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858 MAY 1992

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THE No. 1 INDEPENDENT MAGAZINE for ELECTRONICS, TECHNOLOGY and COMPUTER PROJECTS

VOL. 21 No. 5 MAY 1992

EVERYDAY ELECTRONICS

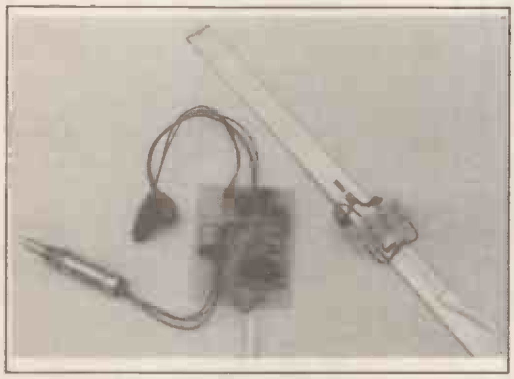
INCORPORATING ELECTRONICS MONTHLY

ABC

The No. 1 Independent Magazine for Electronics, Technology and Computer Projects

ISSN 0262 3617

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



Our June '92 issue will be published on Friday, 1 May 1992. See page 259 for details.

Projects

Series

Features

SPECIAL SUPPLEMENT

2 x 220 watt MOSFET AMPLIFIER

A top-of-the-range performer that will satisfy the most demanding audio enthusiast. If you're looking for an amplifier to power your subwoofer, the **SPARKOMATIC** is all you'll need! Highly sophisticated MOS-FET technology dramatically extends frequency response, separate input sensitivity controls, built-in protection circuitry for overheat and short circuit with l.e.d. indication, output power: 2 x 220 watt maximum and 2 x 110 watt at 0.1% THD, Bridged 440 watt mono maximum and 220 watt mono at 0.5% THD.

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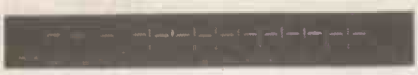
£39.95 postage £3.50

11 BAND COMPONENT GRAPHIC EQUALIZER FOR CARS



This neat unit connects between the line output of your car stereo and your power amplifiers so that you are able to adjust the sound as in a studio compensating for soft furnishing and sound reflections from glass, also it has a subwoofer output to drive a separate amplifier for that extra deep bass sound. FEATURES: 2 channel inputs 4 channel outputs via phono sockets, CD input via 3.5mm jack 11 band graphic. SPECIFICATION RANGE 20Hz-60kHz THD 0.05%, S/N RATIO 85dB. EQ FREQUENCIES 60Hz, 120Hz, 250Hz, 380Hz, 500Hz, 750Hz, 1kHz, 2kHz, 4kHz, 8kHz, 16kHz (boost cut of ±12dB) SIZE 178mm x 25mm x 140mm.

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MO44	5	6.35mm (¼") Stereo Jack sockets	£1
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MO46	12	Coax Sockets chassis mount	£1
MO47	2	Case handles plated U-shape, size 97mm x 50mm	£1
MO48	30	Mixed control knobs	£1
MO49	1	Cassette tape transport mechanism, belt-drive, top loading, six piano key operation with knobs, stereo record/replay erase heads, heavy fly-wheel	£5.50 + £2.65 p&p
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MO52	3	AM I.F. modules'. *Made by Mullard*	£1
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MO86	1	(As above)	£15.00 + £2.80 p&p
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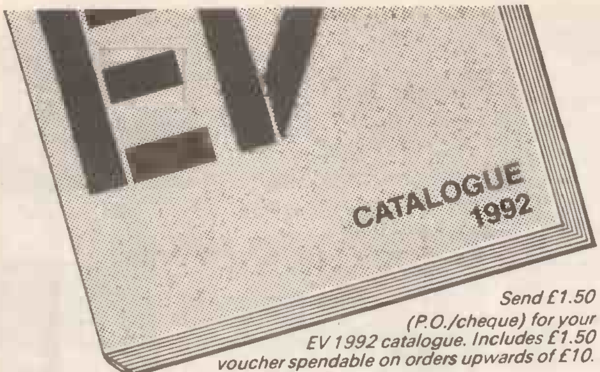
PLUS

News and views, Information Technology, more on Making Your Own P.C.B.s etc. etc.

EVERYDAY ELECTRONICS

JUNE ISSUE ON SALE FRIDAY 1st MAY, 1992



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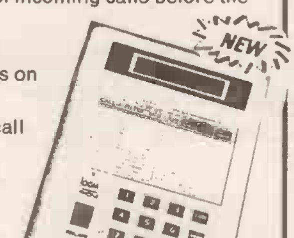

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£14.81

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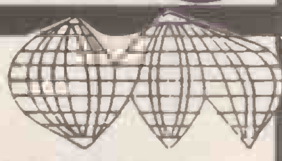

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Covers 1.6–30 MHz in 3 bands using modern miniature coils. Audio output is via a built-in loudspeaker. Advanced design gives excellent stability, sensitivity and selectivity. Simple to build.

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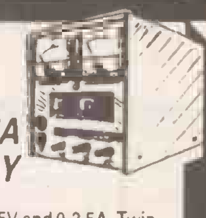
KIT REF 840 £19.86

MOSFET VARIABLE BENCH 25V 2.5A POWER SUPPLY



EE FEB 88

A superb design giving 0.25V and 0-2.5A. Twin panel meters indicate Voltage and Current. Voltage is variable from zero to 25V. A Toroidal transformer MOSFET power output device, and Quad op-amp IC design give excellent performance.

KIT REF 769 £56.82

PORTABLE ULTRASONIC PEsT SCARER

EE AUG '91

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KIT REF 842 £22.56

ACOUSTIC PROBE

EE NOV '87

A very popular project which picks up vibrations by means of a contact probe and passes them on to a pair of headphones or an amplifier. Sounds from engines, watches and speech travelling through walls can be amplified and heard clearly. Useful for mechanics, instrument engineers and nosey parkers!

KIT REF 740 £20.01

4 CHANNEL LIGHT CHASER

EE Jan '90

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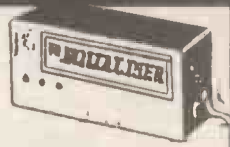
KIT REF 833 £32.13



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EE MAY '87

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KIT REF 707 £17.75

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EE DEC '90

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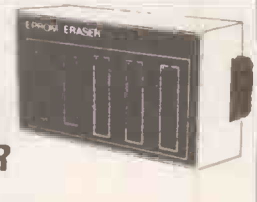
KIT REF 838 £57.17



EPROM ERASER

EE OCT '88

Safe low-cost unit capable of erasing up to four EPROM's simultaneously in less than twenty minutes. Operates from a 12V supply. Safety interlock. Convenient and simple to build and use.

KIT REF 790 £28.51

LIGHT RIDERS

EE OCT '86

Three projects under one title – all simulations of the Knight Rider lights from the TV series. The three are a lapel badge using six LEDs, a larger LED unit with 16 LEDs and a mains version capable of driving six main lamps totalling over 500 watts.

KIT REF 559 CHASER LIGHT	£15.58
KIT REF 560 DISCO LIGHTS	£22.41
KIT REF 561 LAPEL BADGE	£11.65

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EVERYDAY ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

VOL. 21 No. 5 **MAY '92**

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HORSE POWER

While looking for some data on a past project recently I came across the following snippet of information courtesy of Barry Fox from *For Your Entertainment* in 1982. Barry was reporting on Philips museum of science and technology in Eindhoven.

"One of the most popular exhibits is a bicycle with a dynamo in the back wheel that provides just enough power for a TV set and camera focused on the bicycle. To produce a picture of yourself on the TV screen you have to pedal hard enough to produce 75 watts.

You'd be surprised how hard it is. It's a useful reminder of how much energy we take for granted at the turn of a switch.

A human being can develop around 75 watts which is around one tenth of a horse power. In practice a horse delivers only around one half of this amount of energy over a prolonged period. But it eats food that we won't touch.

So to power a modern house we'd need around 100 human beings pedalling a giant dynamo treadmill, or around 20 horses in the garden tethered to an enormous geared system driving a dynamo. And think of all the hay you'd have to give them every day."

You could also grow a lot of roses on the by-product! As Barry said it is a useful reminder of how much energy we take for granted.

ENERGY

The area of alternative energy is one we will be investigating over the summer months – although we will probably not consider true horse power!

Much work is being done on such things as solar, tidal, geothermal, biomass and wind power and we will take a look at what is going on and where it might lead or, in some cases, the resultant generators. In the meantime our *Strain Gauges* article looks at the effects of energy in the form of force and how it can be measured with electronic circuitry, you can even build yourself an inexpensive *Experimental Weighing Scale* with a wide range of applications from ordinary weighing scales to an electronic torque wrench or engine torque calculator, etc. depending on your imagination and innovation.

Mike Kenward

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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.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

We regret that we **cannot provide data or answer queries on projects that are more than five years old.**

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Constructional Project

EXPERIMENTAL WEIGHING SCALE

CHRIS WALKER — PART 2

It could tell you your weight, or let you know when you are under stress and at breaking point!

LAST month we tackled the theory and discussed how strain gauges can be attached to the surface of a material, and used to calculate the size of a force which is applied to the material. The article also described some techniques which are used for incorporating the gauges into electronic systems.

Following on from this, we now look at the practical aspects of using strain gauges in the construction of an Experimental Weighing Scale.

LOAD CELL

The force-to-voltage converter, or Load Cell, used in this design is shown in Fig.1. It consists of a strip of flexible material to which two strain gauges are attached as shown. The strip is then clamped to a bench or similar support and the load to be measured is hung from the free end.

As the strip bends, the top strain gauge (G1) is stretched whilst the bottom one (G2) is compressed. The gauges are wired into a Wheatstone bridge to provide an output voltage which rises as the load is increased. The bridge output is then amplified and can be displayed on a calibrated voltmeter (see later).

This cantilever type of Load Cell is very sensitive to small weights hung on its end. The prototype scale can reliably detect loads less than one gram. The output voltage is *roughly* linear with respect to load, provided the strip is not deflected too far.

The choice of material and the dimensions of the strip are quite important. The prototype uses aluminium which is 3mm thick, 16mm wide and 300mm long. This was obtained as an off-cut from a school technology department.

The deflection for a given load depends on the length and thickness of the strip. For measuring heavier loads, use a shorter and/or thicker strip or one made from a material with a higher Young modulus (see last month), e.g. steel. Conversely, for greater sensitivity use a long thin strip made from a material with low Young modulus.

As a rough guide, the free end of the prototype aluminium strip drops through a distance of about 20mm when a 500g load is applied.

Experimenters who wish to try out other materials should consider their long term properties when assessing suitability. Some polymer plastics tend to "creep" when a load is applied (i.e. they continue to flex even if the load is kept constant) and these are obviously unsuitable.

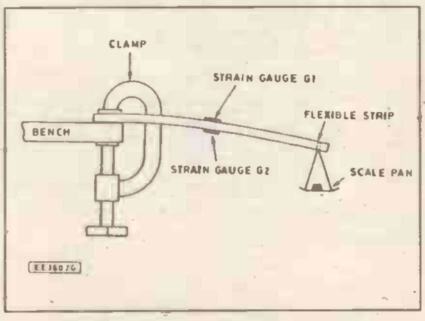


Fig. 1. Experimental "cantilever" type Load Cell set up.

Also unsuitable would be materials which twist or warp over a period of time. Some types of wood may fall into this category.

DIFFERENTIAL AMPLIFIER

The complete circuit diagram of the Experimental Weighing Scale is shown in Fig.2. The principles behind this design were discussed last month but some specific points will now be highlighted.

The Wheatstone bridge is formed by resistors R1, R2 and strain gauges G1, G2. The bridge is supplied with a stable 5V from voltage regulator IC3.

It is very unlikely, even when close-tolerance components are used, that the bridge will be perfectly balanced when constructed and, therefore, preset variable resistor VR1 may need to be included *in parallel* with one of the resistors R1 or R2 to zero the bridge output when the load-cell is experiencing no strain. This preset should be a high stability, multiturn device such as a "cermet" trimmer.

The bridge output is fed to a cross-coupled differential amplifier. This amplifier is formed from three op-amps, IC1a, IC1b and IC1c and resistors R3 to R9.

The overall gain of this amplifier is the product of the *input* gain from sections IC1a and IC1b, and the *differential* gain due to IC1c. As a reminder from last month:

$$\text{Input Gain} = 1 + \frac{2 \times R3}{R4}$$

$$\text{Differential Gain} = \frac{R8}{R6}$$

Overal gain =
Input Gain × Differential Gain

Using the values given, the overall gain is set at about 900. Please feel free to experiment with the gain by adjusting the appropriate resistor values.

The amplifier chosen is an instrument grade type OP-470GP. Whilst rather expensive, it has an excellent common-mode rejection ratio of 120dB which is important in this application. Cheaper amplifiers do not perform very impressively.

All the amplifiers are powered by a split-rail power supply of +9V and −9V from batteries B1 and B2. A *double-pole* switch S1 is required to switch the circuit on and off.

OFFSET CONTROL

Voltage regulator IC4 provides a stable −5V which, along with the +5V from IC3 is used to provide an adjustable offset voltage at the wiper of potentiometer VR2. Op-amp IC2, wired as a voltage-follower, buffers the output from this potentiometer which can be varied over the range of about −250mV to +250mV with the component values specified.

This offset voltage is then "mixed" with the output from the differential amplifier by op-amp IC1d and resistors R10 to R13. The main purpose of the variable offset voltage is to zero the final amplifier output at pin 14 of IC1 under no-load conditions, although coarse zeroing will need to be achieved by trimming the bridge balancing preset VR1 as described earlier.

By employing a multiturn potentiometer for VR2, it will allow the user to fine-zero the output and its use can, of course, extend to a "tare" control, allowing the output to be zeroed even when a small load (e.g. a scale pan) is hung on the Load Cell.

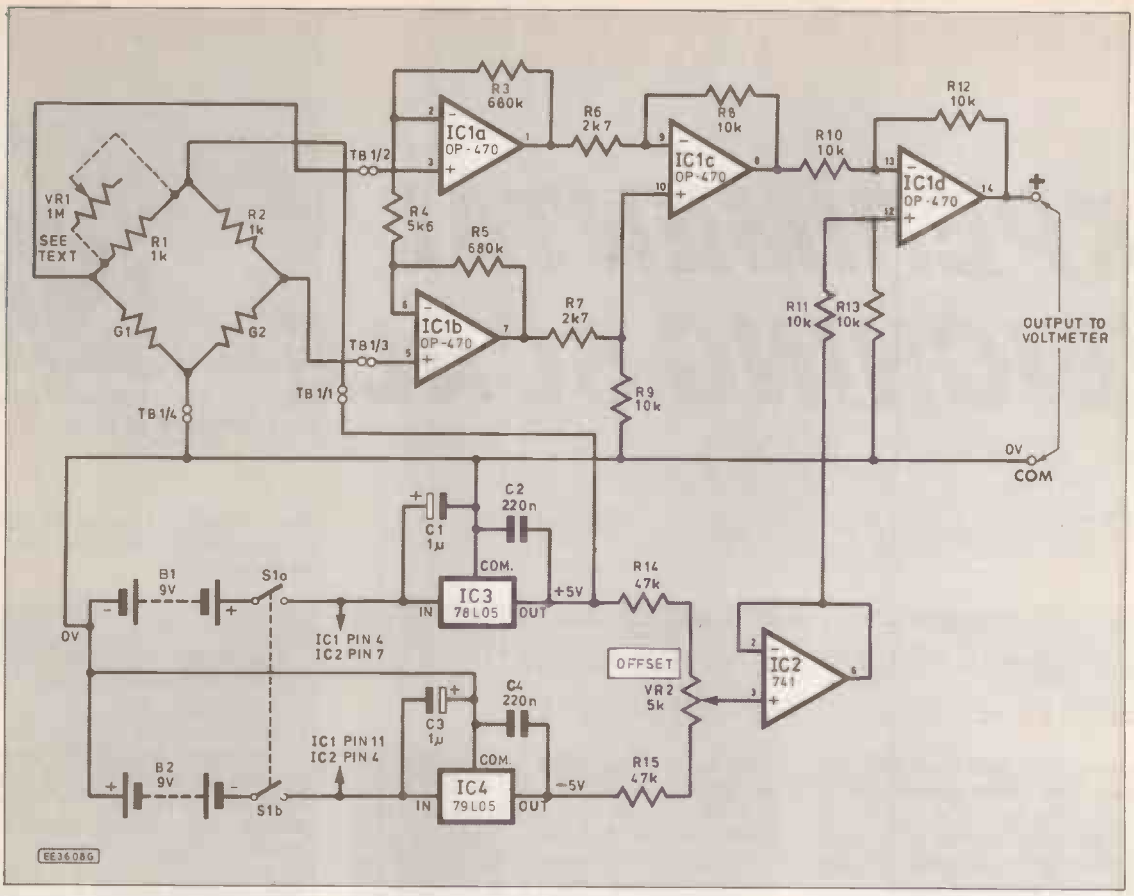


Fig. 2. Complete circuit diagram for the Experimental Weighing Scale. Preset VR1 may be needed to balance or "zero" the bridge.

COMPONENTS

Resistors
- R1, R2 — 1k (2 off)
- R3, R5 — 680k (2 off)
- R4 — 5k6
- R6, R7 — 2k7 (2 off)
- R8 to R13 — 10k (6 off)
- R14, R15 — 47k (2 off)

See SHOP TALK Page

All 0.6W 1% high stability metal film

Potentiometers
- VR1 — 1M multiturn cermet preset – (see text)
- VR2 — 5k (or 4k7) multiturn

Capacitors
- C1, C3 — 1μ axial elect. 100V (2 off)
- C2, C4 — 220n polyester (2 off)

Semiconductors
- IC1 — OP-470GP quad op-amp
- IC2 — 741 op.amp
- IC3 — 78L05 +5V voltage regulator
- IC4 — 79L05 –5V voltage regulator

Miscellaneous
- G1, G2 — foil strain gauge (see *Shoptalk*) (2 off)
- B1, B2 — PP3 9V battery (2 off)
- S1 — double-pole on/off switch

Printed circuit board available from *EE PCB Service*, code EE792; PP3 battery clips (2 off); knob for VR2; 4-way screw terminal block; suitably-sized case; 8-pin d.i.l. socket; 14-pin d.i.l. socket; terminal pins; screened cable; materials for load-cell and gauge application (see text).

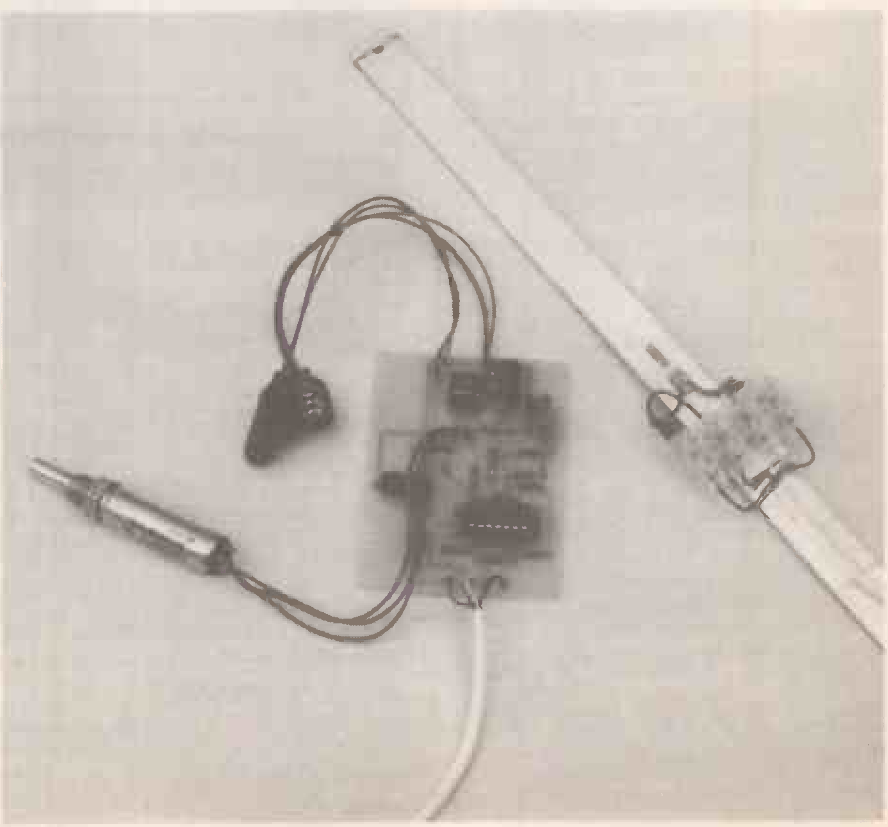
Approx cost guidance only **£26**

GAUGE MOUNTING

Having obtained a suitable strip of material from which to construct the Load Cell, the two strain gauges must be attached on each side of the strip about halfway along its length.

Preparation of the "cantilever" type Load Cell is shown in the sequence of photographs. These outline the process of surface preparation and gauge application and it is recommended that the basic sequence is followed to ensure repeatable results.

Many of the problems which arise when



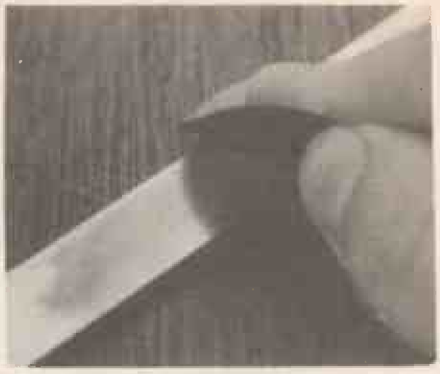


Photo 2 (above) – Using a wet/dry paper disc to abrade the metal strip.

Photo 1 (left) – Line up of materials required to prepare the cantilever to receive the strain gauges.

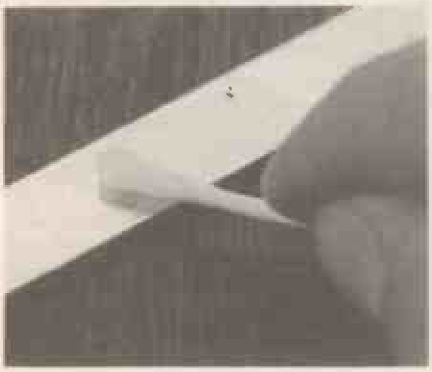


Photo 3 – Cleaning the surface with weak detergent and a "cotton bud".

Photo 4 – Use a small art brush to apply a thin layer of activator liquid.

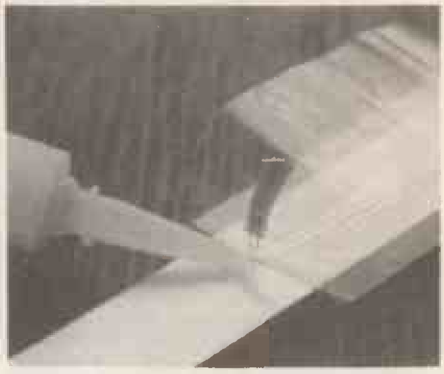


Photo 6 – Applying a small dab of adhesive to the metal surface.

