
4. 5 – surface mounting
5. 3 – electrical switches, white flush mounting
7. 4 – in flex line switches with neons
9. 2 – mains transformers with 6V 1A secondaries
10. 2 – mains transformers with 12V $\frac{1}{2}$A secondaries
11. 1 – extension speaker cabinet for $6\frac{1}{2}$" speaker
13. 12 – glass reed switches
17. 2 – ultrasonic transmitters and 2 receivers with circuit
19. 2 – light dependent resistors
25. 4 – wafer switches – 6p 2 way, 4p 3 way, 2p 6 way, 2p 5 way, 1p 12 way small one hold fixing and good length $\frac{1}{4}$ spindle your choice
28. 1 – 6 digit counter mains voltage
30. 2 – Nicad battery chargers
31. 1 – key switch with key
33. 2 – aerosol cans of ICI Dry Lubricant
34. 96 – 1 metre lengths colour-coded connecting wire
39. 1 – long and medium wave tuner kit
41. 8 – rocker switch 10 amp mains SPST
45. 1 – 24 hour time switch mains operated (s.h.)
49. 10 – neon valves – make good night lights
50. 2 – 12V DC or 24V AC, 3 CO relays
51. 1 – 12V 2 CO miniature relay very sensitive
52. 1 – 12V 4 CO miniature relay
54. 10 – rows of 32 gold plated IC sockets (total 320 sockets)
55. 1 – locking mechanism with 2 keys
56. 1 – miniature uniselector with circuit for electric jigsaw puzzle
60. 5 – ferrite rods 4" × 5/16" diameter aerials
61. 4 – ferrite slab aerials with L & M wave coils
63. 1 – Mullard thyristor trigger module
66. 1 – magnetic brake – stops rotation instantly
67. 1 – low pressure 3 level switch can be mouth operated
69. 2 – 25 watt pots 8 ohm
70. 2 – 25 watt pots 1000 ohm
71. 4 – wire wound pots – 18, 33, 50 and 100 ohm your choice
77. 1 – time reminder adjustable 1-60 mins clockwork
85. 1 – mains shaded pole motor $\frac{3}{4}$" stack – $\frac{1}{4}$ shaft
89. 1 – mains motor with gear box 1 rev per 24 hours
91. 2 – mains motors with gear box 16 rpm
96. 1 – thermostat for fridge
98. 1 – motorised stud switch (s.h.)
101. 1 – $2\frac{1}{2}$ hours delay switch
103. 1 – mains power supply unit – 6V DC
104. 1 – mains power supply unit – $4\frac{1}{2}$V DC
107. 1 – 5" speaker size radio cabinet with handle
112. 1 – heating pad 200 watts mains
114. 1 – 1W amplifier Mullard 1172
115. 1 – wall mounting thermostat 24V
118. 1 – teak effect extension 5" speaker cabinet
120. 2 – p.c. boards with 2 amp full wave and 17 other recs
121. 4 – push push switches for table lamps etc.
122. 10 – mtrs twin screened flex white p.v.c. outer
124. 25 – clear plastic lenses $1\frac{3}{4}$ diameter
127. 4 – pilot bulb lamp metal clip on type
128. 10 – very fine drills for pcbs etc.
129. 4 – extra thin screw drivers for instruments
132. 2 – plastic boxes with windows, ideal for interrupted beam switch
134. 10 – model aircraft motor – require no on/off switch, just spin to start
137. 1 – $6\frac{1}{2}$" 4 ohm 10 watt speaker
142. 10 – 4 8A spanners 1 end open, other end closed
145. 2 – 4 reed relay kits 3V coil normally open or c/o if magnets added
146. 20 – pilot bulbs 6.5V.3A Philips
154. 1 – 12V drip proof relay – ideal for car jobs
155. 3 – varicap push button tuners with knobs
169. 4 – short wave air spaced trimmers 2-30f
172. 10 – 12V 6W bulbs Philips m.e.s.
178. 3 – oblong amber indicators with lilliputs 12V
180. 6 – round amber indicators with neons 240V
181. 100 – p.v.c. grommets $\frac{3}{8}$ hole size
182. 1 – short wave tuning condenser 50 pf with $\frac{1}{4}$" spindle
184. 1 – three gang tuning condenser each section 500 pf with trimmers and good length $\frac{1}{4}$" spindle
188. 1 – plastic box sloping metal front, 16 × 95mm average depth 45mm
193. 6 – 5 amp 3 pin flush sockets brown
195. 5 – B.C. lampholders brown bakelite threaded entry
196. 1 – in flex simmerstat for electric blanket soldering iron etc.
197. 2 – thermostats, spindle setting – adjustable range for ovens etc.
199. 1 – mains operated solenoid with plunger 1" travel
200. 1 – 10 digit switch pad for telephones etc.
201. 8 – computer keyboard switches with knobs, pcb or vero mounting
206. 20 – mtres 80 ohm, standard type co-ax off white
211. 1 – electric clock mains driven, always right time – not cased
216. 1 – stereo pre-amp Mullard EP9001
232. 2 – 12V solenoids, small with plunger
236. 1 – mains transformer 9V 1 amp secondary C core construction
241. 1 – car door speaker (very flat) $6\frac{1}{2}$" 15 ohm made for Radiomobile
241. 2 – speakers 6" × 4" 4 ohm 5 watt made for Radiomobile
243. 2 – speakers 6" × 4" 16 ohm 5 watt made for Radiomobile
244. 1 – mains motor with gear-box very small, toothed output 1 rpm
245. 4 – standard size pots, $\frac{1}{2}$ meg with dp switch
249. 1 – 13A switched socket on double plate with fused spur
266. 2 – mains transformers 9V $\frac{1}{2}$A secondary
267. 1 – mains transformers 15V 1A secondary p.c.b. mounting
291. 1 ten turns 3 watt pot $\frac{1}{4}$ spindle 100 ohm
296. 3 car cigar lighter socket plugs
298. 2 15 amp round pin plugs brown bakelite
300. 1 mains solenoid with plunger compact type
301. 10 ceramic magnets Mullard 1" × 3/8 × 5/16
303. 1 12 pole 3 way ceramic wave charge switch
305. 1 tubular dynamic microphone with desk rest
308. 1 T.V. turret tuner (black & white T.V.)
310. 2 oven thermostats
313. 5 sub miniature micro switches
314. 1 12" 8 watt min fluorescent tube white
315. 1 6" 4 watt min fluorescent tube white
316. 1 round pin kettle plug with moulded on lead
453. 2 – $2\frac{1}{4}$in. 80ohm loudspeakers
454. 2 – $2\frac{1}{4}$in. 8ohm loudspeakers

FROZEN PIPES Can be avoided by winding our heating cable around them, 15 mtrs connected to mains cost only about 10p per week to run. Hundreds of other uses as it is waterproof and very flexible. Resistance 60ohms/metre. Price 28p/metre or 15m for £3.95.

CAR STARTER/CHARGER KIT

Flat Battery! Don't worry you will start your car in a few minutes with this unit – 250 watt transformer 20 amp rectifiers, case and all parts with data **£17.50** post £2.

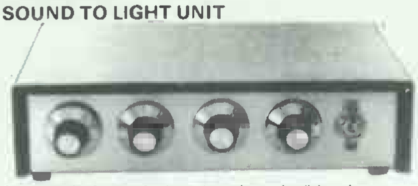


Ex-Electricity Board. Guaranteed 12 months.

VENNER TIME SWITCH

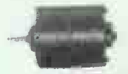
Mains operated with 20 amp switch, one on and one off per 24 hrs. repeats daily automatically correcting for the lengthening or shortening day. An expensive time switch but you can have it for only **£2.95** without case, metal case – **£2.95**, adaptor kit to convert this into a normal 24hr. time switch but with the added advantage of up to 12 on/offs per 24hrs. This makes an ideal controller for the immersion heater. Price of adaptor kit is **£2.30.**

SOUND TO LIGHT UNIT



Complete kit of parts of a three channel sound to light unit controlling over 2000 watts of lighting. Use this at home if you wish but it is plenty rugged enough for disco work. The unit is housed in an attractive two tone metal case and has controls for each channel, and a master on/off. The audio input and output are by $\frac{1}{4}$" sockets and three panel mounting fuse holders provide thyristor protection. A four pin plug and socket facilitate ease of connecting lamps. Special price is **£14.95** in kit form.

12 volt MOTOR BY SMITHS



Made for use in cars, etc. these are very powerful and easily reversible. Size $3\frac{1}{2}$" long by 3" dia. They have a good length of $\frac{1}{4}$" spindle –
1/10 hp **£3.45**
1/8 hp **£5.75.** 1/6 hp **£7.50**

25A ELECTRICAL PROGRAMMER

Learn in your sleep. Have radio playing and kettle boiling as you wake – switch on lights to ward off intruders – have a warm house to come home to. You can do all these and more. By a famous maker with 25 amp on/off switch. A beautiful unit at **£2.50**

THIS MONTH'S SNIP

BENCH ISOLATION TRANSFORMER. Torroidal wound 400 watt but very compact. Has a separate 10V winding which can be added or subtracted to give fine voltage control. Normally £40, our price £10 plus £2 post, ref 10P9.

TANGENTIAL BLOWER HEATERS

We can supply:

1·2KW—quite definitely the smallest tangential blow heater we have ever had, measuring approx. 6 × 6 × 4. This could be just the thing for a small bedroom or to fit under desk or table if you suffer from cold legs. In addition to normal heating functions if put into a simple enclosure this could be a pipe unfreezer (much safer than a blow lamp) possibly even a paint stripper, hair dryer or hand dryer. Price is £5, plus £1 post, ref 5P23.

2·5KW—width approx. 8" (plus motor), elements made up of two 1·2kw sections, so with switch supplied you can have 2kw, 1kw or cold blow. Over heat cut-out eleminates fire risk should fan stop or air flow be impeded. Fan blades are metal. Price £5 plus £1.50 post, ref 5P62.

3KW—width approx. 13" plus motor, element made up of 1kw and 2kw section, supplied with 4 section rocker switch, allowing 3kw, 2kw, 1kw and cold blow. Price £6.95 plus £2.00 post.

2KW D.I.Y. SPECIAL—if you want a really cheap tangential heater, this is your opportunity, made for 115v mains, to use it on 230v. Simply join elements in series, needs only simple on/off switch, as you will only have one heat level 2kw and no cold blow. Price £2 plus £1 post, ref 2P66.

VERY LOW RUNNING COST—only a 300w element. So would cost only approx. $1\frac{1}{2}$p per hour to run. Should be enough for an airing cupboard or a hot box for seed germination. Might even be enough to keep a damp corner dry. Normal construction approx. $4\frac{1}{2}$" plus motor wide. Price £5 plus £1 post, ref 5P78.

500W–115V TRANSFORMER to isolate you or yours from mains to earth shock dangers. We are able to offer these transformers at less than the price of an auto transformer. Our price for the 500w mains to 115v isolation transformer is £10 plus £5 post, ref 10P6.

RESIN CURED FILLER/BUILDER/STICKER made by the famous Holts company, suitable for repairs, not only to car bodies but also to sinks and wash basins, water tanks, drain pipes and gutters, tiles, roofs, filling holes in walls and concrete, repairing cracks in gates, window frames, etc. etc. It is weather resistant and adheres well to metals, wood, concrete and some plastics. Special bargain price 2 large tubes for £1, ref B0464.

STEPPER MOTOR. By American Phillips corporation. Step angle 7·5'. Coil resistance 27 ohms. Operating volts 10–14. Size approx. $2\frac{1}{4}$" dia by $1\frac{3}{4}$" deep on a square mounting plate. This is in fact two bi-directional motors with P.M. rotors. Applying correct pulse causes a 7·5' step angle of spindle. Number of steps through which it rotates and a speed at which it rotates is determined by the applied impulses. Properly used this provides an ideal method of speed and position control. Brand new and unused price £5, ref 5P81.

BIG GLASS FIBRE SHEETS. Virtually unbreakable, size 4' × 3' approx. Flat, approx 1/16" thick. Intended for pcb's but ideal for roof repairs, car port, greenhouse etc. £2 each. Minimum quantity we can despatch is 10. Carriage cost £6.50 per 10. £8.50 for 15.

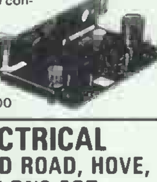
IONISER KIT

Refresh your home, office, shop, work room, etc. with a negative ION generator. Makes you feel better and work harder – a complete mains operated kit, case included. **£11.95** plus £2.00 post.

TELEPHONE BITS

Master socket (has surge arrestor – ringing condenser etc) and takes B.T. plug	**£3.95**
Extension socket	**£2.95**
Dual adaptors (2 from one socket)	**£3.95**
Cord terminating with B.T. plug 3 metres	**£2.95**
Kit for converting old entry terminal box to new B.T. master socket, complete with 4 core cable, cable clips and 2 BT extension sockets	**£11.50**
100 mtrs 4 core telephone cable	**£8.50**

MINI MONO AMP on p.c.b. size 4" × 2" (app.)



Fitted volume control and a hole for a tone control should you require it. The amplifier has three transistors and we estimate the output to be **3W rms.** More technical data will be included with the amp. Brand new, perfect condition, offered at the very low price of **£1.15** each, or 13 for **£12.00**

J & N BULL ELECTRICAL

Dept. E.E., 250 PORTLAND ROAD, HOVE, BRIGHTON, SUSSEX BN3 5QT

MAIL ORDER TERMS: Cash, P.O. or cheque with order. Orders under £20 add £1 service charge. Monthly account orders accepted from schools and public companies. Access & B/card orders accepted. Brighton 0273 734648. Bulk orders: write for quote.

£2 POUNDERS*

- 2P2 – Wall mounting thermostat, high precision with mercury switch and thermometer
- 2P3 – Variable and reversible 8-12v psu for model control
- 2P4 – 24 volt psu with separate channels for stereo made for Mullard UNILEX
- 2P6 – 100W mains to 115V auto-transformer with voltage tappings
- 2P8 – Mains motor with gear box and variable speed selector. Series wound so suitable for further speed control
- 2P9 – Time and set switch. Boxed, glass fronted and with knobs. Controls up to 15 amps. Ideal to program electric heaters
- 2P10 – 12 volt 5 amp mains transformer
- 2P12 – Disk or Tape precision motor – has balanced rotor and is reversible 230v mains operated 1500 rpm
- 2P14 – Mug Stop kit – when thrown emits piercing squawk
- 2P15 – Interrupted Beam kit for burglar alarms, counters, etc.
- 2P17 – 2 rev pr minute mains driven motor, Ideal to operate mirror ball
- 2P18 – Liquid/gas shut off valve mains solenoid operated
- 2P19 – Disco switch-motor drives 6 or more 10 amp change over micro switches supplied ready for mains operation
- 2P20 – 20 metres extension lead, 2 core – ideal most Black and Decker garden tools etc.
- 2P21 – 10 watt amplifier, Mullard module reference 1173
- 2P22 – Motor driven switch 20 secs on or off after push
- 2P26 – Counter resettable mains operated 3 digit
- 2P27 – Goodmans Speaker 6 inch round 8ohm 12 watt
- 2P28 – Drill Pump – always useful couples to any make portable drill
- 2P31 – 4 metres 98 way interconnecting wire easy to strip
- 2P32 – Hot Wire amp meter – $4\frac{1}{2}$ round surface mounting 0-10A – old but working and definitely a bit of history
- 2P34 – Solenoid Air Valve mains operated
- 2P38 – 200 R.P.M. Geared Mains Motor 1" stack quite powerful, definitely large enough to drive a rotating aerial or a tumbler for polishing stones etc.
- 2P43 – Small type blower or extractor fan, motor inset so very compact, 230V
- 2P46 – Our famous drill control kit complete and with prepared case.
- 2P49 – Fire Alarm break glass switch in heavy cast case
- 2P51 – Stereo amplifier, 3w per channel
- 2P55 – Mains motor, extra powerful has $1\frac{1}{2}$" stack and good length of spindle
- 2P62 – 1 pair Goodmans 15 ohm speakers for Unilox
- 2P64 – 1 five bladed fan $6\frac{1}{2}$" with mains motor
- 2P66 – 1 2Kw tangential heater 115v easily convertible for 230V
- 2P67 – 1 12v-0-12v 2 amp mains transformer
- 2P68 – 1 15v-0-15v 2 amp mains transformer
- 2P69 – 1 250v-0-250v 60 mA & 86.3v 5A mains transformer + 50p post
- 2P70 – 1 E.M.I. tape motor two speed and reversible
- 2P72 – 1 115v Muffin fan 4" × 4" approx. (s.h.)
- 2P75 – 1 2 hour timer, plugs into 13A socket
- 2P82 – 9v-0-9v 2 amp mains transformer
- 2P84 – Modem board with press keys for telephone redialler
- 2P85 – 20v-0-20v $\frac{1}{2}$A Mains transformer
- 2P88 – Sangamo 24 hr time switch 20 amp (s.h.)
- 2P89 – 120 min. time switch with knob
- 2P90 – 90 min. time switch with edgewise engraved controller
- 2P94 – Telephone handset for EE home telephone circuit
- 2P95 – 13A socket on satin chrome plate
- 2P97 – mains transformer 24V 2A upright mounting
- 2P98 – 20m 4 core telephone cable, white outer
- 2P99 – 500 hardened pin type staples for telephone cable
- 2P101 – 15V mains transformer 4A upright mounting
- 2P105 – capillary type thermostat for air temperature with c/o switch
- 2P108 – mains motor with gear box giving 110rpm
- 2P109 – 5" wide black adhesive pvc tape 33m, add £1 post if not collecting

OVER 400 GIFTS YOU CAN CHOOSE FROM

There is a total of over 400 packs in our Baker's dozen range and you become entitled to a free gift with each dozen pounds you spend on these packs.

A classified list of these packs and our latest "News Letter" will be enclosed with your goods, and you will automatically receive our next news letters.

£5 POUNDERS*

- 5P1 12 volt submersible pump complete with a tap and switch, an ideal caravan unit.
- 5P2 Sound to light kit complete in case suitable for up to 750 watts.
- 5P3 Silent sentinel ultra sonic transmitter and receive kit, complete.
- 5P6 12V alarm bell with heavy 6" gong, suitable for outside if protected from direct rainfall. Ex GPO but in perfect order.
- 5P12 Equipment cooling fan – mini snail type mains operated.
- 5P13 Ping pong ball blower – or for any job that requires a powerful stream of air – ex computer. Collect or add £2 post.
- 5P15 – Uniselector 4 pole, 25 way 50 volt coil
- 5P18 – motor driven water pump as fitted to many washing machines
- 5P20 – 2 kits, matchbox size, surveillance transmitter and FM receiver
- 5P23 – miniature (appr. $2\frac{1}{2}$" wide) tangential blow heater, 1·2kw
- 5P24 – $\frac{1}{6}$hp motor, ex computer, 230V, mains operation 1450rpm. If not collect add £3 post
- 5P25 – special effects lighting switch. Up to 6 channels of lamps can be on or off for varying time periods
- 5P27 – cartridge player 12V, has high quality stereo amplifier
- 5P28 – gear pump, mains motor driven with inlet and outlet pipe connectors
- 5P32 – large mains operated push or pull solenoid. Heavy so add £1.50 post
- 5P34 – 24V 5A toroidal mains transformer
- 5P35 – modem board from telephone auto dialler, complete with keypad and all ICs
- 5P37 – 24 hour time switch, 2 on/offs and clockwork reserve, ex Elec. Board loading up to 50A. Add £1 post
- 5P41 – 5" extractor fan, very quiet runner (s.h.), gntd 12 mths.
- 5P48 – telephone extension bell in black case, ex-GPO
- 5P51 – 200W auto transformer 230V to 115V torroidal
- 5P52 – mains transformer 26V 10A upright mounting, add £2 post
- 5P54 – mains motor with gear box, final speed 5rpm
- 5P58 – Amstrad stereo tuner FM and LM and S. AM
- 5P60 – DC Muffin type fan 18 to 27V, only 3W
- 5P61 – drill pump mounted on frame, coupled to mains motor
- 5P62 – $2\frac{1}{2}$kw tangential blow heater, add £1.50 post if not collecting
- 5P73C high pressure mains operated gas or water valve with tube connection suitable soldering
- 5P74 6rpm 60W mains motor and gearbox with instant stop
- 5P79 30rpm 80 watt mains driven motor with gearbox
- 5P82 1 25rpm mains 60w motor with gearbox
- 5P84 1 delay time switch, adjust 0-20 seconds
- 7P1 1 instant heat solder gun—mains with renewable tip and job light
- 10P10 1 9" extractor fan 115V so supplied with adaptor

LIGHT CHASER KIT motor driven switch bank with connection diagram, used in connection with 4 sets of xmas lights makes a very eye catching display for home, shop or disco, only £5 ref 5P56.

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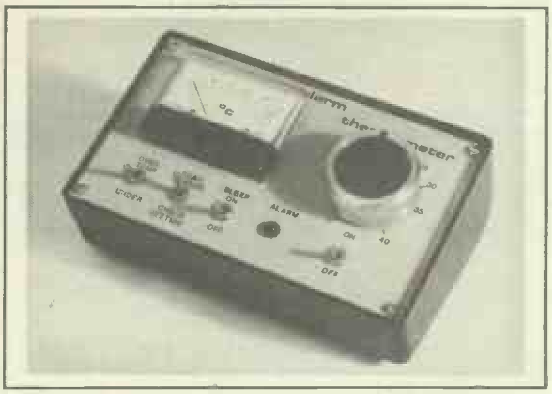
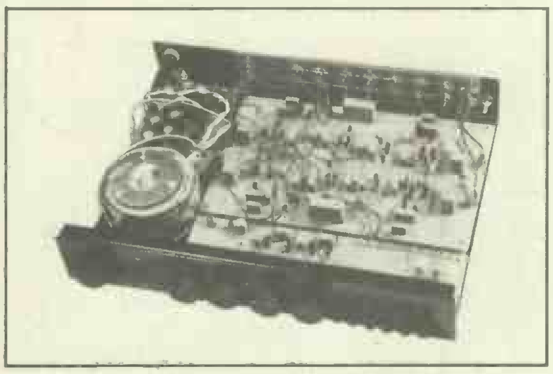
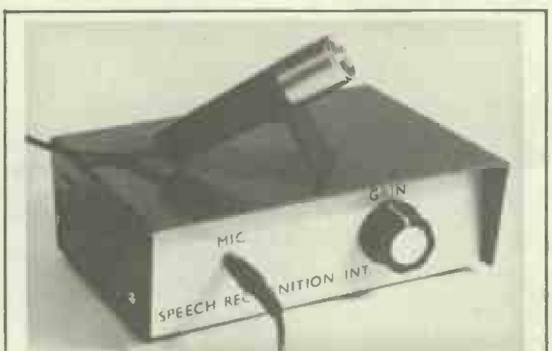
PROJECTS . . . THEORY . . . NEWS . . .
COMMENT . . . POPULAR FEATURES . . .







Projects

Series

Features

Our May 1987 issue will be published on Thursday, 16 April 1987. See page 223 for details.

BI-PAK BARGAINS

RESISTORS

Pak No	Qty	Description	Price
VP1	300	Assorted Resistors mixed values & types	£1.00
VP2	300	Carbon Resistors $^1/_4$–$^1/_2$ watt pre-formed, mixed	£1.00
VP3	200	1/8 watt Min. Carbon Resistors mixed values	£1.00
VP4	200	$^1/_2$–1 watt Resistors mixed values & types	£1.00
VP16	50	Wirewound Resistors mixed watt values	£1.00
VP112	1	Sub Resistance Box. 36 values 5ohms – 1Kohm	£4.75
VP140	50	Precision Resistors 1% Tol.	£1.00
VP181	100	1 and 2 watt Resistors, assorted values	£1.00

CAPACITORS

VP5	200	Assorted Capacitors, all types	£1.00
VP6	200	Ceramic Capacitors Min. mixed values	£1.00
VP8	100	Mixed Ceramic Disc 68pf–.015pf	£1.00
VP9	100	Assorted Polyester/Polystyrene Capacitors	£1.00
VP10	60	C280 Capacitors. Metal foil, mixed values	£1.00
VP11	50	Electrolytics, all sorts	£1.00
VP12	40	Electrolytics 47mf–150mf mixed volts	£1.00
VP13	30	Electrolytics, 150mf–1000mf mixed volts	£1.00
VP15	25	.01/250V Min Layer Metal Caps	£1.00
VP148	25	Solid Tantalum Caps mixed values	£1.00
VP180	25	Tantalum Bead Caps. assorted values	£1.00
VP182	4	1000uf 50v Electrolytics	£1.00
VP192	30	Min. Electrolytics mixed values .47mf–1000mf 6–16v	£1.00
VP193	6	Sub Min. Electrolytics 2x1000/2200/3300mf 10–16v	£1.00

OPTOS

VP24	10	.125" Clear Showing red LED's	£1.00
VP25	10	Mixed shape and colours LED's	£1.00
VP26	15	Small .125" red LED's	£1.00
VP27	15	Large .2" red LED's	£1.00
VP28	10	Rectangular .2" red LED's	£1.00
VP57	25	Opto Special Pack Assorted. Super value	£5.00
VP130	6	RED 7 Seg CC 14mm x 7.5mm RDP FND353 LED Display	£2.00
VP131	4	GREEN 7 Seg CA .6" LDP XAN6520 LED Display	£2.00
VP132	5	RED 7 Seg CC .6" LDP XAN6940 LED Display	£2.00
VP133	6	RED Overflow .6" 3 x CA 3 x CC 6630/50 LED Display	£2.00
VP134	5	GREEN Overflow .6" CA XAN6530 LED Display	£2.00
VP137	3	DUAL RED 7 Seg .51" CA DL727 DPR LED Display	£2.00
VP138	20	Assorted LED Displays – Our mix, with data	£5.00
VP147	1	Pair Opto Coupled Modules	£0.60
VP199	4	DL707R LED Displays CA	£1.00
VP203	15	Triangular shape LED's. Mixed colours	£1.00
VP204	10	Large Green LED's, 5mm	£1.00
VP205	10	Small Green LED's, 3mm	£1.00
VP206	10	Large Yellow LED's, 5mm	£1.00
VP207	10	Small Yellow LED's, 3mm	£1.00
VP208	10	Large LED's Clear showing red .2"	£1.00

DIODES & SCRS.

VP29	30	Assorted volts Zeners 50mw–2w	£1.00
VP30	10	Assorted volts Zeners 10w, coded	£1.00
VP31	10	5a SCR's T066 50–400v, coded	£1.00
VP32	20	3a SCR's T066 up to 400v, uncoded	£1.00
VP33	200	Sil. Diodes like IN4148	£1.00
VP34	200	Sil. Diodes like OA200/BAX13–16	£1.00
VP35	50	1a IN4000 Diodes, all good, uncoded	£1.00
VP49	30	Assorted Sil. Rects. 1a–10a, mixed volts	£1.00
VP141	40	IN4002 Sil. Rects. 1a 100v preformed pitch	£1.00
VP142	4	40a Power Rectifiers, silicon, T048 300PIV	£1.00
VP143	5	BY187 12kV Sil. Diodes in carriers, 2.5mA	£1.00
VP184	3	4a 400v Triacs, plastic	£1.00
VP187	10	SCR's 800MA 200v 2N5064, plastic, T092	£1.00
VP194	50	OA91 point contact Germ Diodes, uncoded	£1.00
VP195	50	OA47 gold bonded Ger. Diodes, uncoded	£1.00
VP196	50	OA70–79 detector Diodes, Germ	£1.00
VP197	50	OA90 type Germ. Diodes, uncoded	£1.00
VP198	40	BA248 Sil Diodes, 350v 2a, fast recovery	£1.00
VP222	20	3a Stud Rectifiers, 50–400v	£1.00

TRANSISTORS

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VP162	5	SJE5451 Sil. Power Trans, NPN 80v 4A Hfe20+	£1.00
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VP164	4	2N6289 Sil. Power Trans. NPN 40v 40w 7A Hfe30+	£1.00
VP170	10	Assorted Power Trans. NPN/PNP coded & data	£1.00
VP171	10	BF355 NPN TO-39 Sil. Trans eqvt. BF258 225v 100mA	£1.00
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VP200	30	OC71 type Germ. AF Transistors, uncoded	£1.00
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VP139	1	Pick-Up Tool, spring loaded	£1.75
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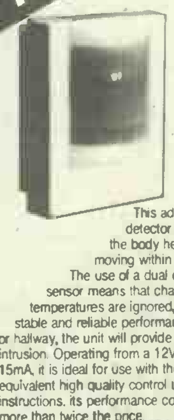

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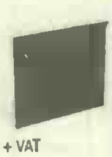

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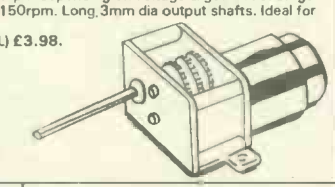

1987 CATALOGUE

Brief details of each kit, our books, & illustrations of our range of tools & components. Also stepper motor, interface kit & simple robotics. Plus circuit ideas for you to build. If you read Everyday Electronics then you need a copy of the MAGENTA catalogue.

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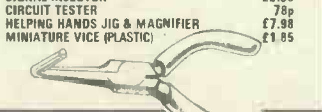

EVERYDAY ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

The Magazine for Electronic & Computer Projects

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EXPERIMENTING

PERHAPS one of the most fascinating aspects of electronics is the ability to experiment. I am sure many readers have enjoyed playing around with various types of electronic equipment just to see what can be achieved. A simple cassette or reel to reel tape recorder can provide hours of fun experimenting with various sounds, etc. Sound is, perhaps, the easiest and most rewarding medium with which to experiment—there is, of course, no need to interpret the results, the brain does that automatically for us. Sound can be anything from complex music to weird noises or just continuous tones, etc.

This month we take the ability to experiment with sound a step further. In effect we have turned the experiments upside down—the noises are now made by humans and the electronics, a computer, interprets them. In this case must of the experimental work is in the form of software development. The article *Experimental Speech Recognition Unit* should open up a whole new world of sound experimenting.

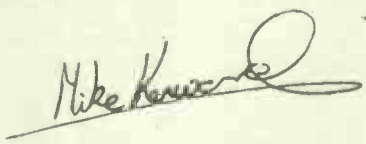
BOOKLET

Our second free 16-page booklet presented with this issue *(Guide to Project Building* was given away last month) should fulfil a need for many readers. We are often asked how to design and make your own p.c.b.s. and this booklet explains it all. The project example used in the booklet also happens to be a simple siren effects units—yet another sound design to experiment with.

Just in case you do not want to make your own p.c.b. one is available for the unit—see *Shop Talk*. So even if all that data on p.c.b.s. is of little interest to you, the booklet could still be used to build the project, then it's up to you to experiment and produce "Star Wars" lasers, police sirens, machine guns, etc.

COVER

In view of the above, I think you will agree that this month's cover design is particularly appropriate. The background is not our usual computer graphic but an unusual, you could say "experimental", photograph based on ribbon cable and a human head. Quite a dramatic cover and very appropriate to experiments with speech recognition and sound generation.



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Certain back issues of EVERYDAY ELECTRONICS and ELECTRONICS MONTHLY are available price £1.50 (£2.00 overseas surface mail) inclusive of postage and packing per copy. Enquiries with remittance, made payable to Everyday Electronics, should be sent to Post Sales Department, Everyday Electronics, 6 Church Street, Wimborne, Dorset BH21 1JH. In the event of non-availability remittances will be returned. *Please allow 28 days for delivery.* **(We have sold out of Oct. and Nov. 85, April and May 86.)**

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All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

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We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

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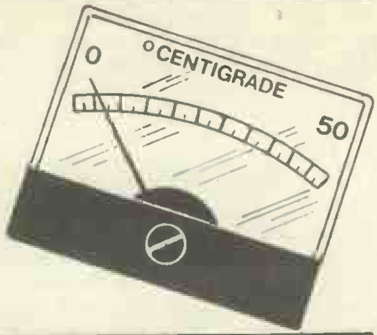
ALARM THERMOMETER



P. W. BOND

Don't be frozen out! Beat hypothermia with this simple alarm.

ORIGINALLY, this project was developed as part of an electronic weather station—giving a direct reading of the atmospheric temperature on a meter. But obviously, the applications for such a device are numerous and no doubt, readers will be able to think of yet more applications in their particular field of interest.

TEMPERATURE SENSOR

The basis for the unit was the specification described for the LM35DZ i.c. which is advertised as a "precision centigrade temperature sensor". Well, the terminology may be a little out of date. (Celsius is the recognised term for the temperature scale), but thankfully the technology is not.

The LM35DZ is the cheaper version of a family of Celsius temperature sensors giving an output voltage which is linearly proportional to the temperature in Celsius on the basis of 10mV per degree Celsius. The device used here, the LM35DZ, has an effective range of 2 to 110 degrees C.

The LM35DZ appears to look no different from a plastic small signal transistor, having only three terminals. Functionally, it is very different. Within the i.c., the small current changes in a semiconductor, which are due to changes in temperature, are converted into a voltage which is directly related to the package temperature, and with an accuracy of just over 0·5 degrees C at 25°C.

The beauty of this i.c. is that, unlike thermistor based circuitry, the appropriate characteristic correction is contained within the i.c. so there's no awkward calibration tweeks and fiddles! All that's required to operate the i.c. is a supply of 4V to 20V d.c. and a measuring instrument such as a high resistance meter, a Digital Voltmeter, or as is quite feasible, the analogue interface to a computer.

The basic thermometer circuit, and a graph of how the output voltage varies with temperature, is shown in Fig. 1.

HOW IT WORKS

Although the basic circuit of Fig. 1 is very easy to construct and takes about 60μA from the supply, the addition of a few extra components can lead to a very useful unit being produced. It is not too difficult to produce a detector circuit which will actually sound an alarm when the sensor temperature has exceeded, or fallen below, a pre-set limit.

The complete circuit diagram of the Alarm Thermometer is shown in Fig. 2. As we have shown, the sensor i.c. produces an output which will vary between 0V and 1·1V in accordance with it's temperature. But for general applications, e.g. ambient temperature sensing, a range of 0 to 50°C is adequate (i.e. 0V to 0·5V).

The alarm level detection is effected by means of a comparator, IC2, which compares the output of the sensor i.c. with the voltage produced by the alarm setting control. To simplify the circuit, the alarm "reference" voltage is adjustable from 0V to 0·5V which, of course, corresponds to the range of temperature we are interested in.

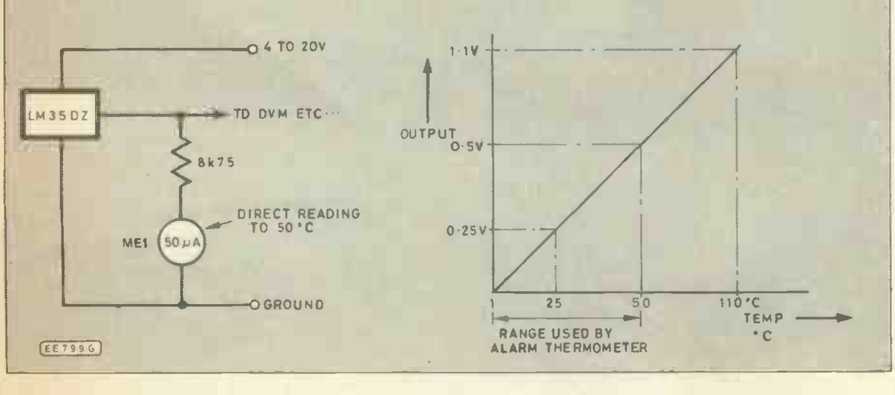
The output of the sensor and the alarm "reference" voltage could be directly applied to the comparator, but to make the unit more versatile they are connected via a polarity reversing switch (S1). This gives the user the option to cause the alarm to activate when the temperature is either above, or below, the alarm threshold value. The output from the comparator is connected so as to enable the oscillator only when alarm conditions exist.

So that the user can set the alarm threshold accurately, the indicator meter ME1 is made switchable between the sensor output and the alarm "reference" control. A biased toggle switch S2 is wired so that normally the sensor is fed to the meter, but when operated it is connected to read the alarm "reference" voltage. This arrangement ensures that in normal use the sensor "temperature" is displayed.

The comparator output IC2 goes "high" when the alarm limit has been exceeded and enables the oscillator IC3 causing LS1 to bleep a warning of hazardous conditions. However, it may be some time before the temperature returns to acceptable levels, so to acknowledge the alarm and switch off the bleep, S3 is arranged to disable the speaker.

As well as an audible warning, a visual indication of alarm conditions is provided by a light emitting diode, D2. As well as disabling the loudspeaker the frequency of the alarm oscillator is changed; in fact it reduces the frequency to about 3Hz, which causes the l.e.d. to flash. To return the audible alarm signal S3 is restored. But by operating the Under Limit/Over Limit switch S1 to the opposite setting, and leaving the bleep switched on, the alarm will sound once again when the temperature returns to the acceptable level.

Fig. 1. Basic thermometer circuit and temperature/voltage graph.



CIRCUIT DESCRIPTION

The sensor IC1 is mounted in a suitably shaped probe (Fig. 6) and connected to the alarm unit via a 2-core screened cable. With long probe leads, the device can go unstable and so to prevent this a *C-R* network is connected across the probe output terminals adjacent to the device itself. For serviceability, the probe is connected to the alarm circuit via a DIN socket SK1.

A bias circuit is effected using divider resistors R1, R2 and the Alarm Threshold control VR1. The sensor output and the wiper of VR1 connect to the Under Limit Over Limit switch S1, and to the meter selector switch S2. The function of S1, is to reverse the action of the comparator IC2.

As shown in the circuit diagram (with the sensor output routed to the non-inverting input of IC2) when the voltage produced by the sensor is more positive than the voltage at the wiper of VR1, IC1 output swings towards the positive supply rail. Operation of S1 changes the roles of the sensor and VR1. So that when the sensor output is more negative (compared to the wiper of VR1), the output swings positive—the temperature is less than the limit setting.

METER

The switch S2 forms the check setting switch. The meter ME1 deflects to it's full scale reading when 50μA flows through it's coil; so why use a microammeter to measure voltage? As is common with all moving coil meters, they operate to current, so to measure a voltage, a resistor is connected in series. It's value is calculated so that the maximum voltage to be measured causes a current to flow through the meter circuit corresponding to the full scale deflection (f.s.d.) current required by the meter.

In our case, using a meter with a resistance of 1250 ohms, to give 50μA through the meter from a 0·5V source (maximum temperature to be measured) the meter resistance works out as 8750 ohms. Resistors R3 and R4 provide the meter resistance for this circuit giving a total resistance of 8760 Ohms.

Bearing in mind the tolerance of the meter itself the values of R3 and R4 are as practically close as possible to the theoretical value. Unless, of course, you like soldering resistors in parallel! And you may need quite a few.

The meter switch S2 is biased to read the sensor (as shown) in the circuit. As the total resistance of the meter circuit approximates very nearly to 10 kilohms, it is important to maintain this circuit load when the meter is switched to measure the alarm threshold setting.

More importantly, the effect of 10 kilohms connected in parallel with VR1 is quite marked. And bearing in mind that this is taken to be our reference it is necessary to simulate the loading when the meter is measuring the probe otherwise when the meter is switched back to measure the sensor, the voltage on the wiper of VR1 will increase giving an alarm threshold which is higher than that measured.

The switch contacts S2b together with resistor R5 solves this problem nicely; presenting a resistance equal to the meter resistance to the source not being measured. Therefore, when the setting is being checked when S2 is operated, the meter is switched to the wiper of VR1 and the load simulating resistance is switched away and applied across the sensor. Capacitor C1, ensures that any a.c. signals picked up on the screen of the sensor cable is removed and eliminates noise in the sensor and meter circuitry.

The output of IC2 swings towards the positive supply rail voltage whenever the temperature has exceeded or fallen below the threshold setting. As this happens, diode D1 becomes reverse bias and allows the timing capacitor C2 of the astable oscillator (built around IC3) to charge up sufficiently to cause the oscillator to start up. Resistors R6, R7 and capacitor C2 determine the frequency of oscillation and their values are chosen so that the output of IC3 is a squarewave of about 760Hz.

The output of IC3 connects directly to the alarm l.e.d., D2 via current limiting resistor R8. The 760Hz squarewave produced under alarm conditions theoretically causes the l.e.d. to flash 760 times a second. Obviously, this is too fast for our eyes to perceive and so whenever S3 is in the "Bleep On" postion the l.e.d. appears to be continuously illuminated.

The alarm signal is a.c. coupled through capacitor C4 and resistor R9 to the loudspeaker LS1 which is heard as a continuous bleep. Operation of switch S3 causes the loudspeaker circuit to be broken, and connects capacitor C3 in parallel with the oscillator timing capacitor C2. The frequency of oscillation is reduced dramatically to 3Hz which can be seen as diode D2 begins to flash.

When the alarm conditions are removed (Conditions Normal) or the setting threshold is readjusted, the alarm oscillator will be disabled once again. To restore the audible alarm signal, S3 is restored to it's normal position.

CONSTRUCTION

A small ABS box with a sloped front panel makes an ideal housing for the unit. The sloped front improves the ergonomics which makes the unit easier to use whether it is positioned on the flat surface or mounted on a wall.

The front-panel drilling details are shown in Fig. 3, dimensions may vary according to the physical dimensions of the components used and some minor alterations may need to be made. Check before drilling and remember if in doubt, draw it out!