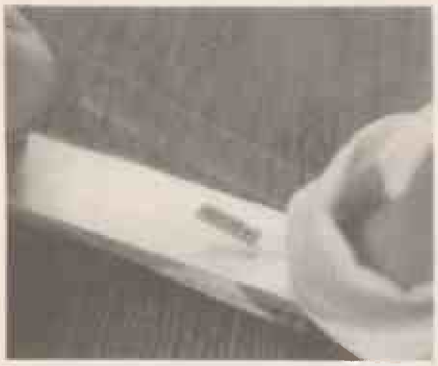


Photo 6 – Rubbing down the gauge with a finger wrapped in a tissue.

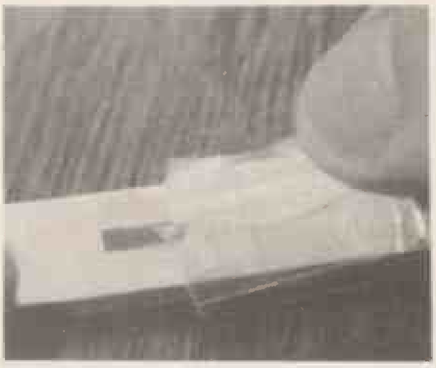


Photo 7 – Carefully peel back the Sellotape to reveal the strain gauge.

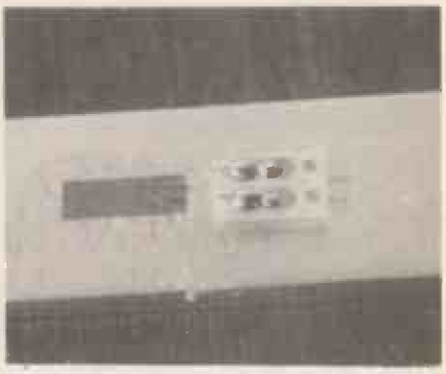


Fig. 8 – The gauge leads soldered to the self-adhesive terminator pad.

using strain gauges are due to bad adhesion between the gauge and its host surface. The first photograph (Photo.1) illustrates the basic equipment that will be required.

If you decide to use a metal strip, start by abrading the surface over the area of installation with very fine 1000-grit silicon carbide wet/dry paper, used with plenty of water (Photo.2).

Occasionally wipe the surface dry with a clean tissue, but continue to abrade until the surface is free from scratches. Prepare *both* sides of the strip in this way before mounting either gauge.

Next, remove grease from the surface with a solvent cleaning fluid (e.g. one containing 1,1,1 trichloroethane). Wipe the fluid off with a clean tissue before it evaporates or it will leave behind deposits. Continue to apply and wipe until the tissue is stain-free.

Finally, clean the surface with a very weak detergent solution applied with a "cotton bud" and wiped dry with a clean tissue (Photo.3). This final cleaning should take place immediately prior to gauge application. Be careful not to contaminate the cleaned area with finger grease.

Do not handle the strain gauge, but pick it up off a clean surface with a piece of Sellotape stuck to its *upper* side (the side to which the leads are attached). Position one end of the tape on the prepared strip so that when the tape is laid flat the gauge is correctly positioned along the length of the material with its sides parallel to the edges of the strip. Fold the tape back to expose the rear of the gauge.

ADHESIVE

At this stage, there is a choice of two types of adhesive. Cyanoacrylate (used along with an activator) is popular because it is a very low viscosity adhesive which ensures that only a very thin layer exists between the gauge and the surface. It also has an extremely fast curing time.

From experience, however, the author prefers to use a fast-setting epoxy-resin which has the advantage of giving one time to think before the darned stuff sets! The drawback with epoxy-resin is that it must be used *very* sparingly otherwise you end up with too much adhesive under the gauge and this causes problems of adhesive flexing and creep.

If you are using cyanoacrylate, a thin layer of activator liquid is applied over the rear of the gauge as shown in Photo.4, and then allowed to dry. A small amount of adhesive is then applied a few millimetres from the edge of the gauge (Photo.5).

Within *three seconds* of adhesive application, the tape/gauge combination must be swept down onto the surface of the strip using firm pressure from your finger, *wrapped in a tissue* (Photo.6). Further thumb pressure should be applied across the gauge for about two minutes.

Using quick-set epoxy-resin makes the whole process a little more sedate. Thoroughly mix the adhesive and hardener and spread a very thin layer over the back of the gauge. The Sellotape/gauge combination is then swept down as above, using finger pressure to exclude air from the adhesive. Clamp the assembly for about half an hour using a sheet of cardboard between the clamp and gauge to ensure an even pressure.

Once the adhesive has set, carefully peel back the tape at a *low angle* (Photo.7) to expose the (hopefully) stuck strain gauge. Cut down the leads and solder them to the self-adhesive lead terminator (Photo.8).

Repeat the procedure for the second gauge on the opposite side of the strip. Preliminary wet abrading should already have been carried out to avoid damage to the first strain gauge.

If the gauges are likely to become dirty or are prone to damage during use, then they can be protected with a "blob" of silicone rubber compound (the flexible substance used to seal around baths and wash-basins) applied over the area of the gauge.

BRIDGE CONSTRUCTION

The Wheatstone bridge circuit is constructed in close proximity to the strain gauges. Fasten a four-way terminal block to the flexible strip using a double-sided sticky pad and wire in resistors R1 and R2, as shown in Fig.3. Connections to each strain gauge lead terminator are made using short lengths of insulated wire.

A length of multi-cored screened cable is used to link the bridge to the amplifier circuit so that noise pick-up is kept to a minimum. The screen connects to 0V as shown and a least three cores are required to make the remaining connections.

AMPLIFIER BOARD

The amplifier is designed to be constructed on a single-sided printed circuit board (p.c.b.). This board is available from the *EE PCB Service*, code E792.

The full size foil pattern and component layout of the amplifier board is shown in Fig.4. Construction is very straightforward and should not present any problems to most experimenters.

For reasons of stability, all resistors should be metal film types with a one per cent tolerance. The off-board connections to the Offset control VR2 should be kept reasonably short to reduce noise.

The output voltage from the prototype is displayed on a digital multimeter set to the 2V range. A load of 500g on the end of the aluminium strip produces an output voltage of about 490mV. Calibration of the system is described later.

If desired, the amplifier p.c.b. batteries, on/off switch and offset control can all be housed inside a small metal or plastic case. Connections to the Load Cell and output voltmeter can be made via a terminal block or a plug/socket arrangement.

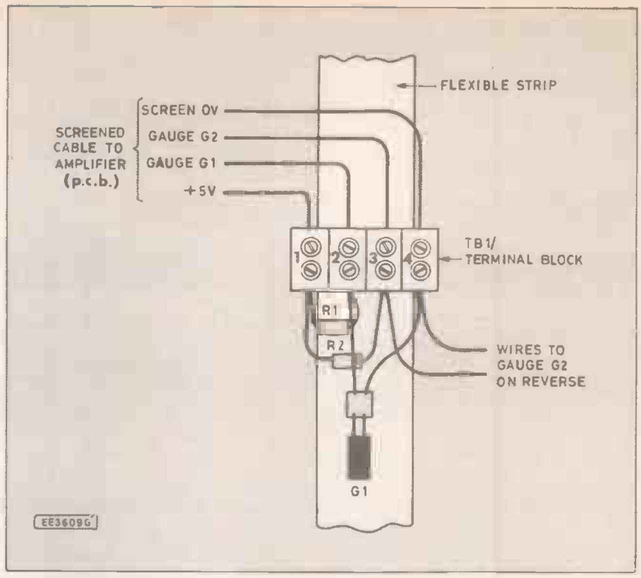


Fig. 3. Using a 4-way terminal block (TB1) to make up the Wheatstone bridge. This is connected to the p.c.b. using multi-cored screened cable.

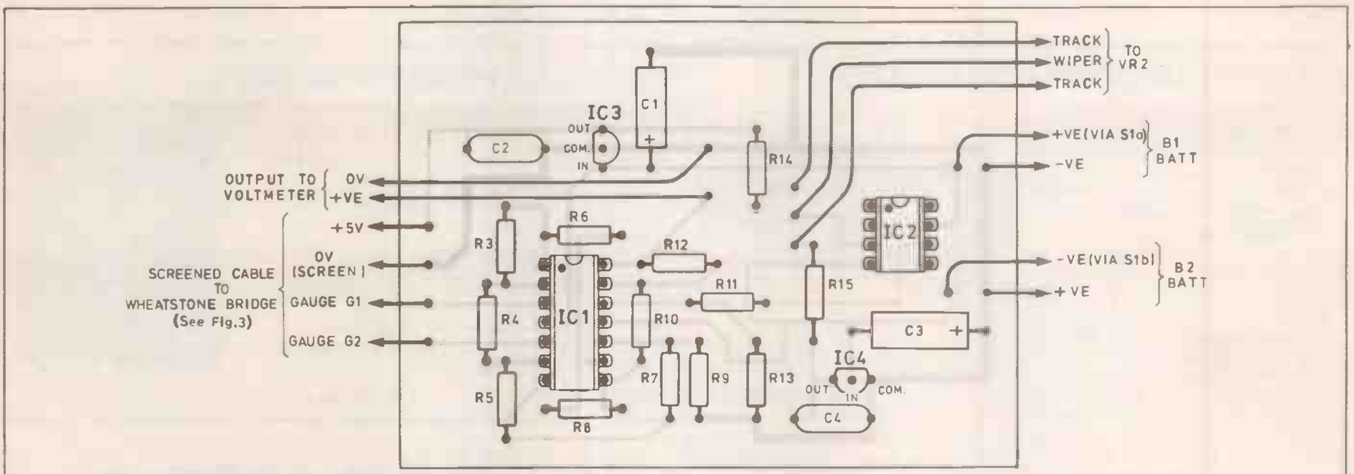
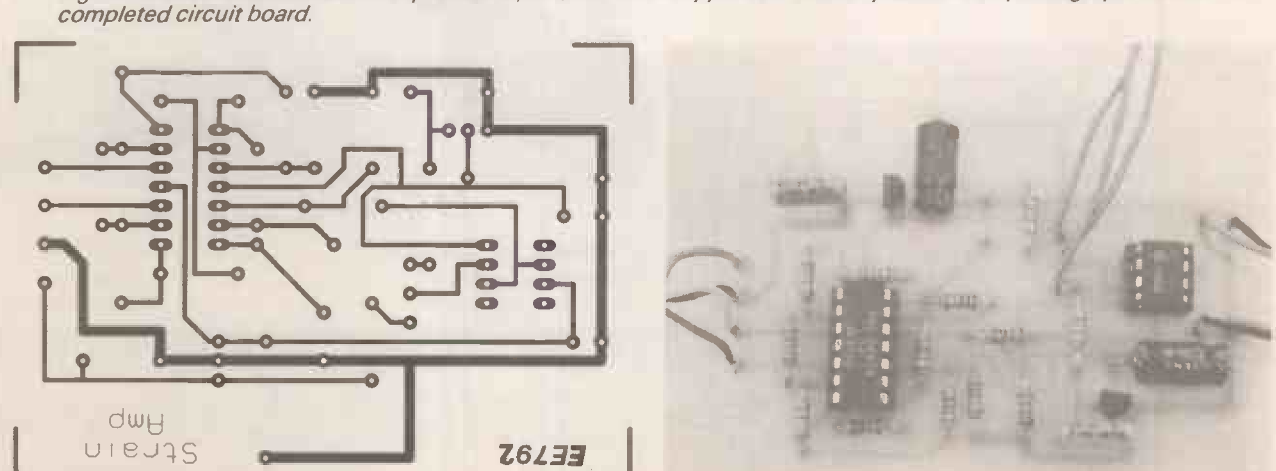


Fig. 4. Printed circuit board component layout, full size copper foil master pattern and photograph of the completed circuit board.



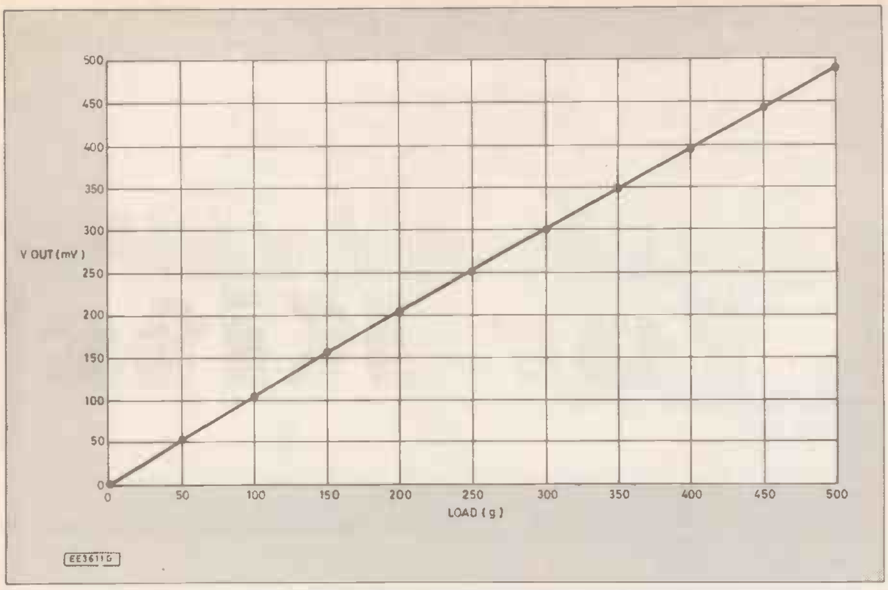


Fig. 5. Typical calibration graph. This is produced by hanging a series of known masses on the Load Cell and recording the output voltage in each case

SETTING UP

Commence the setting up and testing by connecting the Load Cell and a voltmeter to the p.c.b. Attach the batteries and switch the circuit on.

With the Load Cell clamped to the bench but no load applied, set the Offset control VR2 to its half-way position and note the output voltage. If the output is between −250mV and +250mV, it can be zeroed using VR2.

If the output voltage is outside this range then the bridge will require balancing using preset VR1. This preset will need to be connected directly to the Wheatstone bridge terminal block *in parallel* with either resistor R1 or R2, trial and error will determine which one. Adjust this multiturn preset until the amplifier output is about 0V.

It is quite possible, of course, to trim the gain of the amplifier circuit so that a 1g load produces, for instance, a 1mV output. Then, assuming that the output increases linearly with load, the size of the load (in grams) can be read directly from the digital display.

An easier and more reliable method for calibration is to produce a calibration graph such as the one shown in Fig.5. This is easily made by hanging a series of known masses on the Load Cell and recording the output voltage in each case. The size of any other mass can then be found by reading off the output voltage from the graph. The graph will also give an indication of the linearity (or lack of it) of the amplified output.

A further possibility is to use a moving-coil voltmeter (say with 1V or 2V full scale deflection), remove the printed scale and calibrate your own scale using a set of known masses.

BE BRAVE

An electronic torque wrench would make an interesting project, or how about a device to measure the force in a caravan tow-bar? By measuring the reaction force in an engine mount you can calculate the torque that the engine is producing.

Use your imagination . . . ! □

CAMCORDER HEADPHONE AMPLIFIER

CHRIS BROWN

An easy to build stereo pocket amplifier that enables inexpensive headphones to be used with a camcorder or other equipment.

MANY people now own camcorders and most of these have headphone outputs to monitor sound – to make sure you've not got a problem with the wind (!), or that every word is being recorded clearly. Yet few people actually use this facility – or so the journals always tell us! Could this be because of the need for high impedance, (high cost?) 'phones?

My own model requires a 1k impedance, yet all the headphones I've seen are in the 8ohms to 32ohms range. The camera is also stereo. Obviously, some sort of impedance matching is required, with two outputs, and low battery consumption.

A quick look through the various component suppliers catalogues revealed the TDA2822 i.c. This can supply one watt per channel with a nine volt supply, all housed in an eight pin d.i.l. package. It only requires eleven other components, so everything can be crammed into a small case. At the time a small (17mm dia), pot, had just become available so construction began in earnest.

CIRCUIT

The circuit (Fig. 1) consists of two volume controls (each a 17mm pot.), two input capacitors, two output capacitors, a Zobel network on each output, plus a supply decoupling capacitor. Apart from the volume controls, everything else fits easily onto a small piece of stripboard.

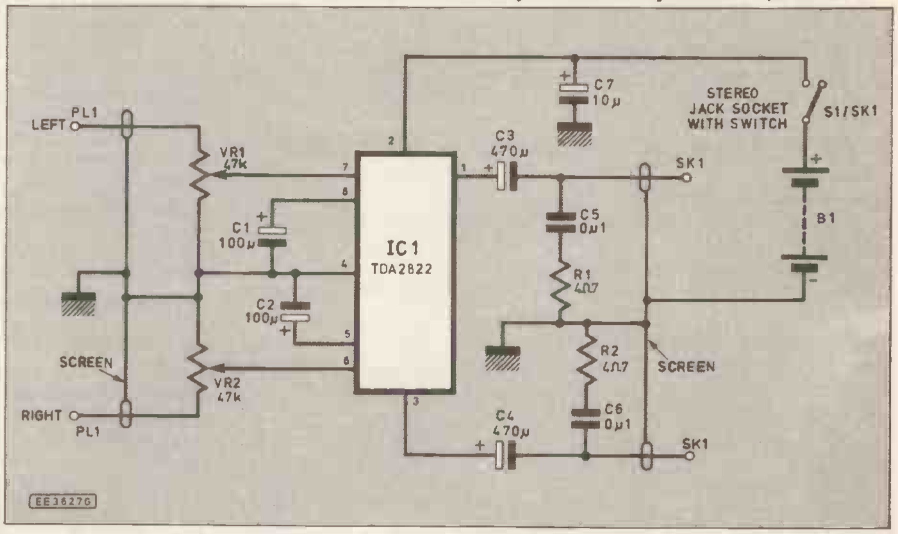


Fig. 1. Complete circuit diagram of the Camcorder Headphone Amplifier. The text refers to S1/SK1.

With such a circuit, where virtually everything is enclosed in one i.c., there is very little that can be said about circuit function. The TDA2822 can operate from a 1.8V to 15V supply and will give 20mW into 32ohm headphones with 3V and 1W into 8ohm headphones, or speakers, with a 9V supply. The input impedance of the circuit is approximately 32k, and set is by the volume controls (47k) and the i.c. input impedance (100k). The use of two volume controls avoids the need for a dual pot plus a balance control.

CONTROLS

The two volume controls sit side by side in the top of the small case with the input cable entering the top of the case slightly off centre. To make construction easier, the pots were wired in "antiphase", (see diagram). This means that to reduce volume, the controls both rotate towards the centre of the case, rather than both turning clockwise/anticlockwise as is the norm.

To save on space, an on/off switch was omitted, instead, a special ¼inch jack socket was used which features a pair of switch contacts as well as the normal audio contacts. This means that as soon as the

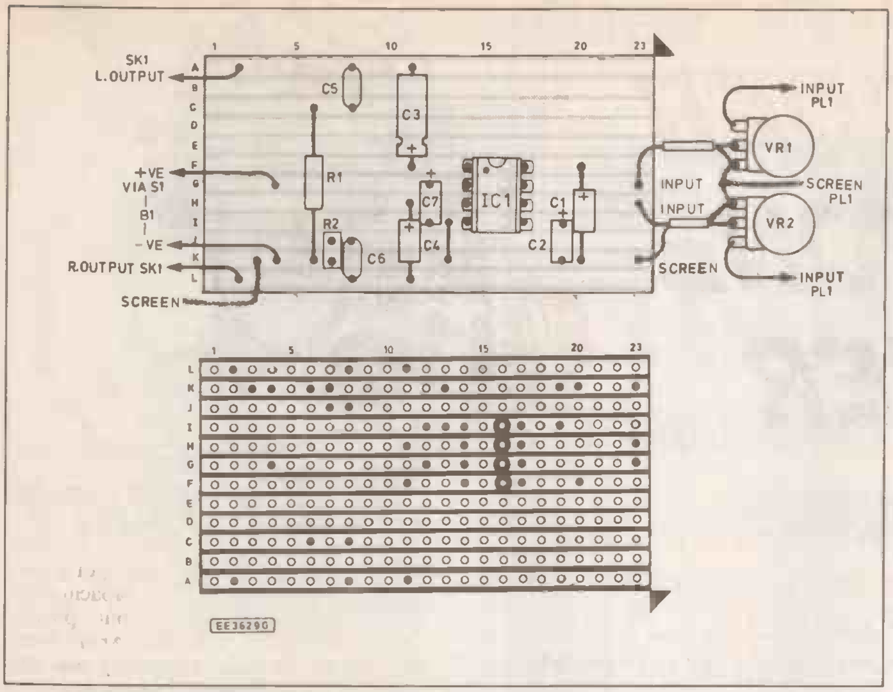
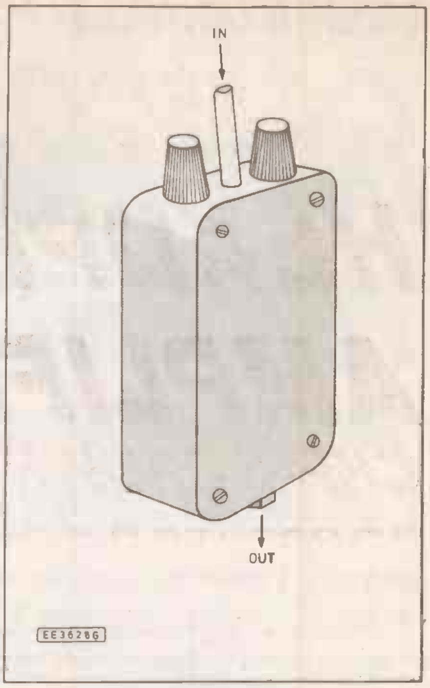


Fig. 2. Stripboard layout and wiring for the Camcorder Headphone Amplifier. Fig. 3 shows S1/SK1 wiring.



Basic layout of the amplifier.

headphone jack is removed, the amp. is switched off.

CONSTRUCTION

Providing you've mastered the art of using a fine tipped soldering iron, you should have few problems building this unit. Commence construction by making the track breaks in the underside of the stripboard as shown in Fig. 2. Then fit the resistors and capacitors in the positions indicated.

The i.c. should be fitted using an 8-pin d.i.l. i.c. holder – make sure the i.c. is fitted the correct way around, this also applies to all the electrolytic capacitors. Finally wire up the jack socket/switch as shown in Fig. 3, and the volume controls and input lead using screened "stereo" lead.

IN USE

To use the unit, simply plug in your headphones to turn it on and set the volume controls as required; remember the higher the volume the shorter the battery life! The unit can easily be used with other equipment where a headphone output might need amplification.

This unit is also a boon to people with a hearing impediment (like myself) as the volume can be raised to suit the individual. In practice the controls are rarely set above ¼ turn as the headphone output is so close to the ears. □

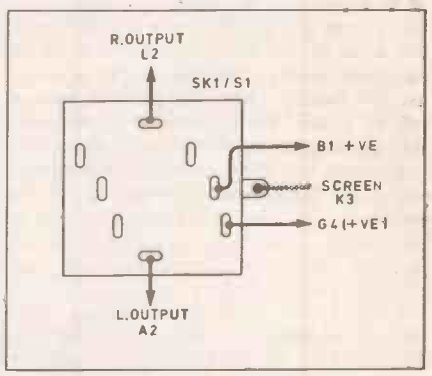


Fig. 3. Wiring of SK1/S2.

COMPONENTS

See SHOP TALK Page

Resistors
R1, R2 4Ω7 (2 off)
¼ W carbon ± 10%.

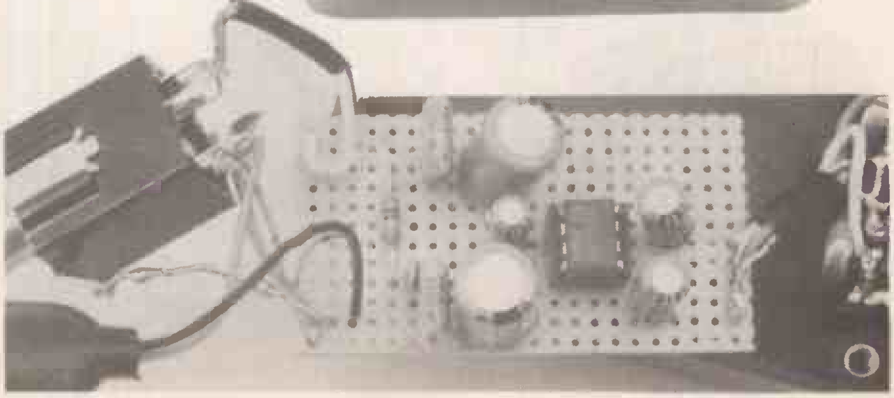
Potentiometers
VR1, VR2 47k minature (17mm) log.

Capacitors
C1, C2 100µ elect. 16V (2 off)
C3, C4 470µ elect. 16V (2 off)
C5, C6 100n ceramic
C7 10µ elect. 16V

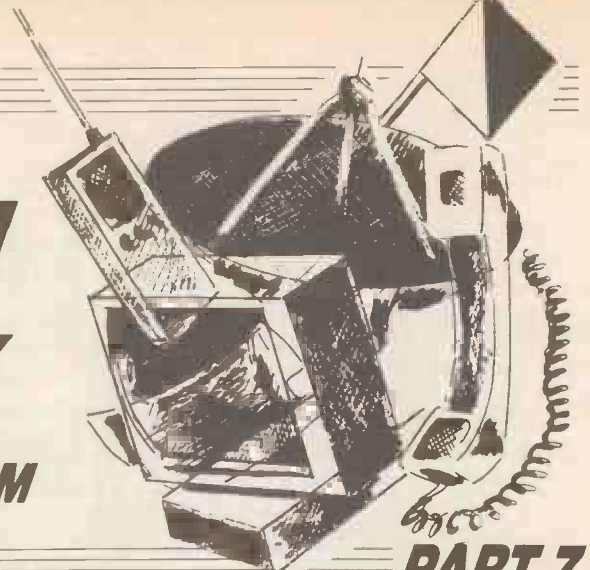
Semiconductors
IC1 TDA2822 stereo power amplifier

Miscellaneous
PL1 Jack plug to suit output of recorder
SK1 stereo jack socket with single pole switch contacts
Stripboard, 23 holes by 12 strips; knobs to suit; screened stereo lead – length as required; 8-pin d.i.l. i.c. holder; 9V PP3 battery and battery connections; plastic case approx. 80mm x 60mm x 40mm; fixings etc.

Approx cost guidance only **£7.50**



Special Series



INFORMATION TECHNOLOGY

AND THE NATIONAL CURRICULUM

T. R. de VAUX BALBIRNIE

PART 7

THIS is the seventh in a 12-part series concerning Information Technology, Microelectronics, Analogue and Digital systems and related matters in the Science National Curriculum. Since this work is applicable to older children we shall now use the word "student" instead of "child"!

This month we shall look at logic gates and their use in control circuits. We shall then consider the differences between analogue and digital signals and instruments.

CONTROL TECHNOLOGY

Many processes in life involve *control* of a system. As an example we may think of a washing machine. Here, we give the machine the correct information (about the type of material to be washed, whether full or economy load, etc.) then allow it to control the washing of the clothes. This will use such things as solenoid valves to turn on the water, sensors to switch them off when the water reaches the correct level, a pump to empty the machine, thermostats and heaters to produce hot water at the right temperature, a motor and circuits to make the drum rotate in alternate directions and to increase the speed for spin drying at the end.

The system will be under the overall control of a time switch to provide the correct times and order of operations. In addition, there will be ancillary devices such as one to prevent the door from being opened while there is still water inside! The system could be controlled by microelectronic circuits but many washing machines still use the old well-known technology of mechanical switches and relays.

LOGIC CONTROL

To illustrate how a single logic gate – a NOT gate – may be used for a very simple control purposes, let us look at the motor control circuit shown in Fig. 1. Note that the NOT gate is made by connecting together the two inputs of a NAND as explained in Part 6 last month. R2 is a light-dependent resistor (l.d.r.) – this component was introduced in Part 5.

The l.d.r. is a device which responds electrically to changes in light intensity. If we connect this component in series with fixed resistor, R1, we find that the voltage appearing between points A and B will fall as the light level rises (it is not appropriate here to explain why this happens in terms of resistance values, potential dividers and so on – anyone interested in this type of detail should consult a textbook). It is important to note, however, that we always refer to a voltage appearing between *two* places. Unless we say otherwise, one of these is always the negative supply line (point B), so we often refer loosely to the voltage at the other point – Point A – this being the input to the NOT gate.

When the LDR is brightly illuminated, the voltage applied to the NOT gate input will be quite low. With the type of gate being used (called a C-Mos gate), it "thinks" that any voltage below approximately one-

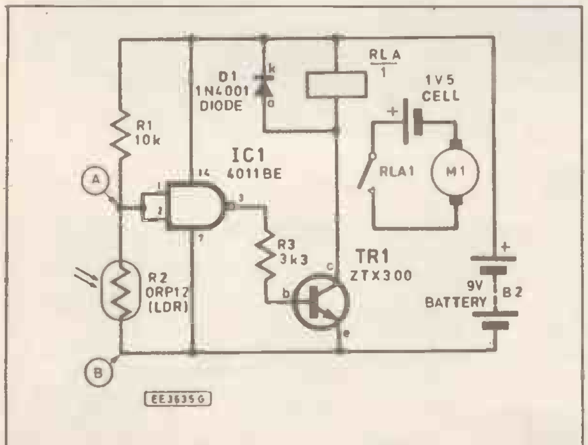


Fig. 1. Motor Control circuit.

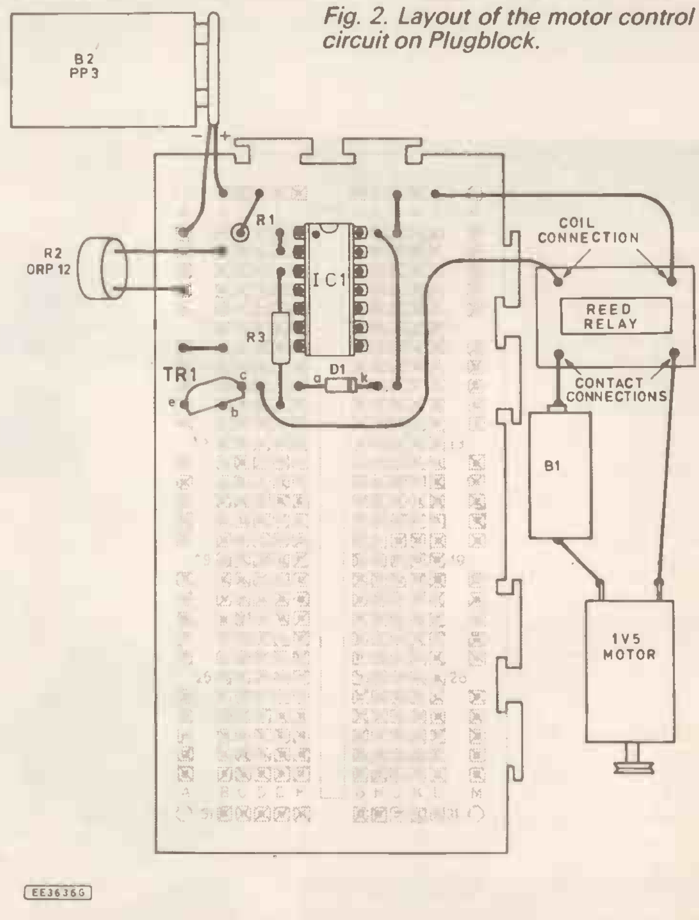


Fig. 2. Layout of the motor control circuit on Plugblock.

half supply voltage (4.5V) is Logic 0. This means that while the light level remains bright, the input is interpreted at Logic 0 and the output of the gate will be Logic 1 – 9V – since it is a NOT gate and inverts the input.

The small output current supplied by the gate output is amplified by transistor, TR1, and this operates the relay coil, RLA. The contacts (RLA1) now close so allowing current from cell, B1, to flow through motor, M1.

At a certain lower light intensity the voltage at the NOT gate input will rise above one-half that of supply battery, B2, and the gate will interpret this as Logic 1. The output then suddenly switches state from Logic 1 to Logic 0, the relay contacts part and the motor switches off. Diode D1 removes the high-voltage pulse which appears when this happens and which could otherwise damage certain components.

This type of circuit could be used to control the process in a furniture factory where a motor moves a sheet of wood along a conveyor belt. While this is happening, a beam of light shines across the conveyor belt onto the l.d.r. This allows the motor to run. When the wood reaches a certain position, it "cuts" the light beam and l.d.r. receives less light. The motor then stops and the wood stays in position while it is sawn or drilled by other machines.

It would be a fairly simple matter for students to design a model of this system and use it to move a small piece of wood into position then stop. Parts could be used from a suitable mechanics kit.

BUILDING THE CIRCUIT

The motor control circuit may be built using a modular electronics kit or by using the Plugblock layout shown in Fig. 2 (the use of a Plugblock was described in Part 5). If you decide to do it this way, you will need the following components in addition to the Plugblock itself and some pieces of connecting wire. If you have been following the series you will find that the starred components are already part of your kit so check before ordering.

- *4011BE NAND gate
- *ORP12 light-dependent resistor
- *ZTX300 transistor
- *1N4001 diode
- *Reed relay (possibly from a modular kit)
- *PP3 battery and connector
- *10k resistor
- *3k3 resistor
- *1.5V cell and holder
- Miniature motor (1.5V operation).

Of course, the output device could be a bulb or buzzer instead of a motor. On the whole, though, a motor is more fun. A thermistor would make an alternative input device. This would make the circuit respond to temperature changes instead of light levels.

It should become clear that logic gates make a very versatile way of designing other similar control circuits and the students should use their imagination freely.

ANALOGUE AND DIGITAL SIGNALS

In Part 1 (November, 1991 issue) we looked at some early methods of long-distance communication. These are often of a digital nature – for example, beacons and bonfires. If you have been following this series, the concept of a digital signal should be clear. This is one which is either *on* or *off* – it has no states in between.

A beacon is either on or off – it is a two-state device. It could just convey one simple message such as "the invasion has begun!" This is an *optical* signal (that is, it is made to be *seen*) but now we are more concerned with *electrical* signals. Optical signals do have their place in modern telecommunications systems but this will be explained next time.

The Morse Code is an example of a *digital code* – an electrical current is turned on and off according to some agreed plan to represent the letters of the alphabet, punctuation marks, numbers, etc. At the distant end, the current pulses can operate a buzzer or flash a lamp and this is interpreted by an operator. The message is then accurately conveyed.

Digital signals should be compared with analogue ones. Whereas a digital signal has only *two* states, an analogue one *varies through an infinite number of states*. A traditional thermometer is an analogue device – the mercury rising smoothly along the capillary tube. Speaking into a telephone provides an analogue signal – it gives a complex electrical copy of all the variations in the human voice.

A traditional record and record player are also analogue by nature. The sound is converted into a wavy groove on the surface of the record. When the pick-up needle runs in the groove, a complex electrical signal is produced which varies smoothly to form a copy of the original sound. The advantage of an analogue signal is that, in theory, it conveys all the information in the original. The disadvantage is that it rarely does so because it is so easily altered as we shall see presently.

THE REAL WORLD

The real world is full of analogue information. Our eyes respond to smooth variations in light intensity (brightness) which occur around us. Our ears respond to smooth changes of sound in a similar way. Our sense of touch responds to smooth changes of pressure applied to our skin. However, if we convert changes such as these into analogue electrical signals and send them over a long distance – that is, if we use them for *communication* – they tend to change i.e. distortion is introduced and false information is picked up on the way – this could take the form of noise and interference. Even so, communication using analogue signals is widely used – radio and TV broadcasts work by sending radio waves which contain the information of the analogue signal and we know this works well in practice.

The technology to do it is also fairly simple. However, we also know that long-distance radio signals can become so distorted that they become difficult to interpret.

The public not only want long-distance communication to be cheap, instant and easy to use – they also demand high-quality. Once, speaking to someone in Australia by telephone could prove difficult on account of the increasing distortion introduced on its long journey. Today the sound is of a much higher quality and readily intelligible. This is because *digital* techniques are used.

ANALOGUE TO DIGITAL

For communication, the "real" world of analogue signals may, with advantage, be turned into digital electrical signals, sent on their way then converted back to analogue ones when they arrive at the other end. We find that by using digital techniques, the signal is transferred almost perfectly. Nicam sound for TV broadcasts is a digital system and produces sound of excellent quality.

To pay for the great benefits to be gained by doing this, we need to use complex technology to perform the conversions and the means of doing it have only been developed relatively recently. One disadvantage of digital processing is that, in theory, the signal cannot faithfully follow every change in the analogue one – it cannot produce a perfect copy. On the other hand, an analogue one is likely to be much worse!

ANALOGUE AND DIGITAL EXPERIMENT

This experiment shows in a very simple way, the difference between an analogue and a digital signal. In addition to the items which you will probably already have in your kit, you will need a wirewound potentiometer of value 20 or 25 ohms and 1 watt rating minimum. These are sometimes available as loudspeaker volume controls. Alternatively, you could use a "rheostat" from a modular electricity kit.

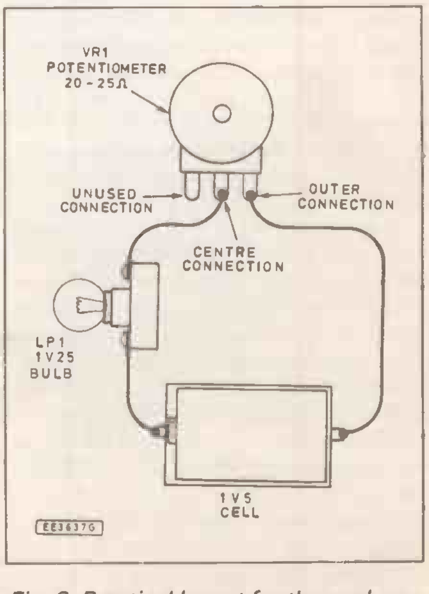


Fig. 3. Practical layout for the analogue circuit.

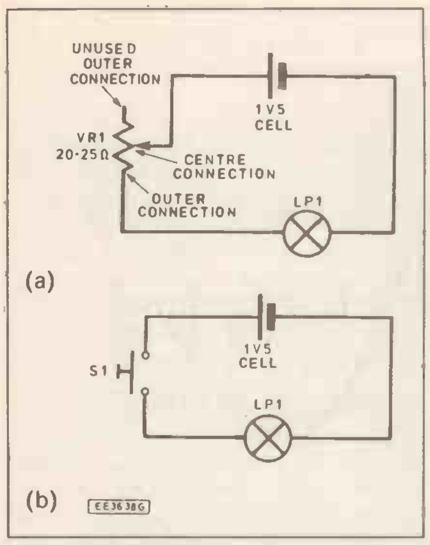


Fig. 4. Analogue (a) and digital (b) circuits.

With a basic potentiometer, you will need to connect short wires to the centre and either of the outer tag connections. This is best done by soldering but you could twist the wires tightly into position or use small crocodile clips (see Fig. 3).

Build the pair of circuits shown in Fig. 4. In (a) the signal is *analogue*. This is because the potentiometer, VR1, can vary the current and hence the brightness of the bulb, LP1, smoothly from virtually off to full brightness. In Fig. 4(b) the signal is *digital* – this is because it can only be on (switch pressed) or off (switch released). The practical layout for the analogue circuit is shown in Fig. 3. The digital one is straightforward.

Next month we shall look at some analogue information transmission systems using both electrical and optical signals.

ANALOGUE AND DIGITAL INSTRUMENTS

An analogue instrument is one which gives a smooth output or display – it can take up any value like the traditional thermometer mentioned earlier. A ruler is an analogue instrument – it will measure a length to any degree of accuracy depending on how well your eyes can read the scale. A traditional clock is analogue – the pointers move smoothly around the face. By contrast, a digital instrument has a display which rises and falls in steps such as a digital clock.

Gather together a variety of analogue and digital instruments and allow the students to use and compare them. Any of the following would be useful: a mercury and a digital thermometer, a traditional and a digital balance (to weigh things), an analogue and a digital clock or watch, a traditional voltmeter and a digital one.

When students are given a choice of instruments, they almost always choose the digital one. When asked why they do this, they often say that the digital one is "more modern" or "more accurate". Digital instruments certainly give an impression of accuracy but this may be an illusion. For example, a digital thermometer may read 32.4 degrees C and it is attractive to think that this is measuring temperature with an accuracy of 0.1 degrees. However, this is not necessarily so – it may be a badly calibrated thermometer. It could be that a laboratory mercury thermometer reading 34 degrees C is more accurate even though it can only be read to an accuracy of one degree.

Digital is not always best! It is not the fact that an instrument is digital or analogue which determines its accuracy – it is the quality of the device, the care taken in calibration and the technology used in making it.

Usually, digital instruments are easier to read and, perhaps, more robust. Sometimes, a digital instrument is more accurate when new but the accuracy drifts as time goes by. On the whole, a digital instrument is more expensive than the corresponding analogue one.

Last month, we discussed logic gates. The inputs and output of these may have only one of two states – Logic 0 or Logic 1. They are therefore digital devices. When something is off we call it Logic 0 and when it is on we call it Logic 1. For students knowing some binary arithmetic, these two numbers will be familiar. For those who do not, it will be necessary to look at the binary system before proceeding.

A BIT ABOUT BINARY

We presume that we humans normally count in tens (the decimal system), not because it is particularly easy but because we happen to have ten fingers. We sometimes call a number a "digit" and, of course, this word means "finger" as well. Presumably, had man been a species with 4 fingers on each hand we would have counted in eights (the octal system) and this would seem just as easy once we got used to it.

In the decimal system, the number 247 means 7 units + 4 tens + 2 hundreds. However, the number 247 in the octal system means 7 units + 4 eights + 2 sixtyfours (8 × 8's) which is 167. In the decimal system, then, the number 167 in octal would mean 247!

Suppose there was a race of people with only one finger on each hand. They would, probably, count in twos. When they wrote a number down (despite the difficulty of holding a pencil), the right hand column would represent units, the next one to the left would be twos, the next one fours (2 x 2) and so on. Clearly, no digits apart from 0's and 1's would exist. This is called the *binary system*. Here is an example of a binary number:

1 0 1 1 0 1

This means:

32's	16's	8's	4's	2's	1's
1	0	1	1	0	1

and the decimal equivalent is:

32 + 8 + 4 + 1 = 45

Any number can be written in binary form and all arithemtic could be done his way. Suppose you wished to tell a distant friend that your birthday was on the 23rd of the month. You could do it by flashing a torch 23 times or, more efficiently, like this (a flash means a 1 and a gap means a 0).

	FLASH	GAP	FLASH	FALSH	FLASH
Means:	1	0	1	1	1
In decimal:	16 +	4 +	2 +	1 =	23.

Unfortunately, in the binary system, although the number of digits used is small (that is, two), the price we have to pay is that even fairly short decimal numbers are very long binary ones. Look at the following binary number:

256's	128's	64's	32's	16's	8's	4's	2's	1's
1	0	1	1	1	0	1	1	0

This means 256 + 64 + 32 + 16 + 4 + 2 = 374 (decimal). Here we have used nine binary digits to represent just three digits in the decimal system. It turns out, then, that the binary system is clumsy for

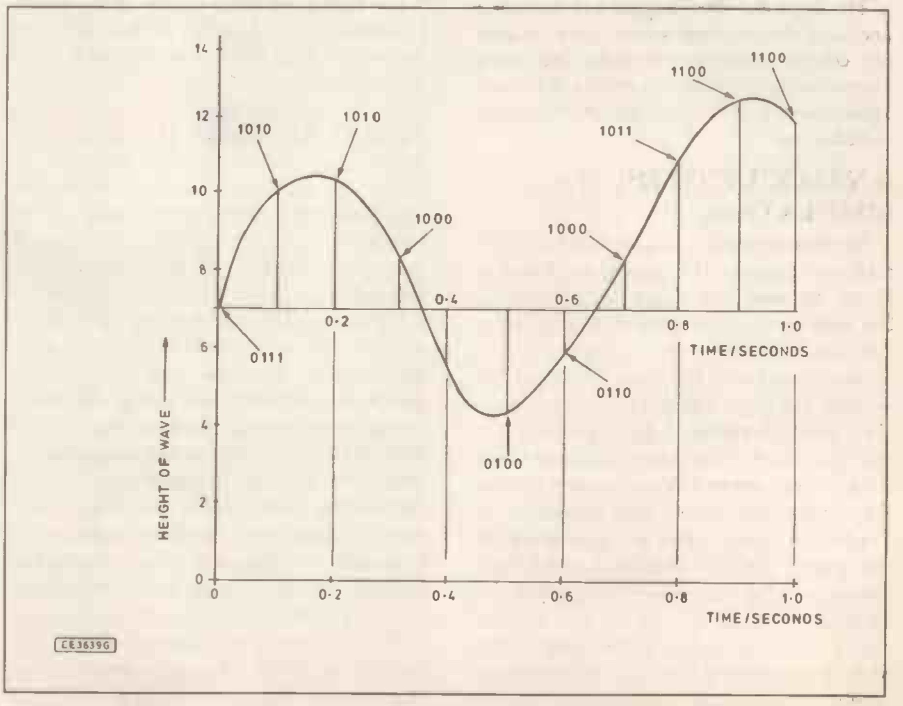


Fig. 5. Sampling the height of an analogue wave.

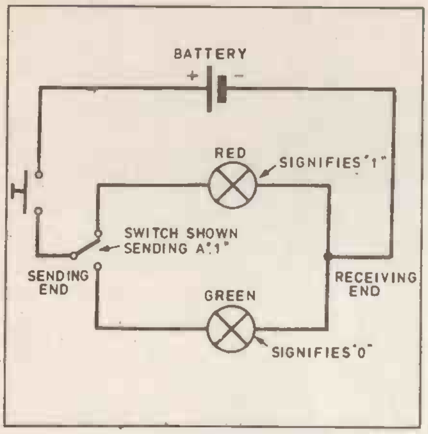


Fig. 6. Binary sending circuit.

humans to use but, as we shall see, very good for machines. By the way, a single binary digit, a 0 or a 1, is called a "bit" (*BI*nary digi*T*).