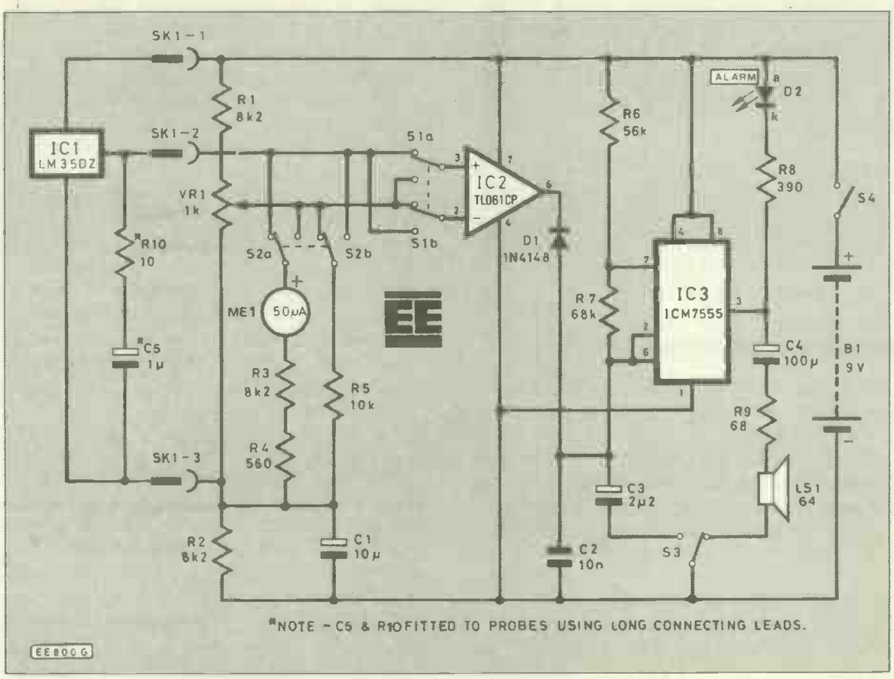
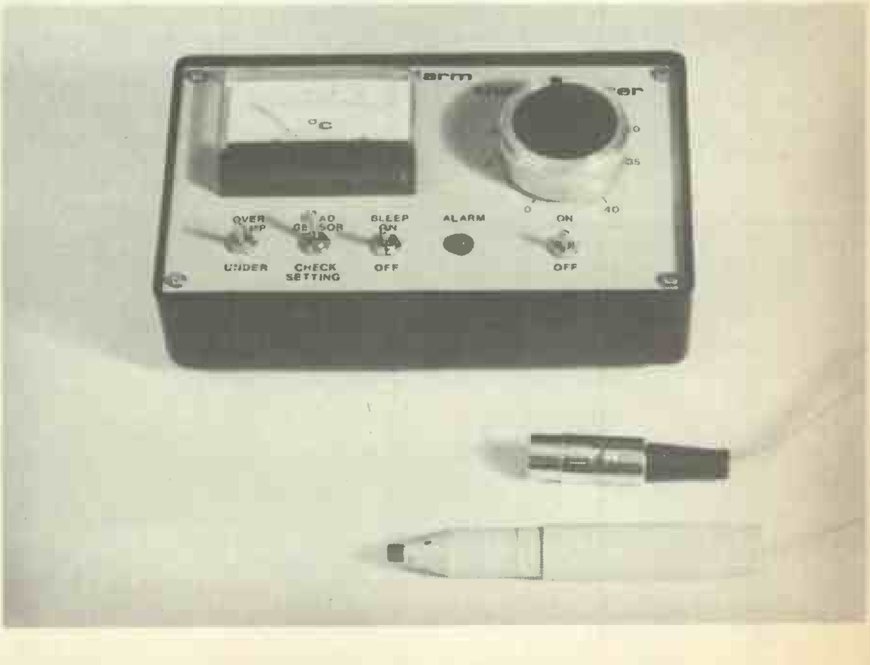


Fig. 2. Complete circuit diagram for the Alarm Thermometer.

The completed Alarm Thermometer with the plug-in temperature sensor probe. If the temperature adjacent to the alarm is to be sensed, then the temperature sensor i.c. may be mounted inside a 3-pin DIN plug. This, of course, will mate directly with the rear socket.



BATTERY CLAMP

The battery clamp, Fig. 4a, is made from a piece of 22s.w.g. aluminium sheet or modeller's tinplate. Whichever material is used, ensure that the edges are smoothed off. If tinplate is used, corners should be rounded and edges folded over.

The battery clamp is held in position behind the front-panel by a 6 B.A. nut and bolt; the bolt or screwhead being countersunk into the front-panel to avoid raising the meter-front. The hole is carefully sited so that it is not visible and does not spoil the appearance of the unit.

The dimensions for the loudspeaker clips is shown in Fig. 4b; these hold the loudspeaker in position in the base of the unit. The sound holes for the loudspeaker itself comprise a matrix of $\frac{1}{4}$in holes encompassing the diaphragm area of the speaker. Two smaller holes ($\frac{1}{8}$in dia.) are drilled in the appropriate position to take the speaker clips. And while the drill is at hand, at this stage, the p.c.b. mounting holes can be drilled.

A standard 3-pin DIN socket SK1 is mounted at the rear of the case clear of the meter movement. Like the speaker clips, and p.c.b., it is held in position with 6 B.A. nuts, bolts and secured with shakeproof washers.

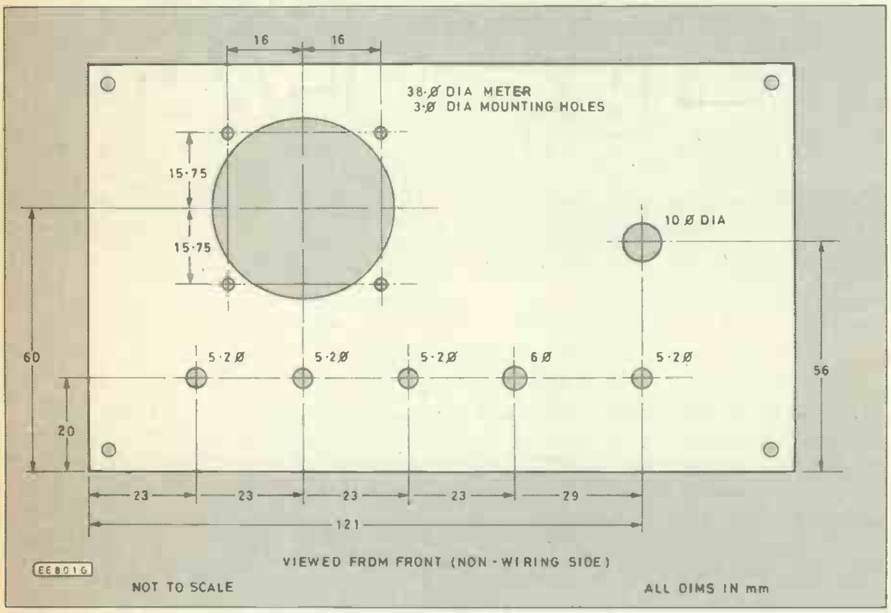


Fig. 3. Front panel drilling details. The lettering for the various controls can be seen in the photograph above.

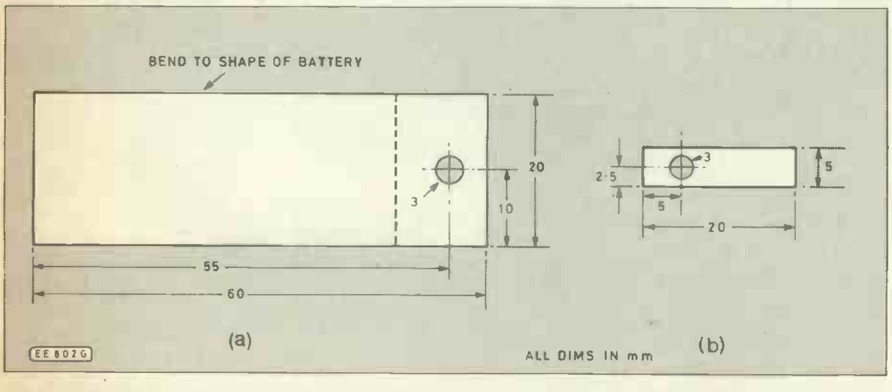


Fig. 4. Dimensions and details for the battery clamp (a) and the loudspeaker clips (b).

CIRCUIT BOARD

The component count of the Alarm Thermometer is quite small and a compact printed circuit board is used to mount the components. The component layout and p.c.b. master pattern is shown in Fig. 5. This board is available from the EE PCB Service, code EE559.

The use of i.c. sockets are suggested for the unit: although the possibility of i.c. damage due to heat is unlikely, failure due to wiring error or device breakdown cannot be dismissed. By using i.c. sockets, rapid replacement can easily be effected.

The connections to the switches, speaker, l.e.d., battery and potentiometer are made from the row of connection pins on the left hand side of the p.c.b. To aid wiring, and hopefully avoid mistakes, they are designated 1 to 10 and details of where these connections are wired to are given in Fig. 6.

Do not attempt to spray and letter the front panel at this stage as the scale for the Alarm Threshold control VR1 will be determined during testing.

TESTING

Having thoroughly checked the wiring, particularly the wiring associated with the double-pole switches, the battery should be connected. At this stage, it is not necessary to use IC1 in it's probe case, instead the i.c. can be plugged directly into SK1.

Switch on and put all the switches in the up position, when viewed from the panel. Turn VR1 fully clockwise. You should be able to see a reading on the meter straight away, typically 15 to 20 for the average room.

Check that the sensor responds to changes in temperature by bringing the tip of your soldering iron close to—NOT TOUCHING—the sensor i.c. If all is well the reading on the meter will begin to rise. If nothing happens check that your soldering iron is still switched on!

ALARM SETTING

Check the alarm setting range by operating S2 and holding it down. Simultaneously turn VR1 anticlockwise and you should see the meter change from about 40 to 0. Note that when the meter reading goes below the actual temperature the alarm tone should be heard, and that the l.e.d. illuminates. Operate S3 to disable the alarm tone and the l.e.d. should now flash.

Still holding switch S2 down you can now mark the alarm setting scale adjacent to the control knob pointer of VR1. Advance VR1 from 0 to 40 and mark the pointer position on the front panel at five degree intervals. Although this scale is not intended to display the absolute setting of the alarm threshold, it does provide a "quick look" guide to the approximate alarm setting. Restore S2 and operate switch S1; it will now be possible to cause the alarm l.e.d. to flash when the alarm setting is *above* the actual temperature. In other words the unit acts as an *UNDER* temperature alarm.

Finally, switch the unit off, and secure the internal, and switch wiring. Remove the front panel components and finish off by lettering the front panel as required. Trace the VR1 scale markings to allow the final scale lettering to be positioned.

COMPONENTS

See Shop Talk page 213

Resistors
R1,R2,R3 8k2
R4 560
R5 10k
R6 56k
R7 68k
} 1% metal film
R8 390
R9 68
R10 10
} 5% carbon

Potentiometer
VR1 1k lin.

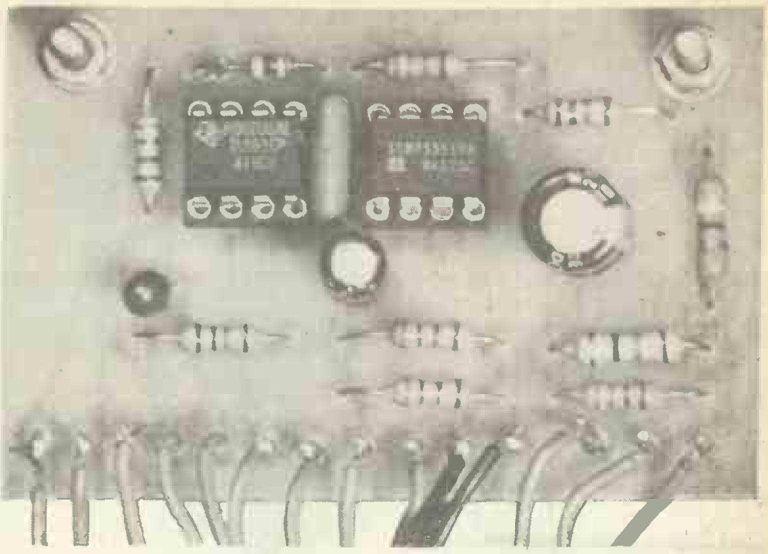
Capacitor
C1 10μ radial elec. 16V
C2 10n polyester or polycar.
C3 2·2μ tant. 35V
C4 100μ radial elec. 25V
C5 1μ min elec. 50V

Semiconductors
IC1 LM35DZ (temperature sensor)
IC2 TL 061CP low power Bi-fet op. amp.
IC3 ICM 7555 (CMOS timer)
D1 1N4148 silicon diode
D2 0·2in red l.e.d. with holder and clip

Switches
S1 Miniature double-pole changeover
S2 Double-pole changeover—biased one way
S3,S4 Single-pole changeover (2 off)

Miscellaneous
LS1 64 ohm miniature loudspeaker
ME1 50μA f.s.d. moving coil meter (2in.), resistance 1250Ω.
8-pin DIL i.c. sockets (2 off); chassis mounting 3-pin DIN socket; 3-pin DIN plug; ABS sloping front case, 161mm × 96mm × 61/39mm; PP3 battery and connector; 2-core screened cable; connecting wire; control knob; 22s.w.g. aluminium for battery clip and speaker clips; printed circuit board, available from *EE PCB Service:* code EE559.

Approx. cost Guidance only £22



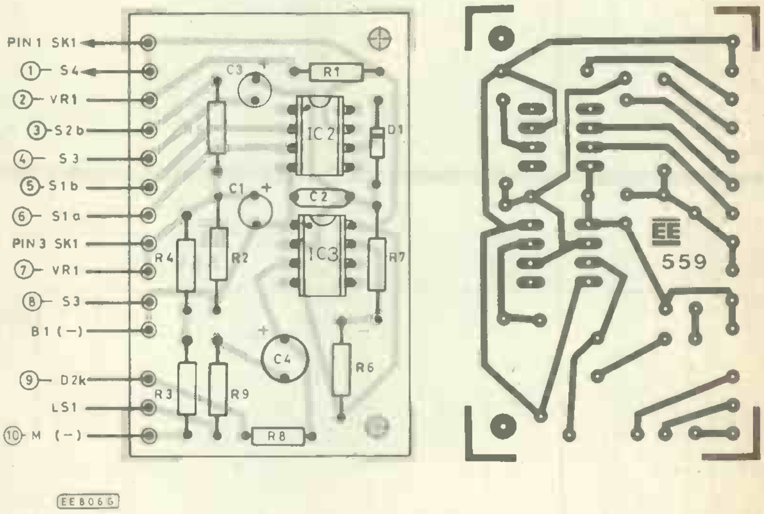
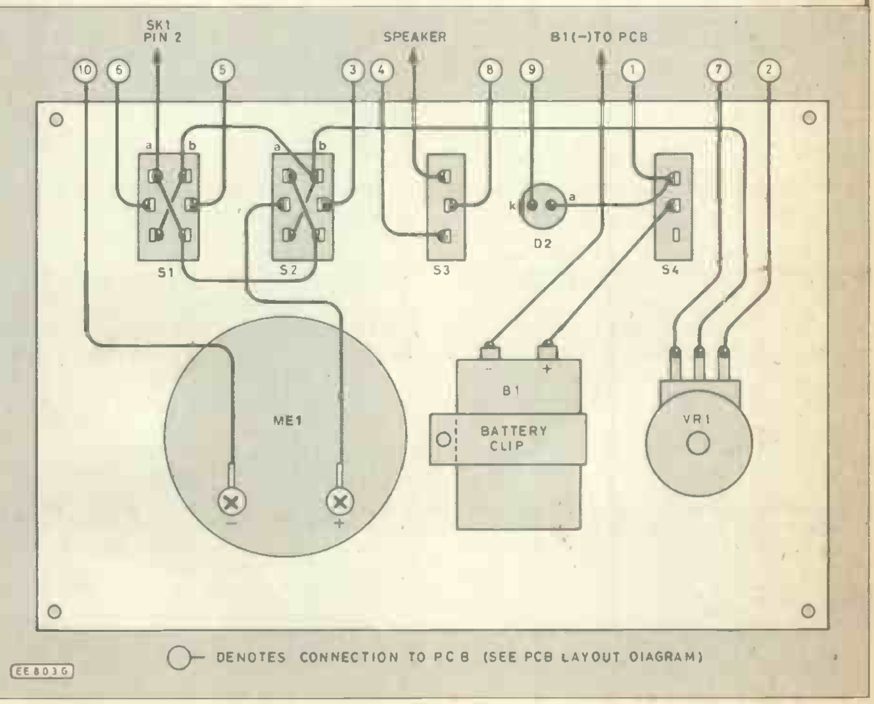
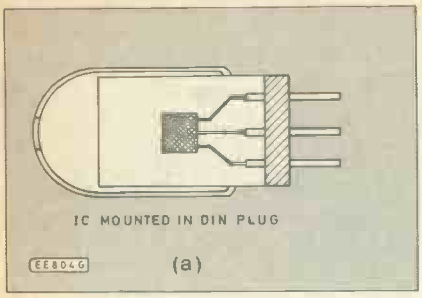


Fig. 5. Printed circuit board component layout and full size p.c.b. master pattern.

Fig. 6 (below). Wiring to the front panel mounted components. The circled numbers refer to connection points on the p.c.b.





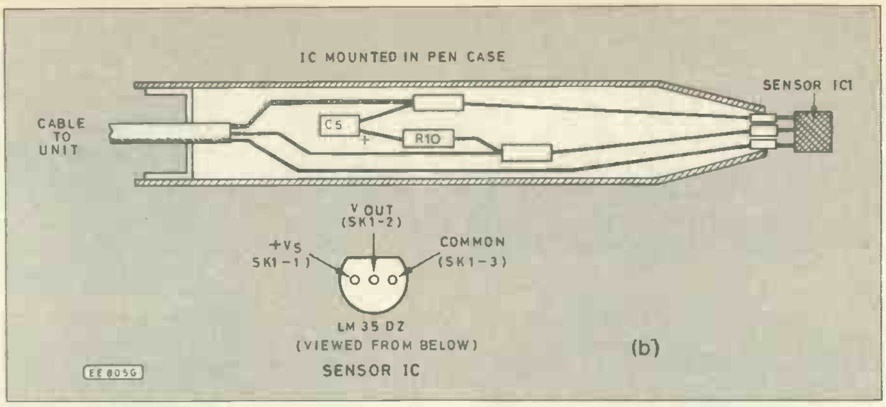
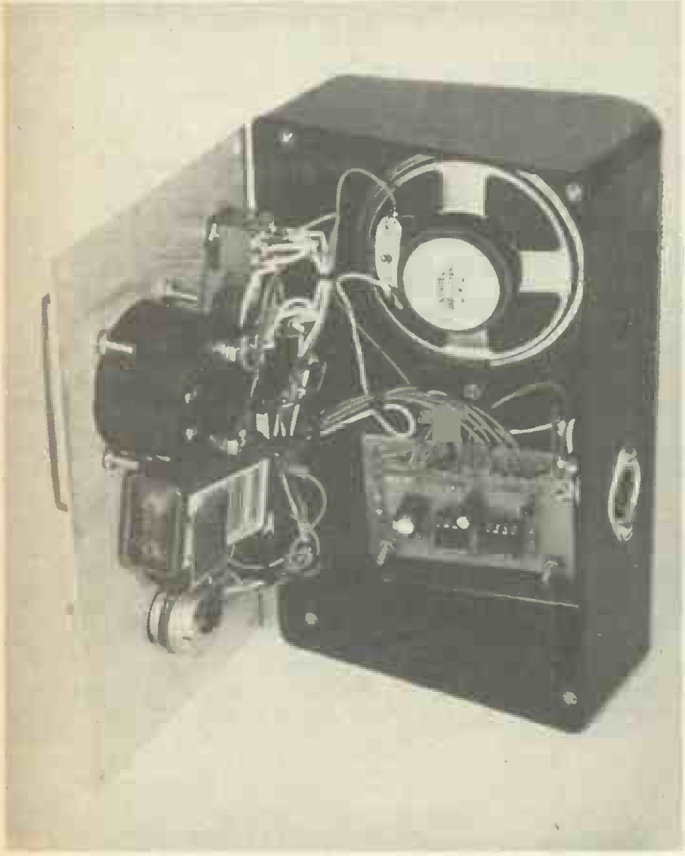
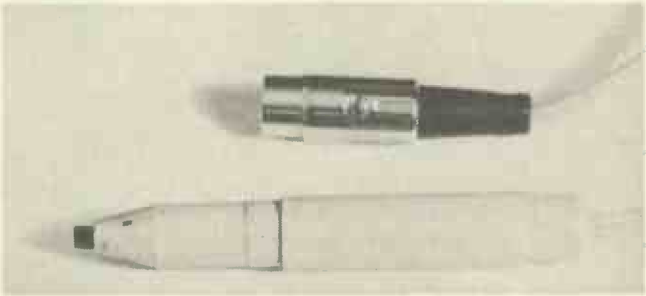


Fig. 7a. The temperature sensor i.c. mounted in a 3-pin DIN plug. (b) an alternative arrangement using a felt marker pen case. The stabilising components for using extended probe leads are also wired inside the probe case.



Internal layout and wiring of the completed alarm.



Completed temperature sensor probe showing the sensor i.c. protruding slightly from the probe tip.

MAKING THE PROBE

The sensor i.c. has to be positioned at the point at which the temperature measurement is to be made. It should be pointed out that the device is *NOT* meant to measure the temperature of liquids unless specialist mechanical design techniques are applied. The hobbyist ***should not*** attempt this; the contact of electricity with flammable liquids is obviously very dangerous, and should be left to other methods best done by professional instrumentation engineers.

To sense the ambient temperature around the probe is quite a simple matter. The inventive hobbyist will, no doubt, be able to devise other methods of siting IC1 than those suggested.

If the temperature adjacent to the alarm unit is to be sensed, then the sensor i.c. can be mounted in a 3-pin DIN plug; this, of course, mates directly with SK1. How this can be done is shown in Fig. 7a, the cable grip and the unused section of the plug cover can be removed leaving the air to enter the plug through the cable feed-in. An alternative design is shown in Fig. 7b, which uses a large marker pen case to support the sensor and, conveniently, the space is adequate to house the stabilising components capacitor C5 and resistor R10.

HEAT ABSORPTION

Those wishing to design their own sensing units should bear in mind the elementary physics of heat absorption and reflection. In other words, try to avoid erroneous readings due to the sensor case absorbing heat from the sun for example. Don't go daubing black paint over the box and wondering why the alarm triggers at an apparently lower temperature that expected. Remember too that reflective surfaces to light also reflect heat. So, to minimise errors due to the sun heating the sensor unit, as was the case in the weather station, an adhesive foil tape was taped around the box.

If the leads to the alarm unit are likely to be over two metres long, the components C5 and R10 must be fitted but for sensors near to the unit they can be omitted. If the unit is likely to be used in the vicinity of high radio frequency fields, e.g., a Ham Radio shack, fit C5 and R10 in all cases. Also, use screened cable to connect the sensor to the unit.

SUGGESTED APPLICATIONS

As it stands at present, the Alarm Thermometer will cater for a whole host of applications. And indeed, several people have offered ideas for applications which were never thought of when the original unit was conceived.

One of the most practical and relevant was a hypothermia warning device. By setting the unit to it's under temperature alarm condition, and setting the alarm threshold to a level where body temperature could fall. The unit can be set up in an old person's room to indicate if the heating is inadequate.

In the winter, of course, most old people are prone to try and save money by switching off their heating supply with the result that their room gets very cold, which can lead to serious reduction in body temperature, and as we all are aware, can lead to death! The audible alarm can be used to warn them of the danger level and to restore their heating until, at least the room is warm enough.

Moving to more technical applications; amateur meterologists can monitor the temperature of the atmosphere some distance away from their instruments. Some adventurous hobbyists may wish to extend the facilities of the unit; for example, by adding an optocoupler (opto l.e.d. wired in series with the existing l.e.d.) an extension of the visual alarm can be added.

Computer buffs may like to consider wiring a second socket on the unit which is connected in parallel with the sensor's output and ground terminals. Applying the sensor voltage to the analogue inputs of their computer can, with the appropriate degree of programming, allow a corresponding temperature measurement to be processed by the computer. □

Robot Roundup

NIGEL CLARK

BEASTY FACELIFT

One of the earliest entrants into the small robot market was Commotion, based in Enfield, Middlesex and run by the enthusiastic Tim Coote. One of his first products was the Beasty servo motor which had been developed by Micro-Robotics of Cambridge. Its uses were expanded by the introduction of the Beasty interface and the Beasty arm, a three-axis device costing in the region of £100.

The arm and the interface have been getting a facelift. The articulated arm has been redesigned and now comes with a standard gripper and has been given a moulded cover to give it, in the words of Commotion, "a sleek new streamlined look".

However, the mechanics remain much the same with its limited strength and capabilities. The major change has been in the documentation which improves on the already impressive manual. In addition to the usual guide to building the arm and ways in which it can be used in the teaching of robotics there are plans for creating another four robots and a simple plotter. There is also a tutorial section which includes descriptions of arms which can be found in industry.

The price is still reasonable and for less than £100 customers get the kit, four servos and the manual. The arm can be controlled via either the Beasty, Beasty Plus or Scorpion interfaces, all of which are supplied by Commotion.

The Beasty Plus was launched in January and, like the original Beasty interface, controls up to eight Beasty servos. In addition it has eight sensor and eight transducer inputs, including eight sockets for digital inputs and two for Lego's shaft encoders. The output can be used for eight on-off or four bi-directional motors. It is supplied with leads to allow it to be used with both Lego and Fischertechnik components.

To complete the package a number of input and output devices are included, such as two d.c. motors, a buzzer, lamps, a reed switch and a range of sensors. With a catalogue covering programming the system and example programs it is available for an inclusive price of £200 with VAT extra.

NEWCOMERS

Spectravideo's hopes of making progress in the education market with its Robotarm machine, mentioned in last month's column, has been assisted by the joint help of Logotron and Resource, two newcomers to the arm market. They have cooperated on the production of an interface and software for the BBC machines at a cost of £89, plus VAT, including the arm.

Previously interfaces for the 4-axis articulated arm were only available for the MSX range and the Commodores.

Resource of Doncaster built the interface, which plugs into the arm's joystick ports and also wrote the BASIC software. Simple pre-written routines can be entered via the keyboard. Robotarm will also accept Logotron's Conrol Logo and is supplied with ready-written driving procedures. The package is completed by some example programs and a manual.

The partners consider the arm to be the answer to the problem of finding an arm at a price schools can afford. They said that the need for robots as a way of giving computers a useful function had been realised in schools. There were buggies and turtles at affordable prices but they thought the arms were too expensive—until now.

BUGGY

In a separate development Resource is selling a small simple buggy for use with BBC Econet. It has two drive wheels, steering being provided by their relative speeds, two microswitch bumpers, a white/black detector, which could be used for line following, and a buzzer.

It comes with an interface and runs with three software packages. Buggy Basic adds some movement instructions such as RIGHT/LEFT and FWD/BACK to the usual set, Control Basic which is more sophisticated and Control IT which is described as a Logo-Style language. It costs £55 plus VAT.

INTERGALACTIC CLOSURE

Intergalactic Robots, IGR for short, has closed. Despite some optimism at the end of the summer for sales of its Zero II buggy, the market did not improve sufficiently for the company to consider it worthwhile to continue.

If the machine continues in any form it will be on the basis of interest shown by the Chinese. They have been assessing it for some time but if they place an order it is likely to be made in the Far East.

The closure marks the end of one of the more ambitious attempts to find a wider market for robots. Originally there were visions of becoming the Sinclair of the robot market without Sinclair's subsequent problems. As ever, however, it came up against the does-it-do-anything-useful? problems and, like many others, failed to answer the question satisfactorily for most potential customers.

It could perform all the usual buggy functions with bump sensors, a line follower and the ability to play a tune and was available for all the popular computers at a reasonable price, in the region of £100. It was intended to add further sensors and have some games programs written for it, but they never came to fruition.

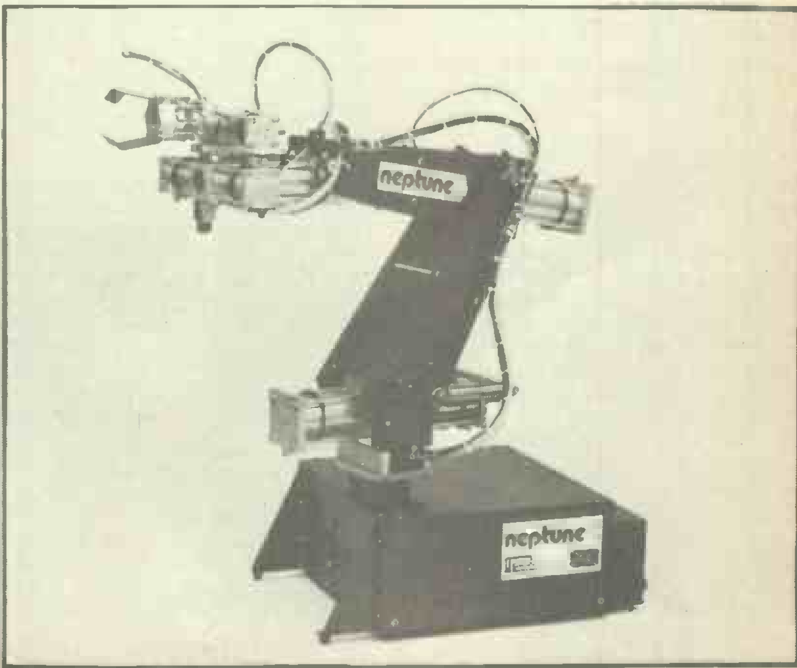
Some impact was made in education but Zero lacked the comprehensive support material available for competitors such as Trekker, which was in the same price range.

FROZEN EXPORTS

An unusual difficulty arose during the freezing temperatures in early January. Frozen pipes and car radiators can be expected when the thermometer plummets—but frozen robots?

Cybernetic Applications uses water in its hydraulically-powered robots Neptune and Naiad and in the depths of the freeze they had to despatch two Neptunes to Norway where the temperatures were even lower than in Britain. The solution to the problem was to fill them with anti-freeze and hope for the best!

The Neptune hydraulically-powered robot from Cybernetic Applications.



BULB LIFE EXTENDER

R.A.PENFOLD

This simple inexpensive unit will prolong the active life of most types of light bulb.

THERE is a popular contemporary joke about the micro-electronics company that was so successful it was able to move to smaller premises. Its pre-micro equivalent was the one about the long-life bulb manufacturer that was so successful it went broke, and there is perhaps more than a filament of truth in this one. Certainly modern bulbs seem to have quite modest lifespans, with both spotlamps and the small or style bulbs of various shapes fitted in many decorative lamps needing regular attention. In the case of the latter, the problem is probably due to the large number of bulbs involved if a few of these fittings are installed.

It may or may not be possible to produce a light bulb which with normal use would have (say) a 10,000 hour operating life, but it is possible to extend the lifespan of ordinary bulbs with a little electronic assistance. This is the purpose of the simple electronic device described in this article. It can either be built as a complete unit with its own case and a mains outlet into which a table, standard lamp, projector etc., can be plugged, or it can be fitted into a standard light switch box.

LIFE ASSURANCE

The easiest way of increasing the life of a bulb is to run it at reduced voltage, and quite a modest reduction in voltage can produce a substantial increase in operating span. This is due to the far from linear voltage/lifespan characteristic of a bulb, and the two extremes of the characteristic help to demonstrate this point. If a bulb was to be run continuously at double its normal working voltage, its lifespan would not be halved, it would in fact burn so brightly that it would in all probability fail within a few seconds. Running a bulb at about a quarter of its normal working voltage would result in a very low filament temperature, with the bulb consequently lasting almost indefinitely.

There are drawbacks to using reduced voltage, and these are a reddening in colour of the light output, and reduced efficiency. This makes it impractical to use a supply which is reduced by more than a few percent, but even this should give a worthwhile improvement in bulb life.

A major factor in the reduction of a bulb's working life is the number of times it is switched on and off. This is partially due to the mechanical stresses imposed on the filament by the rapid heating at switch on, and cooling at switch off. Another major contributory factor is the large pulse of power that flows when the bulb is first switched on, and it is noticeable that most bulbs fail at switch-on rather than while they are operating normally.

This high initial current is caused by the low "cold" resistance of the filament, which is just a result of the well known effect whereby the resistance of a conductor tends to increase with increased temperature. The difference between the "hot" and "cold" resistance of a filament is a lot more than you might expect. On measuring the resistance through a 25 watt "candle" bulb for example, the reading was 190 ohms. With a 240 volt supply this equates to a supply current of over one amp, and a power level in excess of 300 watts. If the bulb should happen to be switched on when the mains supply was at or close to its peak value, the power fed to the bulb at that instant would in fact be around 600 watts. Obviously the filament of the bulb very rapidly rises in temperature when the mains supply is applied to it, taking the power level rapidly down to something like the nominal rating of the bulb. However, in view of these figures it is not surprising that well used bulbs have a tendency to "blow" at switch-on.

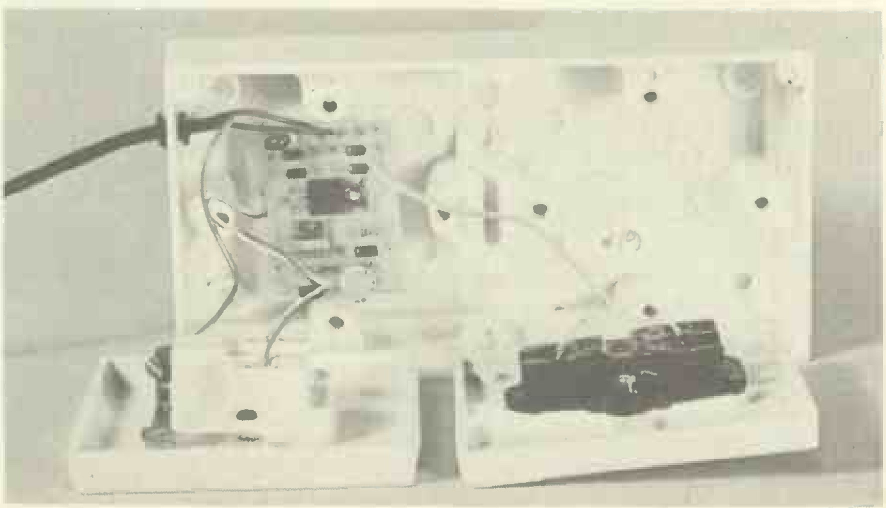
There is a way of avoiding this initial power surge, and it is to gradually bring the bulb up to full power rather than just instantly applying the full mains voltage to it. Thus, the filament warms up and its resistance rises as the voltage fed to it is increased, and at no point is there a combination of high voltage and low filament resistance to produce a power surge.

One further possible cause of reduced bulb life is high voltage noise spikes on the mains supply. These are easily combatted though, and there are transient suppressors which are specifically designed for removing these from the mains supply.

POWER CONTROL

The obvious way of providing the automatic fade-up at switch-on is to use some form of variable resistance element in series with the bulb, with a simple control circuit to provide decreasing resistance when power is applied to the circuit. This would be difficult in practice as the power control device would have to be capable of handling a high voltage a.c. supply, and normal (linear) semiconductor devices are not capable of doing this. There would also be the problem of high power dissipation in the power control device during the fade-up period. Although the power only needs to take a second or so to reach full power, without heatsinking the control device could easily be destroyed during this period. If the unit is to be fitted into the limited space available in a standard switch box it must obviously function with little or no heatsinking.

A more practical way of providing both the automatic fade-up and the slight voltage reduction is to use the so called "phase control" method, as used in ordinary lamp dimmers. This relies on a system of switch-



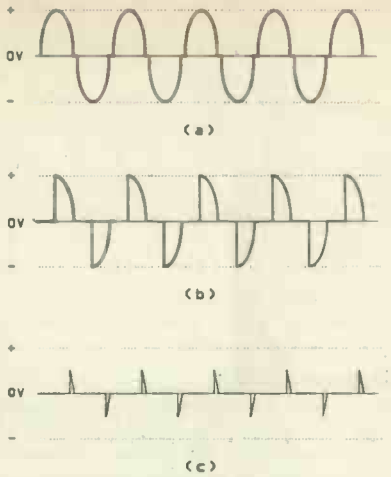


Fig. 1. Lamp dimmers operate by chopping the mains waveform, as in these examples:—
(a) Full, (b) half, and (c) minimum output powers.

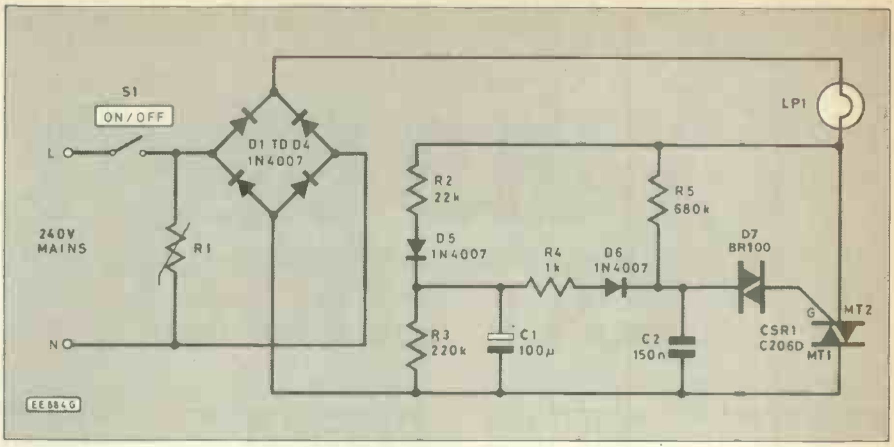


Fig. 3. Circuit diagram of the Bulb Life Extender.

ing to control the power fed to the load, and an ordinary triac or thyristor can be used as the control element. Fig. 1 helps to explain the way in which this system of power control operates.

The power level is controlled by triggering the triac or thyristor at a certain point in each half cycle, and in Fig. 1(a) triggering occurs almost at the beginning of each half cycle. Once triggered, the device remains in a state of conduction until the current flow falls below a certain threshold level which varies from one device to another, but is only a matter of a few milliamps. The device therefore cuts off just prior to the end of each half cycle. This gives what is virtually full power to the load, and the small losses that occur are insignificant.

In Fig. 1(b) the switching device is not turned on until half way through each half cycle, so that only about half power is fed to the load. The device is only triggered at almost the end of each half cycle in Fig. 1(c), so that very little power is fed to the load. In fact the power level would be too low to produce a noticeable glow from a light bulb, and it would effectively be switched off.

This method of power control obviously produces serious waveform distortion as an inevitable consequence of the way it works, but with something like a light bulb it is the mean voltage and not the waveform that is of most importance, and this method works well in practice.

In this application the circuit must be designed to produce a waveform of the type shown in Fig. 2(a), where initially most of each half cycle is removed, but the signal is gradually restored to the full waveform.

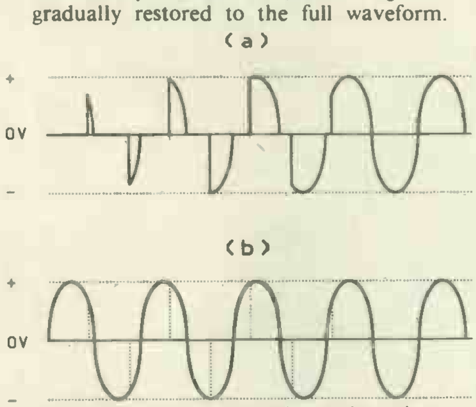


Fig. 2. By triggering the triac at the points shown in (b), the lamp is faded up by the waveform shown in (a).

This is achieved by triggering the control device near the end of each half cycle at first, and then gradually triggering it earlier in each half cycle until the full waveform is restored. Fig. 2(b) shows the trigger points needed to produce the waveform of Fig. 2(a). Of course, in the example waveform the power is brought up to maximum in the course of only three or four cycles, but in reality the power would be faded-up over a period of a second or so, or over about 50 cycles in other words.

CIRCUIT OPERATION

The full circuit diagram of the Bulb Life Extender appears in Fig. 3. Starting at the mains input, S1 is the on/off switch and R1 is the transient suppressor. R1 is not an ordinary resistor, but is a voltage dependent type (VDR or "varistor"). These are little used in modern circuits, but were once used in simple voltage regulator applications. They normally have a high resistance, but if the applied voltage exceeds a certain threshold level the resistance value falls significantly, and as the voltage is increased above threshold level the resistance falls still further.

The action is similar to the familiar avalanche characteristic of a Zener diode, but a voltage dependent resistor is less efficient at voltage regulation. It is good enough for this application though, where R1 normally operates over the high resistance part of its characteristic. However, if a high voltage noise spike occurs, this takes R1 into the low resistance part of its voltage/resistance characteristic, causing it to virtually short circuit the noise spike and clip it at little more than the 340 volt peak mains voltage level. Unlike a Zener diode, a voltage dependent resistor is bidirectional, and it will clip both positive and negative noise spikes.

Diodes D1 to D4 form a conventional bridge rectifier circuit, and this is needed as the soft switch-on circuit will only work with a d.c. signal and will not function properly with an a.c. type. The output to the bulb is actually a pulsing d.c. signal rather than an a.c. type, but this is of no practical consequence.

What is virtually an ordinary lamp dimmer circuit is formed by R5, C2, the diac, and the triac. It differs from the conventional arrangement only in that a fixed resistor is used in the R5 position, instead of a fixed resistor and a potentiometer in series. The high value of R5 results in the circuit providing an output that produces no more than a very dim output from the lamp (LP1).

The way in which a basic dimmer circuit functions is quite straightforward. On each half cycle C2 charges via R5, and eventually the voltage on C5 reaches the trigger level of the diac (about 30 volts or so). The diac's resistance then falls to a very low level, and stays at the level, until the current flowing through the device drops to a few milliamps. This results in C2 being largely discharged into the gate of the triac, and this short but fairly intense pulse of current is sufficient to trigger the triac into conduction. The rectified mains supply is then fed through to LP1, but only until almost the end of the current half cycle, when the current through the triac falls below the

COMPONENTS

See **Shop Talk** page 213

Resistors

R1	Transient suppressor (see text)
R2	22k
R3	220k
R4	1k
R5	680k

All ¼ watt 5% except where noted

Capacitors

C1	100µ radial elect. 40V
C2	150n polyester layer

Semiconductors

CSR1	C206D (400V 3A)
D1 to D6	1N4007 (1000V 1A rectifier—6 off)
D7	BR100 or similar

Miscellaneous

LP1	Existing mains lamp (or lamps) up to 240W total
S1	s.p.s.t. light switch

Printed circuit board, available from the EE PCB Service, order code EE564; surface mounting switch box; pins; wire; solder; etc.

Approx. cost Guidance only **£4.50** plus case

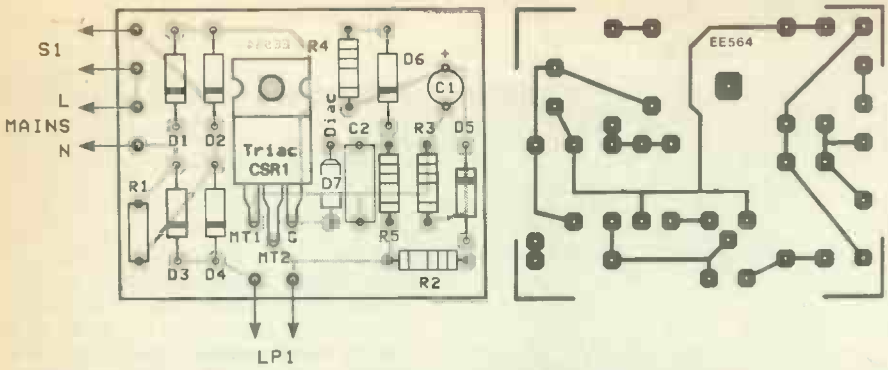


Fig. 4. Printed circuit board layout and wiring.