CONVERSION

Binary numbers are very easy to send in the form of electrical signals because only two states are needed – on and off. Suppose we could convert an analogue signal such as that obtained from a microphone into digital one. This would involve "looking at" the analogue wave and "sampling" its height repeatedly. Fig. 5 shows a waveform with voltage (height) plotted against time. In this example, only 15 heights are specified (remember, there can be a height of 0). The total time is one second.

Suppose we sampled the height every 0.1 second and so, in effect, cut the wave into strips. We could then write down the height of each strip in binary using 4 bit binary numbers ranging from 0000 to 1110. The string of binary digits could then turn an electrical signal on (for a 1) and off (for a 0). This process is called *analogue to digital (A-D) conversion* and the reading of the height of the wave for each sample, *quantization*.

The opposite effect happens at the other end and the original wave is re-created. Of course, these conversions are done electronically at great speed but the principle may be illustrated manually as described below.

ANALOGUE TO DIGITAL SIMULATION

For this simulation, students are divided into two groups. The idea is for the first group to send the shape of a wave to the other group using only binary numbers. In effect, the first group performs an analogue-to-digital conversion and the second group, a digital-to-analogue one. Two identical pieces of graph paper – one for each group – are issued. It is more fun if the groups are in different rooms so that they cannot hear or see one another.

The first group draws a simple wave on the paper perhaps similar to the one shown in Fig. 5. For convenience, a maximum height of 12 – 15 squares should be used since every height may then be expressed as a 4-bit binary number (15 decimal = 1111 in binary). It is not necessary to make a proper time scale – "squares" will do.

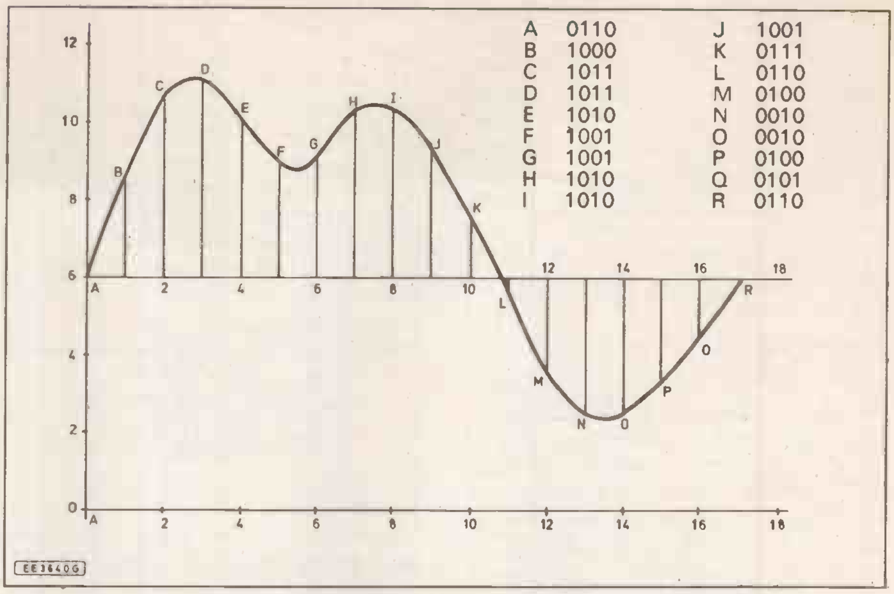


Fig. 7a. Master wave and the representative binary numbers.

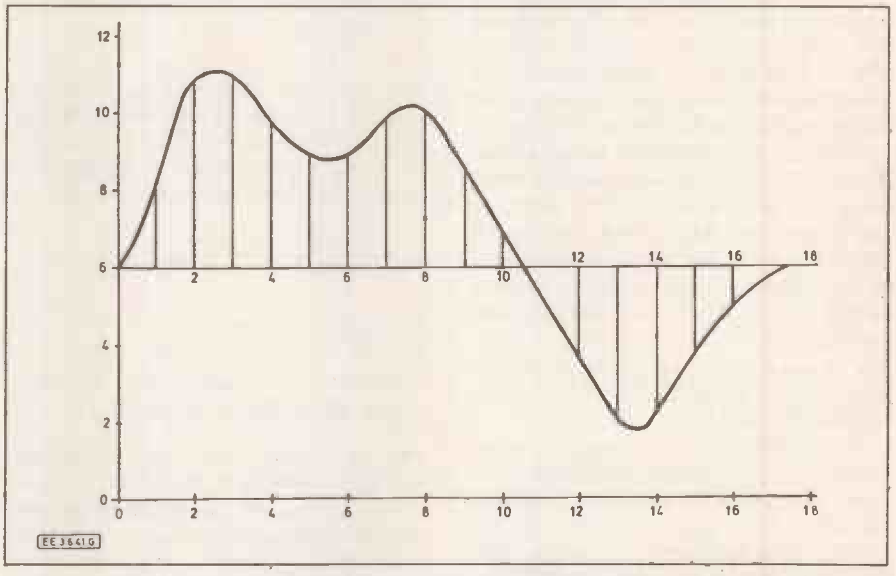


Fig. 7b. Copy waveform made up from "received" binary numbers.

For each horizontal square of the paper, a vertical line is draw up to the wave and the height read off to the nearest square. These numbers are converted into binary form and written down. For example, if the height is 10 squares, this will be written:

1 0 1 0

If the height is one square this will be written:

0 0 0 1

and so on.

Using a switch and battery in a simple series circuit with a bulb at the other end, these sets of digits are sent to the other group. The circuit shown in Fig. 4b would be suitable for this. Because the 0's are difficult to read – that is, the times during which the bulb is *off* rather than on, the experiment works better if a changeover switch is used. One position lights a *red* bulb which represents 1 and the other position operates a *green* bulb to represent a 0 (see Fig. 6).

The second group writes down the groups of 4-bit binary numbers, and re-converts them into their decimal values. Vertical lines are then drawn for each horizontal square of the height calculated. The tops are then joined together smoothly using a pencil. A typical "master" wave is shown Fig. 7a with the "copy" in Fig. 7b.

ACCURACY

The above experiment shows that a signal, however complicated, could be sent using just on and off states. However, the students will notice very quickly that this cannot be done precisely. For high accuracy, the sampling must be done as frequently as possible or some changes in the wave between samples may be missed.

On the other hand, the faster the sampling rate, the more difficult it is to do, so a compromise has to be reached. Also, there will be errors in quantization since the nearest whole number is used for height. The height of the wave at any point will therefore not necessarily match the original unless an enormous number of possible heights are specified and this is what is done in practice. Modern electronic circuits can perform these conversions million of times per second.

You may well wonder whether working digitally is really worth the trouble. Why not simply send the analogue signal itself in the form of smooth changes of current along the wire? The reason is that, even taking into account the limitations of the digital conversions, the end results are far superior to those using purely analogue techniques. This is because in a string of on/off states is it difficult for a 1 to change into a 0 and vice-versa. Thus, the data stream remains intact from beginning to end. This advantage has led to the Digital Revolution!

DIGITAL 'PHONES

The telephone network of the United Kingdom is rapidly becoming digital. This means that the analogue signals produced by the voice are converted into digital ones (A-D conversion) and sent over the trunk network to any other part of the U.K. There, the signal undergoes D-A conversion and is sent to the called party's telephone earpiece.

Anyone who makes regular long-distance calls will know that the quality of the message is now very high thanks to digital techniques. Digital signals lend themselves equally well to being sent by other means – by radio, perhaps in conjunction with satellites. Using optical fibres is another possibility. This method is now widely used and has numerous advantages over the traditional method of using electrical signals in copper wire. More will be said about this in next month's article on information transmission systems.

ANALOGUE TO DIGITAL CONVERSION

A computer with an analogue to digital converter – for example a BBC computer – can be used to change a smoothly varying voltage into a number. The BBC computer has four such analogue to digital (A-D) converters referred to the ADVAL Channels. In the following experiment, only one channel is needed. The computer samples the voltage applied to the channel input every 10ms (100 times per second) and assigns to it a number ranging from 0 to 65520.

The action of the A-D converter can be shown using a light-dependent resistor (l.d.r.) in the circuit shown in Fig. 8. The socket to use is labelled ANALOGUE IN (see Fig. 9). Only the pins relevant to this experiment are labelled with their function. The computer itself provides a reference voltage between pins 11 (+) and 8 (0V) – this is used as the power supply. The analogue input is applied between pin 15 and pin 8.

Obtain a plug (a D-Series 15 pin plug) to fit the socket (these are readily available from a mail-order supplier) and wire it up as shown. Build the circuit using 3 sections of 3A screw terminal block as shown and connect it to the computer (the computer *must* be switched off when you do this). Switch on, type in the following program then type RUN – this program divides the rather large and clumsy number obtained from the A-D converter *direct* by 3300 and gives the whole number part only – this provides a

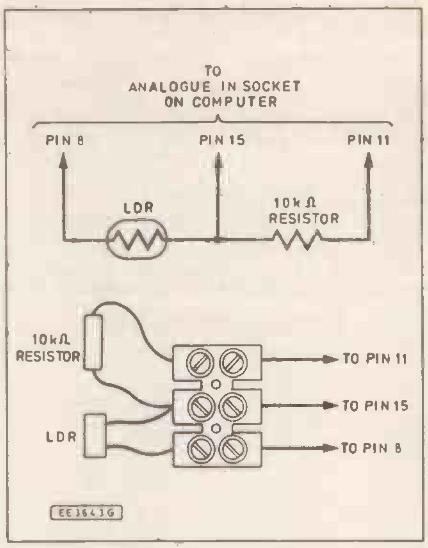


Fig. 8. L.D.R. circuit connected to a BBC Micro.

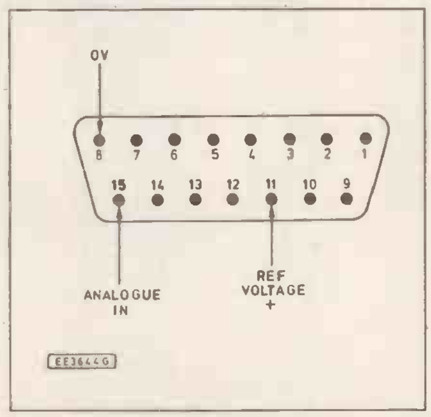


Fig. 9. Plug connections for Fig. 8.

number ranging from 0 to 20 approximately – it then prints it and updates it every half-second. This provides a convenient display on the screen.

```
10 begin=TIME
20 REPEAT UNTIL TIME = begin
   +50
30 PRINT INT(ADVAL1/3300)
40 GOTO 10
```

By shading the LDR with the hand, the smooth changes in light intensity are converted into numbers – i.e. analogue to digital conversion has taken place. The computer works in binary then the binary number is converted into a decimal one for displaying on the screen.

THE COMPACT DISC

The digital revolution is well illustrated by the advent of the Compact Disc. Traditional records are analogue by nature. However, by digitising the sound, the stream of 0's and 1's may be turned into a spiral of pits/no pits on the surface of the compact disc using a high-power laser. A pit could mean 1 and the lack of a pit, 0. The wave is sampled 44,100 times per second and this in practice is fast enough to provide a near-perfect copy of the original sound. A very large number of possible heights is specified to minimise quantization error.

To play the disc, a low-power laser – a bright light source – is focused using a lens to produce a sharp beam which is reflected from the parts on the disc surface where there is no pit. Special circuits keep the laser on course as it "reads" the binary data. This information is picked up by a detector and fed to a digital to analogue converter.

Note that there is no contact with the surface of the disc which cannot, therefore, wear out. Sophisticated error-correction circuits ensure that any mis-reading of the digits is smoothed over. After amplifying the resulting signal and feeding it to a loudspeaker, the original sound is re-created.

The surface of a traditional record is easily damaged and the information stored in the groove altered due to the effects of dirt, etc. Also, the needle wears the groove and causes increasingly distorted sound but none of these things happen with a compact disc. It is interesting to look at the surface of a traditional record under a microscope. Using a magnification of 100 ×, the surface will reveal dirt, scratches and hairs which degrade the sound.

Unfortunately, the digital information on a compact disc is too small to be seen using a low-power microscope. Note that compact discs are not limited to holding sound information. *Pictures* may be digitised and stored on them and also information which is already in digital form – i.e. bulk computer memory storage. Note, however, that in the latter application the compact disc is a "read only" device. That is, information may be retrieved but cannot be changed by the user.

DIGITAL TAPE

Professional tape recorders for the music industry (and very soon domestic ones) use digital techniques. The sound is digitised and stored on the magnetic tape in a series of magnetic dots. Anyone who has copied a cassette on a twin cassette analogue machine will know that the music loses quality with each generation – the signal becomes increasingly distorted and the tape "hiss" worsens. Digital tape recorders eliminate these defects since a 1 will always copy to give a 1 and similarly for a 0. Digital tape recorders will become commonplace in the home in the future.

In television production, pictures are often digitised. While in this form, they may be processed by a computer using the rules of arithmetic. This can lead to all types of visual effects hitherto difficult or possible to do only using painstaking animation techniques. For example, the picture may be made to appear rolled up, re-arranged, cut into squares, etc. Television producers make much use of this type of effect today.

MYSTERY GATE

The truth table for last month's mystery gate is:

A	*B*	*Q*
0	0	0
0	1	1
1	0	1
1	1	0

This is similar to an OR gate but when the inputs are *both* 1, the output is 0. It is called an *Exclusive* OR (EX-OR) gate.

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PROCESSORS

MC6850	£1.00
68000	£5.00
TMS9995	£8.00
8751 (EPROM version)	£6.00
765AC-2 (Floppy Controller)	£2.00
AMR5380 SCSI controller	£1.00

DAC & ADC

ZN425 8 bit D to A	£2.50
ZN426 8 bit D to A	£1.00
ZN427 8 bit A to D	£4.00
ZN429 8 bit D to A	£1.50
PCM53J-I PMI 16 bit D to A	£5.00
20018 SONY 16 BIT A to D	£10.00
AM6070 8 bit companding D to A	£2.50

LINEAR

LF353 op amp	20p
LF356 op amp	35p
LM1036 Transconductance amp 1	£1.25
LM13700 Transconductance amp	50p
LM1458 op amp	15p
LM3080 Transconductance amp	35p
NE5532 op amp	50p
SSM2024 quad VCA	£1.00
TL7705AP voltage supervisor	20p
NM9345CN EEPROM	50p

OPTO'S

4N28	20p
4N35	35p
6N138	75p
3mm Red LED (per 100)	£2.50
3mm Green or Yellow HI Bright (per 100)	£3.00
Otp Emiiter/Detector Pair TIL40/411 (per pair)	25p

SPECIAL MUSIC CHIPS

YAMAHA YM2203 +YM3014 Three Voice FM Chipset (includes implemenatation data)	£12
CURTIS ELECTROMUSIC CEM 3394 Analogue voice chip (VCA/VCO/VCF on a chip)	£10.00
AFL811WF 22kHZ 'Brick Wall' Anti-Aliasing Filter	£10.00

COMPONENT PACKS – £1 EACH PACK

CONNECTORS	**Qty per pack**
XLR Audio In-Line (4 PIN F. 3 PIN M. 3 PIN F.)	3
3 Pin XLR Audio Chassis Male	3
¼in. Stereo Jack Plugs. High Quality	6
Jack Socket Mono or Stereo PCB/Chassis Mount, ¼in.	20
BNC RF Connector Chassis Mount	10
8 PIN DIN Socket PCB Mount	10
Mains Inlet with Filter (EEC)	2
IC SOCKETS	
8 PIN IC Sockets, Turned PIN	20
14 PIN IC Sockets, Turned PIN	10
24/32/40 PIN IC Sockets, Turned PIN	5
64 PIN IC Sockets, Turned PIN	4
PCB CONNECTORS	
32 Way 0.1in. Pitch Single Sided Edge Connector, Panduit	5
40 PIN IDC header (Robinson Nugent)	5
50 Way IDC Plug	2
2/3/4 PIN Molex Header with Friction Lock	20
5/6 PIN Molex Header with Friction Lock	15
9 PIN Molex Header with Friction Lock	10
3M 359 SERIES BOXED DIL IDC HEADERS	
10/16 PIN	3
26/34/50 PIN	2
Cable Assemblies to Match Above	2
CAPACITORS – Specify Value Except Ceramics	
Ceramic Disk 1pF-4700pF assorted	50
DIP Poly + Metal Poly 10n, 22n, 47n, 68n	50
DIP Poly + Metal Poly 220n, 470n,	40
Tant Bead 470n, 1μF	40
Electrolytic 1μF, 2μ2, 4μ5, 10μF	30
Electrolytic 1000μF 16V, 2200μF 25V, 2200μF 40V	5
RESISTORS	
5% ¼W Carbon Film 10R-8Meg assorted	1000
1% ¼W Carbon Film 10R-8Meg assorted	500
Networks 8-14 PIN 47R-10k assorted	30
Submin Skeleton Pre-Sets 4k7, 100k, 1M, 2M, 2M2, – specify	40
Audio Pots 16mm Egan 4mm shaft 100k, 1 Meg – Specify	10
Phillips Potpac 10k, 100k – Specify	15

ODD ITEMS

Switchmode PSU – outputs = +5V 8A, +12V 2.5A, +15V 1A, −15V 1A	£15
9in. Monochrome monitor – uncased	£15 each or £50 for 4
Safeblock (mains)	£4
High Density 3.5 inch Sony Floppy Drives	£30
Papst cooling fan 12V DC 3in. model 8312	£4
Populated PCB's – 100's of components dig/analog/pots etc.	£10
Torroidal TX 0-120, 0-120, 15-0-15 500mA + 0-8V 1A	£4

MISC ELECTRICAL + HARDWARE	**Qty per pack**
Chassis Mount Fuse Holder	4
Fuse 20x5mm Quick Blow 0.25A, 1A, 2A, 4A	50
4mm Collet Knob + Grey Cap Lined	25
¼in. Flanged Knob	5
Rotary Incrementor Control	2
4 Way Switches On/Off 8 PIN DIL	5
Transistor SONY 2SK152 FET	2
Crystal 16 meg, 48 meg	4
Assorted Switches	10
Transistor TIP29	5
Quality Battery Holders Bulgin 4xAA Cells In-Line	3
2M Mains Leads Molded 6A 3PIN EEC Plug	4
5 PIN DIN – 2x3.5mm Jack Plugs Lead	3

USED EQUIPMENT	
Scope TRIO 20meg CS1566A Dual	£80
Scope CROTECH 15meg 3030	£50
Scope IWATSU 40meg 555705 Dual	£200
Scope HAMEG 20meg HM203-5	£150
Gang EPROM Programmer STAG PP16A Module AM16+24 for Stag Module AM16T288 for Stag	£150
Thandar TG101 Function Generator	£50
Thandar TM451 meter	£30
Altai Data Recorders	£5
Monitor + Keyboard Volker-Craig VC4404	£60

Constructional Project

IT'S A KNOCKOUT

ROY BEBBINGTON

A novelty electronic box-of-tricks to make your garden fete or party go with a swing.

THIS project, entitled It's A Knockout, is a compendium of games to give your event a new look with electronic dice, an on-the-button precedence indicator and automatic scoring for a number of popular games.

Although most of the suggested games can be played using the display on the Knockout Box, separate large-scale, easy-to-make electronic displays can be added so that everybody knows what's going on and can join in the fun.

Suggestions for a number of games are given, but readers will no doubt think of many others that can be adapted. Here are a few to set the ball rolling:

Out for a Duck:
A game of skill. Hit a duck with a soft ball and another lights up. If you're not out for a duck, you could score up to nine hits.

Cat o'Nine Lives:
A steady hand as you run the ring around the cat may save a few of his nine lives.

Wheel of Misfortune:
Spin the big wheel to see what question you have the misfortune to answer.

Bull's Eyes:
Get the targets in your sights and fire the light gun. Going for targets alternately calls for greater skill. Your score is automatically recorded.

Buried Treasure:
Roam around a floor map of Treasure Island with a handheld detector. "X" marks the spot on your copy of the map.

Get any Row:
A flashing light display stops suddenly to reveal a letter. Fingers on the button, answer the question, and "get any row" of three letters to win.

Plus: electronic dice and precedence indicator switches for quiz games and assessing contestants, reaction.

MAIN CIRCUIT DESCRIPTION

The circuit diagram of the Knockout Box is shown in Fig. 1. The heart of the unit is IC2, the 4017 decade counter/divider, controlled by either IC3a, IC3b, a free-running pulse generator or IC1, a triggered monostable multivibrator. A solid-state alarm sounds each time the monostable is triggered.

The decade outputs of the counter/divider IC2 are numbered 0 to 9 alongside ten l.e.d.s used for scoring and for random, or anticipated, number selection purposes. Ten transistor (TR1-TR10) open-collector outputs are provided for connection to larger external displays using 12V, 60mA m.e.s. bulbs. An external display is necessary for some games, in which case B1 should be 12V.

In the Free-Run mode, the l.e.d. display, and external display if connected, can be limited to six to provide a Dice facility for many other games. The sequential flashing speed can be varied by the Speed control to give a random, or skilfully anticipated choice, when the Freeze button is pressed.

PRECEDENCE SWITCH

The other half of the 4001 (IC3c, IC3d) forms a switch precedence indicator circuit for two external switch/indicator circuits, each controlled by a player. This type of circuit is familiar in many TV quiz shows. The first player to press a pushbutton sounds the buzzer WD1 and takes precedence in answering a question. This is indicated by an l.e.d. adjacent to the player's pushbutton. While this remains activated, the opponent's pushbutton is ineffective. If release-to-break pushbuttons are used, the first contestant to press *must* continue to hold down the button to prevent takeover by the opponent.

The l.e.d.s are normally off as the input to each inverter (IC3c, IC3d) are held "high" by the bias resistors R5 and R6. The outputs of both inverters are therefore "low" and neither l.e.d. is supplied with current.

If one of the "contestant" pushbuttons is operated it takes an inverter input low. Consequently, the inverter l.e.d. will light. Pressing the other pushbutton merely keeps the circuit in its present state. The operation of a contestant pushbutton also sounds the buzzer by taking IC2 pin 2 low via D11 or D12.

TRIGGER MODE

With the switch S1 in the Trigger position the decade counter IC2 is controlled by the monostable multivibrator IC1. Pin 2 is normally held high by resistor R4 strapped to the positive rail.

Raising funds at a local charity show.

When pin 2 of IC1 is connected to the 0V rail momentarily (SK3 trigger contacts closed), pin 3 goes high for a time depending on the values of capacitor C1 and resistor R1 and then returns to 0V. This short positive pulse activates the solid-state buzzer WD1 and triggers the decade counter IC2. Each clock input on IC2 pin 14 is counted by advancing the numbered l.e.d. display on the outputs. The two trigger contacts (X1 and 0V) on SK3 provide the external connection to the trigger source for each of the games.

At the end of a count, the counter can be returned to zero by pressing the Reset switch S2. The reset input (IC2, pin 15) is normally held low via resistor R3 to prevent reset. Note that the count will return to zero after nine counts (six counts if Dice is selected) to start the next sequence.

In the "DICE" mode, the high on output IC2 pin 5 is switched to provide a reset after the sixth l.e.d. is displayed. Resistor R7 reduces the load on this output pin to ensure that the reset (IC2, pin 15) goes sufficiently high. Similarly, diode D13 blocks this circuit when the RESET button is pressed, as otherwise it could shunt the reset circuit in the "DICE" mode. The trigger facility is usefully employed in several games. For example, in the *"Out for a Duck"* game, SK3 is connected to ten "make" contacts in parallel. The *"Wheel of Misfortune"* and *"Buried Treasure"* games, use magnetic reed switches to provide the trigger source.