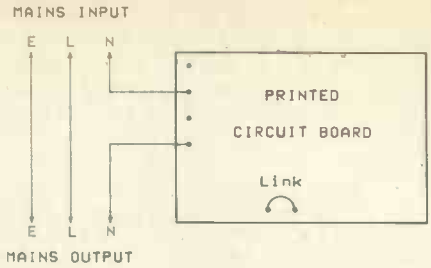


Fig. 5. In many applications it will be preferable to connect the board as shown here (note the link wire).

hold-on threshold, and the triac switches off again.

This whole process repeats on each half cycle, feeding a series of "chopped" half cycles to LP1. If the value of R5 was to be made much lower the triac would be triggered early in each half cycle, giving virtually full output power, but the high specified value results in the trigger potential only being reached just before the end of each half cycle, giving very little output power. This gives the initial low power level, and it is the purpose of the other components in the gate circuit to provide the fade-up effect.

FADE-UP

When power is applied to the circuit C1 charges up by way of R2 and D5, but the long time constant of this circuit means that it takes a second or so for the charge voltage to reach the diac's trigger potential. When this point is reached, R2, D5, R4, and D6 are effectively shunted across R5, and ensure that the diac triggers very early in each half cycle, giving almost full output power.

The power is not suddenly switched to maximum when the charge on C1 reaches its full level, and a reasonably smooth fade-up is provided. This happens because C1 has a much higher value than C2, and there is a low impedance path through R4 and D6 when the charge on C1 exceeds that on C2. In effect, this ensures that C2 starts at the beginning of each half cycle with a charge potential virtually equal to that on C1. As the charge on C1 increases, C2 starts each half cycle closer to the diac's trigger voltage, and takes less time to reach this voltage.

Components D5 and R4 are needed to prevent C1 from being more than slightly discharged during the periods when the triac is conducting, while R3 is needed to discharge C1 when the unit is switched off (so that it is fully discharged and the fade up action is produced next time the unit is activated).

On the face of it the unit does not have a voltage reduction circuit, but in practice there are losses which provide the required voltage reduction of about five per cent. These are partially provided by voltage drops through the rectifiers and triac, but mainly by the fact that the fade up circuit never triggers the triac early enough in each half cycle to genuinely produce full output power.

CONSTRUCTION

Details of the printed circuit board are shown in Fig. 4. There is nothing particularly difficult about construction of this board, but there are a few points worthy of note.

The diac is bidirectional and it can therefore be connected either way round, but be careful to connect the six rectifiers with the right polarity, and check this point thoroughly when the board has been completed. C1 must be connected with the correct polarity, and it must be a physically small type if it is to fit into the available space. It needs to have a voltage rating of at least 35 volts, and it might be necessary to opt for a 63 volt type. Some of these are quite tall, which could be a problem if the unit is to be fitted into a standard switch box. In most cases there will be no difficulty, but if necessary C1 can be mounted horizontally across R4 and D6. This will not look very neat, but it is the simplest solution to the problem. C1 must be a miniature type with 7.5 millimetre lead spacing if it is to fit onto the board easily.

The resistors must be modern miniature $\frac{1}{4}$ watt types. The triac is mounted horizontally, and it is a good idea to bolt it in place on the board. The triac is only handling a d.c. signal in this circuit, and the thyristor equivalent of the C206D (the C106D) should work equally well in the unit. R1 can be a type SO5K250, but these components are often sold simply as mains transient suppressors rather than by a particular type number. Pins are fitted to the board at the six points where connections to off-board components will eventually be made.

FITTING

The prototype is built into a double size switch box fitted with one switch (connected to act as S1) and a mains outlet into which a table lamp is plugged. There is sufficient space for the printed circuit board beneath the mains outlet, and a double-sided adhesive pad can be used to hold it in place. The mains earth lead must be connected through to the mains outlet. Most lamps do not use an earth connection, but the earth lead must be carried through to the output just in case someone should connect a device to the unit which does require an earth connection.

There should be no real difficulty in fitting the unit into an existing switch box if desired, but you must of course switch off the mains lighting supply at the main switch before attempting to fit the unit. Bear in mind that the circuit operates at the mains potential, and it would be **potentially lethal to touch any part of it while the unit is connected to the mains supply.** When using the unit in an existing switch box it will usually be easier to connect the board in the manner shown in Fig. 5. The advantage of this method is that the unit only connects in the 'N' mains lead, and the others just connect through uninterrupted. The system of wiring used in lighting systems is often such that the 'N' lead is the only one available, with this lead being brought in to one side of the light switch, and taken out from the other side. The method of connection shown in Fig. 5 enables the unit to simply be wired in series with the light switch. Do not overlook the link wire across what would normally be the output of the unit—it will just continuously block the supply to the lamp if this link is omitted.

TESTING

Thoroughly check all the wiring before connecting the unit to the mains supply and trying it out. **Errors would probably result in components being damaged, *and could be dangerous.***

At switch-on the lamp will immediately glow very dimly and then, after a very short pause, it should be brought up to full brightness (or at least something closely approaching it) over a period of about one second. If you switch the unit off, wait a few seconds, and then switch it on again, the same effect should be obtained. However, if you switch the unit off and then switch it on again at once, C1 will not have a chance to discharge significantly and the soft turn on will not be obtained. This slight flaw was not deemed important since the light will presumably not be rapidly switched off and on again in this manner in normal use, it will of course also retain some of its heat thus protecting it to a certain extent. □

DIGITAL Trouble Shooting Part Six

MIKE TOOLEY BA

Our nine part series on Digital Troubleshooting aims to provide readers with a practically biased introduction to the diagnosis of faults within digital equipment. The series should also be of interest to anyone wishing to update their knowledge of modern digital devices and circuitry.

IN LAST month's instalment of *Digital Troubleshooting* we introduced microprocessors and microprocessor based systems. This month we shall continue with this theme by taking a look at some common semiconductor memories. These important devices are used for program and data storage within microprocessor based systems. Our companion Digital Test Gear project involves the construction of a current tracer which can be an invaluable aid to pinpointing failures of semiconductor devices in complex systems.

MEMORIES

Last month we mentioned the need for devices which provide a "memory" for the sequences of software instructions (i.e. "programs") and transient information (i.e. "data") used during processing. Various types of memory are available; some provide permanent storage of programs and data and are thus said to be "non-volatile". Other forms of memory provide only temporary storage (their contents being lost when the power supply is disconnected). These memories are said to be "*volatile*".

Whilst some specialised microprocessors (of the type used in simple low-cost control systems) incorporate a limited amount of internal memory for data and program storage, most general purpose microprocessors (including those discussed last month) require external memory devices. Such devices tend to fall into two distinct categories; "*read/write*" memory and "*read-only*" memory.

Read/write memory is simply memory which can be read from and written to. In other words, the contents of the memory can be modified at will. Read-only memory, on the other hand, can only be read from; an attempt to write data to such a memory will have no effect on its contents.

Obvious examples of read-only and read/write memories with which the man in the street will be familiar (particularly if he is a "hi-fi" buff!) are compact discs and compact cassette tapes used for recording music and speech. Once recorded, compact discs cannot be modified whereas a pre-recorded tape cassette can be erased and re-used by simply blanking the record protection slot.

Microprocessor systems use semiconductor memories for compact and high-speed storage and retrieval of data. Semiconductor read-only memories (ROM) are available in various forms depending upon the particular application concerned.

Semiconductor read/write memory is usually implemented by so-called "random access" memories (RAM). The term "random access" simply indicates that one can access stored data anywhere within the memory with equal ease. One should contrast this form of memory with the "sequential access" read/write memory provided by magnetic tape in which data is stored sequentially.

READ-ONLY MEMORY (ROM)

Microprocessors require non-volatile storage for their control programs and, where appropriate, operating systems and high-level language interpreters. This is an ideal application for a ROM. Where the control program is to be updated or the operating system modified, the ROM can be removed and replaced with a later version.

The ROM supplied with an 8-bit microcomputer might, for example, devote approximately 4K bytes to the operating system (dealing amongst other things, with keyboard input, display output, and cassette storage). In addition, a further 12K bytes may be used to implement a BASIC interpreter. The total ROM capacity would then be 16K bytes and this could be provided by one 16K, two 8K, or four 4K ROMs.

Mask programmed read-only memories

When large-scale production of a microprocessor based system is envisaged (as is the case with a home computer, for example), the most cost-effective method of implementing read-only memory is with the aid of a mask programmed device.

Such devices are programmed during manufacture; the mask used determining the actual data stored within the chip. The programming information is supplied to the semiconductor manufacturer by the manufacturer of the microprocessor system. Since the process is only cost-effective for quantities in the tens of thousands, it would be obvious that the manufacturer of the microprocessor system needs to be very confident that the stored data and program is completely free from errors and will not require future modification!

Fusible-link programmable read-only memories

Fusible-link programmable read-only memories (PROM) are cost-effective for medium scale production and are programmed by the equipment manufacturer rather than the semiconductor manufacturer. The PROM consists of an array of nichrome or polysilicon fuses. These fuse links may be "blown" by applying a current pulse of sufficient magnitude to rupture the link.

Programming takes a considerable time but the equipment required is simple and relatively inexpensive. Often, early variants of microprocessor systems are supplied with PROM devices which are later replaced with mask ROM devices as soon as teething troubles and bugs have been eliminated and large scale production commences.

Erasable-programmable read-only memories

The programming of mask-programmed and fusible-link memories is irreversible. Once programmed, devices cannot be "wiped clean" in preparation for fresh programming. The erasable-programmable read only memory (EPROM) is, however, capable of erasure allowing the device to be programmed and re-programmed many times over.

EPROM devices are fitted with a window which allows light to fall upon the memory cell matrix. When this area is exposed to strong ultra-violet (UV) light over a period of several minutes, the stored data is erased. The EPROM may then be reprogrammed using a low-cost device which supplies pulses of current to establish the state of individual memory cells. This process takes several minutes though some EPROM programmers can program several devices at once.

EPROMs are ideal for small-scale production and software development. They are, however, relatively expensive and thus are not used for large-scale production. The following data refers to the most popular series of EPROM devices, the pin-outs for which are shown in Fig. 1:

Type	Size (bits)	Organisation	Package
2716	16384	2K words × 8 bits	24-pin DIL
2732	32768	4K words × 8 bits	24-pin DIL
2764	65536	8K words × 8 bits	28-pin DIL
27128	131072	16K words × 8 bits	28-pin DIL
27256	262144	32K words × 8 bits	28-pin DIL

Electrically alterable/electrically erasable read-only memories

The electrically alterable read-only memory (EAROM) and electrically erasable read-only memory (E^2ROM) are relative newcomers which, unlike the EPROM, can be erased electrically thus avoiding the need for removal from the equipment to which they are fitted. Unfortunately, EAROM and E^2ROM devices are rather expensive and, due to the availability of low-power CMOS RAM devices which may be "battery backed", they have not as yet made much impact on the industry as a whole.

Readers may be forgiven for thinking that EPROM and EAROM devices are really forms of read/write memory. In a sense they are: but a distinction must be made between these memories and "true" read/write memories (e.g. semiconductor RAM) in which individual bytes can be changed at will.

Another important point is the time and ease with which a device may be re-programmed with data. A single byte of data can be accessed from a semiconductor RAM in a typical time interval of 150ns. An entire 8K RAM can have its data changed in a time interval of 8192 × 150ns (plus an additional overhead for the processor). This results in a total programming time which can be measured in milliseconds!

An 8K EPROM, on the other hand, may require several minutes of programming not to mention the time taken for removal and erasure under UV-light! The EAROM fares somewhat better in this respect since it does not require removal for erasure. Even so, the time for re-programming may be several thousand times longer than that associated with a RAM of similar capacity!

RANDOM ACCESS MEMORY (RAM)

Microprocessors also require access to read/write memory in the form of semiconductor RAM. A portion of this memory is used by the operating system for the storage of "system variables" and a specially set-aside area of RAM. The operating system and control program also require access to RAM for temporary storage of data in the form of one or more "stacks".

A further area must be made available for the user to store his own programs and data. In addition, where a raster scanned display is used, an area of RAM is usually devoted to a "screen memory". With modern systems, this reserved area of memory is invariably "bit mapped" (i.e. each bit of "screen RAM" corresponds to a particular pixel).

The typical allocation of RAM on an 8-bit microcomputer might be as follows:

Function	Storage Capacity	Notes
System variables	512 bytes	A fixed address is used for each system variable
Stacks	0–256 bytes	Changes in size during program execution
Screen memory	16K	Bit-mapped screen
User's program and data	up to 31·5K	Amount used depends upon individual program

Bipolar random-access memories

Bipolar random-access memories rely on a conventional bistable arrangement based upon bipolar transistors of the form shown in Fig. 2(a). These memories require considerable power and are only available with relatively small capacities. They are, however, extremely fast and are thus used in high speed applications and to implement buffers between fast processing devices and conventional memories which operate at much slower speeds.

NMOS static memories

NMOS static memories are also based upon a bistable cell configuration as shown in Fig. 2(b). NMOS devices require considerably less power than their bistable counterparts thus permitting much greater densities to be achieved.

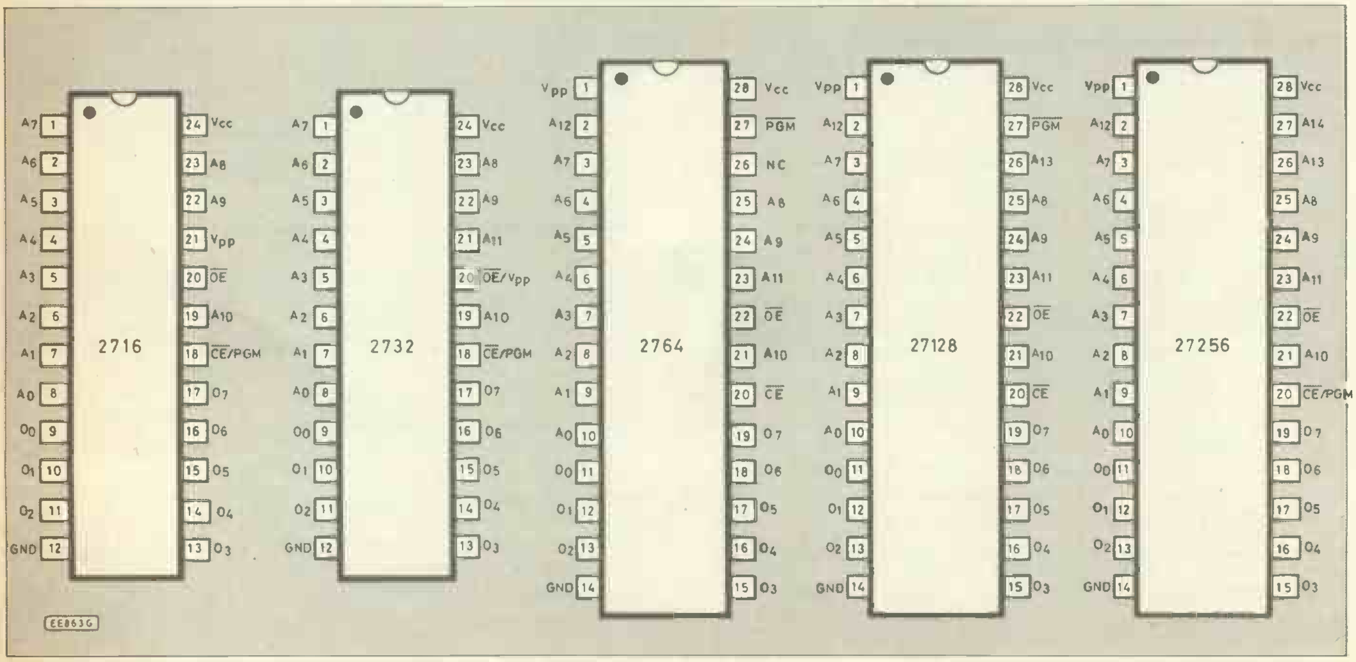
CMOS static memories

CMOS static memories use cell configurations which are similar to those used by their NMOS counterparts. CMOS devices, however, consume negligible power when not operating and thus these devices are ideal for equipment which has to be operated from a battery power supply.

NMOS dynamic memories

NMOS dynamic memories are based upon charge storage within a capacitor rather than the state of a bistable element. The simplified circuit of an NMOS dynamic memory cell is shown in Fig. 2(c). The charge stored in the capacitor, C, inevitably leaks away and thus dynamic memories require periodic "refreshing".

Fig. 6.1. Pin connections for some common EPROM devices.



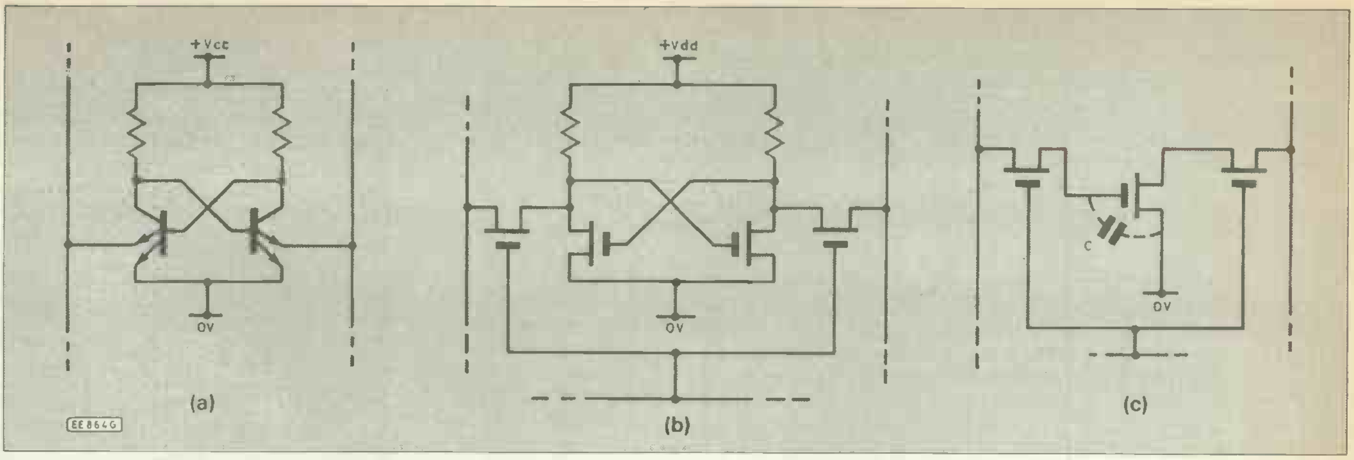


Fig. 6.2. Typical memory cell configurations. (a) bipolar static memory cell. (b) NMOS static memory cell. (c) NMOS dynamic memory cell.

The process of refreshing a dynamic memory involves periodically reading the data stored and then writing it back to the memory. This process may be undertaken by the microprocessor as part of its normal activities or may be consigned to a dedicated dynamic memory controller chip.

The following data refers to a range of the most popular semiconductor devices:

Type	Technology	Size (bits)	Organisation	Package
2114	NMOS static	4096	1K words × 4 bits	18-pin DIL
4116	NMOS dynamic	16384	16K words × 1 bit	16-pin DIL
4164	NMOS dynamic	65536	64K words × 1 bit	16-pin DIL
4256	NMOS dynamic	262144	256K words × 1 bit	16-pin DIL
4464	CMOS static	65536	8K words × 8 bit	28-pin DIL
4864	NMOS dynamic	65536	64K words × 1 bit	16-pin DIL
6116	CMOS static	16384	2K words × 8 bit	24-pin DIL
6264	CMOS static	65536	8K words × 8 bit	28-pin DIL
41256	NMOS dynamic	262144	256K words × 1 bit	16-pin DIL

The pin connections for some common semiconductor RAM devices are shown in Fig. 3.

ADDRESS DECODING

Each location in semiconductor ROM and RAM has its own unique address. At each address a byte (comprising eight bits) is stored. Each ROM, RAM (or bank of RAM devices) accounts for a particular block of memory, its size depending upon the capacity of the ROM or RAM in question.

As an example, a particular system may have a 16K ROM and three blocks of 16K RAM (each comprising eight 16K × 1 bit RAM chips) to make up a complete 64K address range. These devices may have addresses assigned as in the table below:

Device	Capacity (bytes)	Address Range	
		Hexadecimal	Decimal
ROM	16K	0000–3FFF	0–16383
RAM bank 1	16K	4000–7FFF	16384–32767
RAM bank 2	16K	8000–BFFF	32768–49151
RAM bank 3	16K	C000–FFFF	49152–65535

The memory map for this arrangement is shown in Fig. 4.

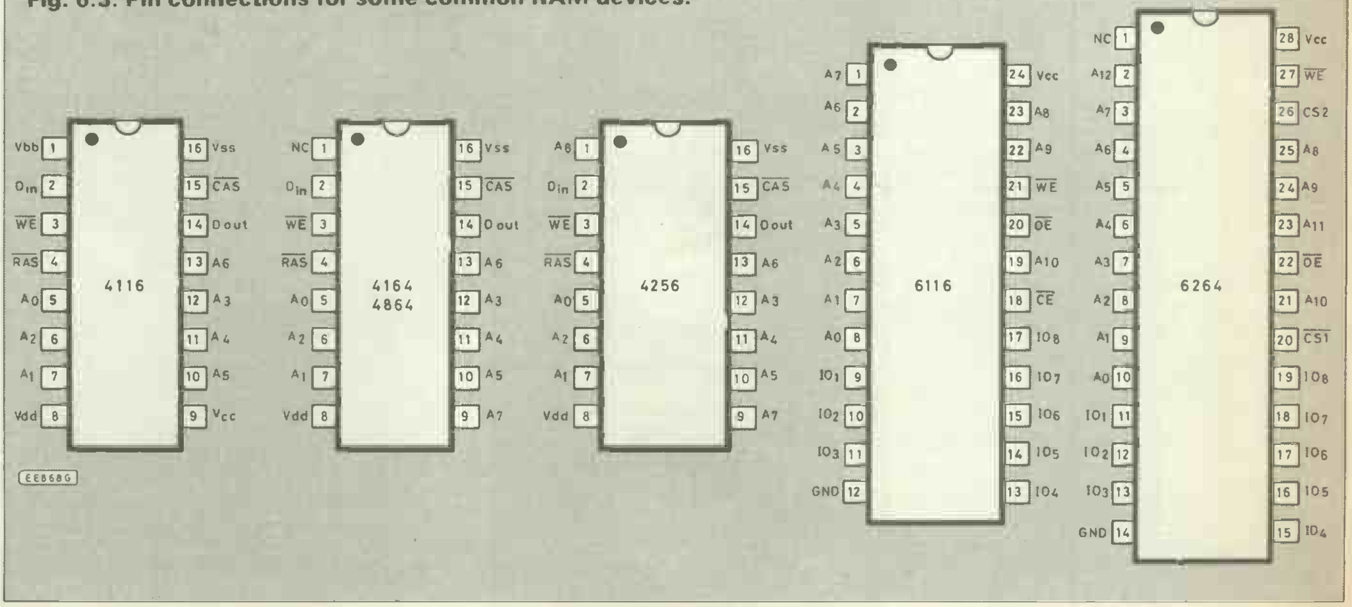
The data inputs and outputs of the RAM devices will be linked (together with the data outputs of the ROM device) to their respective lines on the system data bus.

Each ram device will have fourteen address input lines (A0 to A13) and one chip select ($\overline{CS}$) line. The chip select line is invariably active-low hence, to enable the output of a selected RAM or ROM onto the bus, it will be necessary to ensure that this line is taken low. In addition, all of the semiconductor memory devices will be connected to the read/write line (or a derivative in the form of a memory read/write line).

The address lines of each RAM are connected (together with those of the ROM) to their respective lines on the address bus. Hence, unless we do something to prevent a conflict, we would find that all four blocks of semiconductor memory were being written to or read from at the same time.

What is needed, of course, is a means of decoding the two most significant address lines (A15 and A14) in order to activate the

Fig. 6.3. Pin connections for some common RAM devices.



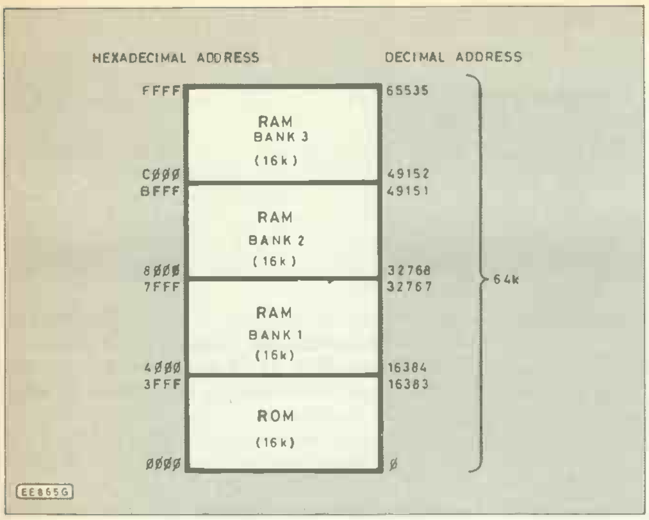


Fig. 6.4. Typical memory map for a fully populated 64K memory.

appropriate chip select ($\overline{CS}$) lines. A suitable decoding scheme is shown in the truth table below:

Address Lines		Chip(s) Selected
A15	A14	
0	0	ROM
0	1	RAM bank 1
1	0	RAM bank 2
1	1	RAM bank 3

The problem of decoding the two most significant address lines is easily resolved using some fairly simple logic (see Fig. 5). Such logic could be based on arrangements of common logic gates or could form part of a larger programmed logic array (PLA).

An alternative solution to the problem of address decoding is that of making use of integrated circuits designed specifically for the application. These devices are known as "decoders" or "demultiplexers" of which the following are common examples:

Device	Function
74LS138	Single 3 to 8 line decoder
74LS139	Dual 2 to 4 line decoder
74LS154	Single 4 to 16 line decoder
74LS238	Single 3 to 8 line decoder

How one of the decoders of a 74LS139 may be used to provide the four active-low chip select signals required by the ROM and three RAM devices of the previous example is shown in Fig. 6. Note that the 74LS139 also has an active-low enable input ($\overline{EN}$). This can be used to disable the chip so that the entire semiconductor memory is simultaneously disabled. Such a provision may prove useful in situations where, for example, it is necessary to "bank" several ROM, RAM or other support devices into the same address space.

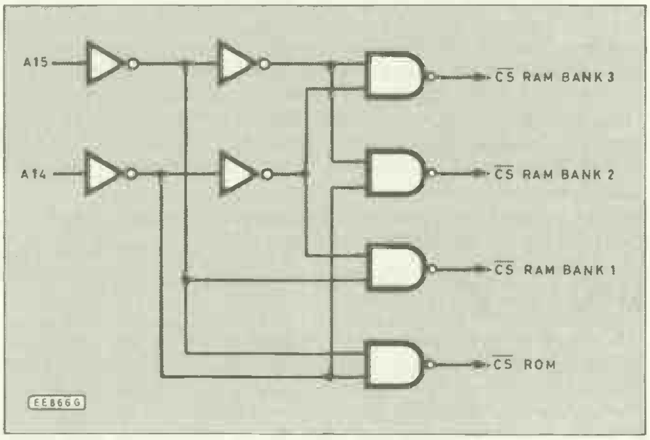


Fig. 6.5. Address decoder logic.

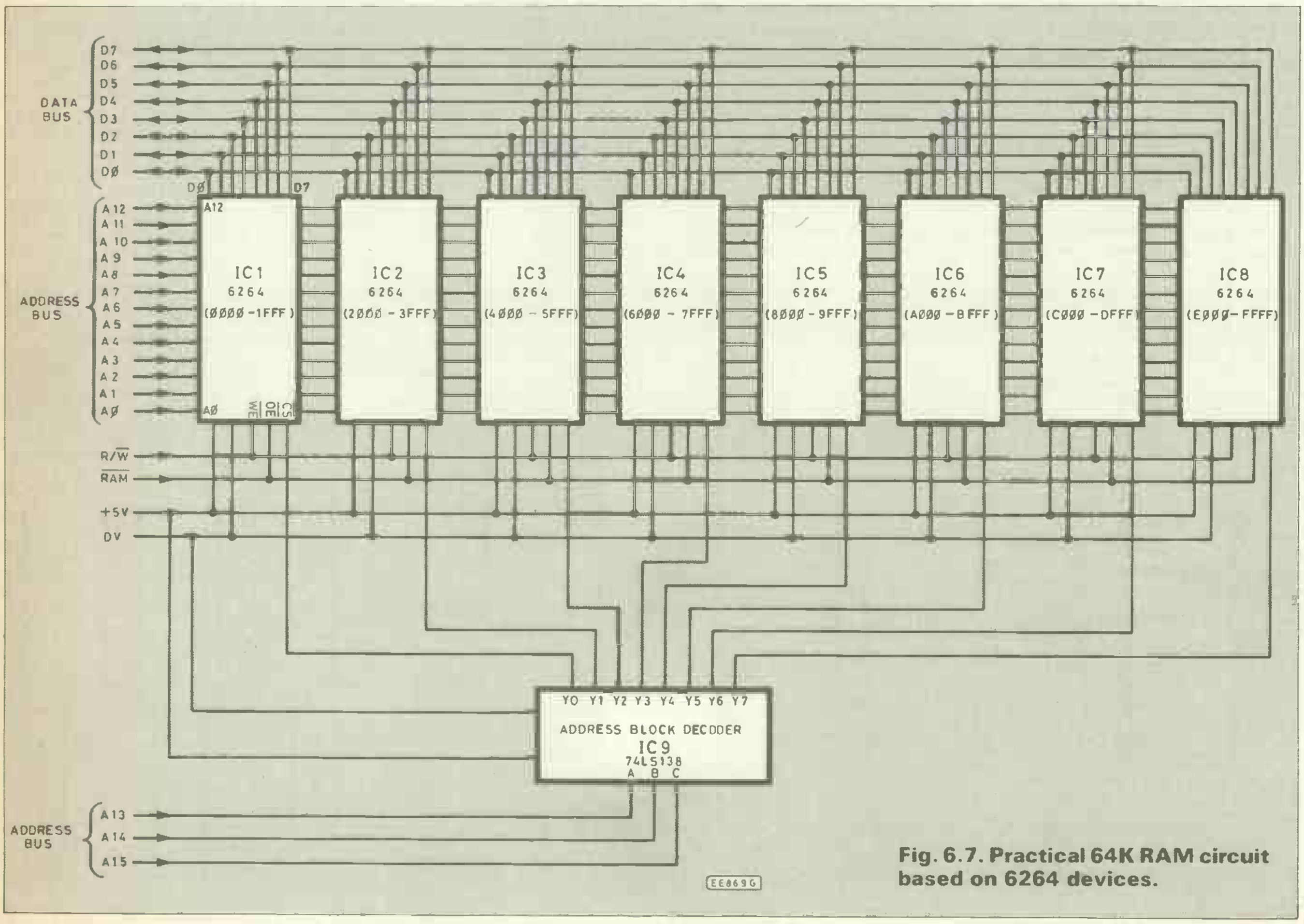


Fig. 6.7. Practical 64K RAM circuit based on 6264 devices.

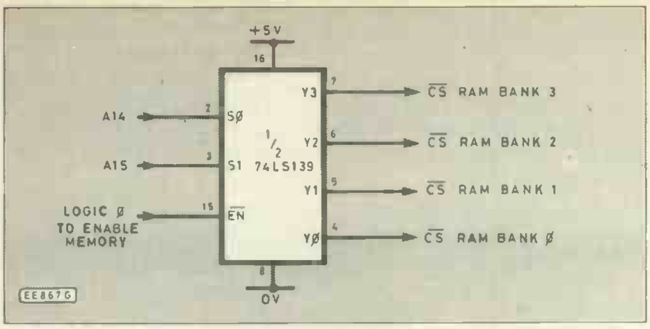


Fig. 6.6. Typical address decoder based on a 74LS139.

PRACTICAL READ/WRITE MEMORIES

The basic arrangement of a practical 64K memory, based on eight RAM devices, is shown in Fig. 7. Each 6264 RAM is organised on the basis of 8K words of 8 bits and thus the 64K memory space is divided into eight 8K blocks (each block corresponding to a particular RAM). A three-to-eight line decoder (IC9) is used to provide the necessary address decoding.

An alternative method of implementing a 64K memory is shown in Fig. 8. This arrangement is based on 4864 devices which are organised on the basis of 64K words of 1 bit and, since conflicts are eliminated in such a configuration, it no longer requires the services of an address block decoder. Many other forms of memory organisation are possible depending upon the particular types of RAM employed, however, the two previous examples show the most commonly used configurations.

FAULT FINDING ON SEMICONDUCTOR MEMORIES

Many modern microprocessor systems incorporate a number of simple system diagnostic routines during the initial phases of execution of their operating system software. These diagnostic routines often check both ROM and RAM devices. In the former case, the contents of each byte of ROM are successively read and a "checksum" is generated. This checksum is then compared with a stored checksum. If any difference is detected an appropriate error message is generated.

In the case of RAM diagnostics, the technique is quite different. Here the process involves writing and reading each byte of RAM in turn. Checking, in each case, that the desired change has been effected. Where a particular bit refuses to be changed, the diagnostic procedure is temporarily halted and an appropriate error message is generated (this may also give the address at which the fault has occurred so that the service technician can trace the fault to a particular chip or bank of chips).

More complex RAM diagnostics involve writing and reading particular patterns of bits according to a rather more complex algorithm. RAM diagnostics can also be carried out on a non-destructive basis. In such cases, the byte read from RAM is replaced immediately after each byte has been tested. It is thus possible to perform a diagnostic check some time after the system has been initialised.

Fault finding on semiconductor memories is obviously considerably simplified where software diagnostic routines are available. In some cases, however, failure of a ROM or RAM device may preclude normal system initialisation and in such cases the steps described last month should be followed.

Failure of individual memory cells can usually be detected using diagnostic software. The task then becomes simply that of identifying the particular failed device. Sometimes the data output of a memory device may be stuck in one or other state. In such cases the fault may usually be readily detected using a logic probe.

EXCESSIVE POWER

In some other cases, the memory failure may be much more dramatic and the faulty chip may be demanding excessive power and running noticeably hot. In this eventuality the following procedure should be adopted:

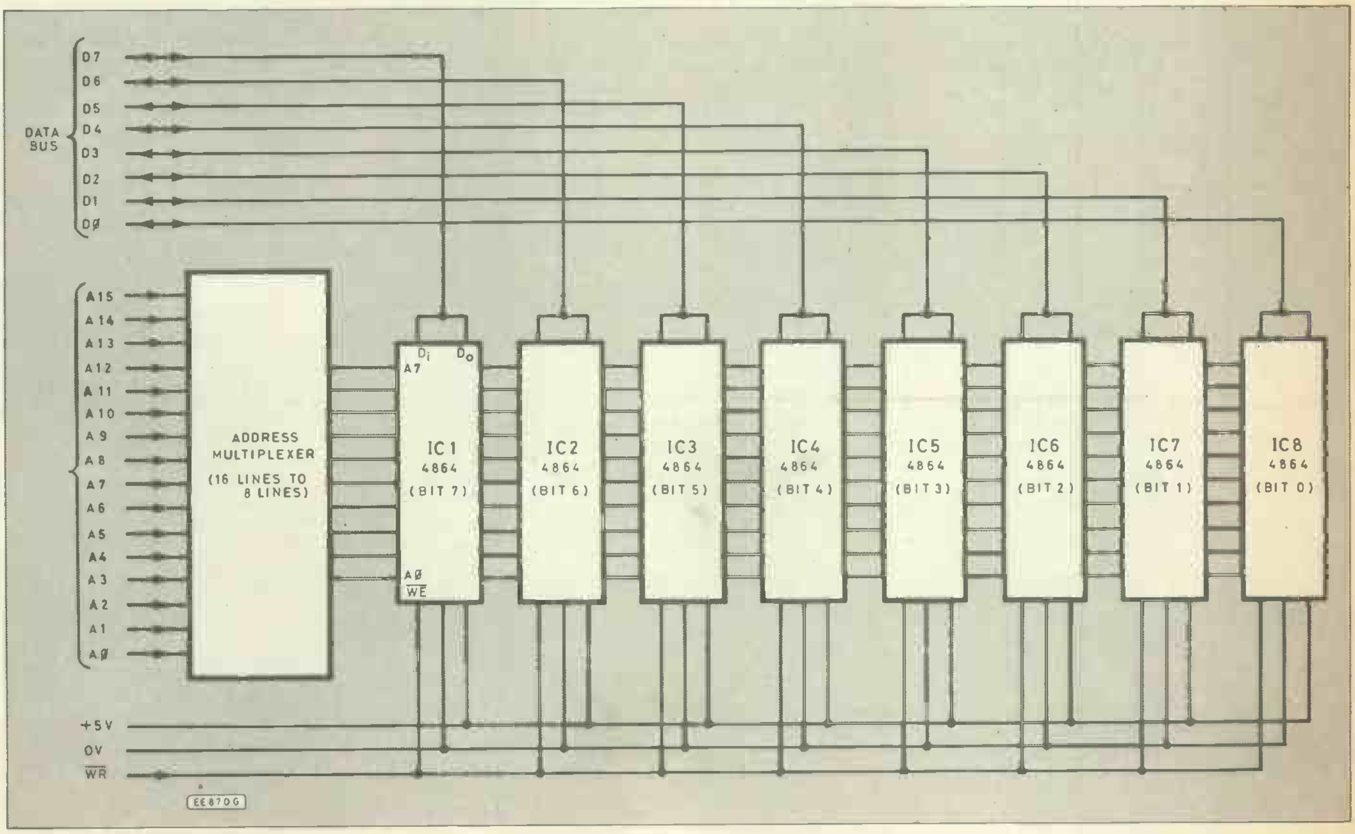
(i) Leave the system running for some time. Then touch the centre of each ROM and RAM chip in turn in order to ascertain its working temperature.

If a chip is running distinctly hot (i.e. very warm or too hot to comfortably touch) it should be considered a prime suspect. If possible compare with the heat produced by a similar chip fitted in the same unit or in another operational unit.

(ii) Where the ROM or RAM chips have been fitted in sockets, carefully remove and replace each suspected device in turn (disconnecting the power, of course, during the process). Replace with known functional devices.

(iii) Where ROM or RAM chips are soldered directly to the p.c.b. a Current Tracer can be usefully employed to pinpoint a failed device. The Current Tracer should be applied to the copper foil side of the p.c.b. at strategic points (i.e. along the supply rails to each device).

Fig. 6.8. Practical 64K RAM circuit based on 4864 devices.

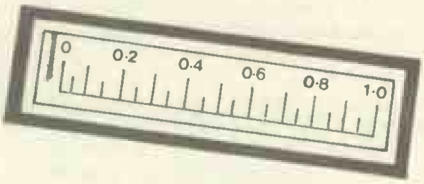


A device which is consuming significantly more (or significantly less) than that of other similar devices should be considered suspect.

Finally, and on a more general note, whenever a suspect chip has to be desoldered from a printed circuit board, it is strongly recommended that readers replace the chip with a socket rather than simply replace it with another soldered-in device. At the cost of only a few pence for a DIL socket, this little precaution can save much aggravation!

Next month: We shall be dealing with I/O and other microprocessor system support devices. Our companion Digital Test Gear Project involves the construction of an Audio Logic Tracer. This novel device allows the user to monitor signals in a complex digital system simply by listening to them!

CURRENT TRACER



MIKE TOOLEY BA

Keep on the right track with this low-cost tester

OUR sixth Digital Test Gear Project deals with the construction of a Current Tracer. This unit provides a means of sensing and indicating the relative magnitudes of the currents present in printed circuit board tracks without having to break the circuit in order to insert a conventional current measuring instrument. The instrument described is capable of sensing current levels of as little as a few milliamps and can be either direct coupled or a.c. coupled to the circuit under test.

Commercial current tracers operate on one of two principles; either sensing the small voltage dropped along a printed circuit track carrying a current or employing a Hall effect device to sense the magnetic field present in the immediate vicinity of a printed circuit track carrying a current.

Generally speaking, Hall effect current tracers are superior since they require no direct contact with the printed circuit tracks and the uncertainty of making an effective contact with the track is eliminated. Unfortunately, such instruments are extremely expensive and the technique is thus inappropriate for a low-cost "home constructed" item.

CIRCUIT DESCRIPTION

The complete circuit diagram of the Current Tracer is shown in Fig. 1. The unit senses the small voltage drop present along a printed circuit track (typically a few hundred microvolts (μV)) and comprises a single inverting operational amplifier IC1. To cope with a wide range of input voltage levels (from a few microvolt (μV) to several hundred millivolts (mV) the operational amplifier is used in a configuration which ensures a logarithmic characteristic (i.e. the voltage gain provided by the circuit falls markedly as the level of the input signal increases).

Switch S1 provides selection of a.c. or d.c. coupling at the input of IC1 whilst potentiometer VR1 provides additional manual gain (Sensitivity) control. The bridge rectifier arrangement formed by diodes D1 to D4 ensures that the signal presented to the meter is of the correct polarity regardless of the polarity of the input. Diodes D5 and D6 provide "last ditch" protection of the meter movement whilst capacitor C3 determines the time constant of the meter display.

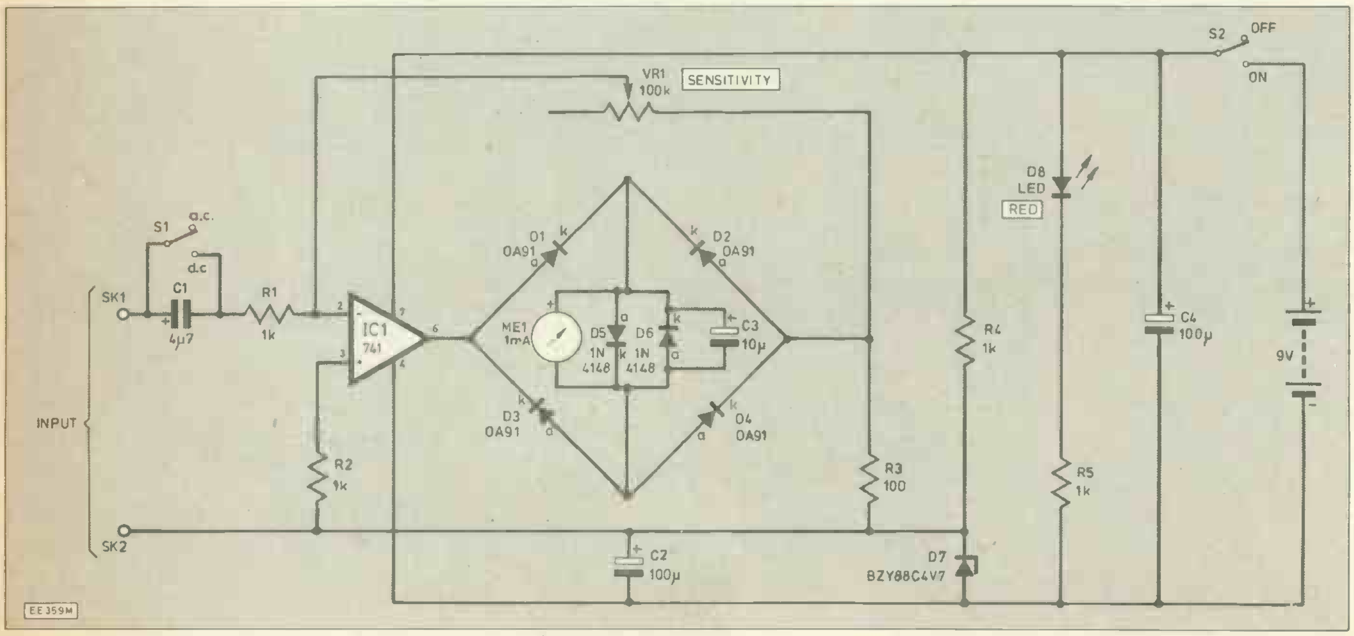
A nominal "half-supply" rail for the operational amplifier inputs is provided by means of a simple shunt Zener diode regulator comprising resistor R4 and diode D7. Capacitors C2 and C4 provide decoupling whilst the l.e.d. D8 indicates that the instrument is switched "on".

CONSTRUCTION

The Current Tracer is extremely simple to construct. With the exception of the battery connector, meter, probe socket, and front panel controls, all components are mounted on a standard size matrix board comprising 24 strips of 23 holes.

The stripboard component layout is shown in Fig. 2. Readers should note that four track breaks in the copper strips are required under the i.c. holder and these should be made using a spot face cutter. If

Fig. 1. Complete circuit diagram for the Current Tracer.



such a tool is unavailable, a sharp drill bit of appropriate size may be used.

The following sequence of component assembly is recommended; i.c. socket, links, capacitors, resistors, diodes, and terminal pins. Before mounting the stripboard in its final position, constructors are advised to carefully check that components, links, and the track breaks have been correctly placed.

It is also worth checking that the polarised components (including electrolytic capacitors and diodes) have been correctly orientated. Constructors should also examine the underside of the board for dry joints, solder splashes, and bridges between tracks. It should go without saying that a few minutes spent checking the board at this stage can save many hours of agony later on!

After the board has been thoroughly checked, it should be mounted horizontally in the base of the case using four short insulated stand-off pillars. The i.c. should then be inserted into its socket, again taking care to ensure correct orientation.

The meter movement, controls and probe connectors are mounted on the front panel according to the photographs and rear panel wiring (Fig. 3). Before finally mounting the front panel components the facia can be lettered according to the photographs.

COMPONENTS

See Shop Talk page 213

Resistors

R1 1k
R2 1k
R3 100
R4 1k
R5 1k
All 0·25W 5% carbon

Potentiometer

VR1 100k lin. carbon

Capacitor

C1 4µ7 tant. 35V
C2 100µ p.c. elec. 16V
C3 10µ p.c. elec. 16V
C4 100µ p.c. elec. 16V

Semiconductors

D1,D2,D3,D4 OA91 (4 off)
D5,D6 1N4148 (2 off)
D7 BZY88 C4V7 Zener
D8 Red l.e.d (with mounting bezel)
IC1 741 Op. Amp

Miscellaneous

ME1 1mA edgewise meter (Electromail 258-209)
S1 SPDT miniature toggle switch
S2 SPDT miniature toggle switch
SK1 2mm socket (red)
SK2 2mm socket (black)

8-pin low-profile DIL socket; case, Verobox measuring approx. 205 × 140 × 110mm; 0·1in. matrix stripboard 65mm × 63mm (24 tracks × 23 holes); single-sided 1mm terminal pins (8 required); insulated threaded mounting pillars (4 required); mounting bolts (4 required); mounting nuts (4 required); Knob; snap-fit PP3 battery connector; PP3 battery; Probes (see text).

Approx. cost Guidance only £25

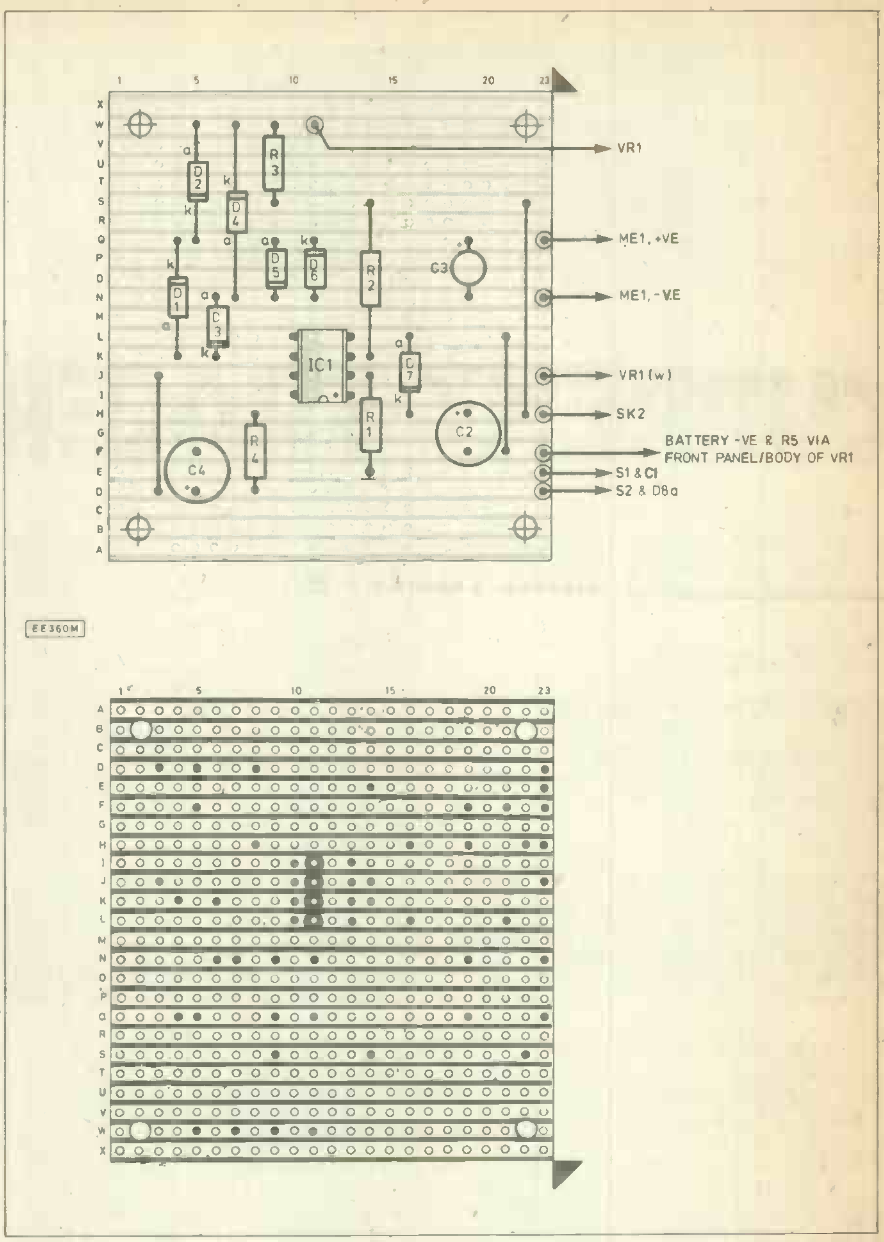


Fig. 2. Circuit board component layout, details of breaks to be made in the underside copper tracks and wiring details to front panel. Note that an i.c. holder should be used to mount IC1 on the board. The VR1 lead marked with a "w" should be taken to the wiper or centre tag of the potentiometer.

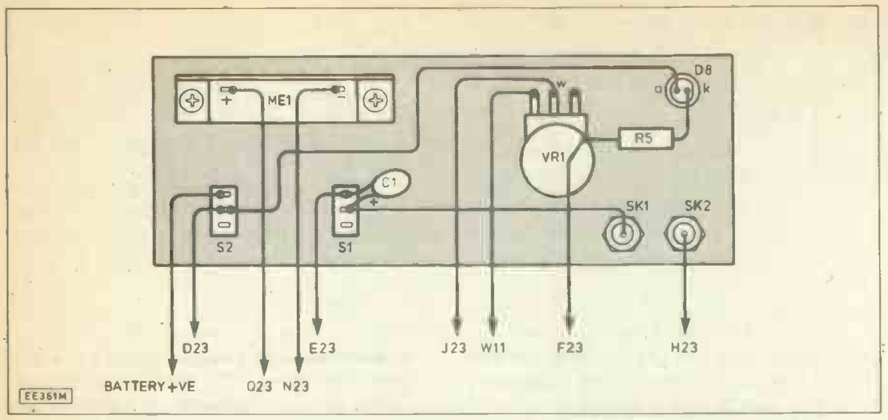


Fig. 3. Interwiring between the front panel mounted components. Note that resistor R5 is soldered to the "metal" body of potentiometer VR1.

Links to the front panel mounted components should be made using short lengths of insulated wire, following the wiring diagram shown in Fig. 3.

TESTING

When complete, constructors should carefully check the internal wiring of the Current Tracer—taking particular care to check the wiring of the battery connector and meter. The PP3 (or similar) battery may then be connected and the unit should be switched "on".

The l.e.d. D8 should be illuminated, indicating the presence of the d.c. supply, and a multimeter—switched to the 10V d.c. voltage range—should be used to check that the voltage developed across the Zener diode D7 is in the range 4·5V to 5V. If this is not the case, constructors should carefully check the internal wiring and component board layout.

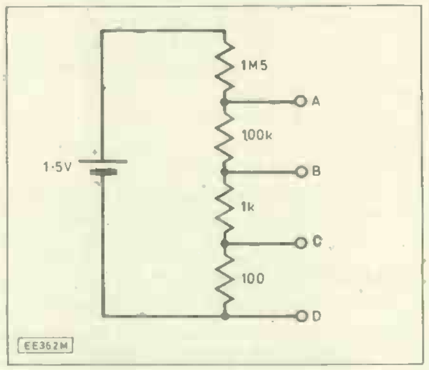


Fig. 4. Current tracer test circuit.

Two probes should then be purchased (or constructed!) bearing in mind that the equipment requires a very effective connection to the track of the printed circuit under test. Each probe should be fitted with an insulated connecting lead terminated with a 2mm plug. The probes should then be used to link the Current Tracer to the test circuit shown in Fig. 4, which provides voltage drops of approximately 100µV, 1mV, and 100mV respectively.

The Current Tracer's Sensitivity control, VR1, should be set to maximum (fully clockwise) and the probes applied to points *A* and *D* of the test circuit. This should produce a full-scale indication on the meter, approximately 1mA.

The probes should then be applied to *B* and *D*. The reading should then fall to approximately 0·6mA. Finally, the probes should be applied to *C* and *D*. In this position, a reading of approximately 0·3mA should be produced.

It should be noted that since the Current Tracer is not "polarity conscious", the polarity of the input connections is unimportant!

The completed Current Tracer showing layout of components within the case. The photograph above shows the front panel lettering and component layout.

IN USE

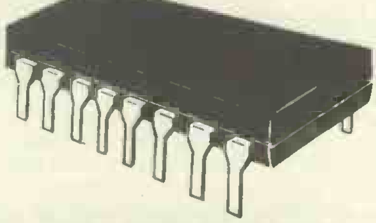
Having confirmed that the Current Tracer is operating correctly, it is well worth spending a little time familiarising oneself with its use. It will, of course, be necessary to enlist the services of an appropriate printed circuit board. This should ideally be populated with a variety of TTL devices and should, of course, be connected to its normal supply.

The Current Tracer's probes should be applied at various points along the printed circuit tracks which convey the supply rails and the indications produced should be observed. A probe separation of 10mm should produce a discernible deflection on a printed circuit track carrying the normal supply current associated with a standard-TTL device.

Increasing the separation of the probes will, of course, increase the indication produced. With practice, it should be possible to make a meaningful assessment of the relative supply current for each chip present!

Finally, the probe can also be used to detect faults in connectors (simply apply the probes either side of similarly numbered pin connections and observe the indication produced), dry or "high resistance" joints, and inadequate decoupling (in this latter application, the instrument should be used in the "a.c." mode and the probes connected between the positive supply rail and 0V). □

Next month: Our companion Digital Test Gear Project is an Audio Logic Tracer. This novel device allows the user to monitor digital systems simply by listening to them!



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FOR YOUR ENTERTAINMENT

BY BARRY FOX

High Flyer

Keep an eye out this summer for what happens to Richard Branson's plan to fly the Atlantic in a hot air balloon. Everyone, or almost everyone, envies Buccaneer Branson the chance to fulfill his schoolboy fantasies—while scoring valuable publicity for his airline and entertainment empire.

The first adventure, winning the Blue Riband prize for fastest Atlantic sea crossing, succeeded at the second attempt. The first boat, the *Virgin Atlantic Challenger*, sunk when it hit debris in the water with just 3 hours to victory. *VAC II* hit fuel supply problems, but broke the record.

Fuel will be Branson's first worry with the *Virgin Atlantic Flyer*. Hot air balloons fly because the air inside the envelope is a few degrees hotter, and thus lighter, than the air outside.

The VAF plan is to use solar power to heat the air. But the balloon will still have to carry 9500kg of liquid propane in cylinders to fire the burners when the sun isn't working. Branson plans to start the flight from New York State and already some people are wondering what will happen if he hits trouble and has to dump fuel for an emergency landing—or crashes with that amount of propane still on board.

Hopefully this problem can be resolved, if necessary by starting the flight from a seaboard site and sticking to a marine route. But there is still the question of communications. Virgin has unveiled grand plans but seems hopelessly unprepared and ill-informed over how to make them work. At the press conference called to unveil the VAF plan, it was clear that the Virgin people hadn't even recognised the problems, let alone talked to each other about them.

They have promised to send back live TV pictures for TVS and the ITV network to broadcast in Britain. But how do you send wide bandwidth video signals from a balloon travelling 3,400 miles at up to 35,000 feet, for 3 days in unpredictable directions dependent entirely on the winds, when the balloon is travelling too fast for a boat to keep up?

Nothing is impossible, but the chances of Virgin and TVS doing this are highly remote. And TVS, I fear, has a history of technical over-enthusiasm. It was TVS who broadcast a feature film in 3D on a Sunday afternoon. The IBA's switchboard was jammed with complaints from viewers who did not have the necessary viewing spectacles and not unreasonably objected to watching 2 hours of drunken double, two-colour images. Experiments are fine for a science programme test transmission, but not for a full length feature at peak viewing time. Since then the IBA has clamped down tighter on everyone, even for sensible experiments.

Military View

The military will be watching Virgin's £0.75 million escapade with disguised interest—just as they kept a close eye on the previous trips. The armed forces would like to learn as much as possible about communicating from high speed, unstable transport.

Japanese company Icom, through Thanet Electronics, will provide h.f. and v.h.f. units by which the balloon can make direct radio links with the ground. If speech proves impractical, the VAF may have to do as the two VAC boats did and use telex. With slow data rate and error correction, telex can usually get messages through when speech links fail.

Don't by the way be confused by the fact that Cellnet is a sponsor. The VAF cannot use cellular radio in the air; the signals would carry far too far and crash the main control computer which is programmed to distribute low power u.h.f. calls from land mobiles through small area cells.

Virgin will use cellular 'phones to help the ground crew and press get to the landing spot ahead of the balloon. With a hot air balloon you only know very roughly where you are going to come down!

Satellite Talk

Virgin talks about keeping the balloon in constant communication with the ground via satellite and using a satellite link to transmit the live television pictures to TVS.

Chris Moss, Virgin's VAF project officer, has an idea on this that sounds neat. The balloon envelope will be the biggest ever built. It is taller than Nelson's Column, almost as large as the Wembley Stadium pitch and can easily swallow a Jumbo jet. *"We will use three video cameras inside the capsule and two outside—and put a satellite dish* ***inside*** *the envelope,"* says Moss.

Others in Virgin are telling how the balloon envelope will be made from a new ICI material. It's laminated nylon with an aluminium coating on the inside. This will let ultra-violet light into the balloon to heat the air, and stem radiation heat losses from inside the balloon.

When I spoke with Virgin it didn't seem to have dawned on anyone that the aluminium film would make a parabolic reflector which will bounce the GHz satellite signals back onto the dish transmitting them. If any signal gets through it will certainly be attenuated.

In fact there are other reasons why the dish can't go in the envelope. Tom Barrow is project manager at Thunder and Colt, the balloon makers.

"There would be too much risk of damage during inflation prior to take-off," says Barrow. *"The communications equipment will have to be outside."*

Other personnel at Virgin talked vaguely of mounting the aerials on an outrigger . . .

It would be possible to transmit live TV pictures to a boat below by line of sight microwave link. But Branson himself ruled this out, when answering a question about safety and whether a rescue boat could follow the balloon.

"Only the Virgin Atlantic Challenger could keep up—and we don't intend trying that again," he says with an engaging smile.

Virgin people talk vaguely about beaming signals up to a communications satellite (it would be *Intelsat* or *Eutelsat*) and from there down to ground. But how?

Newshawk

News crews covering the Falklands crisis failed to transmit in this way from rolling ships. The dish has to be aligned on the satellite with an accuracy of a single degree.

Military dishes are stabilised with a gyroscope. Satellite systems for cars and lorries can work with small wire aerials, but they can handle only written messages with low data rate or, at best, speech.

Land based dishes for communicating with *Intelsat* and *Eutelsat* are many metres in diameter and securely fixed on a concrete land base. ITN, the ITV news company, uses *Newshawk*, a transportable system made by Marconi. Newshawk cost £125,000, weighs nearly 200kg and relies on a 2m dish sector and two 0·9m packages of electronics.

"It is not beyond the wit of man," says Mike Garnett of Marconi, *"to devise a gyro-stabilised system. But it would need long, hard work."*

It is highly unlikely that Virgin has the time for this work before the planned summer launch.

A fixed Newshawk needs 2·5 kilowatts of power at mains voltage. The generator and fuel for this would be bulky. The servo-motors and gyro needed for stabilisation would add yet more weight and consume yet more power and fuel.

The balloon crew could transmit still video pictures over v.h.f. or h.f. radio links, or beam line-of-sight signals to rendezvous craft, provided the craft know where to be. Or Branson could drop videotapes by parachute. If the tapes were packaged with a radio beacon a boat might find them before the VAF reached Europe.

Incidentally, when the BBC televises the Boat Race the engineers use line-of-sight u.h.f. links with aerials on the camera craft lined up by hand on aerials along the shore. For helicopters and balloons, the BBC uses microwave dishes and signals of anything from 2·5GHz upwards.

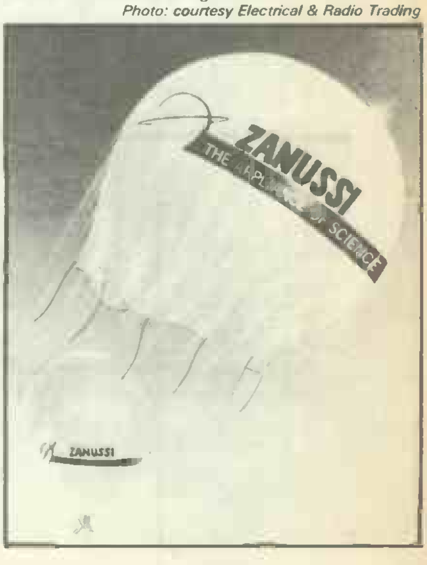
The dishes point down to receiving dishes on the ground below. The higher the frequency the more directional the beam and the more difficult it is to line up the dishes.

As one engineer put it: *"The Virgin satellite scheme sounds loony."*

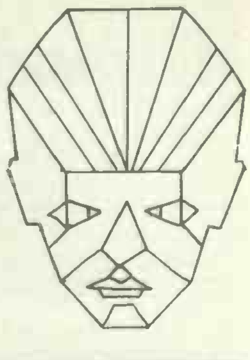
The Challenge

It is rumoured that a Zanussi sponsored balloon, piloted by balloon maker Don Cameron, has challenged Richard Branson to a transatlantic race. Don almost made the crossing in 1978.

Photo: courtesy Electrical & Radio Trading



Experimental SPEECH RECOGNITION UNIT



R.A.PENFOLD

Your computer can recognise speech with the aid of a little electronics

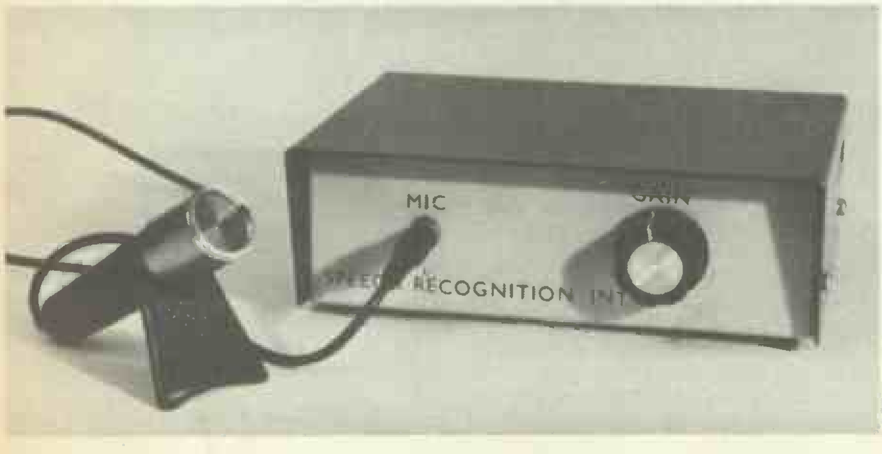
IT IS often said that "computers are idiots", or words to that effect, which can seem to be a rather harsh judgement given that computers are being used to good effect in a seemingly endless range of tasks. Opinion on this is something that is largely governed by the applications in which individuals wish to use computers. While computers can perform what are undoubtedly quite complex tasks in such diverse applications as word processing and the control of manufacturing plants, some quite mundane tasks seem to stretch their capabilities practically to breaking point. The truth of the matter is that by human intelligence standards computers are decidedly dim, and where they perform at their best is in applications which could have been tailor made to suit the computer. In other tasks it requires a lot of ingenuity and skill on the part of both hardware and software designers to get the machines to out-perform an average five year old.

Speech recognition is perhaps the perfect example of this phenomenon. This is something that most of us are able to perform with little difficulty and while doing other tasks, but despite recent advances a computer system with fully the same capability has not yet been produced. If and when such a system is devised it will need far more computing power than the likes of the Spectrum and BBC machines can provide, and will almost certainly be beyond the capabilities of even the up-market 16 bit business machines for that matter.

A computer able to understand a vocabulary of several thousand words, and still able to comprehend these words when strung together into sentences must be the ultimate aim, but in the meantime simple systems capable of responding to a few single words are about all most of us are likely to be able to use.

Speech recognition is a facility that has been available to some computer owners for some time now, but it remains far from a standard feature or even a common add-on. As far as the hardware is concerned it does not require anything particularly complex, and it is really in the software that a speech recognition system stands or falls. For the software enthusiast it represents an interesting line of research and the opportunity to try something a little different.

The system described here is based on a simple home constructed add-on for the BBC model B micro, or one of the later versions of this machine. The BBC computer is the obvious choice for this type of unit as it has a comprehensive range of input/output port, including the analogue port with its four inputs that are utilised in this case. However, the unit should be able to drive other computers that have a suitable analogue port, or are equipped with a suitable add-on port.



APPLICATIONS

Practical applications for simple speech recognition systems are fewer than one might think. The limitation of only being able to recognise (say) half a dozen words is one factor in this, but even this is good enough for many applications. For example, "up", "down", "left", "right", and "stop" are all that are required for speech controlled cursor operation, and a couple of extra words would permit things such as menu options to be selected.

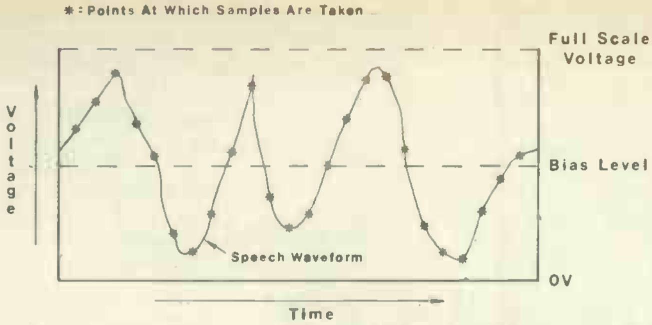
The main problems are the operating speed which tends to be slow, and the memory taken by the speech recognition program leaving relatively little available for an applications program. The memory problem is the less severe of the two, and a recognition program can take up surprisingly little memory. Also, even modestly priced computers seem to have a reasonable amount of RAM these days. The speed problem is a greater limitation, and using fast machine code routines to provide the word recognition is not the complete answer. The response time will still be something less than instant, and obviously words have to be completed before they can be recognised. Although a speech activated joystick might seem like a good idea, it would probably give lower scores from your favourite action game than a conventional type.

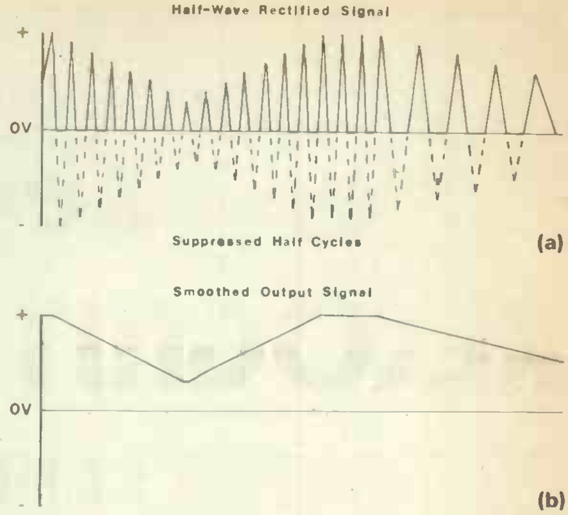
Simple speech recognition systems probably have most potential in adding ease of use to systems intended for non-expert users, and in providing a convenient user interface for the handicapped.

FUNDAMENTALS

Obviously the first requirement of a speech recognition system is to have some means of getting sounds into the computer in a form that enables suitable software to recognise words using some form of pattern matching. There are two basic approaches to this problem, and the more sophisticated of these is to use conventional audio digitising. This requires a high speed analogue-to-digital converter with the input biased to about half the full scale input voltage, which corresponds to a returned reading of about 128 with a conventional 8 bit converter.

The audio input signal varies the input voltage either side of its quiescent level, and a regular series of readings are taken which must track the rises and falls in voltage; Fig. 1 should help to explain this process. This





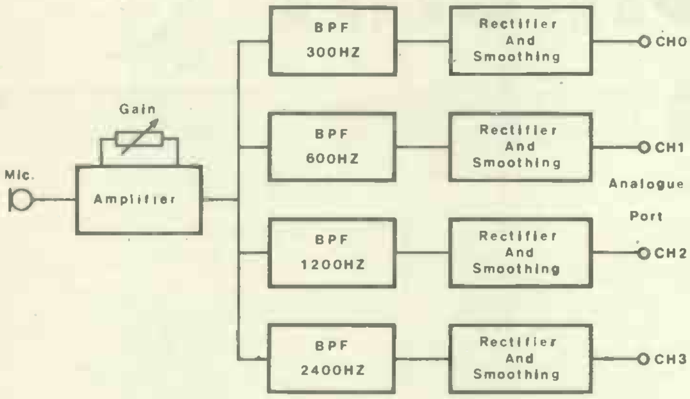


Fig. 1. (top left) Conventional audio digitising gives an accurate numerical representation of the input signal, but requires large amounts of memory.

Fig. 2. (left) Block diagram showing the arrangement used in the system. The input signal is split into four pitch bands and the volume level on each one is recorded.

Fig. 3. (above) The filtered signal is first half-wave rectified as in (a) and then it is smoothed to give a final output as in (b).

method has a lot in its favour, and it gives a very accurate representation of the digitised word which, with the aid of sophisticated pattern matching software, can usually distinguish between quite similar words.

The drawback of this method is the large amount of memory which is taken up by each digitised word. Bear in mind that each word in the system's vocabulary has to be stored in memory so that it can be checked against received words. Also, the input signal has to be sampled at quite a high rate, with 5kHz (5000 samples per second) being about the minimum requirement. In order to store just five words, allowing one second per word, most of the BBC model B computer's available RAM would be taken up in mode 7.

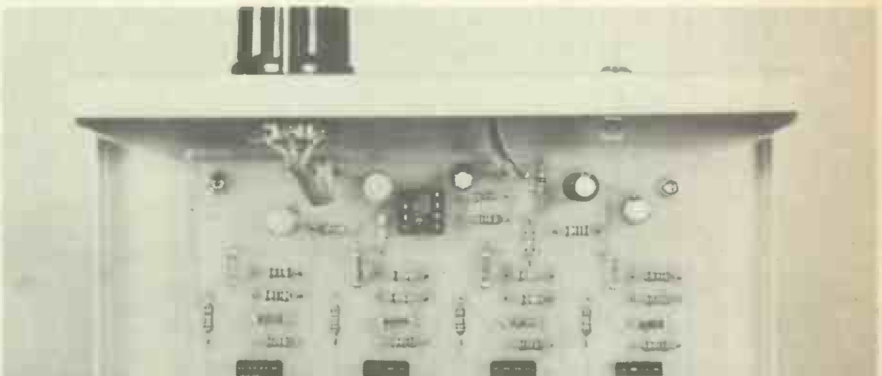
Due to its rather slow maximum sampling rate of about 100 per second, this system is not applicable to the BBC machine's built-in converter. With its four inputs and maximum sampling rate of about 25 samples per channel per second it is just about usable with the alternative method. This uses the arrangement outlined in Fig. 2. The microphone converts the voice sounds into corresponding electrical signals, but these are very weak and must be considerably amplified in order to bring them to a usable level. A gain control enables the sensitivity to be set at a point which gives a reasonably strong output to the computer, but which does not cause the unit to become overloaded on signal peaks.

The amplified signal is split four ways and feeds into four bandpass filters. Each of these enables signals over only a very restricted range of frequencies to pass through to the subsequent stages, and each filter operates over a different frequency range. The filters effectively divide the audio input signal into four separate parts, which are then processed independently. Most of the strong frequency components in a voice signal are in the 200Hz to 3kHz range. The filters are spaced at roughly octave intervals from 300Hz to 2·4kHz so that together they cover the full frequency range that is of interest in this application. The general idea of the system is to record the variations in the volume of the input signal, and to compare these with volume patterns held in memory. In its most basic form this approach is ineffective since many words rise and fall in volume in similar patterns despite the fact that they sound quite different. By splitting the signal into four frequency bands and recording the volume variations of each one a more accurate and individual representation of the sound is obtained. For instance, "sss" and "ssshhh" sounds tend to have strong high frequency components with a relatively weak low frequency content, whereas "rrr" sounds have a strong low frequency content with relatively little in the treble range.

The output from each filter is rectified and smoothed to give a d.c. voltage that is proportional to the volume level. The rectification is a simple half-wave type which just removes the negative half cycles, as in Fig. 3 (a). The smoothing circuit has reasonably fast attack and decay times so that the d.c. output signal follows the quite rapid changes in volume reasonably accurately, but they are made long enough to avoid excessive ripple on the output. This gives an output of the type shown in Fig. 3(b). Assuming a word duration of one second, the system could use as little as 100 bytes of RAM to store each word pattern, which results in very little RAM being eaten up even by ten or so stored patterns.

CIRCUIT

The circuit diagram of the input amplifier is shown in Fig. 4, while the circuit for one filter and rectifier stage appears in Fig. 5. The other filter stages are essentially the same but have the filter component values changed to give the required operating frequencies (the values in Fig. 5 are for the filter having the lowest centre frequency).



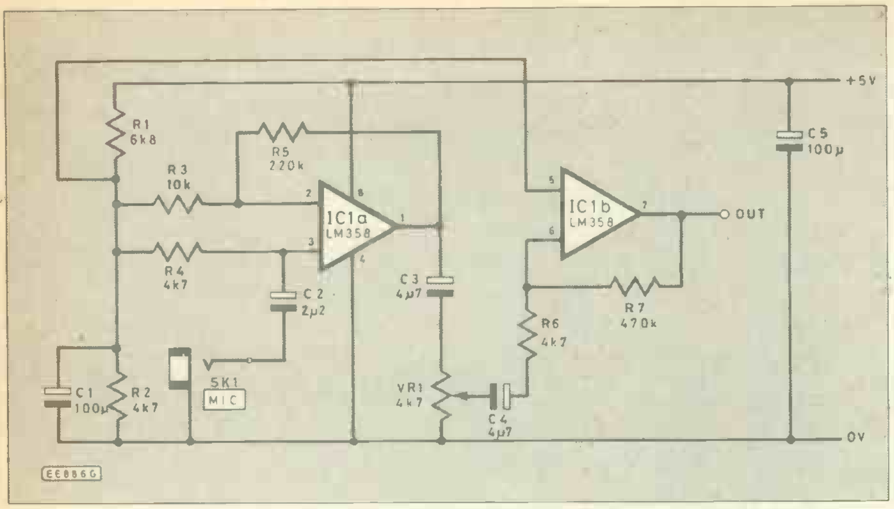


Fig. 4. The input amplifier circuit diagram.

Both circuits are fairly conventional with the input amplifier using a dual operational amplifier to provide a total voltage gain of about 66dB (2000 times). The input is suitable for both low and medium impedance dynamic microphones, or types having similar output characteristics. The low impedance type sold as replacements for use with cassette tape recorders are the cheapest type which is suitable, and crystal microphones are the only common type which are unsuitable.

Integrated circuit IC2a acts as the bandpass filter and it is connected in a standard operational amplifier configuration. Similarly, IC2b operates as a standard precision half-wave rectifier. One slightly unusual aspect of both circuits is that they are operated without a negative supply rail. This is acceptable because the LM358 has input and output stages which will operate at potentials right down to the 0 volt supply rail. Many dual operational amplifiers are pin for pin compatible with the LM358, but few support single supply rail operation. The use of substitutes is unlikely to give satisfactory results and is definitely not recommended. The point of designing the circuit this way is that it enables the interface to be powered from the +5 volt supply output of the BBC computer's analogue port. No buffer stage is needed at the output of each smoothing circuit as the analogue inputs have an extremely high input impedance.

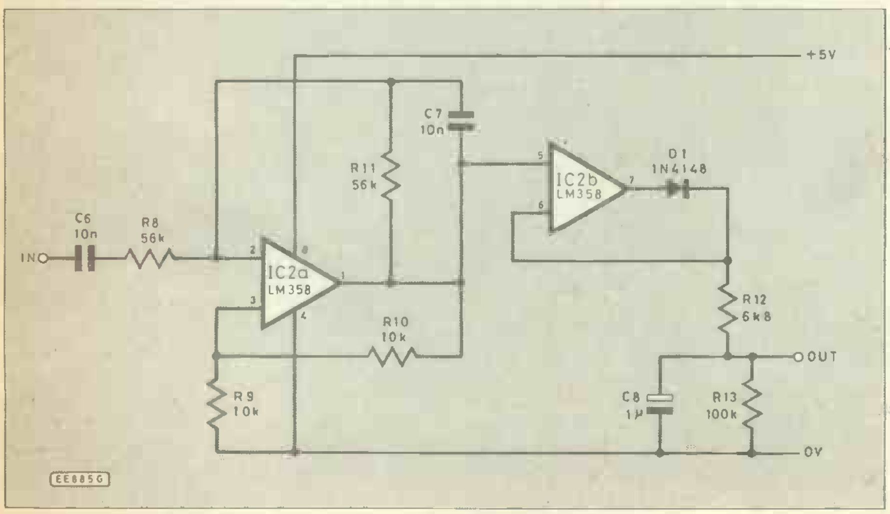
CONSTRUCTION

Details of the printed circuit board track pattern and component layout are shown in Fig. 6. The integrated circuits are not static sensitive types, but it is still probably worthwhile fitting them in integrated circuit holders which are very inexpensive these days. Be careful to fit the semiconductors and electrolytic capacitors the right way round. Pins are fitted to the board at the points where the connections to SK1, PL1 and VR1 will be made.

A metal instrument case having approximate outside dimensions of 150 by 100 by 50 millimetres makes an excellent housing for this project, but any case of about this size should suffice. However, a type which is of all metal construction is preferable as it will provide a degree of screening against sources of electrical interference, and computers, monitors, etc. are often prolific sources of such interference.

Potentiometer VR1 and SK1 are mounted on the front panel, and probably the best type of socket to use for SK1 is a 3·5 millimetre jack type. This matches the type of plug fitted to most cassette recorder microphones. Many of these have an integral on/off switch which connects to a 2·5 millimetre jack plug. Neither the switch or the extra plug are relevant to this application, and they are just ignored. Some microphones have the two plugs in a single moulding which makes them a little awk-

Fig. 5. The circuit diagram for one filter, rectifier, and smoothing circuit. The other three are essentially the same, but have the filter values modified to give the required centre frequencies.



COMPONENTS

See Shop Talk page 213

Resistors

R1,R12,R18, R24,R30	6k8 (5 off)
R2,R4,R6	4k7 (3 off)
R3,R9,R10, R15,R16, R21,R22, R27,R28	10k (9 off)
R5	220k
R7	470k
R8,R11	56k (2 off)
R13,R19, R25,R31	100k (4 off)
R14,R17	47k (2 off)
R20,R23	39k (2 off)
R26,R29	33k (2 off)

All 0·25W 5% carbon film

Potentiometer

VR1	4k7 log

Capacitors

C1,5	100µ radial elect. 10V (2 off)
C2	2µ2 radial elect. 63V
C3,C4	4µ7 radial elect. 63V (2 off)
C6,C7	10n miniature polyester layer (2 off)
C8	1µ radial elect. 63V
C9,C10	4n7 miniature polyester layer (2 off)
C11,C12	2n2 miniature polyester layer (2 off)
C13,C14	1n miniature polyester layer (2 off)

Semiconductors

IC1 to IC5	LM358 (5 off)
D1 to D4	1N4148 (4 off)

Miscellaneous

SK1	3·5mm jack socket
PL1	15-way D plug

Metal instrument case about 150 × 100 × 50mm; control knob; 6-way ribbon cable (0·5 metres); 8-pin d.i.l. i.c. holder (5 off); low or medium impedance dynamic microphone with 3·5mm plug; fixings, wire, solder, etc. Printed circuit board available from the *EE PCB Service*, order code EE563.

Approx. cost Guidance only £14 plus case

PL1

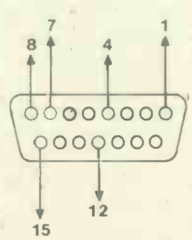


Fig. 7. The connections to the 15-way 'D' plug, PL1.

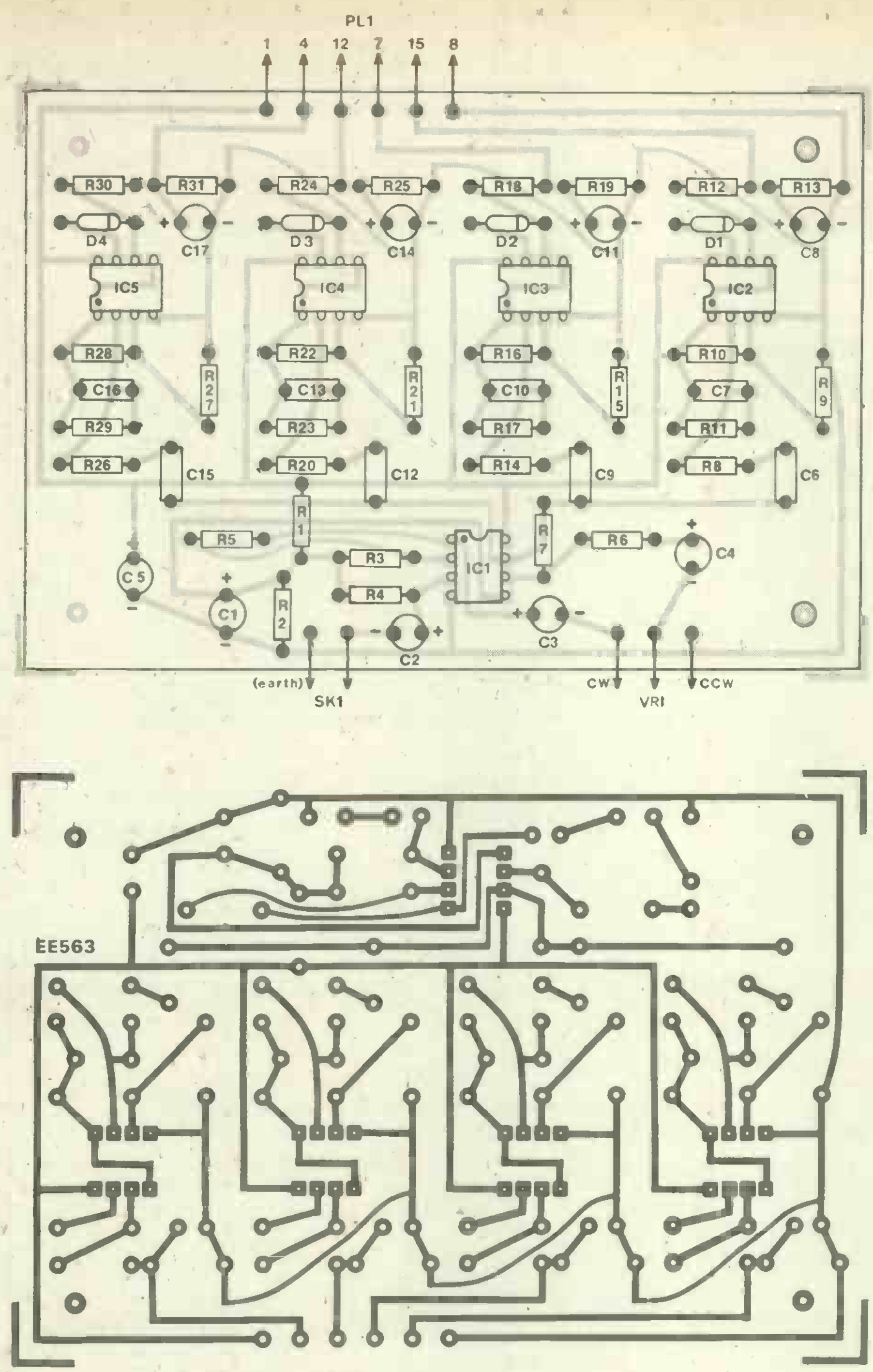


Fig. 6. Details of the printed circuit board.

ward to use in this case. Either a "dummy" 2·5 millimetre socket must then be fitted on the front panel of the interface, or the double plug must be replaced with an ordinary 3·5 millimetre type.