In the *"Bull's Eyes"* game, two light-dependent resistors serve as triggers. The use of two bull's eyes makes the game more skilful as contestants have to take aim again between shots.

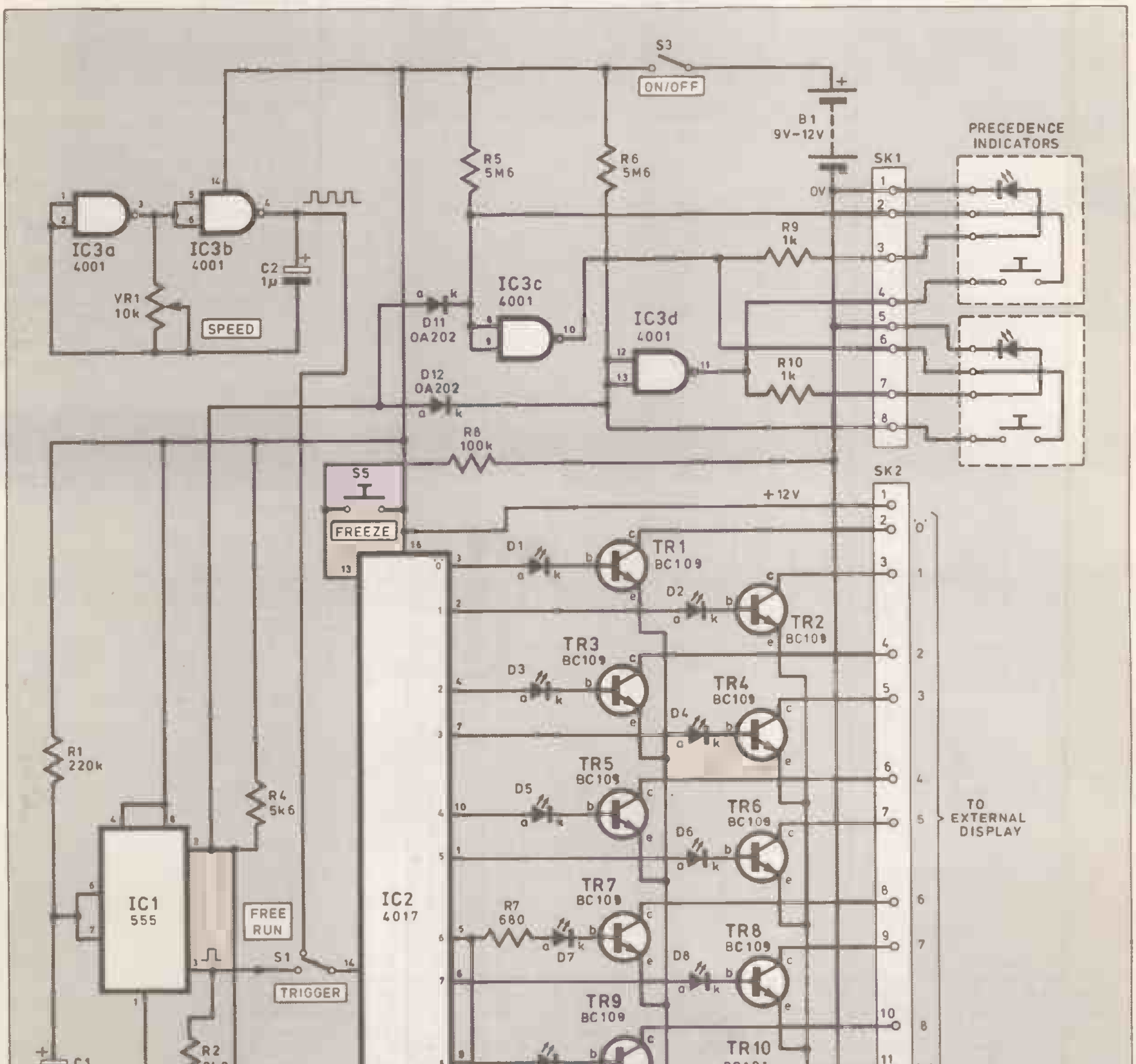
FREE-RUN MODE

When the Free-Run position of S1 is selected, counter IC2 is controlled by the low-frequency pulse generator formed by the two inverters IC3a, IC3b forming an astable multivibrator. The Speed control potentiometer, VR1, varies the frequency from 1Hz to about 100Hz. These pulses are fed to the clock input (pin 14) of the counter to switch the outputs high in turn to flash sequentially the ten l.e.d.s, or six of them if Dice is selected.

The sequence can be temporarily stopped at any time by pressing the Freeze pushbutton S5, which take the chip enable (IC2, pin 13) to the positive rail. This lights one of the numbered l.e.d.s. At faster speeds, selection is pseudo-random, but for some games an element of skill can be introduced by slowing down the speed.

If an external display unit is fitted, it can duplicate the internal display for a wider viewing audience, locate targets in some games and provide special displays for others. For example, in *"Out for a Duck"*, the ten external display lamps are used to indicate the selected target in turn.

Fig. 1. Complete circuit diagram for the It's A Knockout controller box.



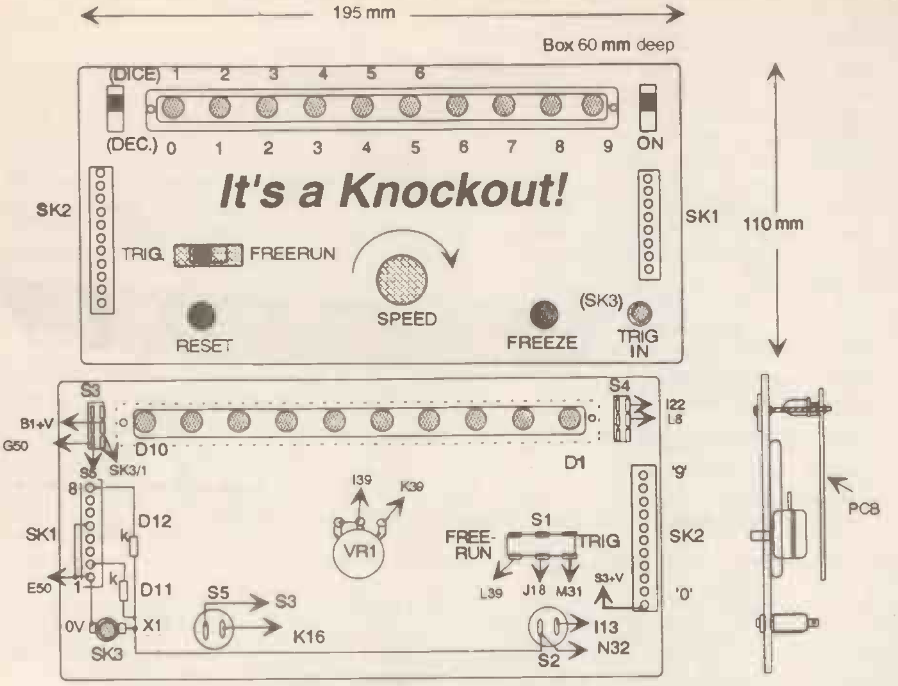


Fig. 3. Front panel layout and wiring from panel mounted components to circuit board. Letters and numbers are board grid references.

COMPONENTS

Resistors

R1	220k	R5, R6	5M6 (2 off)
R2	2k2	R7	680
R3	10k	R8	100k
R4	5k6	R9, R10	1k (2 off)

All 0.25W 5% carbon film

Potentiometer

VR1 10k rotary carbon

Capacitors

C1, C2 1µ radial elect., 63V (2 off)

Semiconductors

- D1 to D10 TIL20 red l.e.d. (10 off)
- D11, D12, D13 OA202 diode (3 off)
- TR1 to TR10 BC109 *npn* silicon transistor (10 off)
- IC1 555 timer
- IC2 4017 CMOS decade counter/divider
- IC3 4001 CMOS quad 2-input NOR gate

Switches

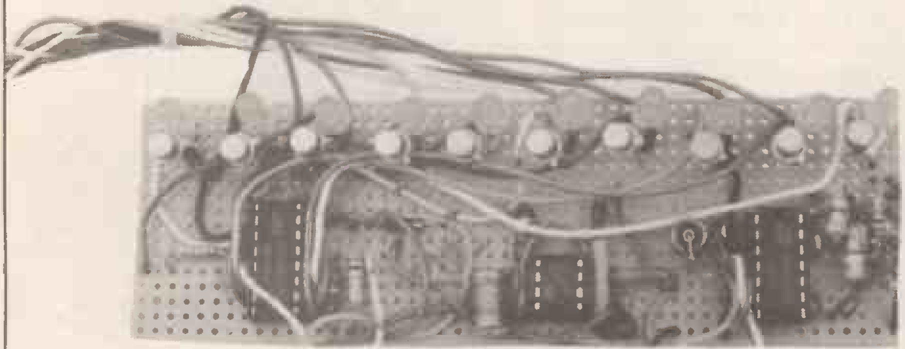
- S1 Single-pole changeover
- S2, S5 Pushbutton, release-to-break (2 off)
- S3, S4 On/Off toggle (2 off)

Miscellaneous

- SK1 8-way terminal strip or screw terminal block
- SK2 11-way terminal strip or screw terminal block
- SK3 mono jack socket
- WD1 9V solid-state sounder

Plastic case, size 190mm x 110mm x 60mm; stripboard 0.1in. matrix, size 16 strips x 50 holes; 9V (PP3) or 12V battery for external display; 8-pin d.i.l. socket; 14-pin d.i.l. socket, 16-pin d.i.l. socket; single-core connecting wire; multistrand connecting wire; nuts and bolts; solder etc.

Approx cost guidance only **£17**



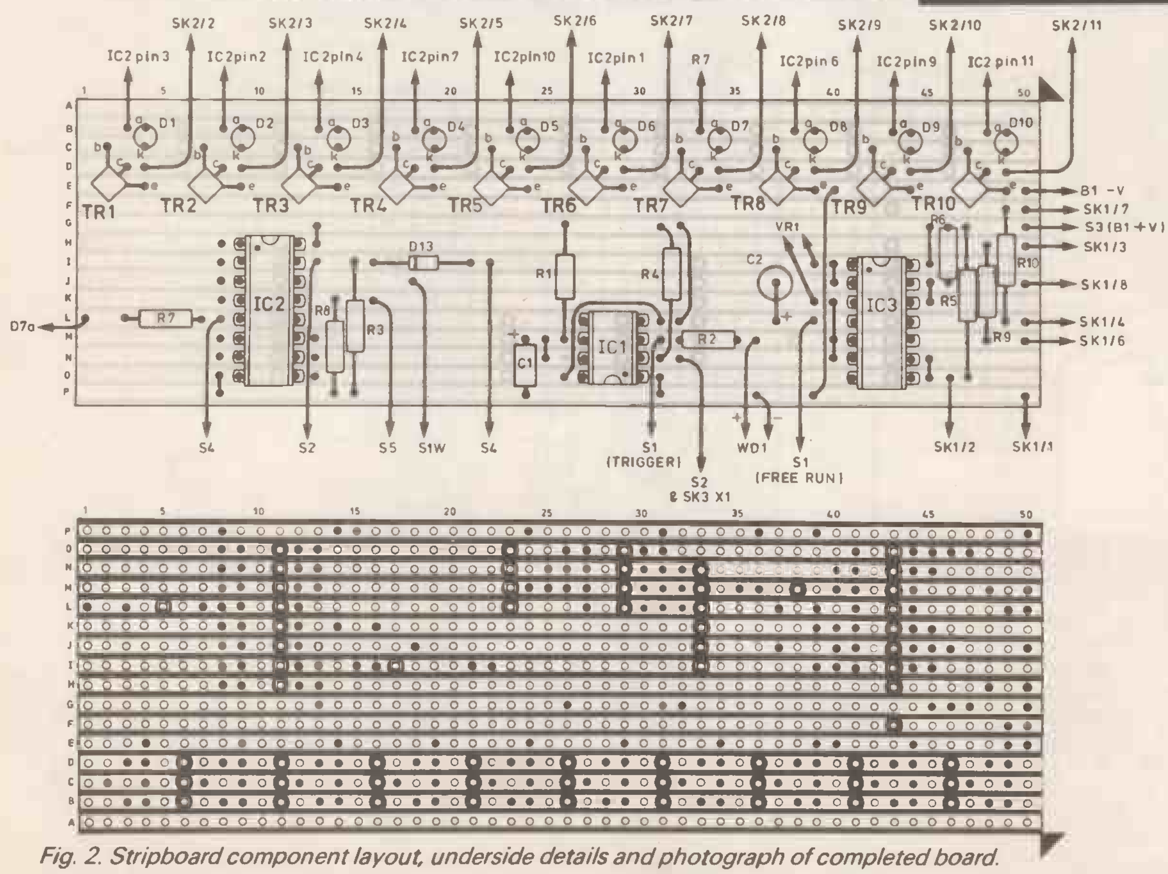
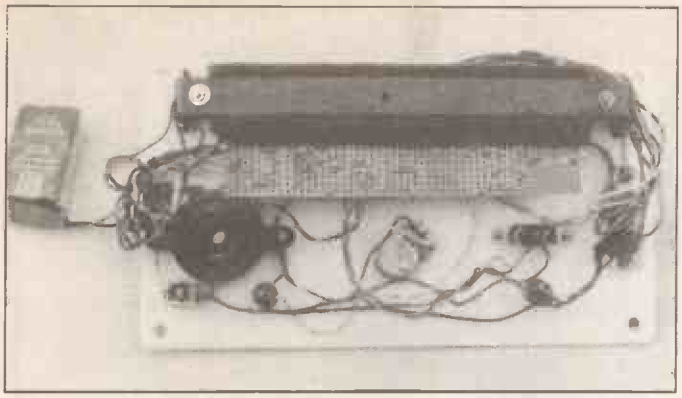


Fig. 2. Stripboard component layout, underside details and photograph of completed board.



The buzzer and board mounted on rear of front panel.

Front panel layout and lettering.

In the *"Get any Row"* game the external lamp display indicates the position in a row and the letter category for the question.

CONSTRUCTION

The control or Knockout circuit is constructed on a piece of 0.1in. matrix stripboard, size 16 strips x 50 holes. The circuit board component layout and details of breaks required in the underside copper tracks is shown in Fig. 2.

Remember that CMOS devices can be damaged by high voltage static charges even though they are equipped with internal protective diodes. Therefore the use of i.c. holders is recommended. It is also advisable to leave the i.c.s in their protective foam until the circuit is constructed, checked and ready for use.

The circuit board is housed in a plastic project box 195mm x 110mm x 60mm. The front panel layout is shown in Fig. 3. A cut-out of 125mm x 8mm is provided to view the display l.e.d.s D1-D10 which are mounted on the stripboard. A strip of thin perspex provides a satisfactory cover plate for the cut-out. The two long mounting screws for the cover plate can also serve to hold the stripboard in place after the control interconnections have been made.

TESTING

After checking the circuit wiring, fit the i.c.s, correctly orientated, and the battery.

Free-Run Circuit

Switch to Free-Run and Decade. With the power switch to ON, all l.e.d.s of the display should flash sequentially at a repetition rate of about one sequence per second upwards depending on the setting of the Speed control (the time constant of C2, VR1 determines the flashing speed).

Press the Freeze button several times and note the display stops on a random number.

Switch to Dice and note that the display is now limited to six l.e.d.s., which at fast speeds gives a dice-like random selection in conjunction with the Freeze button.

Trigger Circuit

Switch to Trigger and Decade and note that the display is frozen on one l.e.d. Press Reset to zero the display.

Short-circuit the Trigger Input contacts repeatedly to step the display sequentially. Note that the solid-state buzzer sounds momentarily at each trigger.

EXTERNAL CIRCUITS

OUT FOR A DUCK

Playing Procedure

Out For A Duck can be an individual game or a team game. Contestants stand several metres away from a panel depicting a riverside scene.

At switch-on, an illuminated duck appears. When this is hit with a soft ball it disappears and another duck is illuminated. The ducks are numbered 0 to 9. The target duck resets to "0" after "9" has been hit or if the Reset button is pressed.

If contestants have say, one or two throws each, then the team aggregate will be registered if the score is not reset after each contestant. Note that if more than 9 is scored then the next his registered (0) will count as 10 and so on. The buzzer sounds momentarily when a hit occurs.

Construction

The target is made from a plywood or hardboard panel about 180cm x 15cm. There are ten duck cut-outs in the panel (see Fig. 4), each of which is covered by a hinged perspex flap which serves two purposes: it actuates the trigger switch when struck, and allows the duck shape to be seen when the target is illuminated.

The construction is fairly simple: 1. Cut out ten duck shapes (10cm x 6cm) from panel. 2. Cut ten rectangles of 1/8th perspex (12cm x 8cm). 3. Fix perspex covers over front of duck cut-outs, hinged at top by adhesive tape. 4. Mount ten "make" contacts to operate when a window is struck by a soft ball. 5. Mount ten 12V 60mA m.e.s. bulbs, one at rear of each duck cut-out. 6. Screen the lamps from each other by boxing in at the rear by thick card or plywood. 7. Paint a number (0 to 9) on each perspex cover (left to right) to indicate score. 8. Paint riverside scene on white sheet or paper fastened over front of panel.

Switch positions: Trigger Decade Reset (to start count).

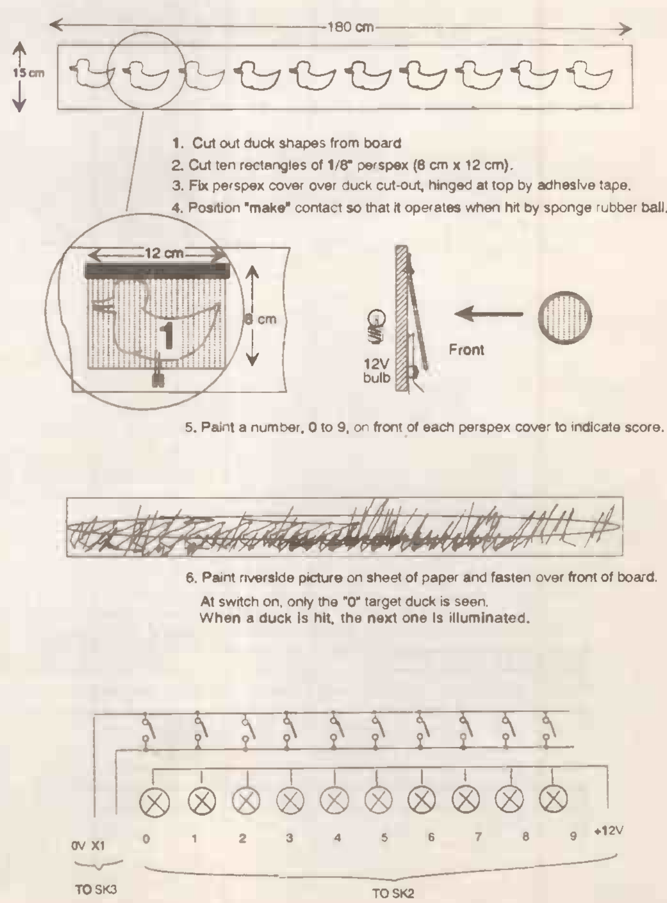


Fig. 4. The Out For A Duck circuit and assembly details.

CAT O'NINE LIVES

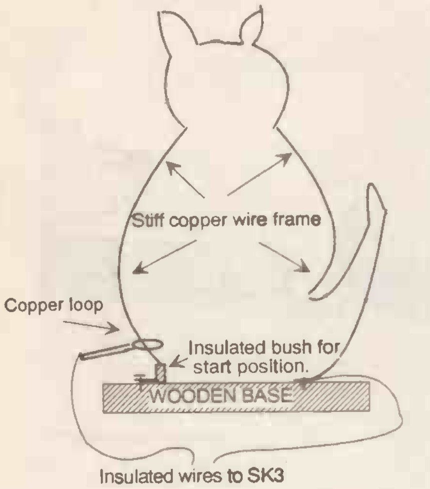


Fig. 5. Assembly details of the Cat O'Nine Lives.

Playing Procedure

The Cat o'Nine Lives is an update of the well-known game that has tested the steadiness of hand of millions of fete and party-goers ever since the invention of the electric bell – running a ring around a wire frame without touching it. In this case, a stiff copper wire frame is in the shape of a cat with nine lives.

Again, this can be an individual or team effort. If nerves are steady and the loop is not too small, the scores can be accumulative for the team instead of resetting for each player.

Construction

A small copper loop is connected by an insulated wire to one contact of SK3. An insulated wire from the copper frame is connected to the other contact of Sk3. Each touch of the frame by the loop means a life lost, sounded by a solid-state buzzer and indicated on the numbered display. If necessary, an external display can be arranged on the wooden base to give a wider indication of the state of the game.

Switch Positions: Free-Run Decade Reset (to start count).

Sockets SK3 (SK2 if external display required).

WHEEL OF MISFORTUNE

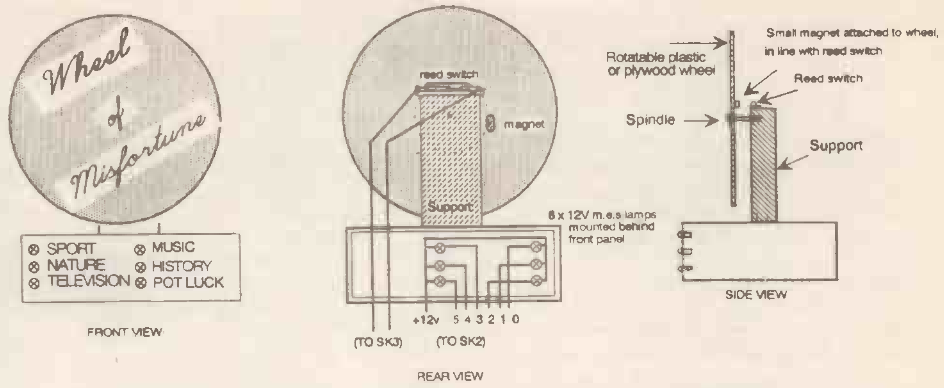


Fig. 6. Assembly and wiring to the Wheel of Misfortune display.

Playing Procedure

The wheel of Misfortune is a team quiz game where subject and questions are decided by two successive spins of the wheel. Select Trigger and Dice.

As each contestant spins the wheel the display lamps flash in sequence, gradually slowing down as the wheel slows down to indicate one of six subject categories, for instance, Sport, Nature, Television, Music, History, Pot Luck. The Quiz Master now selects the appropriate list of ten questions for the subject selected, then switches to DECADE and the contestant has another spin of the wheel (external display now covered or disconnected) to determine from the internal display what number of question has to be answered.

Contestants with good memories can benefit when a repeat question comes up. Normally there are 60 different questions, ten per subject, but the questions can be changed for subsequent games. Failure to answer correctly results in the question being given to the other team who can then take the point.

This game could be played without the wheel circuit/external display by selecting Free-Run and using the Freeze button. However, the spinning of the wheel adds to the fun and the tension as the lights slow down to decide the category of subject.