A hole about 10 millimetres in diameter is made in the rear panel to provide an exit point for the lead to PL1 (which connects to the analogue port on the BBC computer). It is a good idea to fit this hole with a grommet to protect the cable. The printed circuit board is mounted on the base panel of the case using M3 or 6BA fixings which must include spacers about 6 millimetres long to hold the connections on the underside of the board clear of the metal case. The small amount of hard-wiring is then added. Provided the cable from the board to SK1 is kept short it does not have to be a screened type.

The output cable is a piece of 6-way ribbon type about half a metre long. It is unlikely that 6-way ribbon cable will be obtainable, but it is easily stripped from a length of 10-way cable. Fig. 7, in conjunction with Fig. 6, gives connection details for PL1, which is a 15-way 'D' type connector. Be very careful to get these connections right and to avoid any crossed wires. The use of "rainbow" rather than single colour ribbon cable helps in this respect, but double check everything before connecting the unit to the computer and switching on.

SOFTWARE

The "frequency bands display" listing is a useful program for testing the unit and to determine a suitable setting for the gain control. It provides a display in the form of four bargraphs, one for each channel, and the height of each bar corresponds to the strength of the input signal on its respective channel. By speaking into the microphone the bars should respond, with the relative heights varying in sympathy with the types of sound spoken. Find a setting for the gain control which results in the bars almost reaching the top of the screen on volume peaks. Overloading must be avoided as it will result in the changes in volume being ironed out to some extent, effectively reducing the differences between words. On the other hand, having insufficient gain will result in the signal becoming lost in electrical noise and background sounds, again hindering the recognition process.

With a low impedance microphone the gain control will probably need to be fully, or almost fully, advanced, but with a high impedance type it will need to be well backed off. Position the interface and the microphone where they are not in very close proximity to the computer and monitor.

INTOLERANT COMPUTERS

Computers tend to be very intolerant of human inconsistencies unless the software is specifically designed to take this factor into account. The early automatic Morse systems gained notoriety in the communications field because they were able to understand each other perfectly, but were unable to understand human generated Morse code as its timing was far too ragged. By the same token it would be comparatively easy to produce a speech recognition system which could understand the monotonous output of a speech synthesiser with great accuracy, but it is much more difficult to produce one that understands human speech where a word is slightly different each time it is spoken. In order to minimise the problems this causes it is a standard approach with speech recognition systems to teach the system each word by repeating it several times and then averaging the readings to produce the pattern that is stored and used for comparison purposes. This assures that the pattern obtained when the word is fed into the system in earnest is not too radically different to the stored pattern. In the "SPEECH RECOGNITION" listing PROClearn in conjunction with other PROCedures takes five samples of each word that is learned and stores the average readings.

In the early days of speech recognition systems they were often put forward as a form of security device as not only could they be set to only respond to a particular password, but they would also only respond to that word if it was spoken by the person who originally taught the system the password. In truth this is probably more of a drawback than an asset, and it certainly precludes simple speech recognition systems from some potential applications.

This system with simple recognition software will usually work quite well if the voice of the person using it is similar to that of the person who taught the system the stored words, but with (say) a man teaching the system the words it is unlikely to respond to the (generally) higher pitch of a female or child's voice. To have the system respond properly to voices in general rather than one in particular places opposing requirements on the software. It must be sufficiently rigid in its method of pattern matching to be able to distinguish one word from another, but it must be flexible enough to accept a wide range of voice pitches. Only quite sophisticated systems seem to be able to resolve this conflict satisfactorily, and a simple set-up of the type described here will always tend to be rather fussy about who talks to it.

Frequency Bands Display

```
  10 REM Frequency Bands display
  20 MODE 1
  30 VDU24,0;200;1279;800;
  40 VDU29,0;200;
  50 VDU23,1,0;0;0;0;
  60 DIM OH(3)
  65 PROClabels
  70 REPEAT
  80   FOR bands=0 TO 3
  90     H=ADVAL(bands+1)DIV 64
 100     IF H<OH(bands) THEN C=0 ELSE C=1+bands M
OD 2
 110     PROCblock(bands*256+384,bands*256+512)
 120     OH(bands)=H
 130     NEXT bands
 140   UNTIL FALSE
 150
 160
 170 DEF PROCblock(XL,XR)
 180 GCOL 0,C
 190 MOVE XL,OH(bands):MOVE XR,OH(bands)
 200 PLOT 85,XL,H:PLOT 85,XR,H
 210 ENDPROC
 220
 230
 240 DEF PROClabels
 250 PRINTTAB(12,27)"BASS"
 260 PRINTTAB(21,27)"MID"
 270 PRINTTAB(27,27)"TREBLE"
 280 PRINTTAB(36,27)"H.F."
 290 PRINTTAB(2,10)"Voice"
 300 PRINTTAB(2,12)"audio"
 310 PRINTTAB(2,14)"levels."
 320 ENDPROC
```

Speech Recognition

```
  10 REM SPEECH RECOGNITION
  20 REM experimental program
  30 REM for BBC Model B
  40 REM J.W.P vsn 2.2 3/86
  50
  60
  70 DIM intake(25,4),accumulator(25,4),store(25,
4,5),store$(5),score(5)
  80 MODE7
  90 PROClearn
 100 REPEAT
 110   PROCmenu
 120   UNTIL FALSE
 130 END
 140
 150
 160 DEF PROClearn
 170 CLS
 180 PRINTTAB(5,3)"LEARN A WORD"
 190 PRINTTAB(5,5)"Please type in the word"
 200 INPUT TAB(5,7),word$
 210 IF word$="" THEN 200
 220 PROCrepeat
 230 PROCaverage
 240  PRINTTAB(5,13)"Store as word no.(1 - 5)?"
 250  INPUT TAB(5,15),word%
 260  IF word%>5 OR word%<1 THEN VDU7:GOTO 250
 270 PROCstore(word%)
 280 ENDPROC
 290
 300
 310 DEF PROCsample
 320 REPEAT UNTIL ADVAL(2)>20000
 330 FOR S=1 TO 25
 340   REPEAT UNTIL ADVAL(0) DIV 256=4
 350   FOR C=1 TO 4
 360     intake(S,C)=ADVAL(C)
 370     NEXT C
 380   NEXT S
 390 VDU7
 400 PRINTTAB(5,11)"Sample complete..."
 410 ENDPROC
 420
 430
 440 DEF PROCstore(element%)
 450 FOR S=1 TO 25
 460   FOR C=1 TO 4
 470     store(S,C,element%)=ABS(intake(S,C)-inta
ke(S-1,C))
 480     NEXT C
 490   NEXT S
 500 store$(element%)=word$
 510 ENDPROC
 520
 530
 540 DEF PROCmenu
 550 CLS
 560 PRINTTAB(5,3)"PLEASE SELECT"
 570 PRINTTAB(5,7)"1.  LEARN A WORD"
 580 PRINTTAB(5,9)"2.  RECOGNITION MODE"
 590 PRINTTAB(5,11)"3.  EXIT"
 600 PRINTTAB(5,15)"Press number key."
 610 REPEAT
 620   C%=GET
 630   UNTIL C%>48 AND C%<52
 640 C%=VAL(CHR$(C%))
 650 IF C%=1 PROClearn
 660 IF C%=2 PROCtry
 670 IF C%=3 STOP
 680 ENDPROC
 690
 700
 710 DEF PROCtry
 720 CLS
 730 PRINTTAB(5,3)"Recognise a word"
 740 PRINTTAB(5,5)"Say the word now..."
 750 PROCsample
 760 PROCstore(0)
 770 PROCcompare
 780 PROCprint_scores
 790 PROCanother
 800 IF C$="A" OR C$="a" THEN 720
 810 ENDPROC
 820
 830 DEF PROCcompare
 840 PROCclear
 850 FOR words=1 TO 5
 860   FOR C=1 TO 4
 870     FOR S=1 TO 25
 880       IF ABS(store(S,C,words)-store(S,C,0))<
120 THEN score(words)=score(words)+1
 890       NEXT S
 900     NEXT C
 910   NEXT words
 920 ENDPROC
 930
 940
 950 DEF PROCprint_scores
 960 FOR words=1 TO 5
 970   PRINTTAB(5,12+words);store$(words)
 980   PRINTTAB(20,12+words);score(words)
 990   NEXT words
1000 ENDPROC
1010
1020
1030 DEF PROCclear
1040 FOR W=1 TO 5
1050   score(W)=0
1060   NEXT W
1070 ENDPROC
1080
1090
1100 DEF PROCanother
1110 PRINTTAB(5,20)"'A'nother word or any key for
menu"
1120 C$=GET$
1130 ENDPROC
1140
1150
1160 DEF PROCrepeat
1170 FOR samples=1 TO 5
1180   PRINTTAB(5,9)"Say the word now..."
1190   PROCsample
1200   PRINTTAB(5,9)SPC(19)
1210   PROCaccumulate
1220   PRINTTAB(5,11)SPC(18)
1230   NEXT samples
1240 ENDPROC
1250
1260
1270 DEF PROCaccumulate
1280 FOR S=1 TO 25
1290   FOR C=1 TO 4
1300     accumulator(S,C)=accumulator(S,C)+intake
(S,C)
1310     NEXT C
1320   NEXT S
1330 ENDPROC
1340
1350
1360 DEF PROCaverage
1370 FOR S=1 TO 25
1380   FOR C=1 TO 4
1390     intake(S,C)=accumulator(S,C)/5
1400     accumulator(S,C)=0
1410     NEXT C
1420   NEXT S
1430 ENDPROC
```

Changes to print recognised word

```
 780  PROCprint
>
>
>
>
 950 DEF PROCprint
 955 bestscore=0
 960 FOR words=1 TO 5
 965   IF score(words)>bestscore THEN bestscore=s
core(words):best=words
 970   NEXT words
 980 PRINTTAB(5,13)store$(best)
 990 ENDPROC
1000
>
```

PATTERN MATCHING

It is the pattern matching software that to a large extent determines whether or not a speech recognition system is successful. If a vocabulary of only a few words is required it is possible to adopt a fairly simple method such as the one used in the demonstration program. A few simple methods were tried, of which only the one used in the final program worked. The stored samples are not held in their original form, but as differences in value from the previous reading on that channel. The values from a received word are then compared one by one with their equivalents in the stored samples, and a point is scored if the difference is less than 120—zero is scored if it is not. The acceptable error has to be a compromise that does not on one hand give low scores even if the right word is spoken, or on the other hand give very high scores regardless of which word is spoken. In both cases the result would be poor reliability.

The value of 120 was derived by empirical means, but it would be easy to experiment with different values if desired. Although 120 might not seem to allow a very wide margin of error, this is not really the case as the values from the analogue port are left in their raw (0 to 65520) form and are not manipulated in any way before calculating the difference figures.

The program is largely self explanatory in use and does not require any detailed operating instructions here. It enables up to five words to be sampled and stored, and when a word is received in the "RECOGNITION" mode it prints out a score for each of the five stored words. The stored word which matches the one that is spoken should obviously have the highest score. In both the "SAMPLE" and "RECOGNITION" modes the start of a word is detected by the occurrence of a high reading on one of the analogue channels. Twenty-five samples are taken on each channel, giving a one second sample time.

Even if words last more than one second, which the vast majority will not, the first second of the word should be sufficient to enable the recognition system to work properly. High background noise levels and accidentally knocking the microphone should be avoided as these could produce spurious triggering of the unit. This is especially important when teaching the system new words as it could result in inaccurate values being stored for comparison purposes, resulting in poor results.

The third listing provides an alternative PROCprint which instead of printing scores for the five words just prints whichever word achieves the highest score.

REFINEMENTS

It should not be too difficult for someone with a reasonable knowledge of BBC BASIC to experiment with the recognition program and add various refinements. The structured nature of the program makes this task as straightforward as possible. There is plenty of scope for experimentation, and this should prove to be both instructive and good fun. As things stand the values in each sample are unsigned, and an obvious improvement would be to devise a system which does include signing of the values. In its current form it is possible for the program to mistake one word for another due to falls in volume of one word being matched by increases in volume in the other, and vice versa. In practice, this does not seem to be a major problem, but it is a possibility that could be eliminated altogether.

The stored values are held in arrays which is not a very economic way of doing things as far as memory conservation is concerned. For this application 8 bit accuracy should be perfectly adequate, and the values read from the analogue port could be divided by 256 (or processed in some similar way) so that each one would require just a single byte of RAM. The use of machine code routines to provide the pattern matching would speed things up quite considerably at the recognition stage, and would certainly be necessary if the vocabulary is increased to more than a few words.

Checking every reference sample against each received word is a rather slow way of doing things, and a faster response could be obtained by using some means of narrowing down the search so that only a fraction of the stored samples have to be used for comparison purposes. This is analogous to an alphabetical index, but is more difficult to implement. However, without something of this type and an even moderately sized vocabulary the system could make the average spelling checker program seem lightning fast.

One obvious approach is to look at the beginning of each word to find a characteristic which could be used to categorise the word. It could be all but impossible to operate this system in practice, though. A more simple approach would be to have words sampled only while the input signals are above a certain threshold level, rather than for a fixed period of time. Apart from requiring even less memory for sample storage, the length of the words could be used as a means of narrowing down the search. However, bear in mind that there will be a significant variation in the length of a word each time someone says it, and this method should not be used to narrow down the field too tightly. This system should improve reliability since short words will produce silence over about the last half second or so of the one second sampling time used in the original program, tending to give quite a good match between any two very short words. By largely cutting out this blank period better results with small words should be achieved.

A very simple but worthwhile improvement would be to incorporate a short routine which would ask for a word to be repeated if all the stored samples provide a poor match. In its original form (with the alternative PROCprint) the system will always assume it has identified the word, however poor the best match happens to be. Another possibility would be to have a routine which would boost all the values in a received set of samples by a certain factor if the volume levels were generally rather low. The point of this would be to make the system more tolerant of the volume of received words, making the pattern matching more accurate on received words that are rather low in volume. It could also ask for a word to be repeated if obvious overloading occurred, with many of the readings equalling the maximum possible value.

Speech synthesis was revolutionised by the SPO256 speech chip with its allophone system, and possibly recognising parts of words rather than complete ones is where the future of speech recognition systems lies. It would not be easy to produce a working system based on this idea, but it would certainly be an interesting line to pursue.

There is clearly great scope for experiment with a system of this type, and once you have the basic equipment up and running you have really just started. □

OBITUARY

Sadly we must report the death at the age of 73 of a long-time friend, advertiser and contributor to Everyday Electronics*, Alan Sproxton. Alan was the co-founder and driving force behind Home Radio, a company that will be remembered by many older readers as a major component supplier to hobbyists in the sixties and seventies.*

Alan, through Home Radio, was one of the first advertisers in Practical Electronics *when it was launched in 1964; he continued the tradition with the launch of* Everyday Electronics *in 1971. Alan later became a regular contributor to EE under the pen name of Paul Young, the author of* Counter Intelligence. *He contributed book reviews and occasional C.I. items right up to his death.*

Alan was an apprentice with the Marconiphone Company before the war, served in the RAF as a pilot throughout the war, started Home Radio in 1946 and was involved in several other businesses. He also found time to write a book about starting and running a small business, which was reprinted five times.

The Editor and staff of EE would like to extend their sympathy to his wife and family.

a regular feature for the Spectrum Owner...

by Mike Tooley BA

THIS month's instalment of *On Spec* aims to solve some of the perennial problems which beset cassette tape users. Those fortunate enough to have disc or microdrive storage have not been forgotten as we shall be dealing separately with these systems in future instalments of *On Spec*!

Cassette Port

The circuitry associated with the Spectrum's cassette tape interface is extremely simple as shown in Fig. 1. The interface uses a port address 254 (FE hexadecimal) which is decoded within the Spectrum's uncommitted logic array (ULA), IC1.

Since SAVEing and LOADing operations are mutually exclusive, a single pin on the ULA (pin 28) is used for both output to and input from the cassette recorder. This same pin is also used to drive the Spectrum's internal loudspeaker for BEEP operations. The direction of data transfer at pin 28 of the ULA is determined by the state of the read ($\overline{RD}$) and write ($\overline{WR}$) lines which are present at pins 3 and 2 of the ULA respectively.

During a SAVE operation, the Spectrum's Z80 microprocessor performs successive I/O write cycles in which data is transferred from data bus line D3, via pin 28 of the ULA, to the MIC connector. During a LOAD operation, on the other hand, the CPU performs successive I/O read cycles in which the incoming data from the EAR connector is transferred, again via pin 28 of the ULA, to D6 on the system data bus.

It should be obvious from Fig. 1 that the SAVE and BEEP commands both provide outputs via pin 28 of the ULA. During SAVEing, the level of the signal present on the MIC output is barely sufficient to produce any audible ouput from the Spectrum's internal loudspeaker.

When a BEEP operation is performed, however, the CPU writes to address 254 using D4 and the interface is arranged so that loudspeaker is driven at a significantly higher level. This also results in an increased level at the MIC connector (a little more than 2V pk-pk).

ROM Routines

The principal ROM routines which relate to cassette storage can be found at addresses 04C2 hex. (SAVE bytes to tape) and 0556 hex. (LOAD/VERIFY bytes from tape). The normal entry point for cassette operations is, however, found at 0605 hex. This initial entry point is used by all four cassette operations (SAVE, LOAD, VERIFY and MERGE) and deals, amongst other things, with construction of the tape header information and the validation of file names.

Problems

Despite the simplicity of the Spectrum's tape interface, at some time or other, every user must have experienced some difficulties with SAVEing and LOADing. There are, of course, several possible causes of such problems, not the least of which is attributable to the dubious standard of quality control prevailing in some of the larger software houses.

Having recently had to return several tapes to different suppliers I speak from bitter experience. This said, however, it is fair to point out that a significant proportion of tapes returned to suppliers are not, in fact, defective! In such cases, problems arise from defects in cassette recorders such as incorrect speed or head azimuth alignment.

The principal causes of problems associated with cassette storage may be summarised as follows:

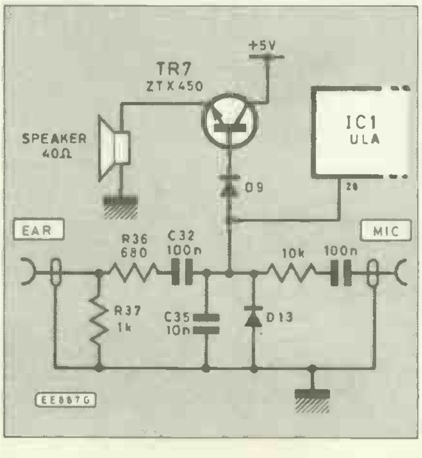
Defective Tape

It is an unfortunate fact of life that cassette tapes are sometimes supplied to users in a defective state and, unlike many other consumer products, there is just no way of telling whether a tape is defective, or not, from a mere visual examination!

Tape defects may generally either be attributed to incorrect assembly of the cassette (such that, for example, an excessive torque is required to drive the tape) or, more usually, the magnetic oxide coating of the tape is inconsistent or defective. Unfortunately, there is very little that the user can do about either problem since the only cure is that of replacing the tape or, in the case of a defective oxide coating, finding a contiguous region of the tape in which the coating is of consistent quality and can thus be relied upon. Faults of this type are particularly prevalent with some of the cheaper brands of "computer tape" and these should be avoided if at all possible.

As with most consumable items for which there is a wide choice of supply, the usual advice is to "experiment" with several brands of cassette tape before deciding upon which type to use. Having found a brand which can be relied upon one should then stick to it!

Fig. 1. The Spectrum cassette tape interface.



A problem of a different type arises when a previously recorded tape becomes damaged by stretching or creasing. This may occur when cheaper cassette recorders are used or where the user is not too careful about handling the tape or encourages tape spillage by failing to stop the tape between "rewind" and "play" operations.

If the take-up mechanism is faulty, excess tape may well find itself being spooled around the pinch-wheel and drive spindle. In severe cases this tape may become wrapped around the pinch wheel until the transport mechanism eventually stalls or the tape breaks. In any event, it is well worth checking that the take-up spindle is capable of exerting sufficient torque to maintain correct take-up tension.

Incorrect Speed

Provided the motor speed is not too inaccurate and is reasonably constant, incorrect motor speed is not normally a problem when the same machine is used for SAVEing and LOADing tape files. Problems do occur, however, when software is being LOADed using a different cassette recorder from the one on which it was previously SAVEd and there is an appreciable difference between the two motor speeds.

Having said that, the Spectrum seems fairly tolerant of speed variations and will, in the writer's experience, usually cope quite happily with motor speed variations of up to around ±15 per cent.

Incorrect Recording Level

Incorrect recording level is not normally a problem in tape recorders which employ automatic gain control (a.g.c.) during recording. There are, however, a few units available which still have manual gain controls and these require careful adjustment in conjunction with the recording level indicator.

If the recording level is too high the result will be saturation and excessive distortion. On the other hand, where the recording level is too low, the result will be excessive noise or an inability to produce a playback signal of adequate level.

One fault which does occur with a.g.c. controlled tape recorders is related to the time constant of the a.g.c. system. This can often take several seconds to adjust to the level of an incoming signal. Hence one often finds that the level of the "header" which precedes data stored on a cassette tape varies considerably. Hopefully, it stabilises to the correct level before the synchronising byte arrives which marks the start of the data!

The reason for this strange effect is that the recording amplifier is operating at maximum sensitivity in the period between pressing Record and Play on the cassette recorder and pressing the Enter key on the Spectrum. Immediately the Enter key is pressed a large signal appears at the MIC input to the tape recorder and, for a millisecond, or so, the recording level is excessive (resulting in considerable distortion due to saturation) before the gain (and signal amplitude) is rapidly reduced by the a.g.c. action.

The gain then slowly increases back towards the correct level and, during this period, the amplitude of the recorded signal slowly rises in an exponential fashion. Eventually, the correct level is achieved by which time one hopes that the synchronising byte hasn't been reached!

Readers will appreciate from this the

importance of having a tape header—it is not important that all of the header has been read correctly. What is vital, however, is that the synchronising byte is detected. Readers should note that many tape loads fail at this point!

Some manufacturers are beginning to wake up to the needs of the computer user and are supplying cassette tape recorders not only with switchable a.g.c. time constants for speech/music and data but also with inputs which are compatible with the level provided at the MIC socket which, in any event, is far greater than that produced by most microphones!

Incorrect Azimuth Adjustment

Just as speed problems are not significant provided one does all one's SAVEing and LOADing on the same machine, head azimuth alignment is a problem which does not generally rear its ugly head until one attempts to load tapes made on other machines (including those made on commercial tape copiers).

With cheap tape recorders (and also with the tape recorder chassis fitted into the Plus Two machine!) heads have been known to be severely misaligned (or not aligned at all!) during manufacture, thus rendering the equipment virtually useless. Indeed, a significant proportion of "service returns" (and also returns of commercial software) can be attributed to nothing more than incorrect head azimuth alignment.

Dirty Record/Playback Head

All record/playback heads inevitably accumulate oxide particles which become detached from the surface of the cassette tape. These particles tend to lodge in the vicinity of the gap in the head and, in severe cases, may result in an appreciable separation between the head and the oxide coated tape surface.

The effect causes a loss of flux density which in turn results in reduced playback signal levels coupled with increased noise and poor high frequency response. The problem can be easily solved by regular head cleaning.

Worn Record/Playback Head

The surface of a record/playback tape head is in regular contact with the tape and is thus liable to wear. After considerable use, this wear may significantly increase the head gap which in turn reduces the level of playback signals, worsens high frequency response, and increases noise and distortion.

Worn heads can readily be detected by means of a visual inspection of the head surface. There is, of course, no cure for a badly worn head apart from replacing it!

Magnetised Record/Playback Head

Occasionally, one may find that the record/playback head has become partially magnetised. The permanent field present may then be responsible for reducing playback levels and increasing the distortion present.

Tape heads should be regularly demagnetised using either a combined tape head cleaner/demagnetiser or using an electronic demagnetiser cartridge, the latter being more effective but relatively expensive.

Preventative Maintenance

Many of the problems associated with cassette operation can be minimised (if not completely eliminated!) with the aid of some simple preventative maintenance. All that is required is a few minutes spent every month and a few basic tools.

The recommended procedure is as follows:

1) After every five hours use or every two months: Clean the heads with a proprietary head cleaning tape.
2) After every ten hours use or every six months: Clean and demagnetise the record/playback head.
3) After every fifteen hours use or every twelve months:
   (a) Carefully clean the record/playback and erase head surfaces, pinch wheel, and drive spindle using ethyl alchohol and a cotton bud.
   (b) Inspect the heads for wear. If appreciable head wear is evident and performance has become degraded, replace the record/playback head. Check azimuth adjustment (see below).

Head Azimuth Adjustment

Fortunately, the procedure for azimuth adjustment of the record/playback head is quite simple and, whilst the better service companies use oscilloscopes in the process, the task can be effectively carried out without recourse to expensive test equipment.

The azimuth angle is the angle made between the head gap and the path followed by a point of the tape. This angle should be precisely 90 degrees. To permit adjustment, the record/playback head is usually arranged so that one end of its mounting may be raised or lowered using an adjusting screw, as shown in Fig. 2.

So that there is no need to dismantle the cassette recorder, the adjusting screw is usually accessible through a small hole in the upper case of the unit. This hole will normally be found on the upper surface of the cassette recorder immediately below the cassette door.

When making an adjustment, readers should note that it will be necessary to press Play first in order that the head moves forward to engage with the cassette tape. A miniature "jewellers" screwdriver should be used to perform the adjustment together with a pre-recorded tape of sufficient duration and quality. Alternatively, a "test tape" can be made using the following BASIC program and a cassette recorder which has a correct azimuth angle:

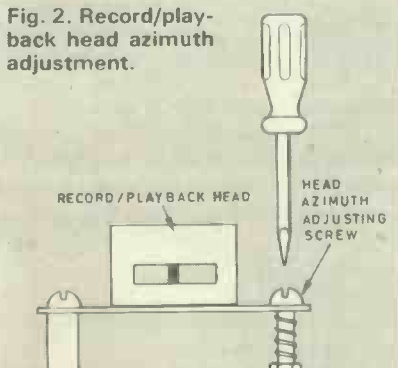
```
10 BEEP 10,40
20 GOTO 10
```

This simple routine generates a square wave signal having a frequency of approximately 2.6kHz at the cassette recorder MIC socket. Since the signal has a rather large amplitude (approximatly 2.2V pk-pk) it should be coupled from the Spectrum's MIC socket to the Auxiliary input of the cassette tape recorder or cassette deck rather than the usual Microphone input.

The BASIC program should be entered and RUN. A good quality blank cassette should be inserted into the recorder and fully rewound. The cassette tape recorder should then be switched to Record and left running for several minutes (the usual "header" is not required and is not generated by the program).

The "test tape" should then be transferred to the cassette recorder under investigation and the azimuth adjustment performed. With care, it is possible to carry out azimuth adjustments by simply listening for the "sharpest" signal. Either side of the desired position the playback signal level will deteriorate and become increasingly "woolly".

Fig. 2. Record/playback head azimuth adjustment.



Operation Caretaker

One of the most novel products (why didn't I think of it first!) to have appeared on the software scene lately must be Global Software's *Operation Caretaker*. This reasonably priced package comprises a head cleaner/demagnetiser tape as well as a separate tape containing software for checking record/playback head azimuth and motor speed. The package also includes a small screwdriver (though this proved to be too large for use with my own cassette recorder!)

The software for *Operation Caretaker* is delightfully simple to use. The user is presented with a very clear display which takes the form of three moving bars together with several status lines. One simply adjusts the azimuth screw for optimum bar length and status indications of "good" rather than "bad" and "ugly"! The number of bytes read and the number of read errors are both displayed as is an indication of the percentage error in speed.

It is also worth noting that the software can be used for setting-up a completely recalcitrant cassette recorder. One simply loads the software from a working machine before disconnecting it and replacing it with the unserviceable machine.

The tape is then removed from the working machine and inserted in the machine to be set-up and the various adjustments made to effect correct alignment. Using this technique, I was able to adjust several machines which had previously totally failed to reliably load commercial software!

Operation Caretaker is an extremely worthwhile product which can banish tape loading problems forever—well done Global!

Global Software is at P.O. Box 67, London, SW11 1BS.

If you have any comments or suggestions or would just like a copy of our *Update*, please drop me a line at the following address and enclose a large (A4 size) stamped addressed envelope:

Mike Tooley, Department of Technology, Brooklands Technical College, Heath Road, Weybridge, Surrey, KT13 8TT.

Next month, we shall describe a Versatile Sound synthesiser for the Spectrum as well as taking a look at some User Defined Graphics.

exploring electronics

OWEN BISHOP

This series is designed to explain the workings of electronic components and circuits by involving the reader in experimenting with them. There will not be masses of theory or formulae but straightforward explanations and circuits to build and experiment with.

Part 10 Timer circuits

MONOSTABLE MULTIVIBRATOR

THE FIRST circuit to be explored this month (Fig. 10.1) has many features in common with the bistable and astable multivibrator circuits described in Part 7 (*EE* January '87 issue).

Once again we have a pair of cross-coupled transistors. In the bistable multivibrator they were coupled by a pair of resistors. In the astable multivibrator they were coupled by a pair of capacitors. In this circuit, the monostable multivibrator (Fig. 10.1), they are coupled by one resistor and one capacitor.

This circuit, like the others, has two states. It remains in one of these states, "the resting state", until it is triggered. After triggering, it remains in the triggered state for a fixed period of time, then returns to the resting state. So it produces just one pulse when triggered, and that is why it is described as *"monostable"*.

HOW IT WORKS

The circuit for the Monostable Multivibrator is shown in Fig. 10.1. When the circuit is triggered by briefly connecting point A to point B, the transistors change state. As TR2 turns on, its collector potential falls. The lamp LP1 lights and the potential of both plates of the capacitor C1 drops sharply, turning TR1 off.

Immediately after triggering, the connection between A and B is broken. Now that transistor TR1 is off, its collector potential rises. Transistor TR2 can continue to receive base current through resistors R1 and R2 even though there is no connection between A and B. The lamp remains on.

However, current flowing through resistor R4 gradually raises the potential of this part of the circuit at a rate depending on the capacitance of C1. The larger the capacitance the longer this takes.

Eventually the potential at the base of TR1 rises to more than 0·6V so that a base current begins to flow. Transistor TR1 turns on, the current previously flowing through resistor R1 to TR2 is now re-routed through TR1 instead. Transistor TR2 no longer receives base current. So TR2 is turned off, the lamp goes out and the circuit is back at its resting state.

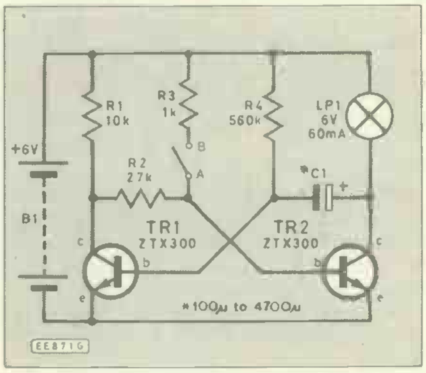


Fig. 10.1. Circuit of a monostable multivibrator.

Fig. 10.2 (right). Demonstration layout for the multivibrator.

CONSTRUCTION AND OPERATION

The demonstration breadboard layout of the Monostable Multivibrator is shown in Fig. 10.2. The capacitor C1 is an electrolytic type with a value between 100µF and 4700µF.

The circuit is triggered by pushing the free end of wire A into the hole marked B (*H*8) and withdrawing it immediately. Alternatively, you could connect a push-button switch between the base of TR2 and the "unconnected" end of resistor R3.

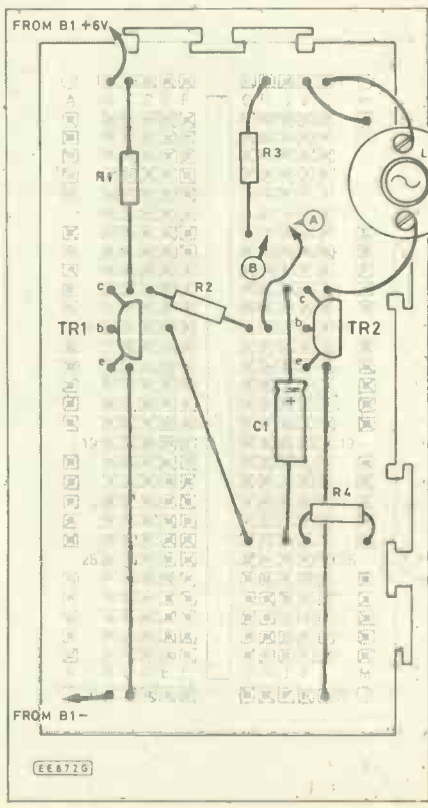
Test the circuit with capacitors of as many different values as you can obtain. In each case, measure the time that the lamp stays on.

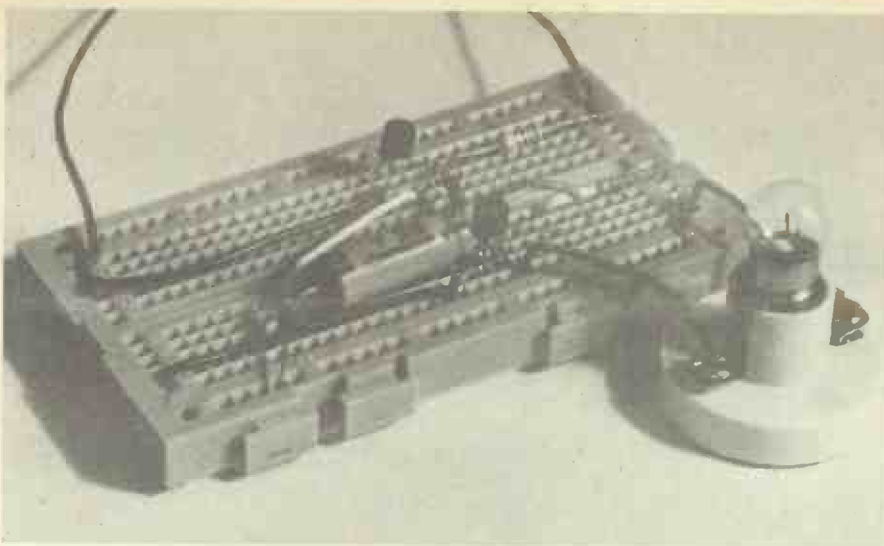
555 TIMER I.C.

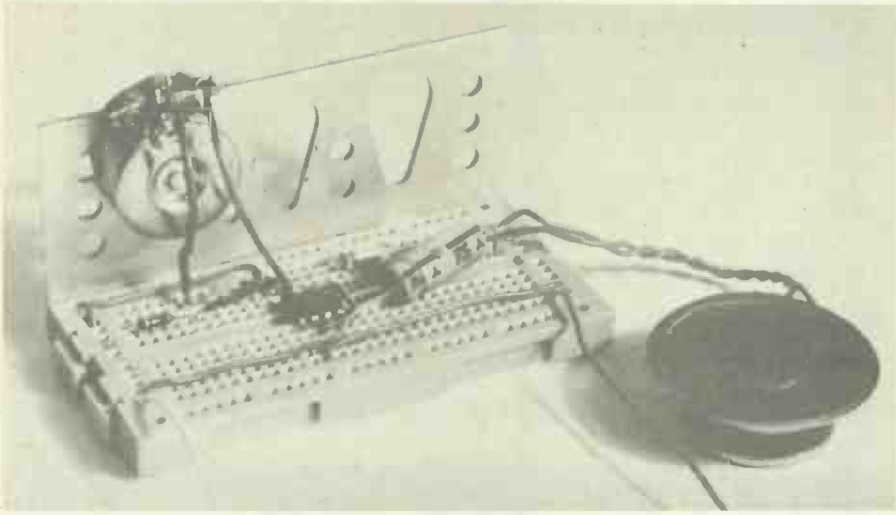
The inexpensive 555 Timer integrated circuit can be used as the basis of innumerable astable and monostable multivibrator circuits. Apart from saving space and simplifying circuit construction, the 555 functions better than its two-transistor counterpart.

You may have noticed that, with the transistor monostable, the lamp gradually becomes dimmer before it finally switches off. With a 555-based circuit, there is a sharp "on-off" action.

Other advantages of the 555 is that timing is precise and repeatable. Timing is not affected by variation in the supply voltage within the operating range of the i.c., approximately 4·5V to 15V.







Long periods, up to about an hour in duration, may be obtained by using a suitably large timing capacitor and high-value resistors. The following project makes use of some of these valuable features.

METRONOME

The Metronome is a device that produces a steady series of clicks or beats at a rate that can be controlled and is an invaluable aid for the musician. It could also have uses in photography where a series of clicks at one-second intervals can help with the timing of exposure during enlarging, or the processing of colour films.

The circuit diagram for a Simple Metronome is shown in Fig. 10.3. This circuit uses the 555 Timer i.c. connected to make an astable multivibrator. It needs only one capacitor and two timing resistors, making it simple to build. It has other advantages, for it can run at a very wide range of frequencies, including very low frequencies, and its frequency is not affected by the voltage of its power supply.

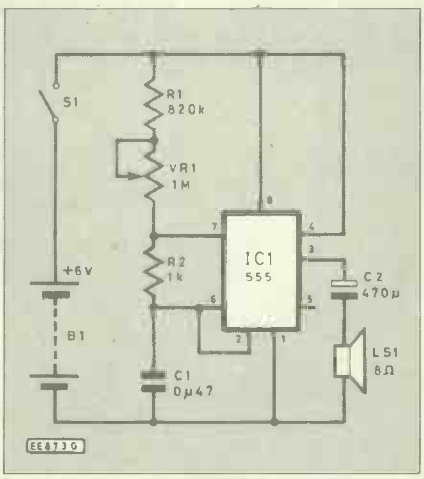


Fig. 10.3. Circuit diagram for a Simple Metronome.

HOW IT WORKS

The timer IC1 is triggered by a low pulse to its input, pin 2, at which instant its output, pin 3, goes from low to high. Until that moment, the capacitor C1 is held charged with a voltage of 2V at the end connected to pin 6. Internal circuits connected to pin 6 sense this voltage.

As long as the i.c. is untriggered and the voltage at pin 6 is 2V, current flowing through resistor R1 and potentiometer VR1 is drained away through pin 7. But when the i.c. is triggered, current no longer passes into pin 7 and the voltage at pin 6 is allowed to rise. The rate at which this happens depends on the total resistance of R1, VR1 and R2.

The voltage rises until it reaches exactly 4V. When pin 6 senses that the voltage has reached 4V, the output of the i.c. goes low and the capacitor is rapidly discharged through pin 7. This brings its voltage back to 2V again.

Charging may take an hour or so if high resistors and capacitor are used.

COMPONENTS

MONOSTABLE

Resistor

R1	10k
R2	27k
R3	1k
R4	560k

All 0·25W 5% carbon

Capacitor

C1 Electrolytic, several values between 100µ and 4700µ

Semiconductors

TR1,TR2 ZTX300 *npn* transistor (2 off)

Miscellaneous

Breadboard (e.g. Verobloc)
LP1 6V, 60mA
B1 4 x 1·5V cells, with battery holder; connecting wire.

METRONOME

Resistors

R1	820k
R2	1k

All 0·25W 5% carbon

See Shop Talk page 213

Potentiometer

VR1 1M lin.

Capacitors

C1	470µ polyester
C2	470µ elec.

Semiconductors

IC1 555 Timer

Miscellaneous

LS1 8 ohm loudspeaker
S1 SPST on/off switch; B1 4 x 1·5V cells, with battery box; breadboard; connecting wire.

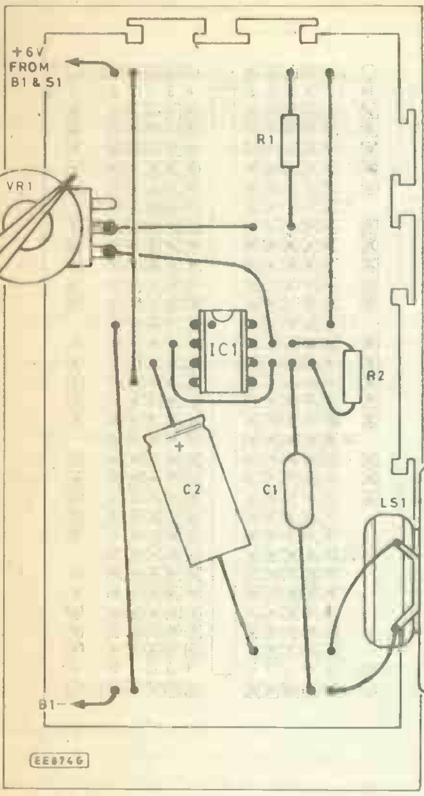


Fig. 10.4. Metronome demonstration layout.

Discharging may also be slow, but in this circuit discharging is very fast because of the low value of resistor R2.

The trigger pin (pin 2) is also connected to the capacitor C1, so the sudden drop in voltage at discharge acts as a trigger pulse. In this way the i.c. is triggered to begin its action all over again. The action of the unit is the same as that of an astable multivibrator.

The output from the 555 is connected to a capacitor C2 and as the output rises and falls, a current passes to and fro through the loudspeaker at the same frequency. This causes either a series of sharp clicks or, if the frequency of clicks is greater than about 30Hz, we hear a tone from the speaker.