Construction

The wheel of plastic or plywood must be mounted on a heavy wooden base to prevent movement when spun. The six display lamps (0 to 5) are mounted on a front panel in the base alongside the categories, and wired as shown in Fig. 6.

Before fixing the magnet permanently to the wheel, ensure that it operates the reed switch. Reposition if necessary before final fixing with glue or tape.

Switch Positions: Trigger Dice and Decade.

Sockets: SK2 (+12V, 0 to 5) SK3.

BULL'S EYES

Playing Procedure

The Bull's Eyes game can also be an individual or team event. The object of the game is to score as many "bull's eyes" as possible with a prescribed number of pulls of the trigger of the light-gun or torch.

The benefit of two targets is that the contestant has to re-aim after each hit, which requires greater skill. Using a light-dependent resistor (l.d.r.) as bull's eye and a spotlight torch, the trigger circuit was sensitive over a range of ten metres.

Construction

The two paralleled light-dependent resistors should be mounted on a panel and located as centres or "pupils" of two painted eyes, see Fig. 7. The two insulated leads are connected to the Trigger Input, SK3.

As an extra to the Knockout Box display, an external display, split between the two targets, could be used to indicate the scoring on the target itself.

Switch Positions: Trigger Decade.

Socket: SK3 (SK2 if external display used).

BURIED TREASURE

Playing Procedure

Buried Treasure is an individual or team game. Each contestant roams around a cardboard island searching for treasure with a detector and a hand-map on which "X" marks the spot or spots.

The idea is to locate as much treasure as possible in a given time. Each time treasure is located, the Knockout circuit buzzes and advances the count by one.

If the treasure hunters are only allowed to visit the island one by one they will not have the advantage of seeing where the previous contestant(s) were searching for the treasure. Scorers must take care that the each treasure point is only recorded once by a contestant (i.e. no repeat runs over the same magnet).

Construction

The construction of a large cardboard floor map can be as elaborate as time or skill permits, see Fig. 8. The small bar magnets that represent the treasure can be easily inserted into corrugated cardboard at various points without being visible.

The locations of the hidden treasure can be indicated by the traditional X on a small hand-map, grid references or more mysterious instructions for the contestants. As a finishing touch, the hand-map could be in the from of a scroll tied with ribbon.

The treasure detector head contains a reed relay switch that is connected to SK3, the Trigger Input. The Island magnets activate the detector head reed switch as it "sweeps" across the floor map.

Switch Positions: Trigger Decade.
Socket: SK3.

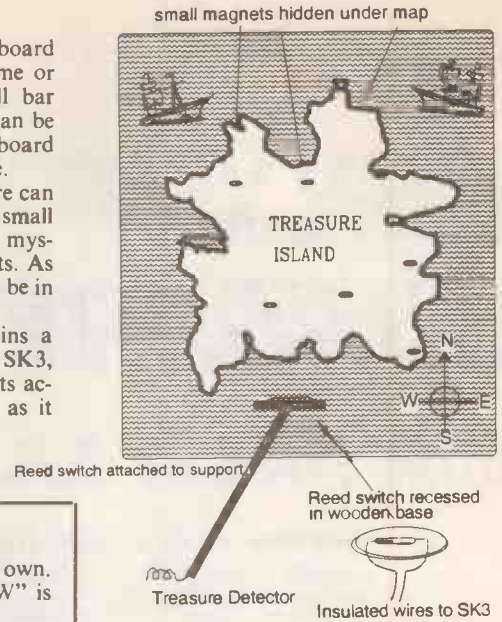


Fig. 8. Buried Treasure map layout and detector head.

GET ANY ROW

Playing Procedure

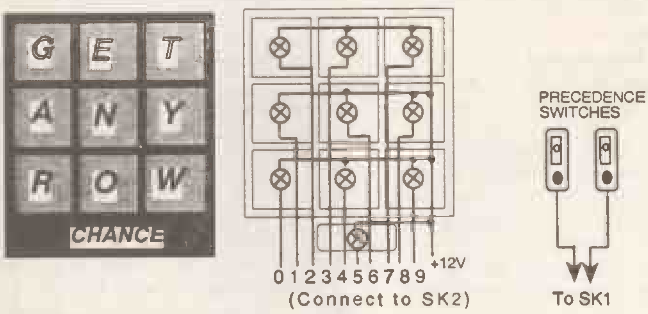
This is a simple variation of the blockbuster quiz game using two players. The idea of the game is for one player to get a complete row of three letters either horizontally, vertically or diagonally.

When Free-Run is selected, the ten lamps flash sequentially until the Freeze button is pressed by the Quiz Master. One of the displayed letters, G-E-T-A-N-Y-R-O-W or CHANCE is then lit. The Quiz Master then asks a question the answer to which begins with that letter, or a general question if CHANCE is lit. The right to answer is determined using the precedence switches see Fig. 9.

Butting in before the end of a question is allowed, but if the answer is incorrect the whole of the question is offered to the other player. Further questions are asked using the same letter if neither contestant answers correctly.

When a question is answered correctly, a team symbol is placed over the illuminated letter and play is resumed. If the CHANCE question is answered correctly, the player can place his symbol on any letter that has not already been taken. If a letter is illuminated that has already been taken, the player who answers correctly can replace an opponent's symbol with his or her own. The first player to "GET ANY ROW" is the winner.

To introduce an element of skill, the Speed control can be set slower and the contestants operate the Freeze button in turn.



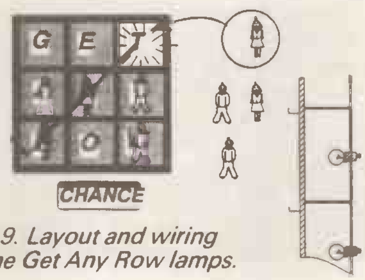


Fig. 9. Layout and wiring to the Get Any Row lamps.

Construction

The display panel must be sufficiently large for viewing by the intended audience. A shallow box, or drawer, divided into ten light-tight compartments is suitable to house the lamps.

The front windows can be cut from thin perspex or translucent plastic material. Paint or glue the letters on to these windows. The team symbols can be hung from small hooks above the windows.

The 12V 60mA m.e.s. lamps are connected as shown in Fig. 9. The order of connection to SK2 0-9 is not important, but the *common* connection of the lamps *must* go to + 12V.

Switch Selection: Free-Run Decade Freeze.
Sockets: SK1 SK3.

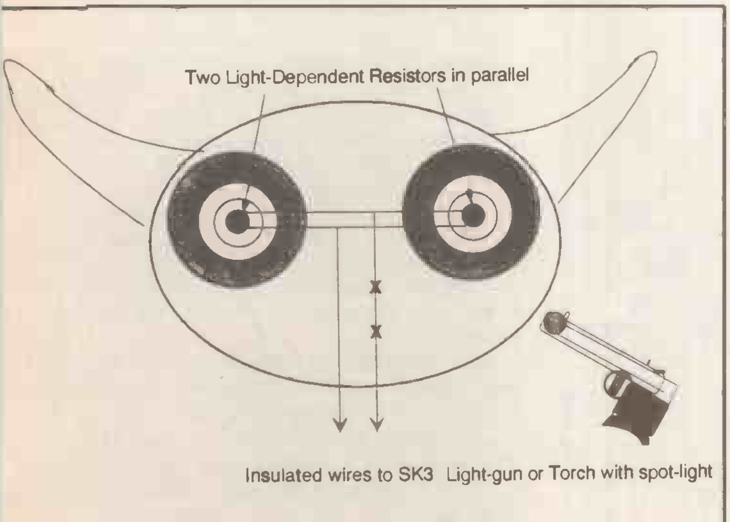
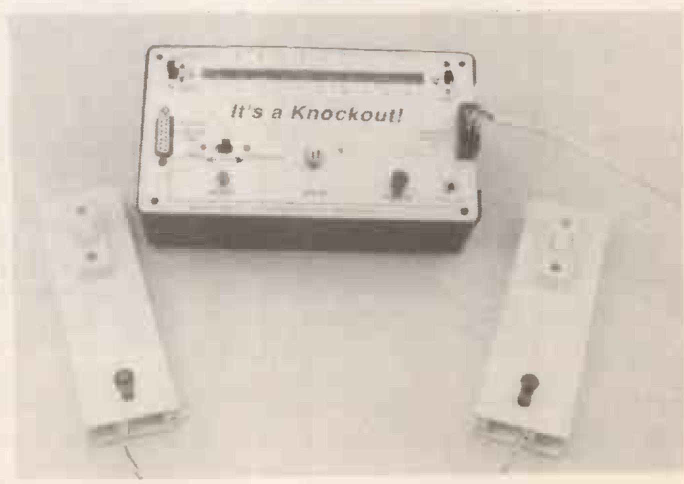
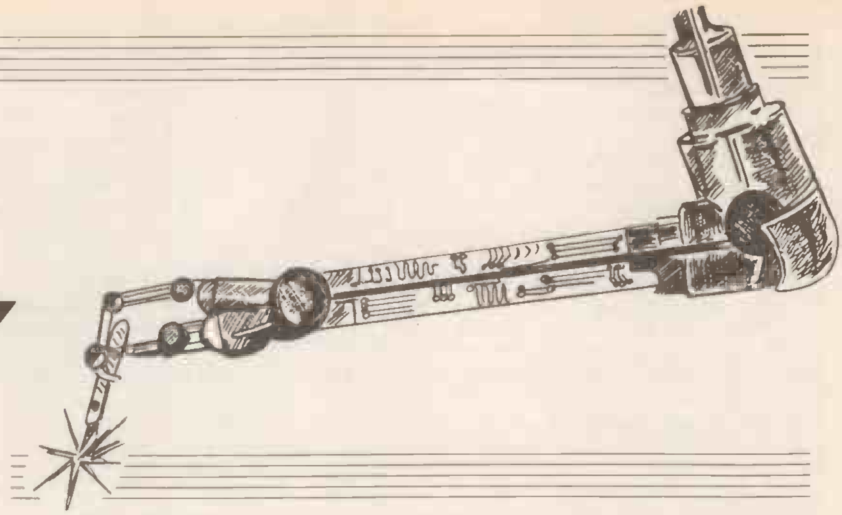


Fig. 7. Wiring to the two LDR "eyes" of the Bull's Eyes display. If ambient light causes premature triggering, insert a 5k potentiometer (wiper and one outer tag) at points "X".



Regular Clinic



CIRCUIT SURGERY

MIKE TOOLEY B.A.

Welcome to Circuit Surgery, our regular clinic for readers' problems. In this month's Surgery we shall be taking a look at a novel use for the ubiquitous LM380. We also have details of a circuit modification for the popular* EE Telesound *which can be used to add baby monitoring facilities to your TV. For good measure, we take a brief look at the problem of replacing obsolete TTL devices with their modern counterparts.

Linear scale resistance measurement

Last month's resistance range extender seems to have aroused interest amongst a number of readers, several of whom have pointed out that the scale calibration is far from linear. Fortunately, a linear resistance scale can be realised quite easily by means of a simple constant current source (see Fig.1).

The unknown resistor is connected into the collector circuit and the meter (switched to the 10V d.c. range) is used to measure the voltage drop developed across the resistor. As an example, assume that the constant current source (the collector of the transistor) is generating a current of 1mA. A resistor, R_x, of 5k connected into the collector circuit will produce a voltage drop given by:

$V = I \times R = 1mA \times 5k = 5V$.

Hence a 1mA constant current source will result in a linear ohms scale of 0 to 10k when the meter is switched to the 10V d.c. range. Alternatively, a 100µA constant current source will give resistance readings over the range 0 to 100k.

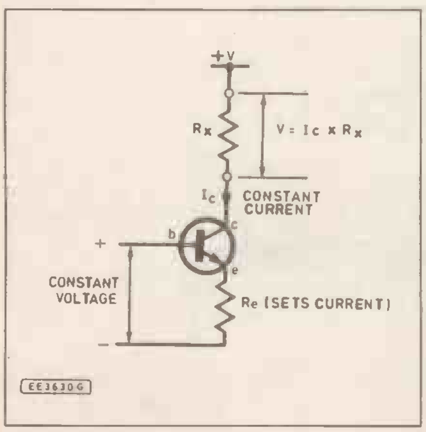


Fig.1 Basic principle of the linear scale ohmmeter.

The complete circuit of a dual-range linear scale ohmmeter (for use with a conventional multimeter connected to the 10V d.c. range) is shown in Fig.2. S1 is used to select the desired resistance range (either 10k or 100k full-scale) and the the constant voltage (approximately 1.2V) required at the base of the transistor is derived from two forward-biased silicon diodes, D1 and D2.

In order to calibrate the instrument, accurate 10k and 100k resistors are required. These are connected in turn to the unknown resistor terminals during which VR1 and VR2 are respectively adjusted to produce a full-scale reading of 10V on the meter with S1 in the 10kΩ and 100kΩ positions respectively.

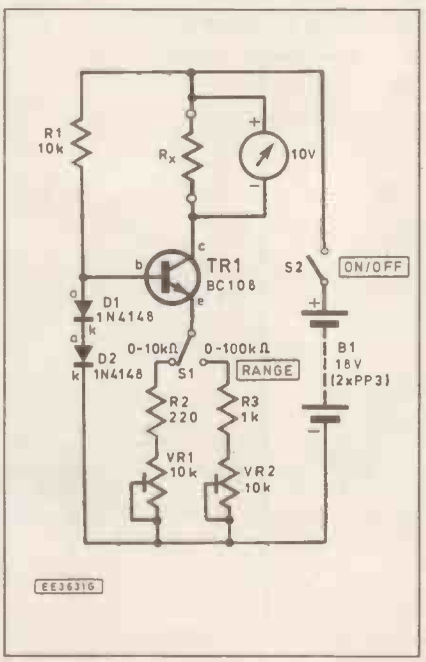


Fig.2 Complete circuit of the linear scale ohmmeter.

Baby monitor based on the E E Telesound

The *EE Telesound* (January 1992) provides a novel method of amplifying the output of a portable cassette player. With the addition of a simple audio pre-amplifier, the same arrangement can be used to provide remote "baby listening" facilites using an ordinary TV. Furthermore, with the aid of a simple aerial splitter and a standard remote controller, it is possible to switch from your favourite TV programme in order to eavesdrop on the nursery without even leaving the comfort of one's armchair!.

The additional circuitry required to provide a "baby listening" facility is shown in Fig. 3. TR1 and TR2 form a two stage high-gain audio amplifier with adjustable voltage gain (by means of VR1). The input signal is derived from a miniature loudspeaker (of between 40 and 80 ohms) which is mounted at a strategic position within the nursery and connected to the amplifier by means of a length of miniature screened audio cable. Alternatively, where the distance is not excessive, a flat twin cable can be used. This arrangement will be somewhat more prone to induced hum and noise, however this should not be too problematic bearing in mind the relatively low impedance of the signal source.

The connecting arrangement which will permit instant changeover from broadcast TV channels to the Telesound baby monitor is shown in Fig. 4. The splitter is a conventional 75 ohm u.h.f. TV signal combiner (available from most TV and video dealers). In use, the amplifier gain should be adjusted (by means of VR1) to produce a signal which is free from extraneous noise but loud enough to match that of a conventional TV audio signal. This will avoid having to make adjustments to the

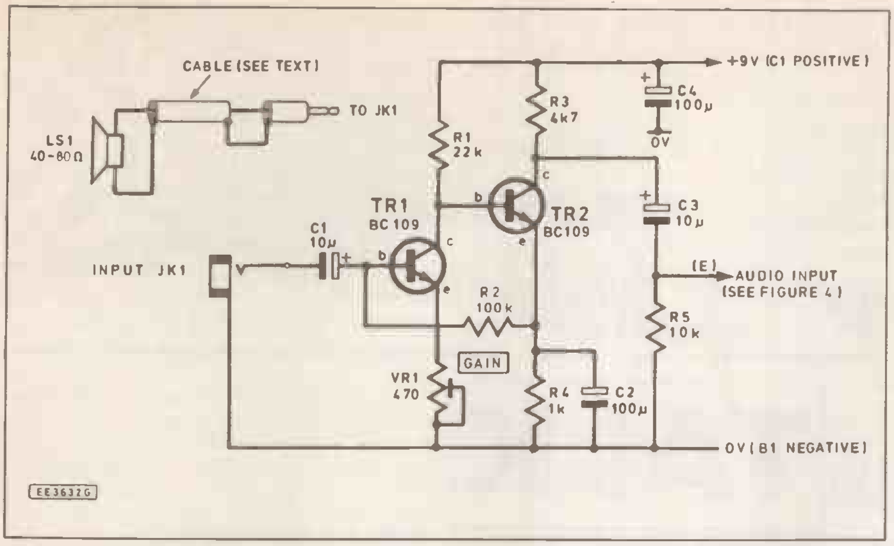


Fig.3 Additional pre-amplifer for use with the EE Telesound *in order to provide "baby listening" facilities.*

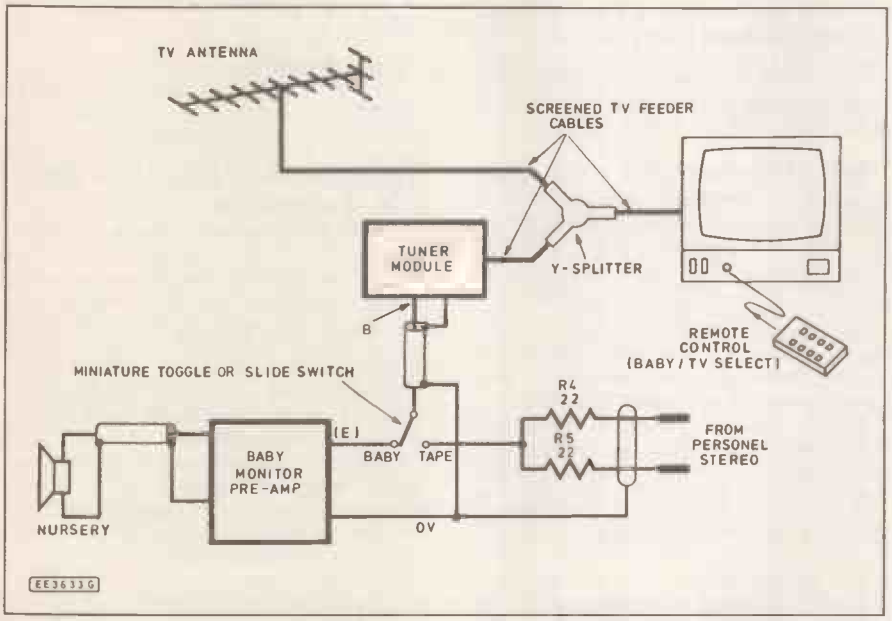


Fig.4 Method of connecting the EE Telesound *to provide switching between TV programmes and baby listening.*

receiver's volume control when switching from a broadcast signal to the Telesound. In any event, a little experimentation will be needed in order to establish the optimum setting for VR1.

Yet another use for the LM380

Mr King from Andover has sent me a very succinct query concerning a power supply problem:

"I have a 12V d.c. supply rated at 1A but need an additional supply of −5V at around 100mA. How can I do it?".

Fortunately the solution to Mr King's problem is quite simple and only requires an LM380, a 79L05 regulator and a few other readily available components (see Fig.5). IC1 LM380 operates as a self-contained power oscillator which provides a 10V square wave output at approximately 4kHz. This is then fed to a rectifier arrangement (D1 and D2) and the resulting unregulated d.c. (approximately-8V) is fed to a conventional plastic three-terminal i.c. voltage regulator (IC2).

This is quite an unusual application for the ubiquitous LM380 but it does show how useful this particular device can bel.

Logical choice

Alan Lamb writes from Penge to ask if I can explain the major differences between the bewildering range of logic chips which is currently available. Alan writes:

"I need a 74S04 chip to replace a device which has failed in a printer interface. On taking a look in the Maplin catalogue, I find that they do not stock this device but do have several other chips with nearly identical type numbers. Would any of these work?"

Well, Alan, the device in question is one of the "74-series" of logic devices. The "S" identifies it as a Schottky device which offers improved switching characteristics when compared with "standard" 74-series devices.

In fact, standard 74-series devices are rarely used these days. Most manufacturers prefer to use pin and function compatible 74LS (low-power Schottky) and 74ALS (advanced low-power Schottky devices).

Both of these chips offer improved performance when compared with their original counterparts.

It would thus be fairly safe to replace your 74S04 device with either a 74LS04 or a 74ALS04. Since Maplin stock the former variety (Order Code, YF04E) this would seem to be an appropriate choice! To put the record straight, the following table summarises some of the differences between the 7404, 74S04, and 74LS04:

	Device		
Characteristic	**7404**	**74S04**	**74LS04**
Supply voltage	5V±5%	5V±5%	5V±5%
Supply current (typ)	12mA	24mA	2.4mA
Low state output current (max)	16mA	20mA	8mA
Propagation delay:			
low-to-high (typ)	12ns	3ns	9ns
high-to-low (typ)	8ns	3ns	10ns

From the above table it should be noted that the 74S04 offers a significantly lower value of propagation delay than its standard and LS counterparts. In the case of Alan's printer interface this is not likely to be a problem as the interface will be operating at a relatively low speed.

The only possible area which *may* cause problems results from the reduced value of output current which the 74LS04 can source when compared with a 74S04 device (8mA as against 20mA). With a modern printer (and using a relatively short length of printer cable) this should not pose a problem

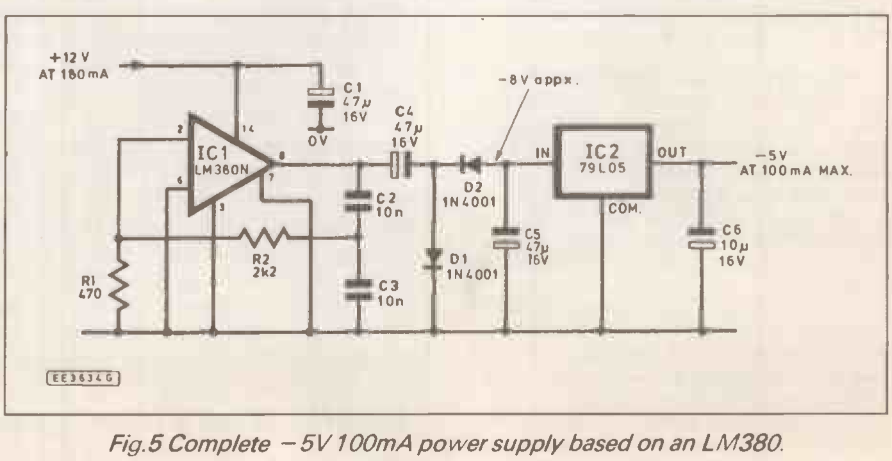


Fig.5 Complete −5V 100mA power supply based on an LM380.

(currents of only a few mA will be present in the data lines).

If Alan's printer is a vintage machine or he is using a very long screened printer cable (which may exhibit appreciable capacitance) there may still be problems. If this is the case, it may be essential to hunt down a genuine 74S04 device or fit an external parallel printer line driver (such as the Accodata Line Extender). This device comprises an external transmitter (plugged into the computer's parallel port) and a receiver (connected to the printer). The system is not particularly cheap but it can cope with data rates of up to 48,000 bits per second and cable runs of up to 350 metres and thus should satisfy even the most demanding of parallel interface requirements!