To simplify the description above, we have referred to 2V and 4V levels. These are the levels when the supply voltage is 6V. Actually the critical levels are respectively ***one third*** and ***two thirds*** of the supply voltage. This is why timing is unaffected by the actual level of supply voltage.

CONSTRUCTION

The demonstration "test-bed" layout for the simple Metronome is given in Fig. 10.4. The breadboard is designed so that it can accept i.c.s without making connections between pins on opposite sides of the i.c. If you are thinking of building this circuit permanently on stripboard, remember to cut the copper strips between pairs of opposite pins.

The frequency you obtain depends on the value of the resistors and capacitor used. Resistor R2 has a low value to make the i.c. trigger itself almost immediately. The result is a series of high pulses with very brief low pulses between them. Each "high-low-high" sequence is heard as a single click.

The values given for resistor R1 and potentiometer VR1 allow you to adjust the frequency to the rate you need for the usual musical tempo. The only problem that may arise is that you do not obtain the full range you need. If this happens, increase or decrease the value of resistor R1.

VARIATIONS

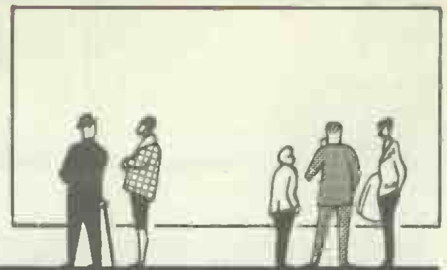
To make a seconds timer, increase the value of resistor R1 to 2·2 megohms. Or, if you replace R1 with a 1 kilohm resistor, frequency is increased and a musical note is heard from the speaker. You can vary its pitch by altering VR1.

If you replace resistor R1 by a light dependent resistor (LDR), such as the one used in Part 3, the pitch of the note can be varied by altering the amount of light shining on the LDR. This light-dependent circuit can then be used as an intruder alarm.

If it is in a darkened room the resistance of the LDR is so high that the circuit does not oscillate. As soon as a light is switched on, or the beam from an electric torch falls on the LDR, the loudspeaker emits a loud note.

Next month: Another simple timer project based on the 555 Timer i.c.

SHOP TALK



BY DAVID BARRINGTON

Careers

It is at this time of the year, before/after "exam time", that parents and students turn their thoughts to future careers and how best to develop their skills to meet todays hi-tech needs. But one of the biggest stumbling blocks seems to be lack of information on just what industry expects and needs, particularly in the field of computing, electrical and electronic engineering.

To try and answer some of these questions and offer career guidance, the Careers and Occupational Information Centre (COIC) have published three booklets highlighting the various requirements required to enter the computing and electronics industry.

The three booklets are entitled "Working in Electrical and Electronic Engineering", "Working in Information Technology" and "Working in Computing". They include profiles of people with different jobs in the various fields covered, explaining what each job entails, what personal and academic qualifications are necessary, details of training courses and tips on ways to enter the chosen career.

Copies of "Working in Information Technology" (16 pages) and "Working in Electrical and Electronic Engineering" (16 pages) cost 99p each. The "Working in Computing" (24 pages) booklet costs £1.95. Copies and further information may be obtained from: **COIC Sales Dept, VF, MSC, Moorfoot, Sheffield, S1 4BR.**

Sound Modules

For those constructors following the current hi fi amplifier design articles but are looking for equipment designed especially for electric instruments, then the latest range from **Delta Physics** should be worth further investigation. By using the latest solid state design techniques, their circuit boards are claimed to enable the constructor to produce authentic sounding electric instrument amplifiers comparable to the best known valve units.

There are three modules available and these are: lead guitar/keyboard preamplifier (P66); power amplifier (P36) and a d.c. power supply (P45). The preamplifier incorporates a springline reverb module and has a claimed input sensitivity of 10mV into 220 kilohms at 1kHz for 775mV into 10 kilohom output. The power amp boasts an output of 36W r.m.s. into 8 ohms and 45W r.m.s. into 4 ohms. Frequency response is reckoned to be 40 to 20kHz ± 1dB.

The modules may be wired in various combinations, amplifier and speakers in one case, or used as self-contained amplifier units driving separate speaker enclosures. The P66 module cost £27.50, the P36 unit £14.75 and the P45 d.c. supply £13.45. The usual 15 per cent VAT and £1.50 p&p must, of course, be added to each order.

For details of the complete range of audio modules contact: **Delta Physics, Dept EE, 52 Codrington Hill, Honor Oak Park, London, SE23 1ND.**

Hot Line

If like many people, including staff members of EE, you were affected by the severe weather conditions recently, and frozen pipes were amongst your unwanted collection of "mishaps", then one of **J & N Bull Electrical's** "bargain items" could be a solution to this annual problem.

Tucked away amongst their advertised items is an offer for "heating cable". This cable is claimed to be waterproof and fairly flexible making it ideal for wrapping around pipes. Available at 28p per metre or 15m for £3.95, when connected to the mains a 15m run is claimed to cost only 10p per week to run.

Being waterproof, another use would be for undersoil heating in the greenhouse.

CONSTRUCTIONAL PROJECTS

Alarm Thermometer

Normally this section of the *Shoptalk* page restricts its content to items of particular interest to the constructor and, more importantly, possible component buying problems likely to be encountered when attempting constructional projects. It is not our usual practice to offer additional ideas about constructional projects as we feel, and hope, that they provide a good mix for all areas of interest in electronics and that readers will find additional enjoyment by developing the circuits further.

However, we feel that in view of the recent "arctic" weather conditions and the effects of the cold on the old, schools and local community groups could develop and build the *Alarm Thermometer* to provide a means of attracting the attention of neighbours and passers-by when conditions in an elderly person's home reach a potentially dangerous level.

This could possibly be achieved by mounting the flashing l.e.d. remote from the unit in one of the windows, or by using optic-fibres to transmit the warning light to a prominent position or by using a relay to switch a mains/battery driven "illuminated sign". This type of arrangement should, hopefully, be visible during the long winter periods of darkness. An additional "audible warning siren" could be mounted outside the home to draw attention during daytime hours.

The only item that is likely to cause sourcing problems is the 50μA f.s.d. meter. The one used in the author's prototype was purchased from Maplin and is from their 2in panel mounting meter range. Provided the guide lines regarding the meter resistance is noted, it should be possible to use other types in this circuit.

EE Apex Hi Fi Amplifier

If readers are to obtain the very high performance expected from the *EE Apex Hi Fi Amplifier* then we strongly advise constructors to adhere to the components specified.

A complete kit of parts, including printed circuit boards, for the "standard" or "enhanced" version may be purchased from **Audiokits Precision Components**. Also, separate individual circuit stage kits, to enable the constructor to spread the costs over several months, are available. The p.c.b.s. are also available separately.

For a complete listing and prices write to **Audiokits Precision Components, Dept EE, 6 Mill Close, Borrowash, Derby DE7 3GU.**

Current Tracer

The only source we have been able to find for the edge meter used in the *Current Tracer* (this month's *Digital Troubleshooting* project) is from Electromail.

This is listed under their "stackable edge meter"' heading and carries the stock number: 258-209. Write to **Electromail, Dept 301, PO Box 33, Corby, Northants, NN17 9EL. Tel: 0536 204555.**

Experimental Speech Recognition

We do not expect readers to have any difficulties in purchasing components for the Experimental Speech Recognition Unit. All components appear to be "off-the-shelf" items and should be carried by most of our advertisers.

The printed circuit board for the Speech Recognition Unit is available from the *EE PCB Service*, code EE563 (see page 228).

Siren Generator

All of the components for the *Siren Generator* project described in the *"Guide To Printed Circuit Boards"* booklet appear to be standard devices and should not cause buying problems.

A full kit of parts, including the printed circuit board, may be obtained from **Becker Phonosonics, Dept EE, 8 Finucane Drive, Orpington, Kent, BR5 4ED.** The printed circuit board may be purchased separately for the sum of £3.90 inclusive.

We cannot foresee any component buying problems for the *Bulb Life Extender* or the *Simple Metronome (Exploring Electronics)* project.

BOOK SERVICE

The books listed below have been selected as being of special interest to our readers, they are supplied from our editorial address direct to your door.

DATA AND REFERENCE

PRACTICAL ELECTRONICS CALCULATIONS AND FORMULAE
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.
Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias—tedious and higher mathematics have been avoided where possible and many tables have been included.
The book is divided into six basic sections: Units and Constants, Direct-current Circuits, Passive Components, Alternating-current Circuits, Networks and Theorems, Measurements.
256 pages **Order Code BP53** **£2.95**

ESSENTIAL THEORY FOR THE ELECTRONICS HOBBYIST
G. T. Rubaroe, T.Eng (C.E.I.), Assoc.I.E.R.E.
The object of this book is to supply the hobbyist with a background knowledge tailored to meet his or her specific requirements and the author has brought together the relevant material and presented it in a readable manner with minimum recourse to mathematics.
128 pages **Order Code 228** **£2.50**

MICROPROCESSING SYSTEMS AND CIRCUITS
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.
A truly comprehensive guide to the elements of microprocessing systems which really starts at the beginning. Teaches the reader the essential fundamentals that are so important for a sound understanding of the subject.
256 pages **Order Code BP77** **£2.95**

COMMUNICATION
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.
A look at the electronic fundamentals over the whole of the communication scene. This book aims to teach the important elements of each branch of the subject in a style as interesting and practical as possible. While not getting involved in the more complicated theory and mathematics, most of the modern transmission system techniques are examined including line, microwave, submarine, satellite and digital multiplex systems, radio and telegraphy. To assist in understanding these more thoroughly, chapters on signal processing, the electromagnetic wave, networks and transmissions assessment are included, finally a short chapter on optical transmission.
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Analysis of the sound wave and an explanation of acoustical quantities prepare the way. These are followed by a study of the mechanism of hearing and examination of the various sounds we hear. A look at room acoustics with a subsequent chapter on microphones and loudspeakers then sets the scene for the main chapter on audio systems—amplifiers, oscillators, disc and magnetic recording and electronic music.
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K. H. Recorr
Shows the reader how, with just a test-meter, to go about recording the particular signature of an unmarked i.c. which should enable the i.c. to then be identified with reference to manufacturers' or other data. An i.c. signature is a specially plotted chart produced by measuring the resistances between all terminal pairs of an i.c.
Chart **Order code BP101** **£0.95**

RADIO AND ELECTRONIC COLOUR CODES AND DATA CHART
B. B. Babani
Although this chart was first published in 1971 it provides basic information on many colour codes in use throughout the world, for most radio and electronic components. Includes resistors, capacitors, transformers, field coils, fuses, battery leads, speakers, etc. It is particularly useful for finding the values of old components.
Chart **Order code BP7** **£0.95**

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M. H. Banani, B.Sc.(Eng.)
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A. Michaels
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BOOK 2 contains: Amplifiers—low level discrete and op-amp circuits, voltage and buffer amplifiers including d.c. types. Also low-noise audio and voltage controlled amplifiers. Filters—high-pass, low-pass, 6, 12, and 24dB per octave types. Miscellaneous—i.c. power amplifiers, mixers, voltage and current regulators, etc.
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EE APEX HIFI AMPLIFIER

PART 2

GRAHAM NALTY

EVEN though the *EE Apex* preamp circuits only consume about one watt of power, the mains transformer should be at least 60VA rating. The preamp case itself will take up to a 120VA toroidal transformer, but if you are really keen to get the very best quality, provision has been made to house the transformer in a separate box away from the preamp. The advantages with this option are twofold. Firstly you can use an even larger mains transformer with a further improvement in sound quality. Secondly removing the transformer from the case eliminates hum in low level disc circuits caused by the transformers magnetic and electric fields and audible distortion caused by the effect of mechanical vibration from the transformer on the sensitive audio circuitry. Even though it does seem hard to beleive at first, mechanical vibration does affect the sound quality of amplifiers (possibly more so with valve amplifiers). In fact most specialist hifi shops stock platforms such as the Mission Isoplat and RATA Torlyte platform at around £20-£40 just to reduce mechanical vibration to turntables amplifiers and other equipment. And they sell them because the improvement in sound quality is worth that much.

Whilst the extra cost of a separate box is quite high (typically around £50 including a pair of high current connectors for a professionally finished unit). The extra cost of going up from 15VA (the smallest available size in toroidal transformer) to 120VA is only a few pounds and the improvement in sound quality should more than justify it.

The power supply includes a voltage dependent resistor R71. These are used a lot nowadays, especially in computers and other digital equipment, to remove high voltage spikes in the mains. Such spikes are caused by switching equipment on and off, and the use of thyristors in control circuits (e.g. lighting) which effectively are switching large loads on and off every fiftieth of a second. Whilst the effect of a large voltage spike on the mains might cause a voltage spike on the d.c. supply line to the i.c.s in a computer and destroy expensive i.c.s, its effect on audio amplifiers is more subtle. Put simply, excessive voltage spikes on the mains will audibly distort the sound quality of an amplifier. The use of a VDR will remove high level voltage spikes and make a useful improvement in sound quality. Further elimination of voltage spikes, and also of r.f. signals present on mains supplies can be achieved by use of a mains input filter. The most suitable of these is manufactured by Deltec in South Wales and filters out radio frequency interference up to 1000MHz. Many commercially available filters advertised in electronic component suppliers catalogue only filter up to about 30 to 100MHz and as such have little effect on Band IV and V television signals.

SUPPLY ELECTRONICS

One area of design that has not been covered adequately in the past in articles by amplifier designers is power supply electronics. This is a very important part of the design of an amplifier and will affect the sound quality considerably in the areas of stereo imagery and clarity and definition of individual voices and instruments. Power supply electronics refers to all the electronic components between the secondary windings of the mains transformer and the d.c. supply lines feeding the circuitry which actually amplifies the signal. The special feature of the Apex is that each part of the circuit has its own separate supply right back to the rectifiers and that separate windings of the transformer are used for left and right channel. This means that the current drawn in one part of the circuit has very little (but never negligible) effect on the sound of any other part of circuit including a preceeding or following stage.

Most preamplifiers use a single d.c. supply which directly feeds all the circuitry of both channels and the result is sound that lacks focus and imagery. Even if such a preamp is the best you have heard in your life, and for many readers of EE, the best preamp they have heard maybe one with such a d.c. supply, the sound will be transformed through the use of separate power supply electronics for each stage.

Adjustable voltage regulators are used rather than fixed voltage regulators (you could use 7824 on the power supply board and 7818 on the disc and output boards but if you do so, use a mains transformer with a secondary winding of 22-24 volts so that a drop in mains voltage supply will not reduce the input to output voltage of the higher voltage regulator below 3V). This is because the output impedance of the variable regulator is lower than fixed regulators. High current regulators in TO-220 cases are used to permit lower temperature generated distortion at their output due to changes in the supply current as the audio signal varies. The use of two regulators in series in all circuits other than the tone amps may be a bit extravagant, but readers wishing to build the best possible preamp may appreciate this feature. The power supply electronics board, containing no fewer than eight regulated outputs maybe useful to readers in building other electronics projects.

INPUT SWITCHING

The input switching circuitry of the EE Apex is very versatile, with facilities for three line inputs (e.g. video, radio and CD) and two tape inputs as well as the disc preamp described in last months article. Input sockets are the phono type and are mounted on a special fibreglass p.c.b. This will be of help to readers who are unable to obtain insulators for mounting phono sockets directly onto a metal chassis. For improved long term performance gold plated sockets are recommended. A special feature of the tape switching circuits is the provision of tape to tape dubbing both ways (depressing Tape 1 button on its own permits dubbing onto Tape 2 and playing Tape 1 signal at the preamp output—the same goes for Tape 2 button) and—by depressing both tape buttons—the facility to play through Tape 1 and Tape 2 in that order. The latter facility will prove extremely useful if you want to use a graphic equaliser to adjust the tonal qualities of new recordings; the tone control circuitry in the preamp itself is not effective via the tape outputs.

My original concept for the Apex preamp was that it should be a "popular" design rather than just a serious hifi enthusiasts design. As a popular design, it has to include the extra inputs that many people, especially recording enthusiasts, require; it has to have tone controls, but the facility to bypass them is included; and it has to look attractive in a domestic surrounding.

Both the preamp and the power amp should be relatively easy to build without sacrificing sound quality. Of slightly lesser importance is the requirement that space should be provided for the highest quality available components including IAR Wondercaps and Siderealkaps which are much larger than polyester or polycarbonate capacitors of the same value. I am regularly in touch with many people who are currently building some of the famous magazine amplifier projects of the past five years who are using much better components to improve the sound and are fitting Wonderkaps "with difficulty" in spaces originally marked out for 10μ Tantalums.

TONE SWITCHING

The decision to make the tone control section switchable had one advantage and one disadvantage. The advantage was that the disc and output preamp sections could be built to a higher sonic standard for the benefit of the user who wanted to switch out the tone control. Put another way the ultimate sound quality of the tone amp was of less overall importance. The disadvantage was that additional design work was required so that the tone control could be switched in and out of circuit without change in volume or absolute phase. As the easiest tone amplifier circuit to design for centre position flat response inverts the signal, an additional inverting amplifier had to be added.

In practice this proved quite simple. As a buffer amplifier is required between the volume control and the tone section to prevent the position of the volume control affecting the tone circuit response, an inverting amplifier was used to invert the signal and act as a low output impedance buffer to the frequency selective tone circuits.

The inverting buffer and the tone amplifier are essentially similar types of amplifier employing two transistors Fig. 15. The first transistor in each pair is a high gain voltage

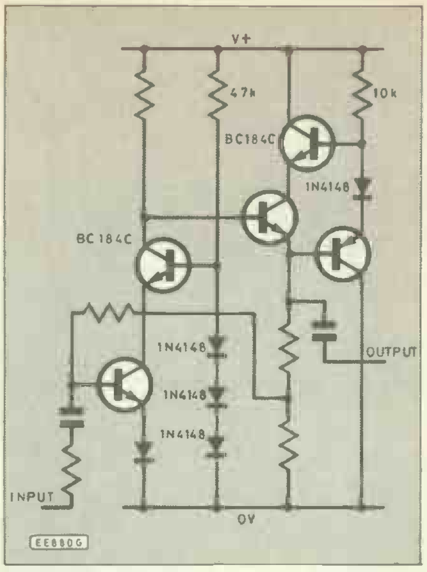


Fig. 16. Tone amp. circuit with added cascode circuitry.

amplifier and the second is an emitter follower which provides a low output impedance. The emitter of the voltage amplifier is taken to ground via a silicon diode. This has a number of advantages, the main benefit is that it raises the maximum voltage swing of the emitter followers from 0.6V to 1.2V. Also the dynamic impedance of the diode reduces the open loop gain and reduces the possibility of high frequency oscillation at treble control extremities.

A useful feature of the tone amp circuitry is that it is self biassing. In other words, no separate d.c. bias voltage is required to maintain the voltage at the base of the first transistor of each pair. If the voltage at the base of the voltage amplifier TR1 falls, the current through R1 falls and the voltage at the base of the emitter follower TR2 rises. This raises the voltage at its emitter and hence increases the bias voltage to TR2 via R1.

I have purposely not used cascode circuitry in the tone amp. This is because a circuit with negative feedback would cause more difficulties to constructors in testing and locating faults. The sonic advantages of cascode circuitry are not so valuable as the tone amp can be switched out of circuit and many serious hifi enthusiasts may wish to have it permanantly wired out of circuit. For the interest of readers who are more ambitious, Fig. 16 shows how a cascode version of the tone amp might be constructed. For the same reasons, I have provided less opportunity to upgrade the capacitors than on the disc or output boards. There is space to replace some caps by polypropylene box types but not Wondercaps.

POWER SUPPLY BOARD

The Apex preamp power supply board is capable of providing completely separate power supplies to each circuit of each channel. In all there are eight regulated outputs and as the disc and output stages have additional regulators on the board, their circuits are powered through two regulators in series giving a further improvement in sound quality. When twin winding transformers are used, and these are commonly available from firms such as Wye Windings, Cotswolds, ILP and Airlink, channel separation is further improved. This may seem elaborate, but such measures are essential if you really want to enjoy a preamp of the highest quality.

The Power supply board is a very useful piece of equipment. It can be used in circuits where two supplies need to be isolated from each other, or where two or more different voltages are required. Negative regulators can be used if you take account of different lead configuration either by bending the leads or changing the layout of the p.c.b. track. A further refinement which may be added, but which was not fitted to the prototype, is to attach the eight regulators to a heat sink. Fig. 17 show the construction of a suitable heat sink. Do not forget that the metal tabs of each regulator must be insulated electrically from each other. Therefore it is necessary to place insulating washers between at least seven of the regulators and the heat sink. (Silicon rubber washers allow better heat transfer than mica washers and do not require heat sink compound—which is messy to use).

LISTENING TEST

If you are not certain of the benefits of using separate supplies to each different circuit, you can easily conduct a simple experiment to verify it. Build the preamp exactly as described except to take all the power supply leads from the disc and tone boards to the output of one regulator. Listen to a record (ideally for this experiment via a moving coil cartridge) and note the quality. Next take all leads for one channel off and feed them from a regulator fed from the other winding of the transformer, see if you notice the improvement in sound quality. Then split each channel's supplies into two (all circuits before the volume control and all circuits after the volume control). Listen to the same record again and then connect each circuit separately as described in the text. At each change you should notice an improvement in sound quality and you will

Fig. 15. Basic amplifier circuit used in the tone amp.

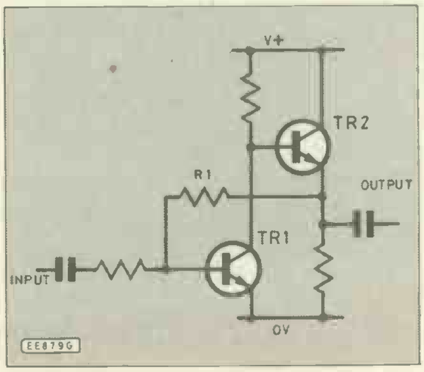
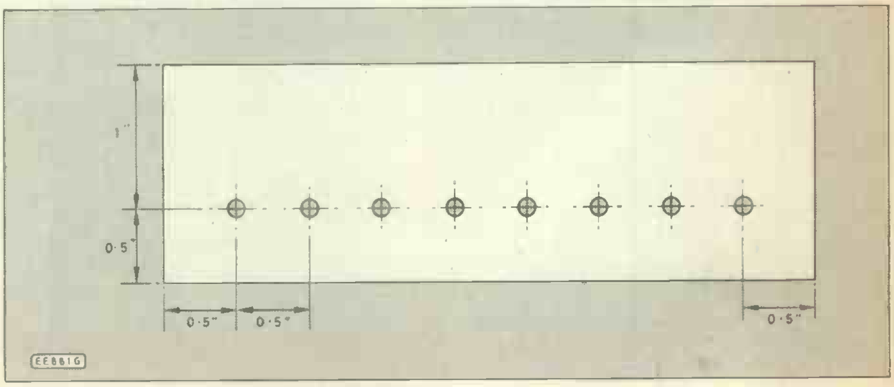


Fig. 17. Heat sink bracket for regulators on power supply board.



realise why it is worth using separate supplies.

TRANSFORMER

Although the preamplifier circuits consume less than a watt of power, the prototype was fitted with a transformer rated at 120VA simply because that was the largest that could be fitted into the box. The reason for this is quite simply that the sound quality of a preamp fitted with a large transformer sounds better than with a small transformer. And the sound could be improved even farther by removing the transformer and substituting a much larger transformer (330VA is the largest size commonly available) in a remote box. This is not too difficult to do as can be seen from the circuit of Fig. 18. You will not need the mains fuse in the preamp but you can still use the mains switch to turn the preamp on and off. From the purists point of view the amplifier will sound better if the switch is bypassed. This switch will not turn the mains transformer off, so you are free to use it or not as you wish. Readers who want the very best sound quality can build a remote power supply box based around the circuit of Fig. 18. A 300VA transformer is the same size as the one used in the power amp to give a power output of 50 watts/channel. But it will sound better than the 120VA normally provided. Those who use the remote supply should be able to find room in the power amp for 500VA transformer.

CONSTRUCTION

Soldering components to the tone and power supply boards follows the usual rule of starting with the smallest parts first. Wire links up to 12mm are best made with cut-off portions of resistor leads after resistors have been soldered to the boards. Longer links can be made with whatever hook up wire you use to connect between the boards. The leads from Holco resistors are slightly longer than most other resistors so they could prove useful. If you are fortunate enough to be using IAR Wondercaps, the leads are very long (to enable the capacitors to be mounted end-on on boards where they are used to replace smaller polyester or polycarbonate caps) and these would be ideal for the longer links. When mounting the switches on the board, you will need to take care to see that each switch is parallel to the board from the back to the front and if the switches are mounted inaccurately, the knobs may not easily fit into the holes in the front panel. The push button switches have a marker at the back to assist location, but not at the front. The switches are spaced exactly 15mm apart so you can fit them into readily available channels and arrange latching facilities between the switches. In this way, when you switch, say the radio input in, you switch out the video input. The silver plated switches are easier to install because they have locating markers both at the front and the rear.

In the normal course of operation, the switch to the furthest right will take precedance, so if you want the disc input, all the switches to its right must be switched out. There should be no problems in attaching the four potentiometers for volume, balance, bass and treble to the tone boards, but it is helpful to hold these from below as you are soldering so that the spindles are horizontal. If you are using improved components, fitting C17, C18, C117, C118

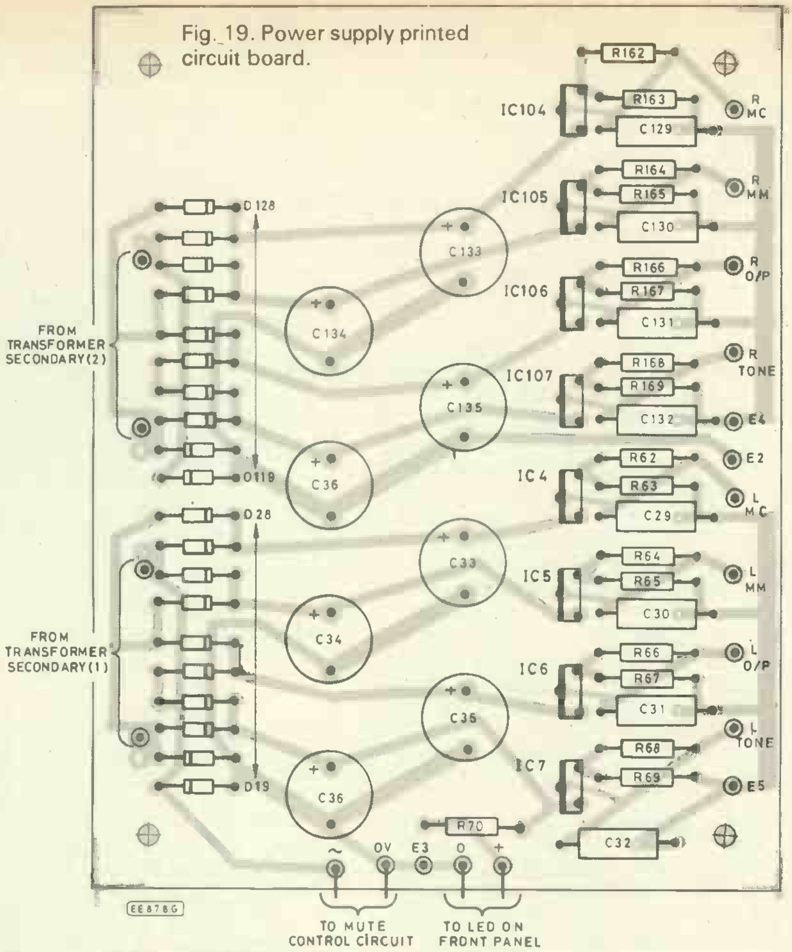


Fig. 19. Power supply printed circuit board.

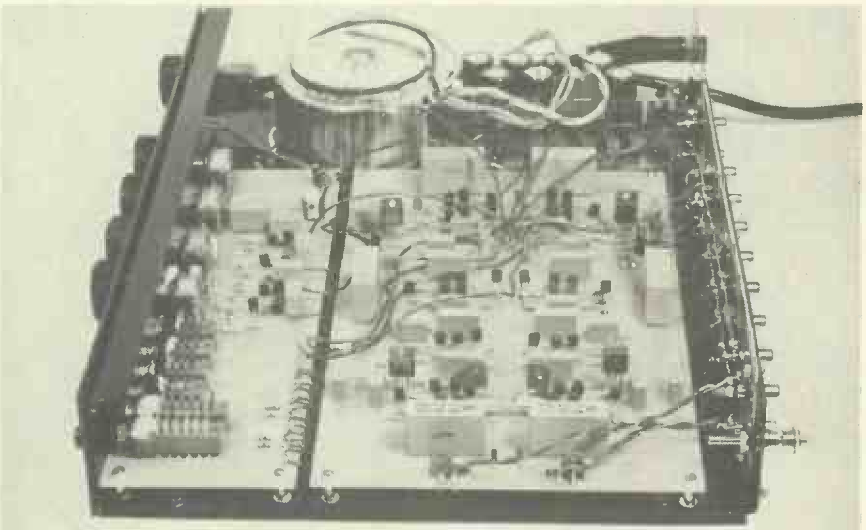
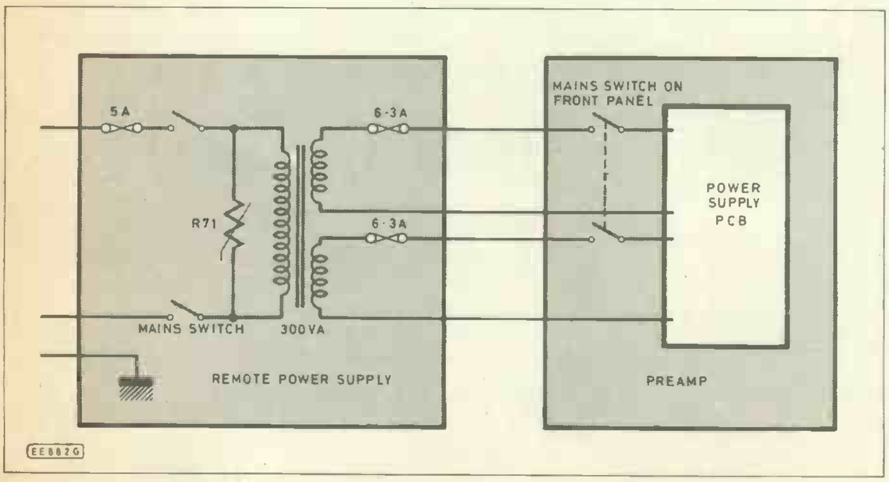


Fig. 18. Circuit for remote mains transformer.



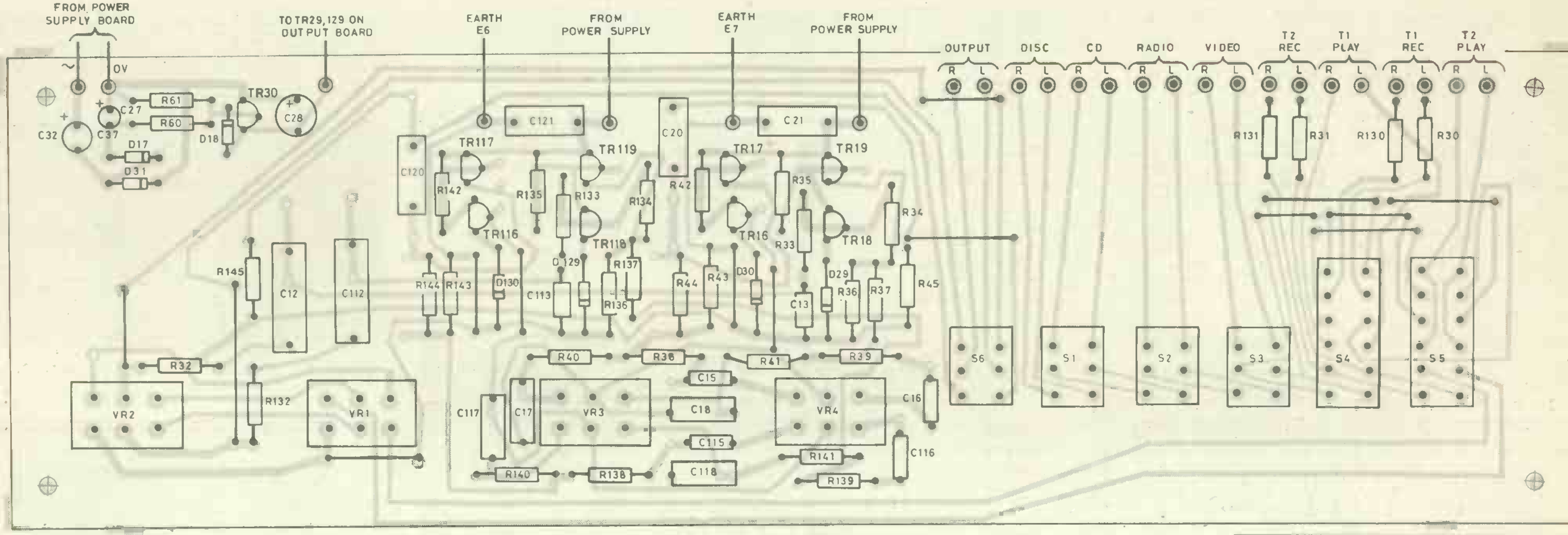


Fig. 20. Tone and switching printed circuit board.

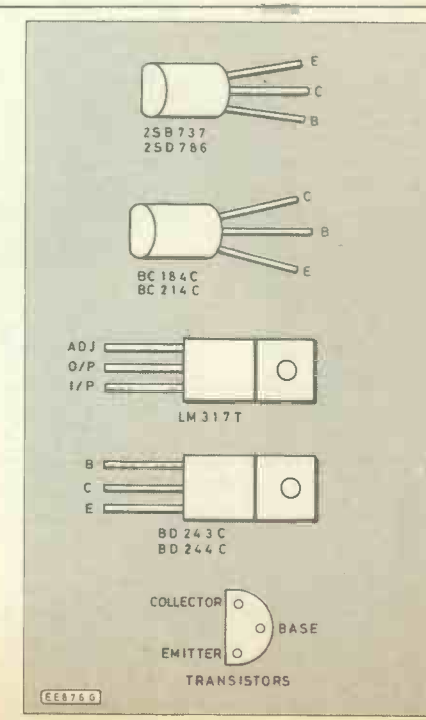
TABLE 1

Cable	Length (mm)	Colour (alter-native)
Tape 2 Play L	310	Blue
Tape 2 Play R	285	Red (Brown)
Tape 2 Rec L	285	Blue
Tape 2 Rec R	260	Red (Brown)
Tape 1 Play L	275	Blue
Tape 1 Play R	245	Red (Brown)
Tape 1 Rec L	260	Blue
Tape 1 Rec R	240	Red (Brown)
Video L	250	Blue
Video R	220	Red (Brown)
Radio L	240	Blue
Radio R	215	Red (Brown)
CD L	240	Blue
CD R	200	Red (Brown)
Mains-fuseholder to switch	255	Red (Brown)
A.C. to mute control	125	*Red (Brown)

Cable	Length	Colour
OV to mute control	125	*Green
Earth on p.c.b. to		
chassis earth	125	*Green
E2	100	Green (Black)
E3	150	Green (Black)
E4	125	Green (Black)
E5	100	Green (Black)
E6	100	Green (Black)
E7	100	Green (Black)
Power supply lead to:		
Tone amp L	240	Blue
Tone amp R	240	Red (Brown)
Output amp L	180	Blue
Output amp R	125	Red (Brown)
mm amp L	205	Blue
mm amp R	125	Red (Brown)
MC L	215	BLue
MC R	115	Red (Brown)
Earth to 6 line inputs L	115	Green (Black)
inputs R	90	Green (Black)

Cable	Length	Colour
Preamp output		
L signal	125	Blue
L Earth	135	Green (Black)
R Signal	70	Red (Brown)
R Earth	65	Green (Black)
Tone amp to output amp L	150	Blue
Tone amp to output amp R	125	Red (Brown)
Disc amp to switches L	160	Blue
Disc amp to switches R	180	Red (Brown)
Disc input L signal	125	Blue
L earth	125	Green (Black)
R signal	75	Red (Brown)
R earth	80	Green (Black)
–C28/D18 to TR29/R9	125	*Blue

*cables marked this need not be audio quality cables



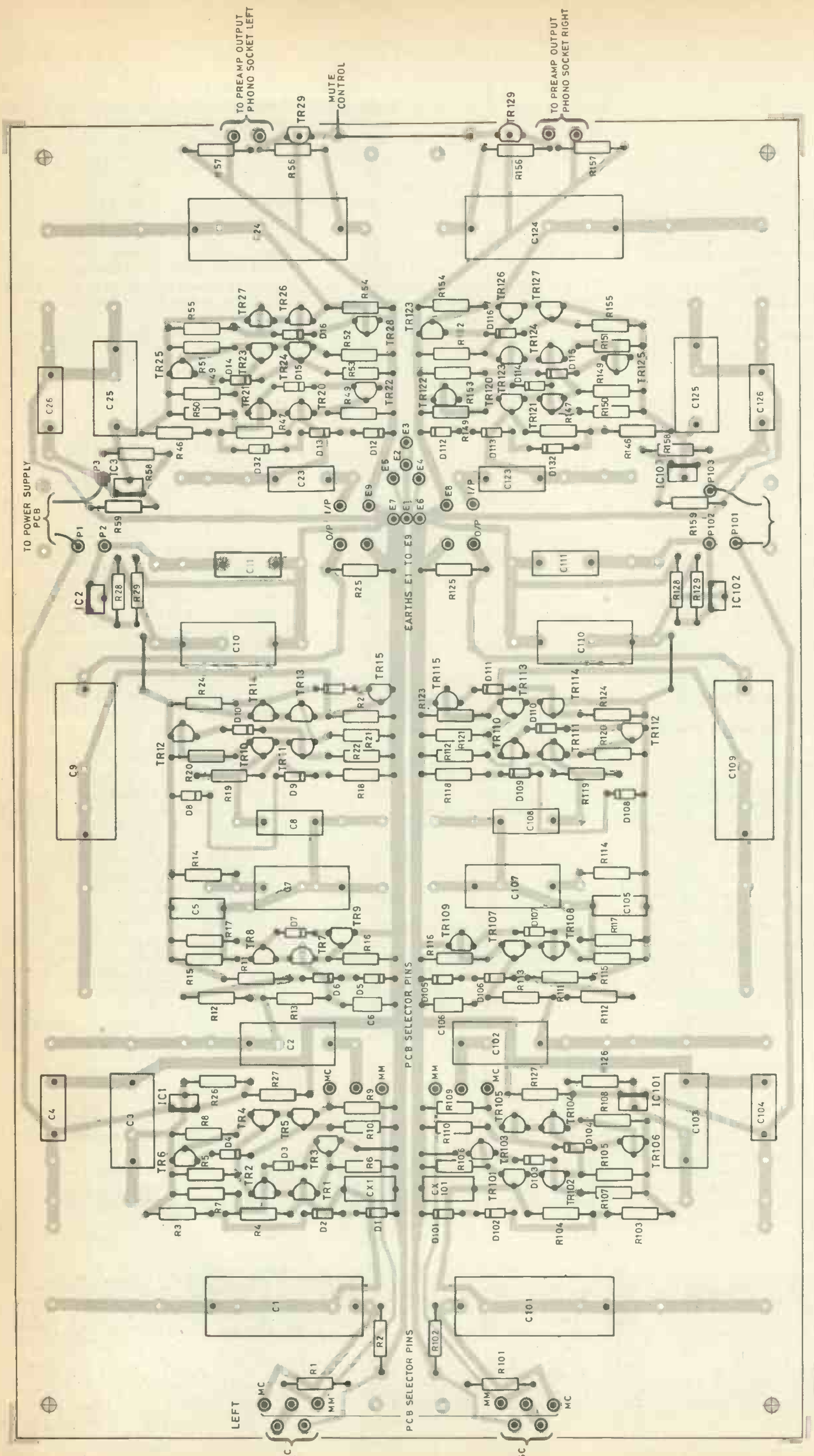


Fig. 21. Preamplifier main printed circuit board. All p.c.b.s are available from the kit supplier (see Shop Talk) alternatively prints of the fail patterns are available from the EE editorial office for 50p (to cover postage).

TABLE 2

Test voltage at:	
Collector TR5	0.2V-2V
Collector TR8	7V-11V
Emitter TR13	5V-10V
Emitter TR17	1.1V-1.4V
Emitter TR19	1.1V-1.4V
Emitter TR26	3V-12V

(56nEXFS/RP) will be a bit of a challenge, but it is possible to fit them (after you have fitted all other components) by taking full advantage of their long leads.

When you have completed the tone and switching board, it is wise to check over all components. In particular, check the polarity of electrolytic capacitors and diodes, as these are easiest to place the wrong way round and the faults caused, if not disastrous, may be time consuming to trace.

The power supply board is reasonably straightforward to assemble, but the polarity of rectifiers an electrolytics and the pin position of i.c. regulators should be checked and double checked as a fault in these areas *could be disastrous.* The power supply board is mounted lower than the other boards, closer to the chassis than the other boards to allow more clearance above for the mains cable. Mains cable should never be located under p.c.b.s where the ends of component leads may rub against its insulation. In place of the usual screw pillar, two washers and two 6BA nuts are used between the board and chassis. Fixing bolts should be 12mm long. Although not shown in the prototype, ¼inch blades form the best connection between the mains transformer and power supply board and these will be supplied with kits.

The Apex preamp uses almost nine metres of internal wiring. As some of the very best audio cables are quite expensive, and many constructors will want to use the best available cable, it is necessary to spell out the length of cable required for each connection. Table 1 shows a list of all internal cables required in order of assembly.

Many specialist audio wires are directional and sound better in one direction than another. Kimber cable is supplied with arrows to show the direction. When installing the cable the arrows should point in the direction of signal flow (i.e. from cartridge towards speakers) or power supply (from power supply to audio circuits.) Kimber cable is available in red, blue and black, whilst brown, blue and green cables are used in the prototype.

CONNECTORS

All the signal inputs and output connections are by means of phono sockets mounted on a cut-out fibreglass board. The earth tags for the sockets other than disc input and the output to the power amp should be mounted in a line so that a common earth lead can be easily attached to them using two 150mm lengths of uninsulated tinned copper wire. This is best done before attaching the socket board to the chassis. In all six earth connections are made from the input socket board to the disc/output board. Two on the disc input are connected close to their respective signal input and the two high level input earths are connected to their respective positions near the main earth as shown on the component overlay diagram.

For ease of installation the amplifier should be constructed in the following order.