Next month: In next month's Surgery we shall be describing a simple method of measuring unknown capacitors. We also have details of a simple low-battery indicator circuit which can be incorporated into any item of battery operated equipment in order to provide warning of impending battery failure. In the meantime, if you have any comments or suggestions for inclusion in Circuit Surgery, please drop me a line at: Faculty of Technology, Brooklands College, Heath Road, Weybridge, Surrey, KT13 8TT. Please note that I cannot undertake to reply to individual queries from readers however I will do my best to answer all questions from readers through the medium of this column

SHOP TALK

with David Barrington

Experimental Weighing Scale

Running through the components required to construct the *Experimental Weighing Scale*, several items could possibly cause local sourcing problems and call for further comment.

As outlined in the article, the OP-470GP op.amp (IC1) is an instrument grade i.c. with a good common-mode rejection ratio (120dB) and should be used in this project. This 14-pin device is currently listed by **Maplin** (☎ *0702 554161*) code UL06G, **Electromail** (☎ *0536 204555*) code 647-277 and **Farnell** (☎ *0532-636311*) code OP-470GP.

The foil strain gauges were purchased from Electromail and are the 5mm aluminium version, code 632-180. These do not appear to be available from any other source and two are used in the model.

We thought that there would be no problem locating a multiturn "rotary" type potentiometer, but we were wrong.

The only ones we have been able to find are 10-turn *wirewound* versions from the same company that supplies the strain gauges. The author's version is a 5k type rated at 1.5W, enclosed in a nickel-plated brass case and costs over £13; but the plastics (phenolic) cased 3W version (code 173-401) at just £3.98 seems a better buy for this application.

The original cleaning solvents and adhesive gel used to prepare the aluminium "cantilever" load bridge are no longer listed; anyway, at over £12 they were far too expensive. Quite a few of our advertisers now list "environment friendly" degreasing cleaners (such as Electrolube products) and cyanoacrylate adhesive (Superglue) at just over £1 to £2 each.

The single-sided printed circuit board for the Weighing Scale is available from the *EE PCB Service*, code EE792 (see page 323).

Camcorder Headphone Amplifier

The TDA2822 1W stereo amplifier i.c. used in the *Camcorder Headphone Amplifier* is a popular device and should be stocked by most good component suppliers. This i.c. will operate from 15V down to 1.8V supply, at 3V will give 20mW into 32 ohms and at 9V will give 1W into 8 ohm, just right for low cost, low impedance headphones.

The jack socket, with switch contacts, used in the model is the type with the contact tags on the end of the body. The one used in the prototype is the **Maplin** d.p.d.t. 6.3mm stereo socket, code BW80B.

Due to the small size of the case, when purchasing the potentiometers indicate that they must be the miniature 17mm diameter (or less) rotary carbon type. Also, be sure to specify that you want "LOG" law controls.

It should be noted that all the electrolytic capacitors used in this project are miniature *radial* types, i.e. both leads at one end.

12V Drill Charger/PSU

It is most important to use only high current carrying wires were specified in the *12V Drill Charger/PSU*. The standard power-in plug (code HH625) and the switched socket (Code FT97F) used in the model were obtained from **Maplin**.

The case was also purchased from the same source and is from their Free-Standing PSU Box range. The "ventilated" version is required and is coded YU32K.

To keep costs to readers to a minimum, the two small printed circuit boards for this project have been combined into a single board which readers are asked to separate. This board is available from the *EE PCB Service*, code EE793 (see page 323).

It's A Knockout

All the discrete or electronics components needed to complete the construction of the *It's A Knockout* game(s) are standard "over the counter" items and readily available from our advertisers. However, the layout and assembly hardware materials for the additional large external displays is left to individual choice. The hardware materials should be found at most DIY shops or stores.

On the prototype model, double-pole slide switches were used for S1, S3 and S4 as they were to hand and are shown in the wiring diagram. Only one set of contacts should be used or, as suggested in the "comp list", you can use single-pole changeover toggle switches.

The pushbutton switches S2 and S5 are the press-to-make type and the "non-locking" or release to brake version must be ordered.

Fridge Warning

The circuit board mounting relay called for in the *Fridge Warning* project is from Maplin's micro miniature range. The one used is the 6V 80ohm coil version, code FM89W. Other relays can, of course, be used provided they have indentical electrical characteristics and will fit on the board.

Most components advertisers appear to carry good selections of panel meters and can usually suggest a suitable large scale type. If readers experience any supply difficulties, the 50μA moving coil meter used in the model has an internal resistance of 4300 ohms and is from the Maplin 100mm (4 in.) range, code RX54J.

Bead thermistors are now stocked fairly widely and should not cause any sourcing problem. The one used is rated 47k at 25°C and may be colour coded as follows: yellow, violet, orange and silver.

The plug and socket used for connecting the remote thermistor to the main circuit is a standard 2.1mm Power-In type.

PLEASE TAKE NOTE

Programmable Timer *(Feb. '92)*

Page 101, Fig. 4. The annotations for resistor R2 and capacitor C3 have been transposed. Resistor R2 should be at the top right corner.

Special Supplement

MAKING YOUR OWN P.C.B.s

ALAN WINSTANLEY

It's easy if you have the right chemistry

This supplement looks at p.c.b.s in general and at their various forms, it then goes on to investigate p.c.b. fabrication techniques available to the hobbyist. Follow up parts will cover Ultra-Violet Processing Techniques and Originating Your Own Artwork. We will also publish a couple of back-up projects – an Artwork Light-box and a U.V. Exposure Timer – to help

Introducing the P.C.B.

Although new types of components or integrated circuits occasionally appear in a project, one thing which will never change is the requirement to connect all the parts together one way or another to form a complete circuit!

As component manufacturing and design technology evolves, so new techniques are adopted to accommodate them. Often, great strides in the industry result from aeronautical or military requirements, with spin-offs into the consumer market which can be of benefit to everyone – especially the electronics constructor!

Whilst modern electronic components are much smaller and more efficient than their forbears, miniaturisation can bring with it the headache of physically connecting the device to the outside word. For example, a standard dual-in-line integrated circuit is actually much larger than the sliver of silicon it contains: the bulk of the package is necessitated by the relatively large size of the terminals and pins which are linked to the chip inside, to enable the i.c. to be connected to the rest of the external circuit.

Early circuits using thermionic valves were relatively simple – albeit operating at lethal voltages! The connections to the various component parts were often effected using insulated panels bearing "turret tags", to which components were soldered and hooked up to valves and other parts with spaghetti-like masses of wire. Each component panel was hand-made.

With the advent of semiconductor junction devices – especially the "transfer resistor" (transistor) – and then the integrated circuit (i.c.), the demand grew for a method of interconnecting ever smaller, more efficient components with a view to reliably mass-producing electronic circuit boards. Gone were the days of wiring up Paxolin panels using hot poker soldering irons, enter the pick-and-place machine and wave-solder bath!

Circuit Boards

There are several techniques available to enable circuit boards to be fabricated by the electronics constructor, and they all have their own advantages as well as drawbacks. This series will deal with the methods used to produce printed circuit boards (p.c.b.s) – showing you how to prepare the initial "artwork" as well as actually making the p.c.b. itself. We will be looking at: *components; basic p.c.b. fabrication;* and the more advanced *ultra-violet process,* too.

Regular readers of *Everyday Electronics* will be familiar with stripboard or "Veroboard" as a method of circuit assembly. This product is very frequently used to assemble circuits, either for prototype work or as the finalised version, and it has many features to commend it.

In particular:-

Stripboard does not require any involved fabrication methods – It's readily available off the shelf, in various sizes and types.

It lends itself admirably to experimentation work, since the circuit can be modified and components can be added later, as required.

It's ideal as a construction medium for simpler circuits.

But stripboard does have its disadvantages:-

Complex circuits require interconnecting jumper wires, making assembly slow and rather a chore. It's possible to miss a link, or to connect to the wrong locations.

It's quite easy to accidentally short adjacent copper strips with wisps of solder. Conversely, when making copper breaks in the conductors, it's easy to overlook an incomplete break, so that the strip is still joined.

The product itself is not particularly strong, and is not really recommended for heavier components such as p.c.b. mounted mains transformers. Stripboard is not preferred if the circuit has to operate under arduous conditions.

With the advent of microprocessor technology especially, the basic stripboard has gained several "big brothers" which have been specially adapted to the digital/computer field. For instance, plug-in boards which are compatible with various makes of PC are available, permitting experimental boards to be prototyped and either soldered in the traditional way or wire-wrapped.

Clean Job

Printed circuit boards are much more widely used as a method of hobbyist's circuit construction than they used to be (even with simple circuits where stripboard might ordinarily have sufficed) thanks

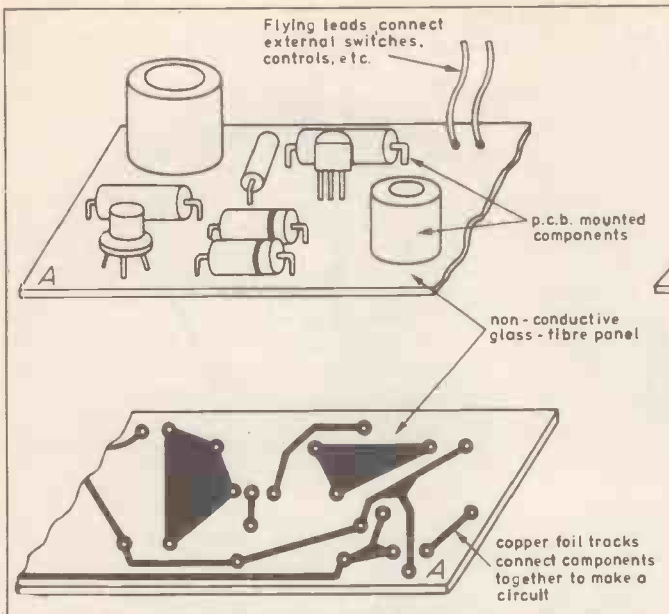


Fig. 1. Single-sided printed circuit board where the copper tracks are all on one side of the board. The components are soldered to the copper pads to form a complete circuit.

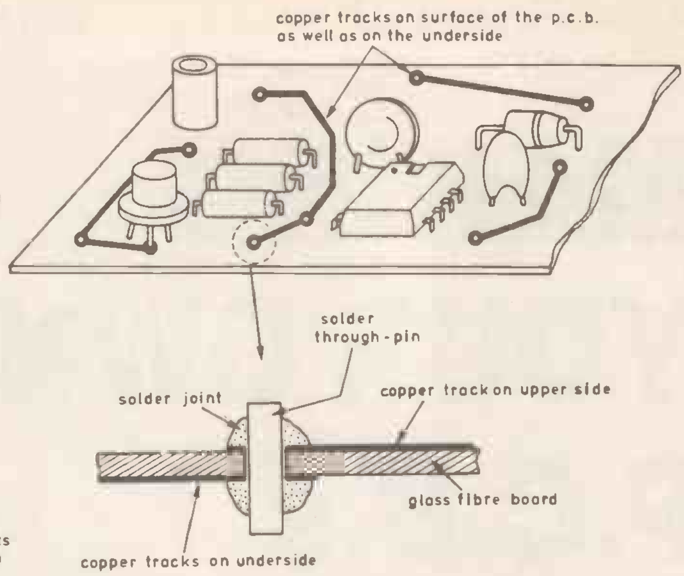


Fig. 2. Double-sided p.c.b. where some copper tracks are placed on the surface of the board, and are connected to the main track pattern underneath by using through-pins.

partly to the availability of computer-aided design (CAD) packages which enable designers to draft the necessary artwork on a PC and print it out directly. Additionally, the speciality chemicals and processing techniques required have been refined to make the job somewhat cleaner and easier than before.

Certainly from the constructor's point of view, a p.c.b. removes a lot of the aggravation of having to follow diagrams and interlink many copper strips, which is a boon when building a complex circuit. A p.c.b. is virtually fool-proof, and using them helps to ensure that the circuit should work first time. Your project will also be much more professional-looking.

One further advantage of a p.c.b. is that in practice it is generally fabricated on glass-reinforced plastic, which is virtually unbreakable: it is infinitely more durable than Paxolin-type stripboard.

No Redundancy

This does not mean that stripboard is redundant – far from it! The product is still used a great deal in the initial stages of prototyping. A new circuit may well initially be created on a plug-in breadboard and may then be transferred to stripboard for trials at an intermediate stage. Only when the circuit of the stripboard version is finalised might the p.c.b. be designed.

In fact experienced designers might build the circuit on stripboard or wire-wrap it as they go along, eliminating the breadboard stage altogether. But it's never wise to produce a p.c.b. for anything but the simplest circuits unless you have fully prototyped it beforehand. Failure to fully sort out the "bugs" in a circuit prior to committing to a printed circuit board version can result in the board bearing some lashed-together modifications, or being scrapped altogether in extreme cases. It happens though, even in professionally-manufactured equipment!

Also of course, there are still plenty of opportunities to assemble circuits on stripboard, as a quick check through the *Everyday Electronics* project pages will prove.

The disadvantages of printed circuits include the fact that the design of complex p.c.b. layouts can be quite involved; there is no simple way round this unless you have a CAD package on a PC, and even they might not be perfect. Anybody can design a circuit layout onto stripboard, however, using nothing more advanced than some graph or ruled paper and a pencil. The actual design of a p.c.b. is of course not something the reader needs to worry about when constructing an *Everyday Electronics* project – all the work has been done by the designer.

Making Out

In making your own printed circuit boards, you will also have to contend with some special equipment and the various chemicals used to produce the board, and this can involve the use of potentially hazardous processes. The techniques are perfectly safe provided that the chemicals are used sensibly and common-sense safety precautions are taken.

Some electronics "purists" might also say that using a p.c.b. instead of stripboard is a form of cheating; it takes away half the fun of building a project yourself and getting it up and running. Assembling a complex circuit on stripboard is fine if you relish the potential challenge of all that double-checking and fault finding! There is actually a lot of satisfaction to be derived from making the printed circuit board yourself.

In general, a p.c.b. will vastly reduce for the constructor the chore of any component interwiring, and will help to ensure that you can get your project up and running with the minimum of delay and troubleshooting. You'll also get professional-looking results into the bargain.

If a designer has specified that a printed circuit board is to be used for assembly, then the constructor has the choice of purchasing ready-prepared p.c.b.'s from the *EE PCB Service*, or they can set about making the board for themselves. This series will hopefully dispel some of the mysteries of do-it-yourself p.c.b. production, for those who have not contemplated this aspect of project building before.

Basic Concept

The basic concept of a simple p.c.b. is described in Fig. 1, which shows part of a typical printed circuit board.

All components are mounted on one side of the board and their leadouts pass through holes in the p.c.b. to the underside. A specially-designed network of cooper tracks – more about this later – links the components together underneath as required, with each component being soldered to a copper connecting "pad" around each leadout. With copper tracks on one side of the board only, this style is known as a "single-sided" p.c.b., and is the most common type used by hobbyists.

This type is quite adequate for even fairly complex circuits, but there are occasions when the circuit itself might be so complicated that the designer cannot fit the copper track pattern into the size of p.c.b. that he has to work with. Of course, one way round this is to simply design and build the circuit onto a much larger single-sided board, thereby giving himself more room to fit all the tracks in, but this can be very wasteful (and expensive).

Double Top

A simple remedy for this problem is shown in Fig. 2. By moving some of the copper track pattern to the less-crowded component side of the p.c.b., it is easy to save quite a lot of space compared with a normal single-sided board. The top-side copper tracks are connected through to the main copper track pattern underneath by soldering in "through pins" on both sides of the p.c.b., though on professional equipment these through-holes are not soldered but during the production process are filled with a conductive deposit to create a "plated-through hole" or P.T.H.

Because copper tracks exist on both sides of the board, this type of p.c.b. is known as a "double-sided" board; components themselves might also be fitted on both sides of the board (not a method adopted by EE), sometimes using their leadouts as the through-pin if the circuit design will allow.

You will occasionally see double-sided boards appearing in projects, but they can be rather tricky to make with basic p.c.b. production

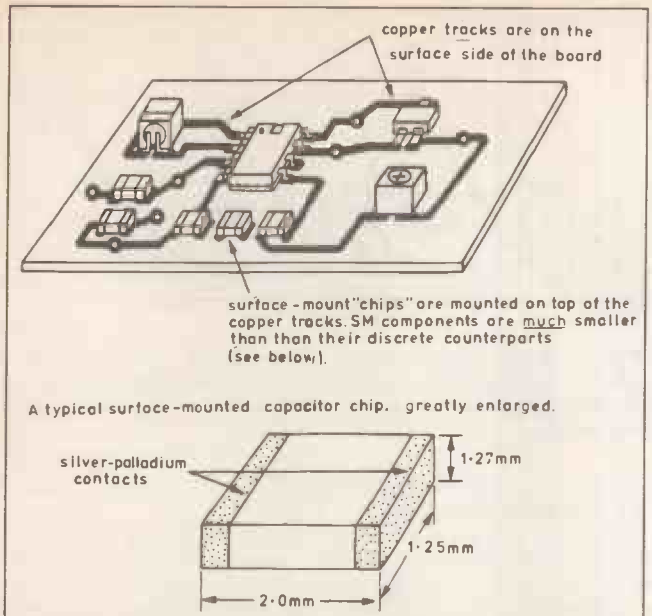


Fig. 3. Illustrating the principles of Surface Mount Technology. Very complex circuits can now be built using SM integrated circuits which occupy a very small board. The small sizes of the parts require some soldering skill

equipment. In particular, it is vital that the copper foil patterns on each side perfectly align with each other where through-holes are located. Any "registration" errors (misalignment) will mean that the connections between the top and underside conductors cannot be made properly, and at worst the board might have to be scrapped.

On The Surface

A relative newcomer to the hobby scene – although extensively used in industry – is Surface Mount Technology (SMT). This technique involves the use of miniaturised components (often called "chips", even though they may be simply resistors, for example, and not integrated circuits) which do not have normal lead-outs as such but have specially formed terminations.

Most low-power components including resistors, capacitors, many integrated circuits, even light-emitting diodes and switches, are now available in a surface-mount style. The p.c.b. is designed "upside down", so to speak, with the copper foil pattern on the upper side of the board.

A solder paste is deposited onto the copper pads and then the tiny SM component chips are temporarily bonded to the board such that they rest across their designated locations on the solder pads. They are then all soldered en-masse (in an infra red oven, for example) where the solder deposit reflows to make all the connections.

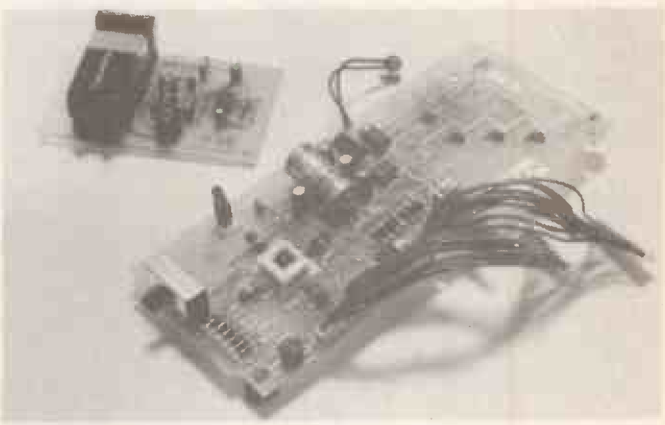
Needless to say, this process involves a host of miniature tools, handling equipment and specialist chemical processes, but basic tools and adhesives – not to mention the components themselves – are now available on the retail market to enable surface-mounted circuits to be constructed at home, and undoubtedly SMT projects will become more popular in the coming years.

They are only of use to experienced constructors because of the high degree of soldering skills required when soldering the boards by hand. De-soldering and troubleshooting them is another story!

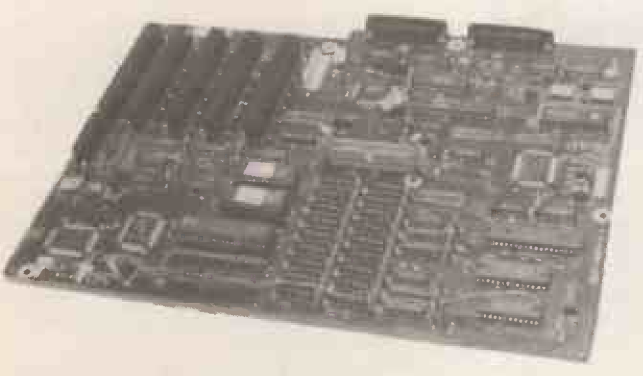
Advantages of SMT boards include their extreme compactness and generally very high reliability, plus the fact that the component chips do not require holes to be drilled through the board to accept them – since the parts are connected together on the surface of the board, as shown in Fig. 3.

In case readers find this a little overwhelming, the author points out that he has in his possession a Japanese radio/cassette player which is some *thirteen* years old. It is made almost entirely with surface-mount components. You may draw your own conclusions!

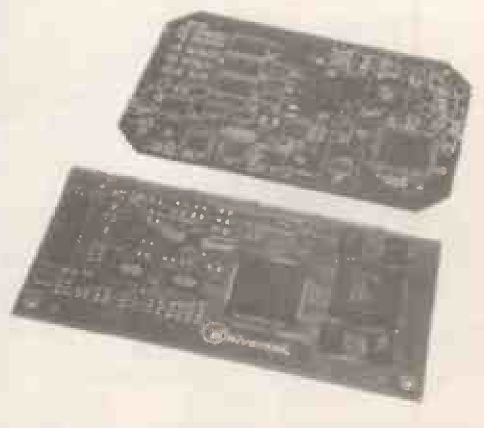
A selection of components specially made for mounting on printed circuit boards.



(Left) Typical single-sided printed circuit board – note the p.c.b.-mounted battery holder. (Right) A double-sided p.c.b. – the copper tracks on the upper side and the through-pins can clearly be seen.



A double-sided p.c.b. combining many dual-in-line (d.i.l.) and four surface-mounted (SM) devices. This is the main board of a Victor Personal Computer.



(Below) A surface-mounted p.c.b. – note the flat-pack SM integrated circuits and the tiny capacitor and resistor "chips". (Above) A commercial 4-level multi-layer p.c.b. prior to fitting with components. The darker tracks which can just be seen are actually within the board itself.

Multi-Storey

There are many instances of modern commercial equipment where even a double-sided printed circuit board might not be compact enough. Mobile equipment and portable computers, for instance, do not have a great deal of space inside to accommodate the electronics, and a clever technique that designers now use to save space is to use a "multi-layered" p.c.b., see Fig. 4.

These marvels of miniaturisation are strictly the domain of professional manufacturers with CAD/CAM equipment (computer-aided design/manufacture) – for now, anyway! They consist of several layers of printed circuit boards bonded together with total accuracy. Not only are there copper tracks on the top and underside of the complete board, but actually inside it as well! An 8-level board (or more) is not unusual, and plated-through holes will interconnect different levels of the sandwich just like a normal double-sided board.

By using a combination of surface-mount technology and multi-layered boards, the complexity and performance of a small board can be staggering.