1. Attach fixtures to case (e.g. mains switch, fuseholder, cable grommet, earth terminal and mounting spacers for p.c.b.s)
2. Attach power supply p.c.b. followed by tone/output p.c.b. Connect two leads from power supply board to mute control circuit on tone/switching p.c.b.
3. Attach input socket board to rear of chassis.
4. Wire signal connections from input socket board to tone switching board for CD, radio, video and both tapes. Note that although most of the pin terminals follow the reverse sequence of the socket inputs, the tape record positions do not (see tape switching board component overlay).
5. Attach disc/output board. Connect all earth lines from tone/switching board and power supply board to the disc output board, also connect the l.e.d. indicator to the power supply board via wires long enough to go around the mains transformer when installed. The negative or cathode end of the l.e.d. is usually indicated by a "flat" on the side of the lens and (sometimes) a slightly shorter lead.
6. Install the mains cables, mains transformer and connect all the mains wiring. Both the mains fuse and the mains switch should be covered by insulating boots as protection against live mains voltages when testing etc. The voltage dependent resistor (VDR) R71, is soldered direct to the mains switch in parallel with the transformer primary leads and hidden under the rectangular insulating boot. The earth line of the mains input cable should be soldered to a 6BA earth tag.

   A wire (130mm long) should be soldered to the central earth position on the disc/output board and a second 6BA earth tag attached. Both earth tags should be fixed to the chassis earth (identified on the special cases by the small unpainted circle) by means of a 6BA nut and bolt (6mm long). Finally place ¼inch blade connector insulators on the four transformer secondary leads and then solder ¼inch blade connectors to each lead.

TESTING

The mains transformer has two separate secondary windings. Usually these are colour coded with red and yellow making one pair and grey and blue making the other. However a quick test with a multimeter on the resistance range will identify each pair if you are not certain. Taking the first pair connect one end direct to the power supply p.c.b. blade nearest the transformer. Do not connect the second end directly to the p.c.b. but connect a 100ohm carbon resistor between the next blade on the p.c.b. (solder the resistor to the base of the blade—not the top as you might not be able to get the connector on it if the blade is covered with solder) and the blade connector on the second end. Placing the lead of the resistor into the connector should be adequate because the wires of the transformer secondary are quite stiff and can easily hold the resistor this way. The other leads from the transformer should be covered by the blade connector covers and placed so they cannot touch any metalwork or electrical connections. Now switch on.

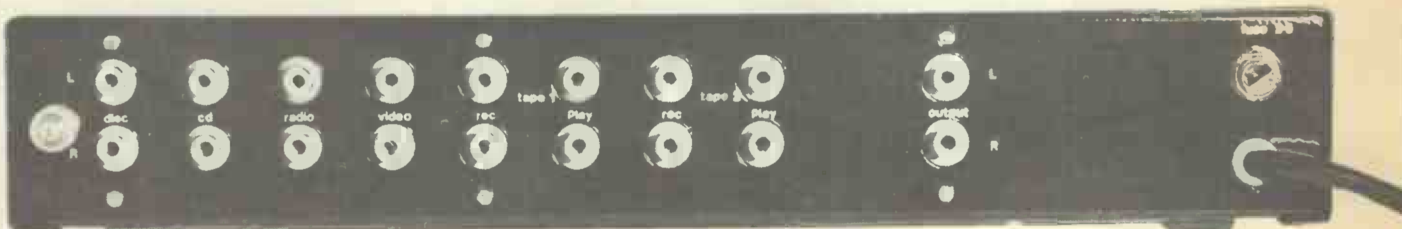
The l.e.d. should light. Check the output voltages from the output of IC4, IC5, IC6, IC7. These should be about 21V. If not look for a fault in wiring or wrongly connected capacitor or an earth connection to the disc/output board not made. If the resistor overheats visibly, then it is likely that a diode is connected the wrong way. If all is correct switch off, remove the 100ohm resistor and connect the transformer lead directly to the same blade. Then repeat for the right hand channel with the second transformer secondary and second pair of ¼inch blades on the power supply p.c.b.

When the power supply has been completely tested, switch off and allow the capacitors time to discharge. Next connect the eight outputs from the power supply p.c.b. to the respective pins on the disc/output board (six) and tone board (two). Switch on the mains supply and measure the voltages at the outputs from the power supply board. These should not have changed. If the output voltage has dropped significantly or any of the regulators has become hot (they will become warm) remove the wire from the regulator board and check for results.

There are several ways to check for faults.
i) visible inspection above board for wrong polarity connections.
ii) visible inspection below board for poor soldering and solder between tracks.
iii) resistance tests with multimeter—ideal way of testing in stereo amplifiers because a different reading between channels, will indicate approximate location of fault.
iv) Place low value resistor (e.g. 100ohm carbon) in series with power supply. If the resistor gets very hot this indicates a short circuit. If excessive volts drop shows across the resistor this measures the circuit current. Sketch a copy of the circuit diagram and chart the current paths by measuring the voltage across resistors.

If all the regulators on the power supply have the correct output voltage, check the outputs from IC1, IC2, IC3, IC101, IC102, IC103. These should read close to 16V. Now check the voltage levels across each transistor V_{be} junction and each IN4148 diode. All these should read between 0.5 and 0.7V. If you are using BD243C or BD244C Power transistors in an upgraded version you may record slightly lower V_{be} readings of 0.4 to 0.5V.

The test voltages in Table 2 show the



voltage required to give adequate headroom for audio signals. By fine adjustment to the biassing circuits, the headroom can be increased.

If all the d.c. measurements are satisfactory, remaining audio signal leads can be connected:

From disc input sockets to p.c.b. (including earth). If you are not using screened cable, twist the leads to avoid picking up hum. (L125mm, R80mm).

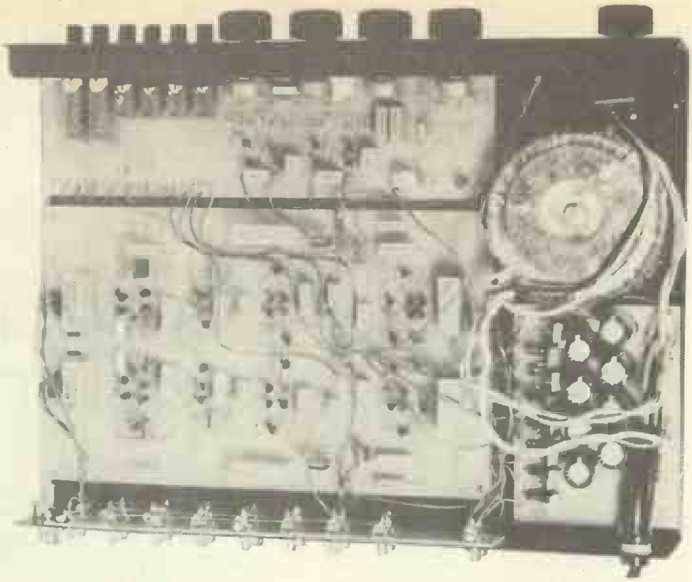
From output amp to power amp output socket including earth). (L135mm, R70mm)

From disc output to disc input on switching/tone board. (L160mm, R180mm).

From tone/switching circuit output to input of output amp. (L150mm, R180mm)

From C28/D18 mute control to TR29 and TR129 (125mm).

When the preamplifier is operating correctly, the front panel may be attached by removing the nut from the mains switch and replacing it when the front panel is in position. A second fixture from a countersunk bolt and nut near the centre attaches the panel firmly and this bolt is hidden when the control knobs are attached. If you are using metal knobs, you will need to earth the body of the four potentiometers.



First scrape the uppermost part of the potentiometers with a small file. Solder a length (about 120mm) of bare tinned copper wire to each potentiometer. Then make a connection to a spare earth terminal on the p.c.b. with a 150mm length of wire (green insulated).

Next Month. The power amplifier.

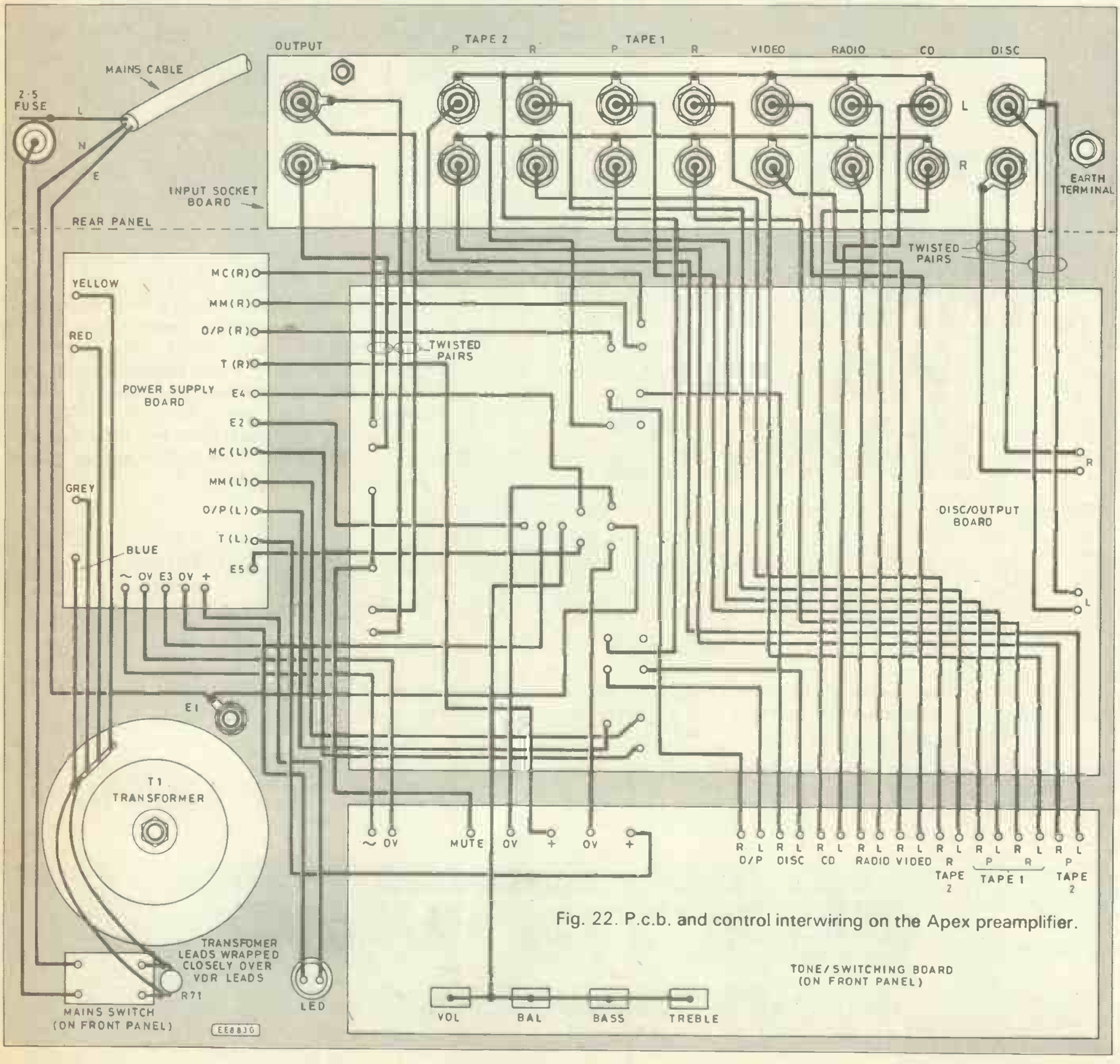
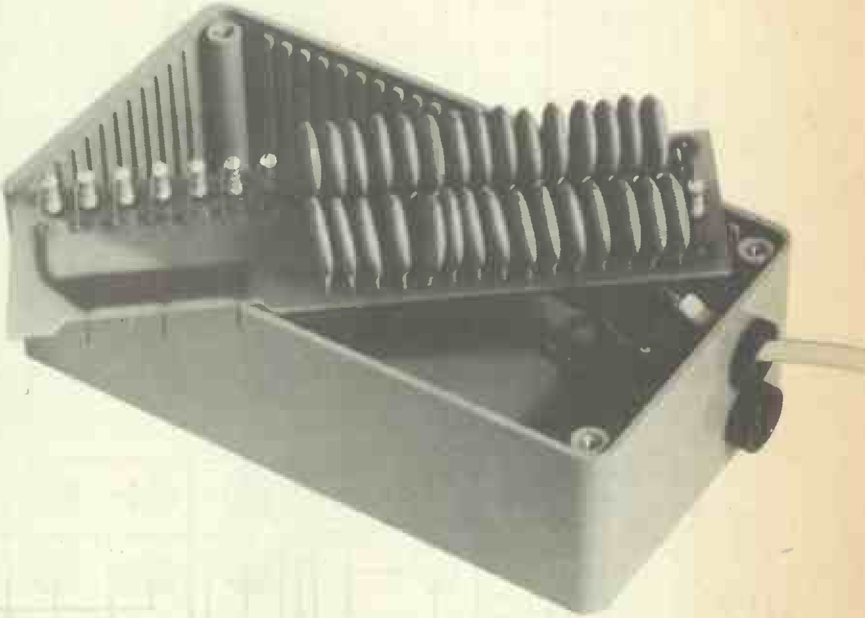


Fig. 22. P.c.b. and control interwiring on the Apex preamplifier.

MAY FEATURES...

EE EQUALISER



An ioniser is a device for injecting a stream of negative ions into the surrounding air. The reason for doing so is based on the discovery that rural areas, where the air is supposedly "fresh", have far higher concentrations of natural negative ions in the air than urban places; ergo, if the ion levels in our living rooms are artificially increased, we should become healthier, or at least feel better! The *EE Equaliser* is a simple negative ion generator.

WINDSCREEN WASHER WARNING

The law requires car windscreen washers to be kept in good working order. The water bottle is often badly located, however, and the average motorist does not check the contents before every journey. Driving under poor weather conditions, the water can be used up very quickly and a dangerous situation develops. This unit delivers a bleep each time the washers are used if the water has fallen below some predetermined level.

AUDIO LOGIC TRACER

By listening to the signals in a microprocessor based system, it is possible to gain a meaningful impression of what is going on. The Audio Logic Tracer will not only indicate that a particular line is active but it will also provide an indication of the frequency at which the line is pulsed and whether or not the pattern is repetitive.

EXPLORING ELECTRONICS ~ *SIMPLE TIMER*

EVERYDAY ELECTRONICS

OUR MAY ISSUE IS ON SALE THURSDAY, APRIL 16

b...Beeb...Beeb...Beeb...Bee

. . . Timers and Frequency Counters . . .

LAST month we saw how timer 1 of the user port could be used to generate an output signal on line PB7, and in this month's article we will consider timer 2 in some detail, including its use as a counter for an external logic signal fed to PB6. This is a very useful feature which enables the BBC micro to operate in a number of simple counter and frequency meter applications.

As explained last month, timer 2 is at addresses &FE68 and &FE69. It is, like timer 1, a 16 bit binary down counter, and it therefore has to be read and loaded in two 8 bit bytes from the 8 bit data bus of the BBC micro. &FE68 is the low byte while &FE69 is the high byte. In many applications it is only necessary to load timer 1 with values, with it never being necessary to read its contents. Timer 2 can also be used in this way, but as it cannot be operated in a mode that generates an output signal, it is not a matter of loading it with values and then just letting it get on with things. If it is not read to determine the value it contains, then it would be used to set a flag (and probably generate an interrupt) each time the count reached zero. For the present we will only consider using it as a simple counter where its contents are read from the appropriate two addresses.

Mode

Before using timer 2 it must be set to the correct operating mode, and there are only two possible modes for this counter. It can either have its input fed from the 1MHz system clock, or it can use PB6 as the source of input pulses. It is controlled by bit 5 of the auxiliary control register (?&FE6B), and this is set to 0 to have the system clock as the signal source, or to 1 to count pulses on PB6. In other words:

?&FE6B=0 sets timer 2 to the mode that uses the system clock, or:

?&FE6B=32 sets timer 2 to the mode where pulses on PB6 are counted. Timer 2 has no mode which generates any form of output signal, and it consequently has no single shot or free running mode.

One obvious problem is that timer 2 provides a down count, but many counter applications require an upwards counting action. There is no way of setting the hardware to act as an up counter, but software can easily give an effective conversion. It is just a matter of deducting the value in the counter from 65535. The latter is, of course, the maximum value (in decimal) that the counter can contain. For this method to work the counter is set to zero by loading it with 65535, so that when 65535 is deducted from it, a value of 0 is obtained. As the value in the counter decreases the value obtained when it is deducted from 65535 increases, giving the required inversion effect.

There are probably simple timer applications in which timer 2 could be used on its own. For instance, it could act as a batch counter or something of this nature, where it would be fed with input pulses at a fairly low rate, and it would either give a total at the end of the day (or whatever), or the contents of the timer would be periodically checked until a certain number of pulses had been counted in. Timer 2 becomes much more versatile, though, when it is used in conjunction with timer 1.

Long Timer

One way of operating the two timers in tandem is to have timer 1 generate pulses on line PB7, and then to count these on timer 2 by coupling them across to PB6. The point here is that the timers normally count in microseconds, and while this gives high resolution and accuracy, with a 16 bit counter it gives a maximum time of well under a tenth of a second. PB6 can produce pulses at a frequency of under ten Hertz, and by counting these it is possible for timer 2 to operate at a maximum time of over two and a quarter hours. A useful way of using this set up is with timer 1 providing a ten Hertz signal, and then, by dividing the count from timer 2 by ten, an answer in seconds is obtained, with a resolution of a tenth of a second. This enables times up to 1·8 hours or so be accommodated. If preferred, a higher output frequency can be used so as to obtain higher resolution, but with a lower maximum time. With suitable software the "timeouts" of the counter can be counted, and both very long timing periods and high resolution can be attained.

As a useful introduction to using timer 1 and timer 2 together you can try connecting PB6 to PB7 on the user port and then running this simple program:

```
5 REM timer1/2 demo prog
10 CLS
20 ?&FE6B=224
30 ?&FE64=80
40 ?&FE65=195
50 ?&FE68=255
60 ?&FE69=255
70 A=?&FE68
80 B=?&FE69 * 256
90 C=65535 - (A + B)
100 PRINTTAB(10,10)"      "
110 PRINTTAB(10,10)C/10
120 FOR D=1 TO 30:NEXT
130 GOTO 70
```

Line 20 sets timer 1 to the free running mode with output on PB7 and timer 2 to the mode where it uses PB6 for input. At lines 30 and 40 timer 1 is loaded with values that produce an output frequency of ten Hertz. With a 1MHz clock frequency a total division rate of 100,000 is needed, but the circuit driving PB7 effectively acts as a divide by two flip/flop, and the counter only needs to provide a division rate of 50,000. It is not difficult to work out the two counter values required for a given division rate with a little help from the BBC micro.

Using the command mode, the division rate is divided by 256 to give the number for the high byte, with any figures after the decimal point being ignored. With a division rate of 50,000 this gives an answer of 195. Then the MOD function is used to find the number for the low byte (i.e. **PRINT 50,000 MOD 256**) which gives an answer of 80. Lines 50 and 60 set the two bytes of timer 2 at maximum value, which effectively zeros them in this case.

Some simple mathematical manipulation is then used to read the two bytes of timer 2, combine and invert them, and then divide the answer by ten before displaying the final figure on the screen. The program loops indefinitely so that the readout is frequently updated. The readout is in seconds, of course, with 0·1 seconds resolution. You should find that the count can be stopped and started by breaking and restoring the link between PB6 and PB7.

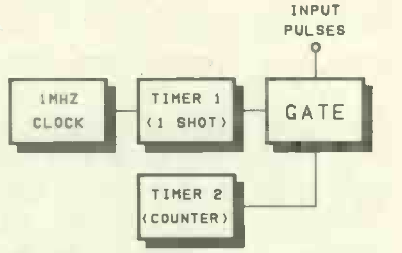


Fig. 1. The basic frequency meter set up.

Frequency Counter

For the electronics enthusiast the most interesting way of using the two timers is probably to have an arrangement of the type outlined in Fig. 1. Here timer 1 is operated in the one shot mode, and it operates an external gate circuit. The signal controlled by the gate is fed to PB6 and then through to timer 2. This gives a basic digital frequency meter arrangement, and if timer 1 gives a gate pulse duration of, say, 10ms (a hundredth of a second in other words), multiplying the final value in timer 2 by 100 gives the input frequency in Hertz, with a resolution of 100Hz. Of course, the controlling software must set everything up correctly, and timer 2 must be correctly zeroed before timer 1 provides the gate pulse, and this gate signal must be permitted to finish before timer 2 is read.

There are a number of possible variations on this arrangement, and timer 1 could, for example, be used in the free running mode so that a fresh reading would be taken at regular intervals (although much the same result could be achieved using the one shot mode and suitable controlling software). These basic arrangements are unable to produce long gate times and cannot give a resolution of better than about 15Hz, but a

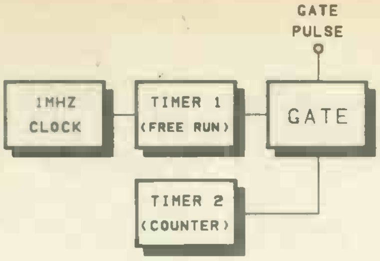


Fig. 2. The basic event timer set up.

divider circuit driven with the output from PB7 can be used to give longer gate times if necessary. Similarly, a prescaler (a divider circuit ahead of the gate) can be used to overcome the 1Mhz maximum clock rate and enable higher frequencies to be measured.

Another interesting possibility is the revamped arrangement of Fig. 2. Here timer 1 is providing a clock signal to timer 2 via a gate circuit, and an external detector circuit of some kind supplies the gate pulse. This gives a simple event timer set up and, depending on the clock frequency used, it can accurately measure times from a few milliseconds to a few hours.

Overflow

When using timer 2 in the kinds of arrangement outlined in this article there is a danger of the count going right down through zero and back to 65535, and then continuing the down count from here. This would obviously give totally inaccurate and misleading results, and is something that has to be guarded against.

Timer 1 and timer 2 both set a flag in the interrupt flag register at ?&FE6D if they reach zero. The relevant bits are 5 and 6 for timers 2 and 1 respectively. Therefore, from BASIC **"PRINT ?&FE6D AND 32"** would read the flag for timer 2, returning a value of 32 if it is set, or 0 if it is not. The flags are not automatically reset when the interrupt flag register is read, and in order to reset them it is necessary to either read the low byte or the relevant timer, or to write to the high byte of the correct timer.

By setting the appropriate bits of the interrupt enable register the timers are set to automatically generate an interrupt by pulling the IRQ line of the 6522 VIA low. This can be a very useful technique, but it is one that requires a fair amount of expertise if it is to produce the desired result, and will simply crash the computer if it is not used correctly. The use of the timers with interrupts is a subject we will return to in a later article.

Experimenting

If you want to experiment with the timers and an external gate to control the flow of pulses into PB6, nothing particularly elaborate is required. In fact, a single two input AND gate is suitable if connected as shown in Fig. 3. One section of a CMOS 4081BE or an LSTTL 74LS08 are suitable for use in this circuit. The output of a two input AND gate goes high if both inputs are taken high, but is low if only one or neither of the inputs are set to the high state. By taking the control input high, the output therefore goes high and low in sympathy with the signal at the other input, but with the control input taken low it is not possible for both inputs to be in the high state. Consequently the output is held permanently low, and the input signal is blocked. This arrangement, therefore, gives the required action with a low control level blocking the signal, and a high one enabling it to pass.

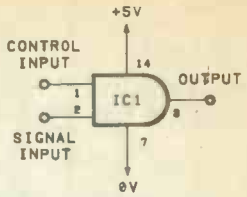


Fig. 3. Using a 2 input AND gate as a signal control gate.

Next month we will progress to some simple hardware and software which enables the timers to function as the basis of an r.p.m. meter and an event timer.

NEW · NEW · NEW · NEW

PRODUCTS

NEW · NEW · NEW · NEW

BODYGUARD

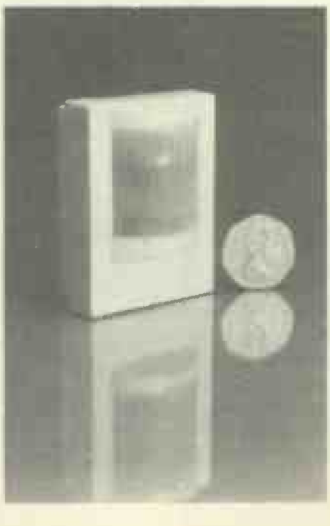
A NEW Passive Infra-red Intruder Detector has been announced by **Riscomp Ltd.** Known as the RP33, it operates by sensing the body heat of an intruder within the protected area.

The detector, which uses the latest Fresnel lens, provides volumetric coverage through an 85 degree angle, with 24 zones over a range of 12 metres. Its miniature size, 80mm × 60mm × 40mm, permits it to be easily installed on any flat surface or corner location, whilst vertical adjustment of the detection pattern over a 10 degree range is provided in order to achieve the most effective coverage in each installation.

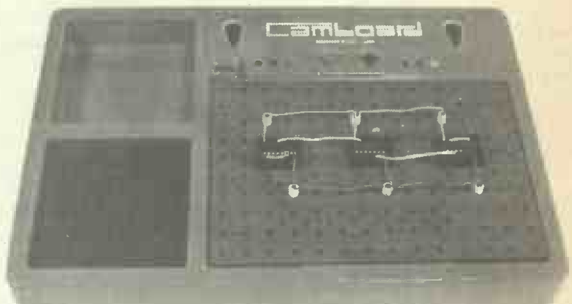
A further aid to installation is provided by a switchable "walk test" indicator, which provides a visual indication of the effective range. Requiring only 15mA operating current from a conventional 12V supply, the unit is suitable for use in most security installations.

Supplied with full installation instructions, the RP33 infra-red intrusion detector costs £23.95 plus VAT.

Riscomp Ltd.,
Dept EE, 51 Poppy Road,
Princes Risborough,
Bucks, HP17 9DB.
Tel. 084 44 6326.



SOLDERLESS BOARD



CAMBOARD have taken the normal breadboard and produced it in smaller sections, to form mini-breadboards, which can then be spaced out on a mounting board to give a lot more room. Schematic diagrams can be copied component to component and wire to wire straight onto their board, which, it is claimed, saves time trying to convert the circuit diagram to the strips of contacts on other systems.

A mini-breadboard consists of a high quality plugblock where integrated circuits are inserted in the centre and connect with wires and components to form a small circuit or to other mini boards for larger circuits.

Each mini-breadboard is placed on the mounting board at either 90 or 180 degrees permitting a theory layout to be achieved. Bus bar terminals can be positioned to provide power for each mini breadboard, these can also be used for connecting up discrete components.

The mounting board has an alpha-numeric grid layout and measures 180mm × 129mm, giving plenty of room for more complex circuits. The mounting board sits in a plastics tray which also stores components. Conductive foam is fitted in one recess so that i.c.s can be "stored" before they are used on the main board; this protects them from static.

When not in use the breadboard can simply be turned over to protect the components on it. Cut-out holes in the tray enable switches, potentiometer etc., to be mounted, two colour coded power terminals connect up with a battery or a separate power supply unit.

Camboard,
Dept EE, Unit 16,
Barnwell Business Park,
Barnwell Road,
Cambridge, CB5 8UZ.

Tel. 0223 240926

Actually Doing it!!

PUTTING labels onto a completed project is one of those tasks which looks ridiculously simple, but is actually quite tricky if professional results are to be achieved. For really attractive and durable labels there are simple photographic methods which can be used, but these represent a relatively difficult and expensive way of doing things, and are certainly not a good starting point for someone taking up electronics construction as a hobby. There are alternative methods available, and the most practical of these is to use rub-on transfers. Extremely attractive results can be obtained using these, but they are not quite as durable as photographically produced labels.

TYPES

One form of transfer that used to be quite popular is the type which consists of words on a self-adhesive transparent backing material. These are very easy to use, and represent an easy way of producing neat panel labels, but unfortunately they do not seem to be manufactured any more. The nearest equivalent currently available is ordinary rub-on transfers which consist of complete words rather than just single letters and figures.

Both types represent an easy way of obtaining neat results since the problem of having to line up individual characters is avoided, and it is just a matter of getting the words accurately positioned on the panel. The disadvantage of whole words is that however well chosen the selection of electronic oriented words happens to be, there are going to be occasions when a suitable word will not be available. Also, there is a tendency to run out of some words when no more than a few percent of the transfers on the sheet have been used up. Sheets of single letters are not perfect in this respect, but in general give far less wastage. If you are not very good at this type of thing then the sheets having whole words probably represent the best option, but otherwise the single letter sheets are the type that I would recommend.

A range of rub-down transfers are available from graphic art suppliers and stationers (including W. H. Smith). Exactly what is available varies from one retailer to another, but there is normally a variety of letter sizes available, and often a selection of different type styles as well. In the current context some of the fancier type styles are not really suitable, and something plain and easy to read is probably best for labelling controls etc. (the popular "Helvetica Medium Bold" typeface for example). Some of the fancy lettering styles are well suited to large labels intended mainly for decorative purposes, such as labels showing the name of the project. The computer style lettering available from W. H. Smith for instance, would obviously be well suited to a computer add-on or a digital project of some kind.

For labelling controls etc. quite small letters are required, say around 2·5 to 5 millimetres high. It is advisable to have at least two sizes as 2·5 or 3 millimetre letters will be far from conspicuous on a large project, and there is unlikely to be enough panel space to accommodate 4 or 5 millimetre high letters on a miniature project. For larger labels a letter height of around 6 to 10 millimetres is suitable.

POSITIONING

Some thought needs to be given to the positioning of labels, which should be functional as well as decorative. In general it is better to place them above rather than below controls and sockets, as they are then less likely to be obscured from view in normal use. Remember to take into account the size of control knobs, sockets, and anything else that covers part of the panel. It is very easy to spend an hour or so preparing a front panel, only to find that when everything is fitted into place some of the labels are partially obscured by the control knobs. Accurate measuring is very important, especially for a front panel where there is little room to accommodate the labels.

We will assume that the panel is a type which can be removed from the case, or that it is at least a type where with the controls etc. removed, it provides a nice flat working surface. Ideally you should fit the labels onto the panel before final assembly of the project, but many constructors prefer to get the project up and running first, and then fit the panel legends. Even if this entails a fair amount of work, it is well worth dismounting all the panel mounted components before trying to add the labels. With even minor obstructions on the panel it will be difficult to accurately position the transfer sheet, and the transfers on the sheet will tend to get scratched and chipped.

Some form of marking is needed in order to help with the correct positioning and alignment of the transfers. Some transfers are supplied with strips of self-adhesive coloured paper which can be placed on the panel and used as a guide line. This is a good way of doing things as once the labelling has been completed the paper can be peeled off and will leave no marks on the panel. Marking guide lines with a pen or pencil will leave marks that will be more difficult to remove, and you might find that in removing the marks some of the transfers are taken with them. I would therefore recommend the use of the self-adhesive strips, or improvising with something like insulation tape if these are not available.

When first using transfers there is a strong temptation to start with the first letter of a word, working through to the last one. While this might seem like the logical way of undertaking the task, it is a relatively difficult method. For the labels to look neat it is essential that they are reasonably well centred with the control, or whatever is being labelled. In order to achieve this when starting with the first letter it is necessary to work out the length of the word (in millimetres not letters), and then position the first letter accordingly.

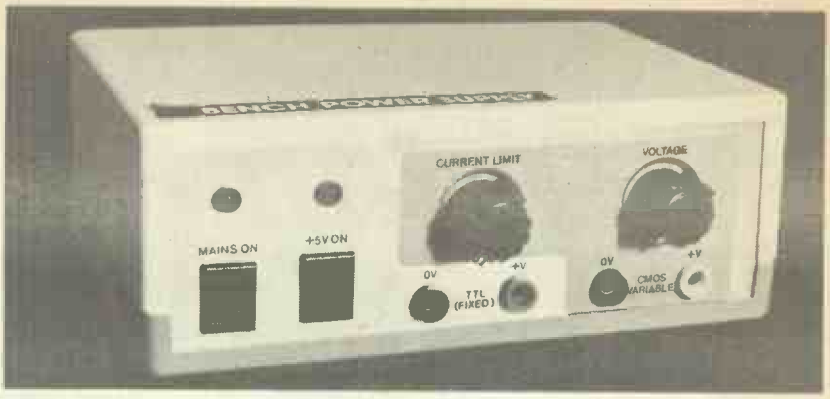
It is generally easier to mark the position of the middle letter (a line or spot on the paper strip will suffice) and then work outwards from this. If the word has an even number of letters, then it is a matter of marking the centre point again, and then placing the middle two letters just to either side of the mark. There is a slight complication in that not all letters are the same width, and "w" for example, is much wider than "i" or "l". For perfect results it is necessary to take this into account, and adjust the position of the middle letter(s) slightly if necessary. This is something which becomes easier with practice, and might prove to be a little awkward at first.

All the makes of transfer sheet I have ever come across provide some sort of guide line beneath each set of letters which can be matched up with the guide line on the panel to ensure that the letters are all at the correct height. Some types have an individual line beneath each letter, with the length of the line indicating the space required by each letter. The general idea is to rub down the letter onto the panel, and the line onto the strip of paper providing the guide line. By butting the lines accurately together the letters are placed both at the right height, and with neat accurate spacing. Most transfer sheets do not provide any help with spacing of the letters, and it is then just a matter of doing things by eye. This is again something which becomes easier with practice. Whether the letters are placed very close together or well spaced out is not something that will greatly affect the end result unless done to excess, and the main thing is to strive for even spacing.

It is possible to rub down the transfers using something like and old ballpoint pen or a fairly blunt pencil, but the proper spatula does not cost a great deal, and I have always found one of these to give much better results than any improvised tool. The amount of pressure required varies from one make of transfer to another, but in general only moderate

pressure is needed. Too little pressure and part of each letter will be left on the sheet—too much and letters will tend to become distorted. The backing sheet will also tend to get distorted, making it difficult to accurately lay down the remaining characters on the sheet. Be careful not to move the transfer sheet slightly while letters are being rubbed down, as this will also result in distorted characters.

When a word has been finished, place a vacant area of the transfer sheet over it, and gently rub over it with the spatula. This is known as "burnishing", and makes sure that the letters are all fully rubbed down into place.



AWKWARD PANELS

If the case has a large panel which can be removed, or even a flat and unobstructed panel which has to be left in place, then applying the transfers should not really be too difficult. Unfortunately, not all cases are in one of these categories, and it is sometimes necessary to fit transfers into inaccessible positions. This is really just a matter of doing the best you can, however you can. In really awkward situations it might be necessary to abandon the idea of directly applying the transfers to the panel. A simple alternative is to make up labels of whole words by rubbing down the letters onto pieces of self adhesive transparent plastic. These can then be cut down to size, and fixed in place on the panel. This enables labels to be put into positions where it would be impossible to apply them straight onto the panel.

There are variations on this method, one of which is to apply the transfers to a sheet of aluminium. With a piece of clear adhesive tape pressed down firmly onto the word, it should lift off the lettering when it is removed, again giving a label which can easily be fitted into an awkward spot on a panel. The drawback of this system is that it may not always work, and some of the lettering might be left behind on the aluminium sheet. It has the advantage of providing a strong protective layer over the transfers so that the lettering is not easily chipped or scratched.

The fact that rub-on transfers rub off almost as easily always tends to be a problem. Spraying the finished panel with something like Scotch Sprayfix helps to some extent, but the lettering still needs to be treated with respect if damage is to be avoided. Covering with a layer of self-adhesive transparent plastic gives better protection, but it is essential to get the plastic to lay down flat against the panel the first time it is fitted. Removing it for repositioning would almost certainly result in large amounts of lettering coming away on the plastic film.

A drawback of using word labels made up on a transparent self adhesive material of some kind is that the perimeter of the label is often plainly visible. Spraying with Scotch Sprayfix or a similar clear lacquer will help, but is unlikely to take things to the point where you can't see the proverbial join. One way around the problem is to make no attempt at disguising the fact that the lettering is on a backing material of some kind. For example, very attractive labels can be made by applying transfers to pieces of brushed aluminium effect veneer. These are very effective when used on most types of case and work particularly well with inexpensive black plastic types.

Robert Penfold

PCB SERVICE

Printed circuit boards for certain constructional projects are now available from the PCB Service, see list. These are fabricated in glass-fibre, and are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £1 per board for overseas airmail. Remittances should be sent to: The PCB Service, Everyday Electronics and Electronics Monthly Editorial Offices, 6 Church Street, Wimborne, Dorset BH21 1JH. Cheques should be crossed and made payable to Everyday Electronics. *(Payment in £ sterling only.)*

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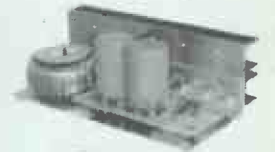

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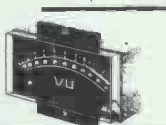

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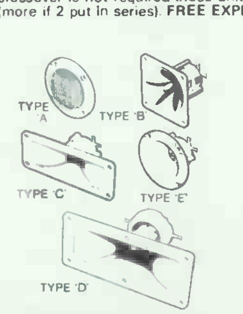

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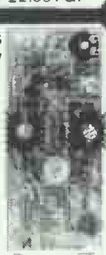

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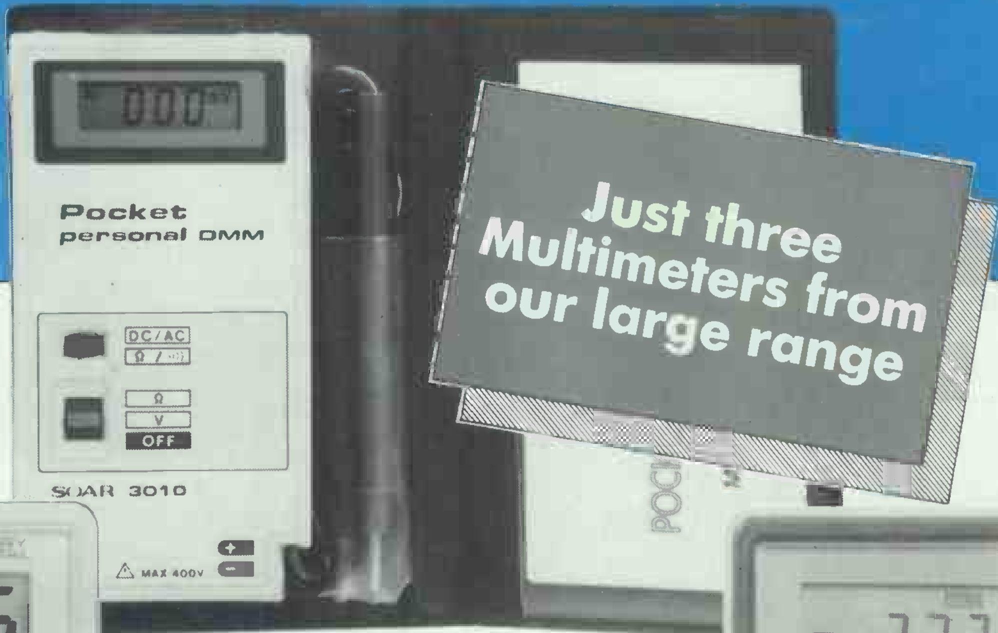

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Guide to...

PRINTED CIRCUIT BOARDS

Design · Layout · Construction

To the uninitiated printed circuit board layout, design and construction can be something of a mystery. Here John Becker explains just how to do it, using a siren generator project as an example. See how the p.c.b. was designed, make it, build the project and then enjoy yourself with police cars, star wars, space invaders, machine guns etc.

It is apparent that some constructors regard printed circuit boards as an entwined collection of apparently random tracks that are meaningless to the uninitiated. The intention of this article is to demystify the nature of simple p.c.b. design and production. Hopefully after reading it more constructors will be persuaded that producing their own p.c.b. for a particular project is often easier and better than cutting and connecting tracks of copper clad strip boards.

This is not to say that strip boards are unnecessary. Far from it. There are occasions when producing a large scale prototype, that a degree of uncertainty exists with regard to the feasibility of some ideas. In these instances it may be undesirable to go straight for a p.c.b. layout, as the original brainwave and the final product may differ. For this type of testing strip boards are essential as modifications to the circuit can be readily incorporated.

Having arrived at the final theoretical circuit, then, it is well worthwhile producing a fibreglass p.c.b. specially for it. This is particularly true if you are thinking of having your circuit published, or of producing more than one copy of it. Even if you are not considering either, the satisfaction of looking at and using a p.c.b. that you have designed is enormous, and they give a professional appearance to any project. I am as addicted to designing them as some are to doing crosswords.

SIMPLICITY

P.c.b.s are not difficult to design, nor to make for yourself. Indeed as a child you may well have found pleasure in a game that is not all that far removed from p.c.b. designing. No doubt most of you will remember books with pages having various numbers scattered across them. When lines were drawn connecting them together in the correct order, a picture would emerge. Quite likely you would then have gone on to creating your own series of numbers to produce other pictures. The art of designing them was to ensure that no two lines would cross each other.

In some respects p.c.b. design is easier for lines can be permitted to cross each other providing that the crossover is made by a component or a link wire, and as the whole object is to link components with the track lines, the game is nearly won! For ambitious boards, the crossovers can be made by using tracks on either side. Industry even uses multilayer p.c.b.s with tracking on each layer. This though is getting into the world of three dimensions, and for most amateur electronic constructors, single sided p.c.b.s are the simple and satisfactory answer.

Drawing the track layout direct onto copper clad board with an etch resistant pen is all very well for simple circuits where the spacing between components is not critical, but it is not easy to evenly draw closely spaced tracks or i.c. leg pads with them, and if you need more than one copy each has to be made separately. In the way that I shall describe very accurate spacing and linearity can be achieved. The method enables many prints to be made, and at the same time minimises the area of fibreglass that each p.c.b. will use. This may not matter too much if you are only designing for your own one off use, but if many such boards are to be made then area means expense. The more boards you can cut from a sheet of fibreglass, the more the costs reduce, not only the costs of the board itself, but also of the chemicals that are used.

PREPARATION

The process is divided into five simple steps; sketching a component and track layout, producing a tape master using adhesive pads and tapes, printing one or more copies onto fibreglass, etching and drilling the final boards.

In order to achieve accuracy, going straight for a life-sized board is not necessarily the easiest way, and if you have access to a suitable reduction photocopier or photographic equipment, it is best to work to a drawing and master track layout that is twice life size. For specialist applications, enlargement ratios far higher than this are used, but for most purposes designing to an exact ratio of two to one is nice and convenient in terms of calculating

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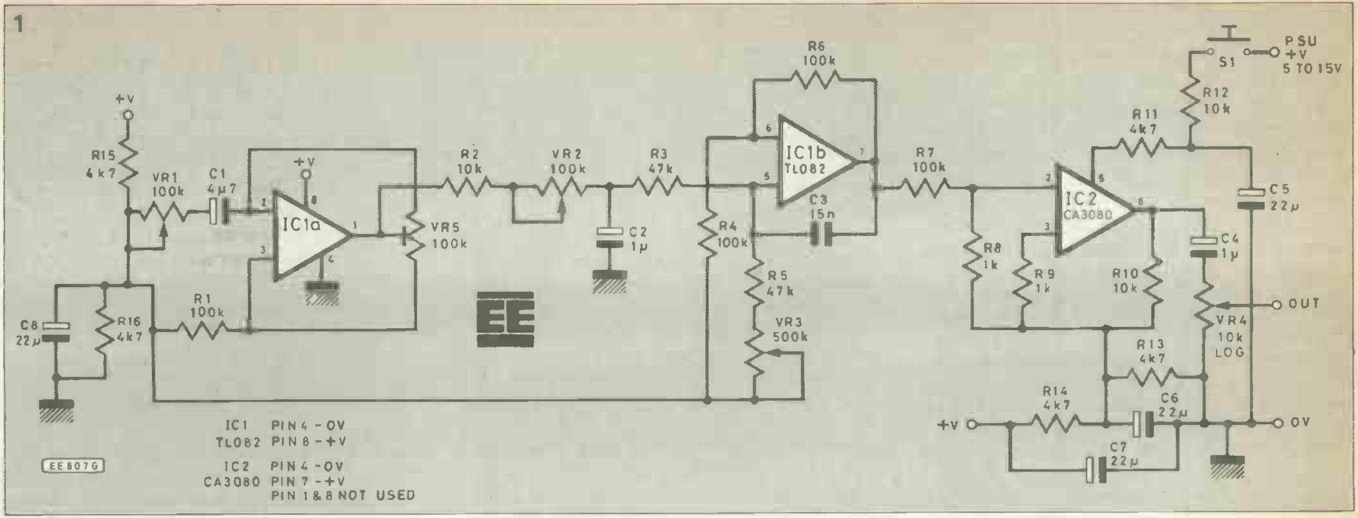


component sizes, and availability of drafting materials.

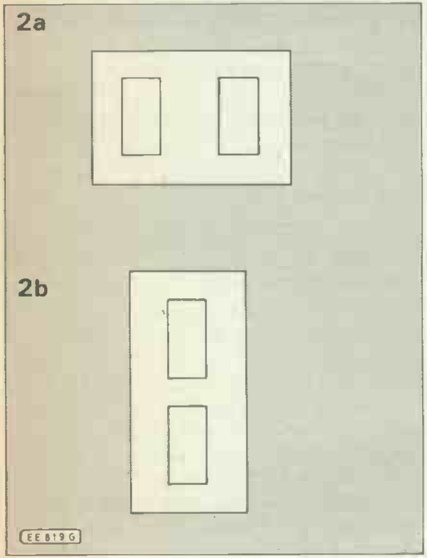
However, before designing for this ratio, you should check that you can obtain a reduction print. Most photocopy shops have a reduction copier, and some of these can copy direct onto clear film. Alternatively your local photographer might produce a reduction print for you. If neither facility is available, then you should work to a life size master and produce your p.c.b.s directly from that.

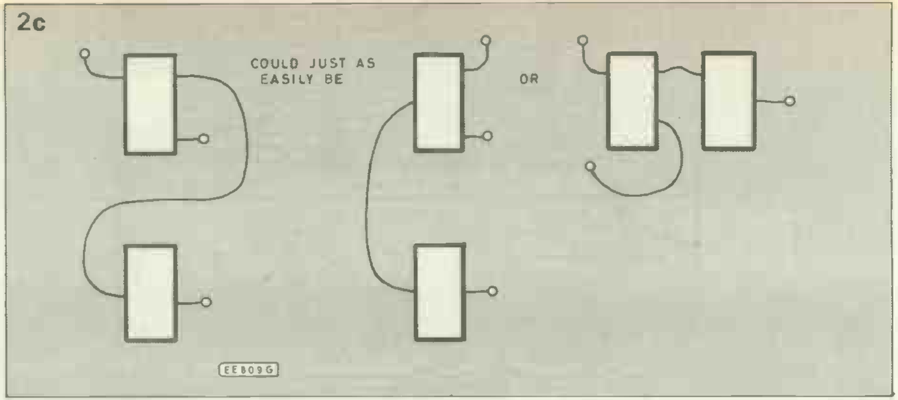
The first thing that you need is a good soft pencil and rubber. Pencils of grade 2B I find are best as the line drawn can be readily seen, and equally important, can be easily erased if you change your mind about a particular routing. Secondly, you need graph paper upon which to draw the scaled component layout sketch. In many ways we are now a metric nation, but in this instance I find that by using measurements in tenths of inches, component sizes are more readily interpreted on the layout. In fact, although component sizes are usually quoted in metric, the equivalent in tenths of an inch is often an exact number. For this reason I use graph paper ruled in 0·1 inch squares. Most stationers still stock it, or can readily obtain it.

STARTING

Probably the hardest point of p.c.b. design is the beginning! Where to start? Let's look at a practical example. Assume that you already have your theoretical circuit, either of your own design, or one published in a magazine. The one I've chosen, somewhat at random, generates siren sounds at the press of a button, and is controlled by various panel pots. Circuit operation will be explained later; let's see what we have physically (Fig. 1).

There are two op-amps IC1a and IC1b, and another amp IC2. Although IC1a and b are drawn separately they are treated as one here as the chip used contains both in the same package. Looking at the upper side of the i.c. with the locating notch at the top, the pins run downwards on the left from 1 to 4, and then upwards on the right from 5 to 8. For this example the panel controls, VR1 to VR4, and S1 can be largely disregarded as they will not be mounted on the p.c.b., though given pots with p.c.b. mounting tags, they equally well could be incorporated on the board.



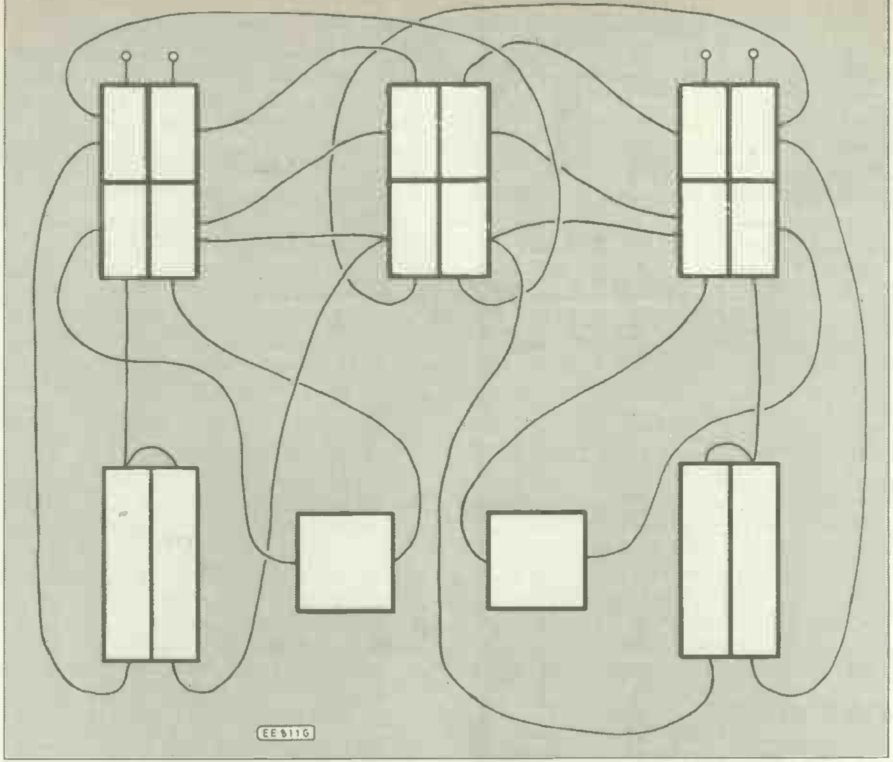


The sizes of the other components should now be measured in tenths of an inch. IC1 and IC2 are both 8-pin d.i.l. i.c.s, with lengthways spacing between legs of 0·1 inches and crossways 0·3 inches. Resistors can usually be regarded as being 0·1 wide by 0·4 long when the leads have been bent down to go into the board. In this instance C3 has the same spacing, and the electrolytics are 0·2 by 0·6. The preset pot has its base legs at 0·2 and its wiper leg at 0·4 centrally out from the base line. These measurements of course may vary between manufacturers, so always check the sizes before designing the layout. Remember that if you are working to twice life size, then sizes on the drawings all need to be doubled.

Personally I like symmetry on a p.c.b., and to facilitate drilling, prefer the holes to be pretty much in straight lines. It is amazing how much extra drilling time mounts up if you have to align the drill in different planes for each hole. It is much easier and quicker to move along an evenly spaced line of holes. Symmetry is not vital though, and in most cases all that really matters is that components are correctly connected to each other by the right conducting copper tracks.

Initially we have two choices, whether

2d



the two i.c.s should be in line astern, or line abreast (Fig. 2). I've opted for line astern as I know that this is usually the easiest way of achieving evenness on a board of this sort. For a more complex circuit I would probably first do a rough block layout showing the main signal routings, as for example in Fig. 2d. The equivalent routing for this simple project are shown in Fig. 2c.

Internally, IC1 has two identical halves, and here it does not matter which half is used for which purpose, the pin numbers could just as well be transposed. Being right handed I prefer to work from left to right and from top to bottom. So following the circuit diagram, the uppermost and first op-amp section is going to be the left hand part of IC1. The power line connections to IC1 are +ve for pin 8, and 0V for pin 4. For IC2, pin 7 is +ve and pin 4 is 0V. It usually makes life simpler if chips are orientated so that power lines of the same polarity are on the same side, so let's draw this first stage on the graph paper.

We are working here as though looking at the top of the p.c.b., so we will put dots representing the leg holes for IC1 somewhere up the paper, and some distance down the dots representing the holes for IC2. No need to be too critical of the relative positioning of the two i.c.s, as the rubber can correct things later if necessary. Mark the identity number within the dots, and a mark to represent the orientation. Now in freehand draw two lines down between the legs of each i.c., connecting to the correct power supply pins, and mark the end of these lines with the power line polarity (Fig. 3).

I find that it is best not to draw interconnecting lines too straight as slightly

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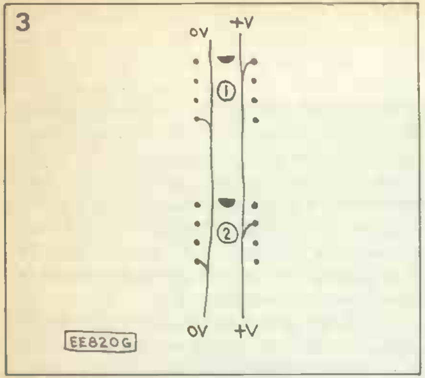

crooked lines are easier to discern from component outlines on a complex board. Everything will be straightened up when doing the final track layout.

Looking at IC1a, we see that VR5 is connected to three of its pins. There is really only one place for it, on the left hand side. It could perhaps go to the top of IC1, but we do not yet know whether the power lines will be finally brought out at the top or bottom ends of the p.c.b., so positioning to the left is preferable at the moment. Only the leg holes need to be marked, but remember that the body size actually extends around the legs. To allow for the width of IC1 as well, leave about 0·6 gap between IC1 and VR5.

This now sets the basis for the remaining component line down the p.c.b. C1 and R2 both connect to the outside world of the panel controls, and their positioning is obvious, marking the output connection points with their ultimate destinations. The other end of R1 is seen from the diagram to ultimately connect up with various other components, so for the moment it is left loose, and marked with its function, in this case it is a split reference level line. Study of the circuit shows that IC1a needs no other connections on the board.

Moving to the right, R3 to R6 and C3 can easily be positioned, and still retain a degree of symmetry. Although the width of many components would actually allow them to be placed closer together, the drafting pads that will be used have a diameter that also must be taken into account. The ones I use are 0·2 inches in diameter, and I prefer to have a layout gap between them of no less than 0·1 inch.

Occasionally if pressed for space I will bring them to within half of a 0·1 square of each other, but any closer could make for difficulties on the final reduction print. For similar reasons tracks should not be too close together either. With industrial boards this distance can be much less, but the resolving power of most reproduction equipment available to amateurs is probably insufficient to allow closer spacing.

LINK WIRES

We now have a dilemma, pin 7 of IC1 needs to connect to pin 2 of IC2 via R7. It would be very ugly to extend the leads of R7 and twist them to a shape that will take them directly to their proper points. It would also be unnecessarily devious to take a track right round the side of the p.c.b. and to connect the two points, and in any case at this moment we don't know what else needs to come in between on the lower end of the board. Another major consideration is that long tracks looping around a board can pick up signals from other tracks running close to them.

In digital circuits, the induced pick-up is not usually likely to cause problems as the levels will be too low to matter, but on an audio board, this pick-up may be heard at the output as an undesirable background signal. The shortest route is nearly always the best. The answer here is to put a link wire in, connecting pin 7 IC1 to R7 as shown. Only the representational dots for the holes are shown, and the link is assumed, or marked in lightly. In actual fact examination shows that the connecting track could pass from pin 7 IC2 between the pads of R4 and C3 if they were moved further apart, but I have not done so as I want to make the point about link wires. With single sided digital p.c.b.s it is highly unlikely that all tracking can be made without using them.

Still retaining symmetry, R8 to R12, C4 and C5 can be marked in, as can C2, but again with a short link wire as well. The main layout is now complete, as shown in Fig. 4.

There are still a number of loose ends to tie up though. In particular the voltage

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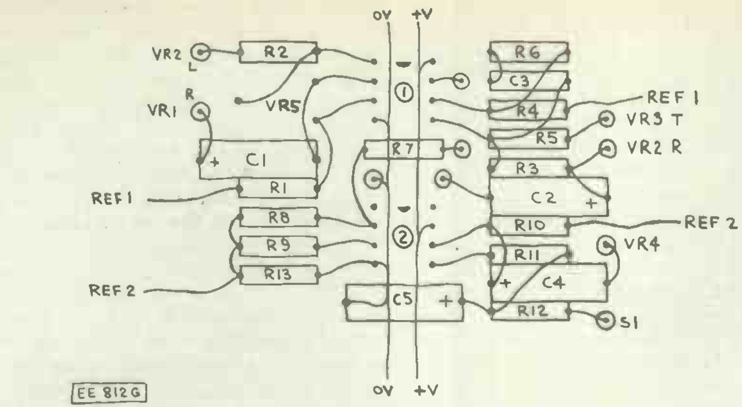

reference components C6 to C8 and R12 to R16. These have been left to last as their position is not especially determined by pin connections to the chips. Studying the board layout so far shows that symmetry can be improved upon, and that in particular a spare area around the bottom left hand side exists, and the top end is clear. The missing parts can be readily put into these areas, moving C5 in the process, and the remaining connections joined up, as in Fig. 5. I often leave larger components to be fitted in on the outside edges as symmetry is then usually more easily satisfied.

CHECKING

We now have a rough pencil layout of the component positions and track connections. Before continuing, it is worthwhile, especially on larger p.c.b.s, to actually check that the drawing coincides with the circuit diagram and that you have not omitted anything or routed it wrongly. Take two sheets of tracing paper and secure them over the circuit and layout diagrams. Better still, use a photocopy of the two drawings. Trace over each line of the circuit and do likewise with its layout counterpart. Any errors will soon become evident, and can be corrected.

DRAFTING MATERIALS

The drafting materials for the tape master are available through good office stationers and from component suppliers. Three of the manufacturers are Mecanorma, Chartpak and Alfac, though there are others equally as good.

The master is produced by positioning self-adhesive pads and tracks onto tracing paper or drafting film. The film is better as it is tougher and does not stretch, but for small boards, good quality tracing paper is a reasonable substitute.

The pads that will eventually become the drilling points and soldering areas on the p.c.b. are available in two forms, self-adhesive crepe paper or rub down. They are usually sold in rolls or strips and are easily applied by positioning the pad on the film and rubbing with a fingernail. The clear backing material then peals off leaving the pad in position. The crepe ones are somewhat easier as they can readily be lifted on a pointed knife and repositioned, whereas the rub down ones need to be scraped off with a razor edge if a mistake is made. Both sorts come in hundreds of shapes and sizes for different purposes (Fig. 6) but usually you will only need the twice life size d.i.l. pad strips, and the 0·2 diameter single round pad strips. These are also available in standard spacing d.i.l. strips and 0·1 if you are working to life size.

The self-adhesive connecting tracks are sold in continuous roll form and are easily positioned and cut to length with a pointed

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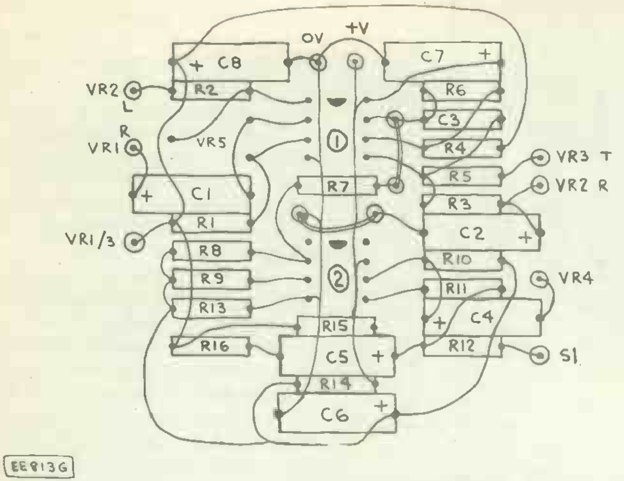


knife. Various widths are available, but for most double size tracking I prefer the 0·1in width, or 3mm if I cannot get 0·1. For life size the equivalents are 0·05in and 1·5mm. These widths are narrow enough to pass two between i.c. pad rows but wide enough to etch cleanly on the final p.c.b. The tracking is very easy to work with, and can be laid and subsequently lifted to be repositioned if necessary. It is also possible to extend a track by overlapping two sections. A slight increase in track height results, but in most cases this will not be apparent to the copying system. I would avoid a triple overlap thickness as this could perhaps cause a shadow area when processed.

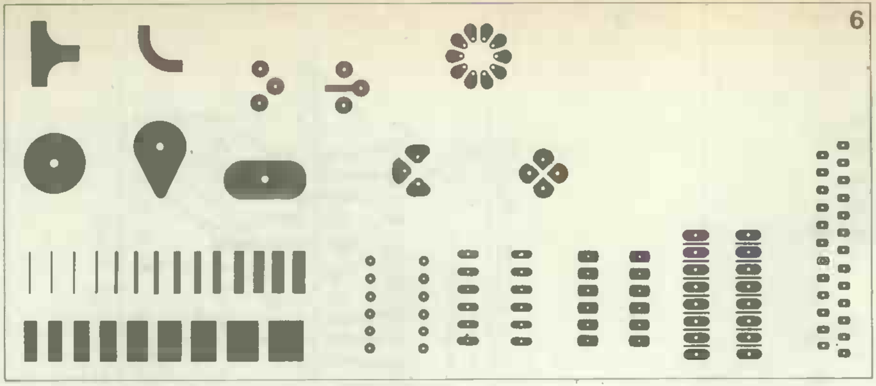
Most pads and tracks can be obtained in black, red and blue, but only the black is suitable for amateur use unless sophisticated photographic equipment is available. The coloured ones are for double sided layouts where selective colour filtering is used in the photography.

PADDING AND TRACKING

Now take a sheet of tracing paper or drafting film and Sellotape it to a clean sheet of graph paper. The squared markings will show through clearly. Do not try putting the film directly over the pencil drawing for the taping up as this can obscure lines and cause errors. The printed circuit dot symbols can now be applied. First lay down the 8 pads for IC1, positioning their centre holes very carefully above the correct lines as seen through the tracing paper. Looking at the layout drawing there are more components on the right hand side than the left, so position all of these pads next. This will reconfirm the length of the board. Now apply the IC2 pads, correctly positioned vertically with respect to IC1, and horizontally in respect of the components. The remaining pads can now be applied and you will have a dot pattern as in Fig. 7.

In this instance we have taken care in the exactness of the pencil layout positioning. On other boards, and with acquired experience, the layout drawing may quite likely be a really rough sketch of relative positionings and trackings. The precise positioning of component pads can then be judged during track laying, following the procedure similar to the above, and possibly taping up as you go along. Here we will systematically join up the pads with tracking now the dotting is complete.

Most connections are straight lines, but some need to go round corners. Some



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designers will probably take their tracking round a corner in a smooth curve though I prefer a more angular approach. For most connecting tracks it is quite easy to position one end of the tape so that it overlaps the edge of one pad, and then extend it to overlap another in a straight line, trimming with a sharp pointed knife. I use a Stanley knife as I like the weight but others may prefer a model maker's knife, a scalpel, or a safety razor blade. For long lengths of parallel tracks or for turning corners, it is often best to lay down a longer length first, make the next overlap connection, and then trim off the surplus. Fig. 8 shows this board half way through tracking, several excess ends are now evident. Fig. 9 shows the completed layout.

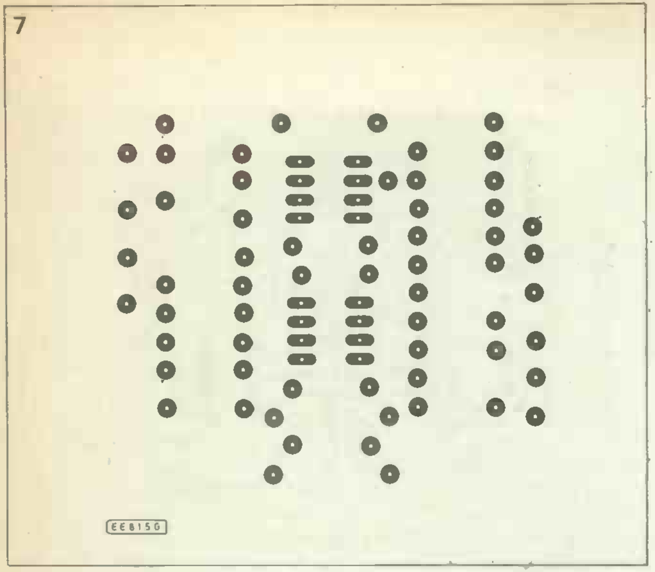
Note that the perimeter corners have also been taped in marking an adequate edge for guillotining or hacksawing the final board and also allowing it to be inserted in an assembly frame during component insertion. Pads for the holes through which the p.c.b. will be mounted to the chassis or box have also been positioned. Normally I place these corner holes about 0·3 inches from the board edge, and far enough away from any components so as not to interfere with them.

Although you may not want to mount your own board by means of the corner supports, if you are designing a board for manufacture, they should be regarded as vital. It is conventional with boards of this type, for several to be stacked for drilling simultaneously, the quantity depending on their thickness. To ensure correct registration, pins are inserted at two diagonally opposite corners, and possibly at all four. If the registration holes are omitted at the design stage, this could present manufacturing problems.

You will also notice that I have thickened selective areas of the power line and reference level tracks. On a board like this it is not really necessary, but I do it for two reasons. Firstly, it makes the power line tracks obvious, which can be advantageous when experimenting with a prototype. But more particularly it decreases the resistance of these tracks.

Any wire or track has resistance and as you know from Ohm's law, resistance and current cause a voltage drop. If a circuit is current hungry and the tracking introduces too much resistance, there can be quite a significant voltage difference between one end of the track and the other. This can cause all sorts of problems for the circuit and so is best minimised by increasing track widths.

With units where this sort of interaction could be a problem, you should also consider the best track routing to reduce it. If tracks are widened, make sure that any pads along the track are left clearly visible, as you will see that I have done for C7 on the right hand side, and R1 on the left. It is easy to miss drilling them if they are obscured. Also if the pad is too much part of a wide track, heat can be drawn away



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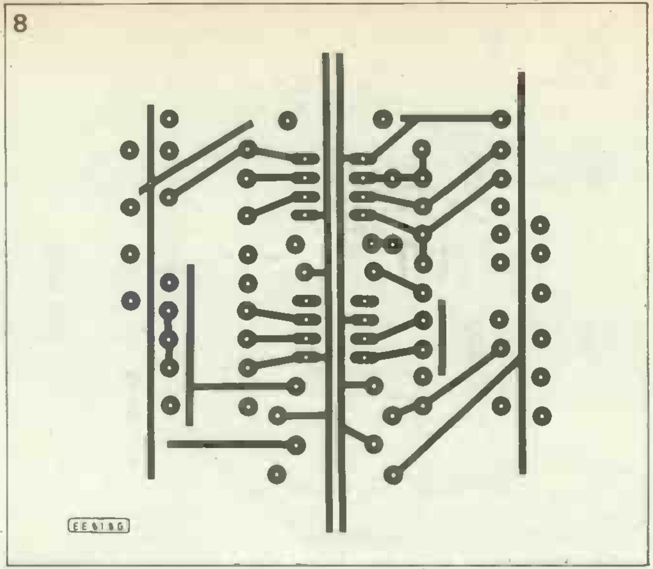

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from the soldering iron, which in extreme cases could cause inadequate soldering. In professional assembly lines boards are sometimes kept heated during soldering to minimise heat sinking.

When track laying is complete, it is now essential that further checking be carried out, in the same way as previously. If necessary tracks and pads can be lifted and repositioned. The self-adhesive pads will usually stand quite a lot of lifting and repositioning, but the rub down type will need to be scraped off with a sharp razor blade. If a rub down pad is slightly damaged when lifting a track, another can normally be rubbed down over it without removing the damaged one.

REDUCTION

If you are working to a master tape layout of twice life size, then a reduction print has to be made. There are two options on this, one photographic, and the other xerographic. For most constructors, the xerographic, or photocopy reduction is the most convenient if a local shop has a reduction copier that can print onto clear film, though the quality will be lower. Their machine will not normally go straight from twice life size to actual size in one step, but it can be done in two stages. A paper print is first taken from the tape master on the A3 to A4 reduction setting. This print is

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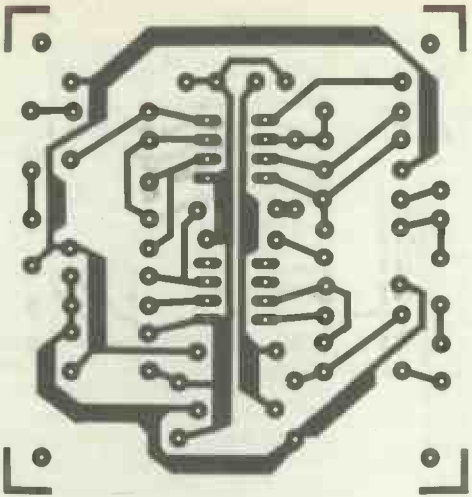

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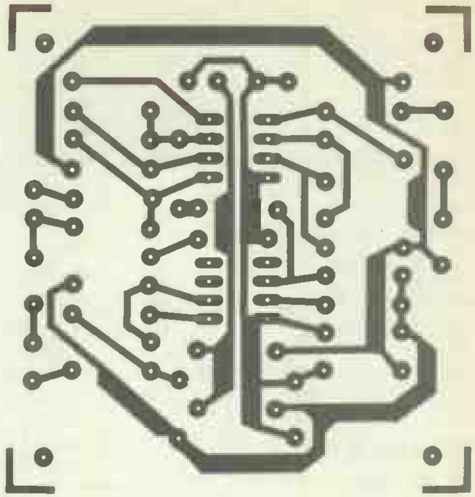

then used to produce a further reduction onto acetate film, also on the A3 to A4 setting, resulting in a lifesize final. In my area this costs about 20p per print onto clear film.

Check that the photocopier produces a reasonably dense black on the film, and if necessary ask the shop to change the contrast setting on their machine. The image is unlikely to be as dense as that produced photographically, but the tracking on the assembled p.c.b. can be run over with solder to increase the conductivity and cover any minor speckling. Particularly bad areas on the film could also be obscured with a dense ink, or with Letraset rubbed over the offending area. Note though that some types of copier are incapable of producing a dense enough image onto film and you should check on this before designing to a double size layout.

For a photographic reduction, your local photographer may undertake the job for you, or if you have your own camera and enlarging equipment, you can make your own quite easily. Tape the master to the inside of a window. On the outside tape a piece of white paper, slightly larger than the master. Position two lights on either side of the inside window to illuminate the track. Having the white paper behind the glass helps to reduce the possibility of shadows blocking the space between the track areas. Professionally the master would be held in a vacuum unit to keep it flat so that shadows would not cause problems.

Using black and white high speed film, photograph the track layout, and develop for a high contrast. This negative is then enlarged to the exact size needed, printing onto high contrast sheet film, such as Agfa-Gevaert Copyline HDU 3P Type 2, or similar. When developed, this is your lifesize track master from which you make your board. (The developer for the above film is Litex G 90T, from Agfa.)

COPPER PRINTING

From the life size master, whether it is from film or original taping, you can now make your fibreglass p.c.b. You will basically need four things, photosensitive copper clad fibreglass, ultraviolet light source, photoresist developer, and copper etchant. Several companies advertise in electronic magazines for p.c.b. production materials, though chemicals can be bought through a chemist. The chemicals should be handled using rubber gloves, they are no more harmful than ordinary photographic materials providing the instructions are followed.

Various low cost ultraviolet light boxes are available but alternatively an ultraviolet lamp such as sometimes used in discos could be used, though at an extended exposure time, found by experiment. Perhaps even a sunray lamp might be used. On my 90W UV strip light unit exposure at a distance of about 50mm is between two and five minutes, depending on the board emulsion sensitivity and image density. All the processing can be done in ordinary artificial light, but avoid daylight creeping in as this of course has a high UV content.

The p.c.b. track film is positioned over the photosensitive side of the fibreglass, from which the protective plastic covering has been removed, and held in position with a sheet of clean glass. Remember that all the layouts and tapings have been made as though looking at the components side of the p.c.b., consequently the track image must be placed the other way up on the board to get the image the correct way round Fig. 10. It is then exposed to UV for the required time.

ALTERNATIVE MASTERS

You can also buy special lifesize etch resistant pads and tracks that can be directly put onto ordinary copper clad board, allowing a single one off p.c.b. to be readily made. You lose the ability for doing multiple copies, but eliminate the need for reduction and UV exposure. There is also a special spray called "ISO-draft" that can be used to make a paper print translucent enough from which to print while wet. I have not tried it, but it is available from Cannon & Wrin, 68 High Street, Chislehurst, Kent. Telephone 01-476 0935.

DEVELOPING AND ETCHING

Developing of the image can be done in sodium hydroxide, diluted in cold water at about 15 to 25 grams per litre. Keep the board agitated in the solution, and you will see the unrequired areas of the emulsion coating disappear in about two to three minutes leaving clean copper and an etch resistant track image. When the image is clean, rinse thoroughly under cold water, preferably sprayed on from a shower head. Allow it to dry, using a hairdryer or similar if available. Be careful not to scratch the image though, if necessary, scratches or pin holes in the track can be inked in with an ordinary etch resistant pen.

Etching is then done in a ferric chloride solution. The technique here will depend on the type of ferric chloride etchant as some have extra additives. With the simpler ones the temperature needs to be really hot, at least 60 degrees C. Ideally air should be bubbled through the solution at the same time, but alternatively dip the board in and out of the solution every few seconds to allow air to it, until the copper has etched away leaving the track areas untouched. Do not over-etch as the etchant will dissolve the copper sideways as well as down, which could under-cut the tracking area. Then wash thoroughly in running water and dry it.

Some etch-resist coatings can be soldered to directly, but often it is preferable to remove the resist first to expose the clean copper tracking. Special resist stripping liquids and aerosol sprays are available, and even amyl-acetate or nail varnish remover might do the job in many cases. Otherwise it can be done, very gently, with a household cleaning powder such as Vim or Ajax, or with a copper cleaning abrasive pad.

Drilling can now be undertaken Fig. 11, positioning the drill at the centre of each pad. Most components need a 1mm drill bit, but some such as preset pots may need a 1·3mm bit. Preferably tungsten carbide drills should be used, for although they are brittle and can break easily if you are careless, they drill a cleaner hole and last many times longer before they are too blunt to use. However, they are not always easy to find in a retail shop, in which case hardened steel drills can be used.

Once drilled the board can be assembled in the normal way. Then run solder over the tracks to increase the density if the image is a bit thin. If some time elapses before assembly, the copper may oxidise slightly, looking a bit discoloured, in which case reclean it, otherwise soldering may be difficult.

COMMERCIAL DIFFERENCES

I have already mentioned some ways that commerical p.c.b. production may differ from the ways open to the average amateur. Some other differences that I know of include for example, computer aided p.c.b. design. In this method the computer is given data on component sizes and their connections in the theoretical circuit. It then calculates and prints out the final track master. The speed can be dramatic.

Silk screen printing is universally used to put an etch resistant image on copper clad board, and both manual and automatic printers are available. Conveyor belt etching processes are used by large companies, smaller ones use thermostatically controlled manual immersion baths with bubble agitation. Drilling machines vary from high speed hand operated single drills, to multihead computer controlled units that maintain the required accuracy needed for automatic assembly. Various sorts of tinning machine are used to deposit a thin metallic layer on the clean copper tracks to prevent oxidising, and assist soldering.

Through-hole-plating is standard for nearly all double-sided boards. As the name implies tracks on either side of the board are connected at specific points by an applied plated layer so that link wires are not needed.

Robotic component insertion machines crop and shape leads, then insert parts into their correct board locations. This is why you may frequently be supplied with components on bandolier strips. Soldering

11

too can be carried out on a conveyor system that carries assembled boards over a wave of molten solder, performing in seconds a process that could take a worker hours to accomplish with a soldering iron. Even wiring between boards can be carried out by high speed wire wrapping tools, eliminating the need to solder them. Industry would be much poorer without printed circuit boards and their associated equipment. Incredibly though, I understand that the man who invented p.c.b.s never patented the idea!

THE CIRCUIT

Having come this far, you are probably wondering what the circuit we have been using as an example does. Basically it is a siren type generator that can be plugged into any normal amplifier to produce all sorts of weird noises such as police cars, star wars, space invaders, machine guns, etc. all depending on the control settings. It consists of two oscillators Fig. 12, the first controlling the second, and a voltage controlled amplifier.

The first oscillator is a low frequency square wave generator, running at a rate set by C1 and VR1. VR5 sets the basic range within which VR1 provides control, and is set somewhere around the midway point to the range needed. It is not too critical providing you don't go too far to either side of the centre which could stop the oscillator. The output square wave charges and discharges C2 at a rate set by the depth control VR3, and so varies the frequency of the second oscillator around IC1b. This is an audio frequency oscillator with a frequency set by C3, VR4 and the controlling level on C2.

The output passes to the v.c.a. IC2, which allows the signal through at a level depending on the control current at pin five IC2. With S1 open this is normally held low, and so the v.c.a. is closed. When S1 is pressed, C5 charges up via R12, so turning on the v.c.a. allowing the sound through. When S1 opens again C5 discharges, and the v.c.a. closes. VR4 sets the final maximum output level. Setting any of VR1 to VR3 varies the sound effect.

Resistors R13, R14 and C6 provide one split level reference voltage, and R15, R16 and C8 another, both at approximately half

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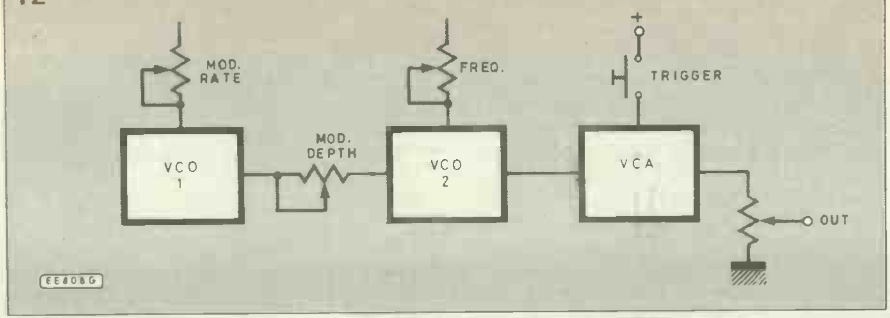
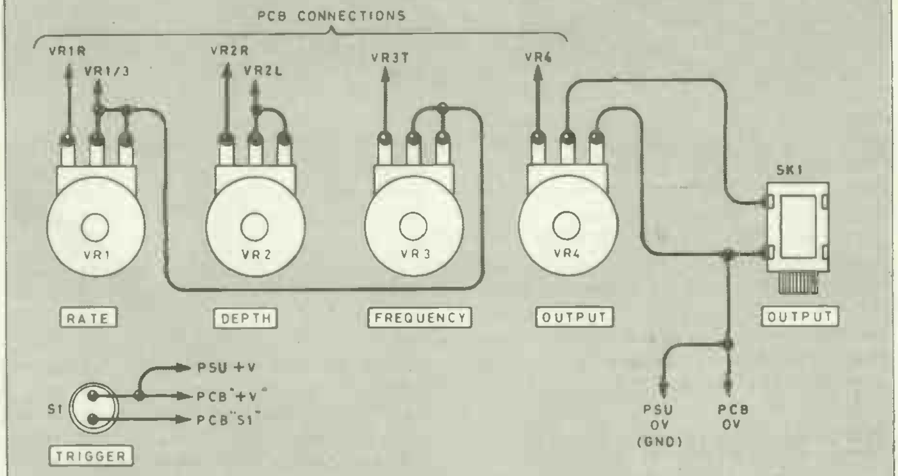
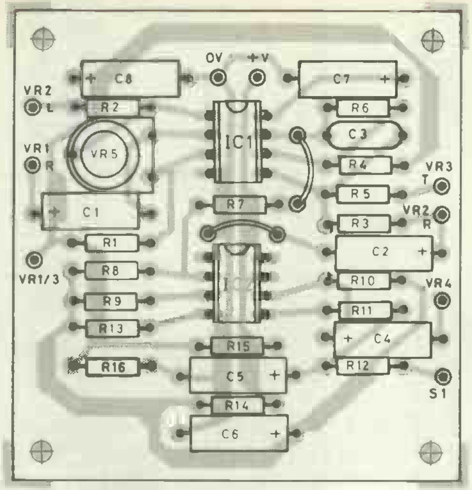


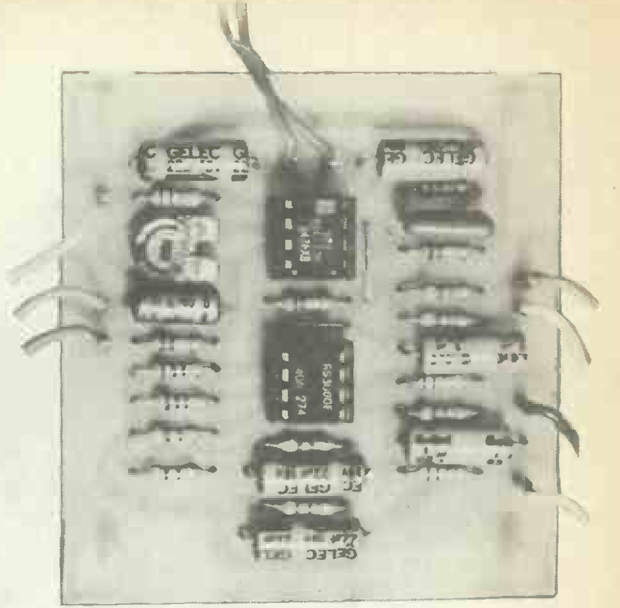


Control wiring



EE817G

Final p.c.b. layout and wiring



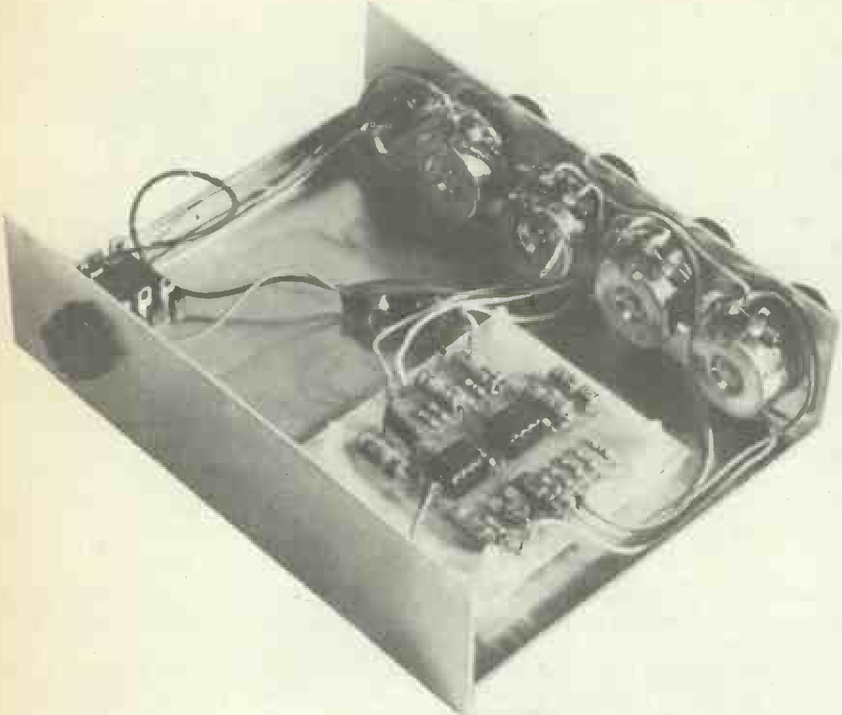
the line level. The unit will operate from a single 9V battery, or any d.c. supply between about 5V and 15V.

GET TRACKING!

I hope that I have given an insight into simple p.c.b. design and production, and maybe encouraged some of you to design and make your own. In published magazine articles there are often circuits, or parts of circuits that are well worth building, and p.c.b.s can easily be made for them. In many cases it may not be necessary to design a board if a life sized track layout had been published, then if your photo-copy shop can do it, this can be directly photocopied onto film and a board quickly made.

Even if you have to design a p.c.b. it does not take long. On occasion I have designed a circuit, taped, photographed, printed, etched, drilled, built and had it working in an evening. Try it, it's fun! □

The completed unit showing how the p.c.b. is mounted on plastic pillars and wiring to controls, battery etc.



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