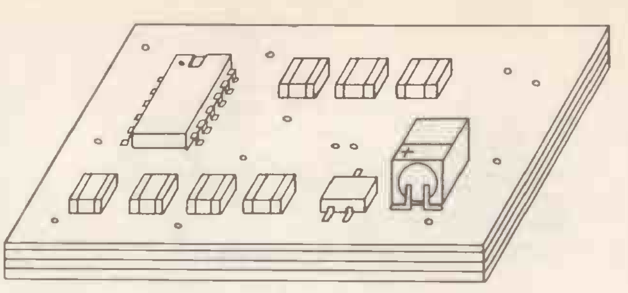


Fig.. 4. A multi-layer printed circuit board, comprising of several double-sided boards bonded precisely together. Plated-through holes connect both sides of the layers as necessary.

Back to Earth

Back to Earth! Having looked at the state of the art of printed circuit boards, let us consider various components which are specially made for mounting on a "normal" (single/double sided) p.c.b., before moving on to describe the process of making your own printed circuit boards.

All resistors, capacitors, transistors and other devices which can be used on stripboard can be accommodated by a p.c.b. of course. Most smaller capacitors are designed for p.c.b. soldering anyway, and radial-lead electrolytics are specifically designed as a space-saver by having both leads at one end, permitting vertical fixing on a p.c.b.

However, a p.c.b. lends itself to carrying other parts which you might otherwise have mounted on the chassis of the cabinet or box which houses the project. By putting all the parts onto a single p.c.b., you will also reduce, or in some cases eliminate altogether, the need to interwire between the component board and any external parts such as relays, switches, fuses, transformers etc.

Mains power supply sections especially will benefit from being mounted on the same board as the circuit they drive. Mains transformers and fuseholders are readily available for p.c.b. mounting, and you are then saved the task of hooking up all the mains-powered section with interconnecting wire. This results in a much safer and more reliable assembly – it might let you employ a smaller housing, also.

Right Connection

Connectors too are available in many types including printed circuit board mounting styles. Their use will once again save the constructor the chore of having to wire up between chassis-mounted connectors and the component board, and the p.c.b. is fitted into the project box such that external plugs can be inserted directly through cut-outs in the box into their respective sockets on the board.

This does however require the constructor to accurately fabricate the housing so that when the board is finally in place, any p.c.b.-mounted sockets will align with suitable apertures made in the box to enable connectors to be inserted.

Also available are various types of p.c.b. interconnector, which permit ribbon cables or multi-cored wires to be employed as a means of linking one circuit board to another. Often an IDC (Insulation Displacement Connector) cable will be specially made for the job, as they are suitable for mass production and are generally very reliable, being solderless. These do appear occasionally in projects.

Screw terminal blocks are commonly available in a p.c.b.-mount style, and these should be used whenever any mains wires or heavy load-carrying wires are to be connected to the circuit board. Many screw-terminal systems have the ability to interlock with a dovetail device, to enable the constructor to assemble much longer, multi-way terminals as required.

Often, individual wires (especially low current interconnections) are soldered directly to the p.c.b. which is perfectly adequate, but more elaborate boards may use multi-way crimp terminal blocks for terminating them. A "pin header" is soldered to the p.c.b. and various external wire connections are brought to the board through a matching socket assembly; this then enables the constructor to rapidly plug in or disconnect the board if desired.

The connectors often have a vibration-proof latch and also a polarising feature so that they will only fit one way round – there is no danger of accidentally reversing them. Multi-way plugs and sockets are of special use in commercial equipment where a faulty board can quickly be changed by a service engineer.

Unfortunately a special hand tool is generally required for the crimp connections, and they can actually be unreliable because the crimp itself can be too tight, eventually causing the wire conductor to fracture in service. The author has seen several failures in "professional" equipment due to this.

Other special connectors available include the popular "D" types with which computer users will be familair, and additionally the entire p.c.b. itself can be terminated in an edge-card pattern to enable it to be plugged into a matching socket mounted elsewhere. Again, computer users will be aware of "short" and "long" expansion sockets available on a PC motherboard, which permit extra boards (e.g. memory expansion or graphics boards) to be plugged in.

Finally, potentiometers are readily available with p.c.b.-mounting tags and it is common to design a board with a number of potentiometers mounted along one side. The threaded bushes of the pots. are then utilised to mount the board against the front panel of the project, so that the board does not require any other mounting hardware.

Fabrication

So having decided to build a project which utilises a printed circuit board, how can you make your own? There are essentially two methods available to the home constructor: a *"direct etch"* method and also a more advanced *"photo-sensitive"* system which employs ultra-violet light sensitive chemistry.

The basic process of fabricating a board starts with a "blank" board which initially is fully covered on one side with copper foil. We then coat the copper foil with the desired copper-track pattern (which will form the conducting tracks interconnecting the components) using a corrosion-proof "resist" ink. The uncoated area which remains represents unwanted copper foil which must be removed.

Removing this copper area is achieved simply by submerging the entire board into a highly corrosive chemical. This etches away all of the copper foil except the etch-resistant areas of the copper track pattern.

After etching, the resist coating is removed, leaving the required copper track layout. Finally, holes of suitable diameter (generally between 0.8mm and 1.3mm or so) are drilled as required to accommodate the lead-outs of the components which will afterwards be soldered onto the board.

The etchant most commonly used is Ferric Chloride and this is widely available from electronics suppliers. It is generally supplied in the form of crystals or granules which are added to water to produce the required solution. It is extremely corrosive and must be treated with respect, but is safe when used with common-sense precautions.

Direct Etching

The "direct etching" method of producing printed circuit boards is the simplest, and involves applying etch-resist directly onto the copper foil, the board is then processed to leave the required copper track on the foil.

This technique is fine for simpler one-off circuits, but it has the major disadvantage that all the etch-resist pattern must be removed from the board after etching has taken place – therefore the etch-resist is destroyed. If you want to make another board – perhaps you made a mistake or you want to incorporate a slight modification to the design – you have to lay down the etch resist all over again, a nightmare with complex circuits! The ultra-violet method to be described in detail next month allows you to retain the original artwork so that boards can be repeated or modified later on as required.

The basic steps for producing a single-sided board by the "direct etch" method are as follows. Firstly, a board of the required dimensions is cut from a plain copper-clad board. Generally 1.6mm thick uncoated (i.e. bare copper) board is used, with a copper density of 1oz. per square foot, and this should be suitable for the vast majority of projects, see Fig. 5.

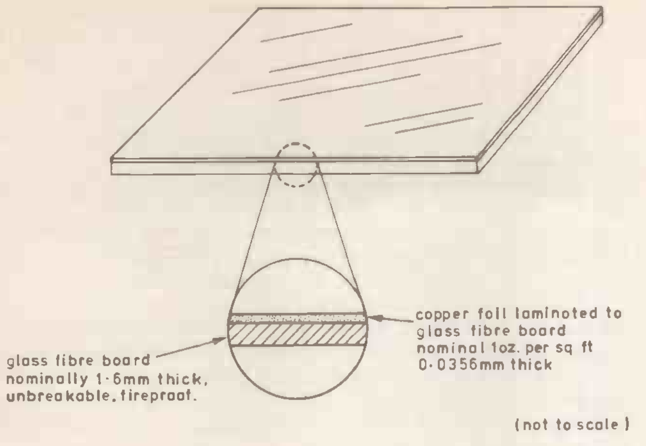


Fig. 5. Cross section of a typical copper-clad printed circuit board prior to processing.

The board is normally made from G.R.P. (fibreglass) which is extremely strong and virtually unbreakable. Paxolin may also occasionally appear, but this is extremely brittle and far inferior to fibreglass board.

The edges of the cut board are filed until smooth, to remove any copper burrs or rough edges; it is also not a bad habit to file off any sharp corners. Note that the dust produced by filing or cutting glass-reinforced plastic should not be inhaled and it is sensible to wear a nose-and-mouth dust mask as a precaution. The dust might also irritate sensitive skin.

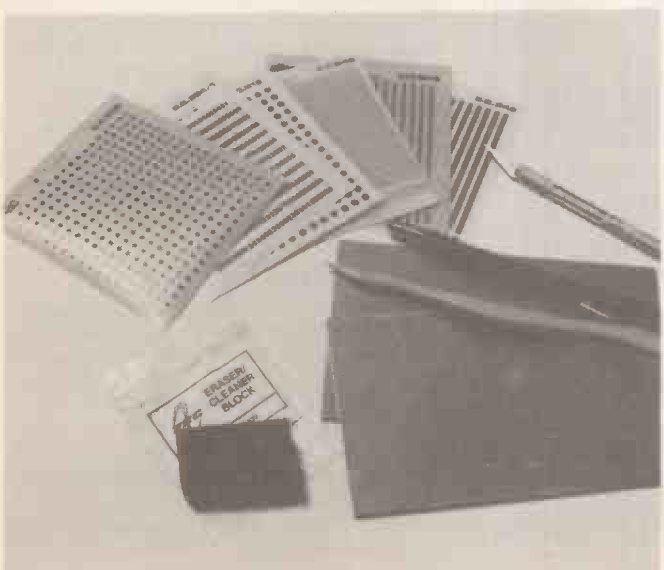
Having cut the board to size, the next step is to clean the copper foil thoroughly. Special rubberised abrasive blocks are available for this purpose and they are simply used like a small sanding block to remove any oxidation or other deposits which might interfere with the etching process. Other methods of cleaning up include the use of household scouring powder or a specially-made fibreglass brush. After thoroughly cleaning the foil, it is best not to touch the copper because acidic deposits and fingerprints left by the skin can tarnish the board again.

Layout

At this point the etch-resist pattern is now applied to the copper foil. The designer will show the required copper foil layout and this has to be transferred to your plain board. Each constructor may tend to have his own favourite way of doing this, and there are no hard and fast rules in this respect.

The principal requirement is that all the copper pads must be correctly distanced to accommodate the components. Although the actual distance between the components themselves may not be too critical, certain dimensions definitely are, such as the centres for radial-lead (vertically-mounted) electrolytic capacitor leads, integrated circuit pins or perhaps other p.c.b.-mounted gear like connectors or relays.

Materials reqired for preparing your own printed circuit boards ready for etching: Alfac transfers, scalpel, burnishing tool, Dalo Etch Resist Pen, cleaner block, copper-clad boards.



Copper-clad board, cut to size, being cleaned with an abrasive cleaning block.

One way to start with the etch-resist is to use a piece of tracing paper to copy from the designer's artwork layout (copper foil master pattern) and mark the centres of all the copper pads (to which components will be soldered). These centres are then transferred over to the copper foil of your p.c.b. using say an automatic centre punch (not on Paxolin) or a scriber to physically mark them through the tracing paper onto the copper.

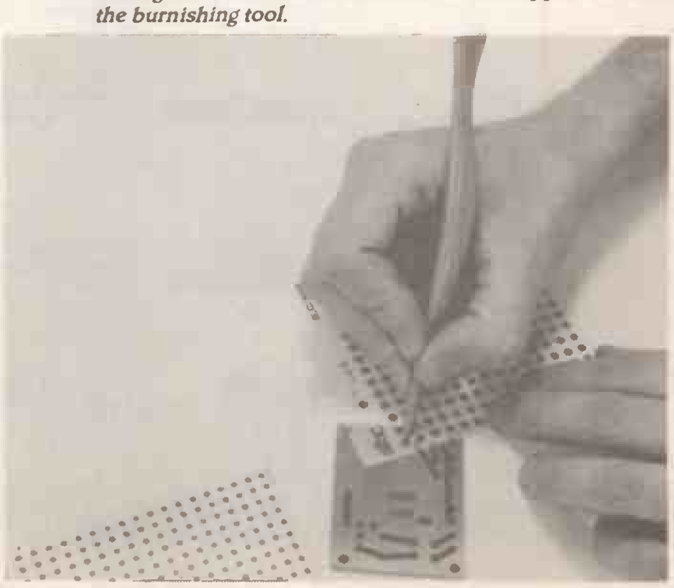
Transfers

The next requirement is to lay down etch resist transfers on the positions marked for the copper pad centres, and this is best effected with special etch-resistant transfers which are very similar in operation to the familiar "rub down" dry transfer lettering. Various different diameters are available and it is wise to use larger-diameter pads for heavier components or parts which have to carry high currents.

This will have been considered by the designer and the constructor simply rubs down the transfer circles of the appropriate diameter with a round-pointed implement onto the centres marked on the copper earlier, using the published artwork as a guide.

The author recommends the use of "Alfac" dry transfer etch-resistant symbols and these are available in various sizes and styles from electronic component suppliers. Probably the most useful circle pads

Adding Alfac etch-resist transfers to the copper foil with the burnishing tool.



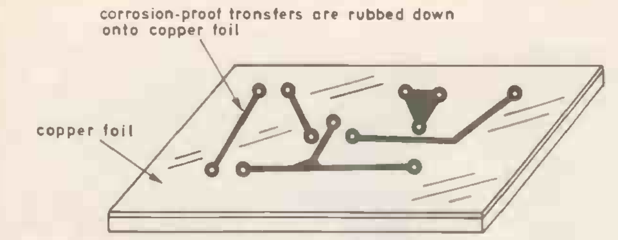


Fig. Fig. 6. Etch-resistant transfers are applied to the clean copper foil, in the desired layout of the copper track pattern. This is the "direct etch" and simplest method, of producing a p.c.b.

to buy are the Alfac EC910 (2.4mm diameter) and EC912 (3.6mm diameter), the former being a general purpose size.

Also available as transfers are a range of dual-in-line pads for integrated circuits (Alfac No. 994, for example). They allow you to accurately position all the pads of the i.c. preventing any misalignment. Some transfers have "through tracks" (e.g. Alfac No. 997) which simplify the task of having to route any tracks in between neighbouring i.c. pads. Transistor pads in TO-5/TO-18 "triangular" formation can also be put down in this way (Alfac EC961).

On Line

Continue putting down the etch-resist by adding the lines which interconnect the pads, following the artwork carefully, see Fig. 6. Again, special dry transfers are used in the form of straight lines, with various widths available. Generally, 0.8mm and 1.00mm widths are adequate for general use, with 0.4mm employed for fine work: wider 2.5mm lines might be used for conductors carrying heavier currents (say up to 5A or so) or which are at mains voltages.

Wider lines results in wider copper conductors which are able to carry more current, another aspect which the designer will have taken into account. Simply follow the artwork given.

The application of the dry transfer lines may require a little practice and you will probably develop your own technique. The author uses a scalpel to physically cut the etch-resist lines on the transfer sheet to the desired length, and the required portion of the line is then rubbed down onto the board with a burnishing spatula.

Doubtless you will have to apply several different lengths to copy the route of the tracks as per the artwork; it is a simple matter to cut the etch-resist to length, but when laying down a length to join onto the end of another strip – to form a bend in the route, for example – it is imperative that the lines butt up to each other properly, otherwise the result may be a break in the conductor when the board is etched, see Fig. 7.

It is also important to ensure that the transfers are not damaged when being applied, as any flaws (e.g. cracks in the transfer) will permit the etchant to eat away the copper at that point, perhaps resulting in weak points or complete breaks in the conductor.

Pen and Ink

An alternative to using transfers is to employ a special pen (e.g. the Dalo Etch-Resist pen) which contains etch-resistant ink so that the required pattern is simply drawn onto the copper to join up the pads as per the artwork. The flow of ink is controlled by pressing down the point to open the valve, releasing more ink.

These pens are fine for simpler circuits or quick one-offs but it is sometimes difficult to obtain consistent results. The etching process will reproduce any flaws in the etch resist ink which in extreme cases results in breaks in the copper conductor. Dry transfers give much sharper results and though it is worthwhile experimenting with such a pen, the author confines their use to manually "touching up" any etch-resist flaws prior to etching the board.

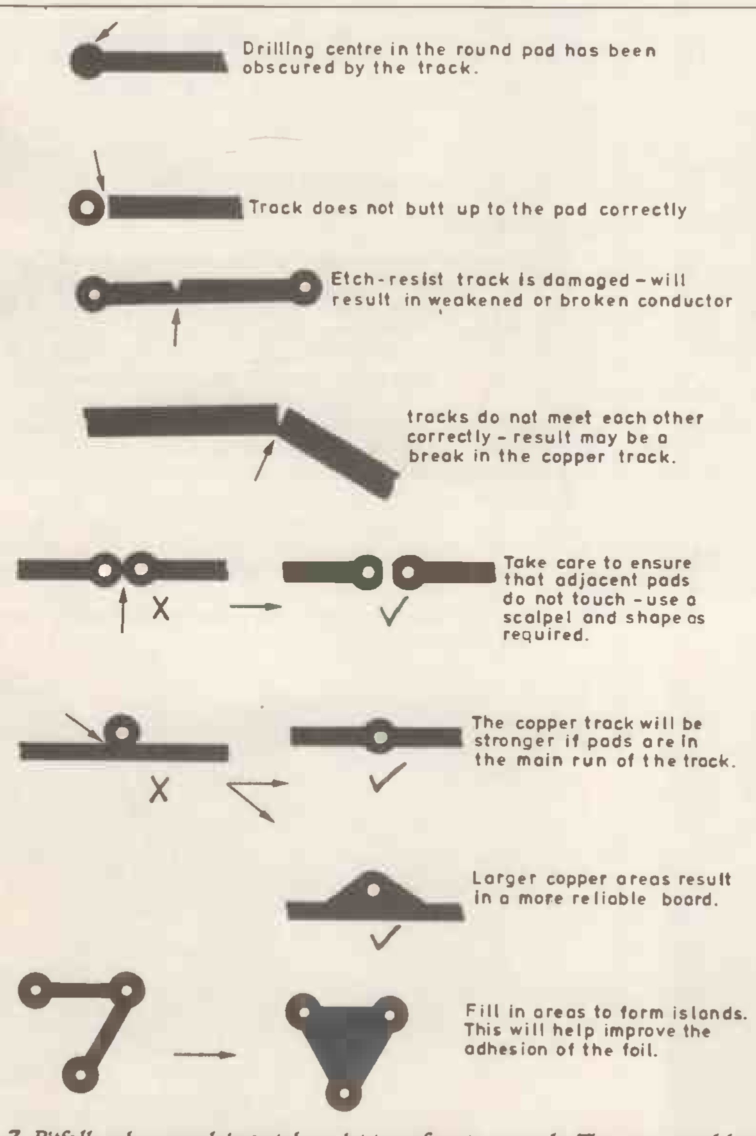


Fig. 7. Pitfalls when applying etch resist transfers to a p.c.b. The same problems can arise when preparing artwork for use with the ultra-violet method, described fully next month.

Etching Materials

Having laid down the desired etch-resist pattern onto the copper foil, the next stage involves the etching away of the remaining copper foil with, generally, Ferric Chloride solution.

You will require the following basic materials to etch your circuit board safely:-

- Two plastic trays with pouring lips, of the type used by photographers for developing prints.
- A pair of plastic tongs, again available from photographic suppliers, or plastic tweezers.
- Two plastic spoons or scoops (one for handling raw etchant, another for stirring the solution).
- Ferric Chloride Etchant – available from electronics suppliers in the form of granules, crystals, or ready made solution.
- Disposable polythene gloves or gauntlets, and a pair of safety goggles (not glasses) to protect eyesight from splashes.
- Glass or plastic bottles with plastic screw caps, for storing etchant, and a plastic funnel.

Handle With Care

As every chemistry student will know, the *correct way* to prepare a solution is to *slowly add the chemical to water,* and NOT the other way round – otherwise any intense chemical reaction which ensues would cause concentrated Ferric Chloride to be thrown out.

Etching should be carried out in a well ventilated place on say a garage workbench or perhaps a work surface covered with plenty of newspaper. Unless you have bought ready-mixed etchant, prepare the etchant solution as follows:

Wearing safety goggles and gauntlets, pour a quantity of warm water into one of the trays, and fill the other tray with cold water. The latter try will be used for rinsing boards.

Using a plastic scoop, place a *little* Ferric Chloride at a time into the warm water, stirring gently and mixing the crystals throughout the water. The reaction is exothermic, generating some heat as the crystals dissolve into the water – hence only add a *small* scoopful at a time to prevent any excessive "local" heating.

Continue to add the Ferric Chloride until the required strength is obtained, stirring continuously. As a guide, use two or three parts (by weight) warm water to one part Ferric Chloride. Hence a maximum strength solution would consist of 500 grammes of Ferric Chloride and one litre of water. A weaker solution will only result in longer etching times.

Storage

Having made the etchant solution, you should always observe the following storage and handling precautions:-

The product is of course highly corrosive – keep away from any metal surfaces (e.g. taps or kitchen fittings). The (invisible) fumes emitted are corrosive also, over a long period of time.

Store etchant in airtight glass or plastic vessels only. CLEARLY MARK THE CONTAINER WITH A WARNING LABEL ("Corrosive, Irritant."). Keep locked away from children!

Anhydrous (dry) Ferric Chloride crystals and pellets, being deliquescent, have the ability to draw moisture from the atmosphere and turn itself into a corrosive solution! Hence, never store even dry product in a metal container because it will corrode through.

Ferric Chloride must be KEPT OFF THE SKIN and away from the EYES. It is extremely irritant, and stains the skin (and almost everything else, for that matter) a yellow/brown colour which can be hard to remove.

In case of spillage, wash down with plenty of water as soon as possible. If any etchant is ever splashed into eyes, rinse with copious amounts of water immediately (use that cold water tray!) and seek medical attention if any irritation persists.

Etching

Still wearing goggles and gloves, to etch the printed circuit board, use plastic tongs or tweezers to place it gently into the solution, copper side up. The copper areas of the board will turn salmon-pink as the etchant attacks it, and to speed the process occasionally agitate the board gently to wash away copper particles.

The speed of the etching also depends on the temperature of the solution, but will take approximately 10 minutes or so with fresh etchant.

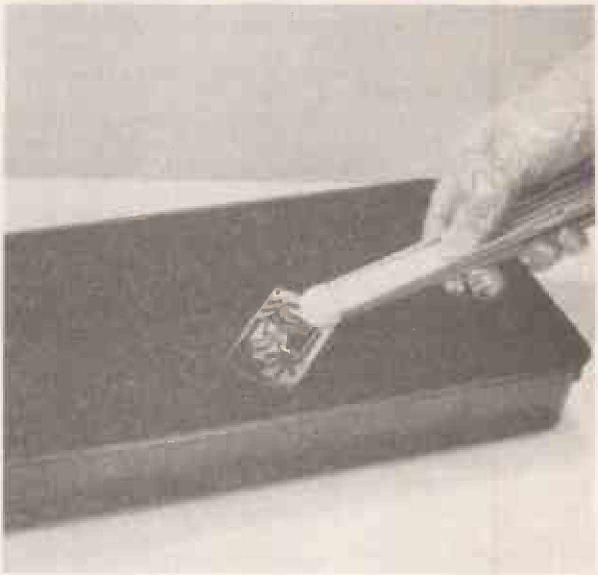
When all the unwanted copper foil has been etched away, remove the p.c.b. and place it into the clean water tray for rinsing. The etchant can be stored in a suitable vessel for future use, rinsing the etchant tray and any utensils with clean water.

The etchant does have a finite life and with use you will notice that the etching period does lengthen. When it takes more than say 20-25 minutes or so, it is time to dispose of the solution, and this can be done by diluting it considerably and pouring down an open outside drain, accompanied by running water. Never pour neat product away without watering it down extensively.

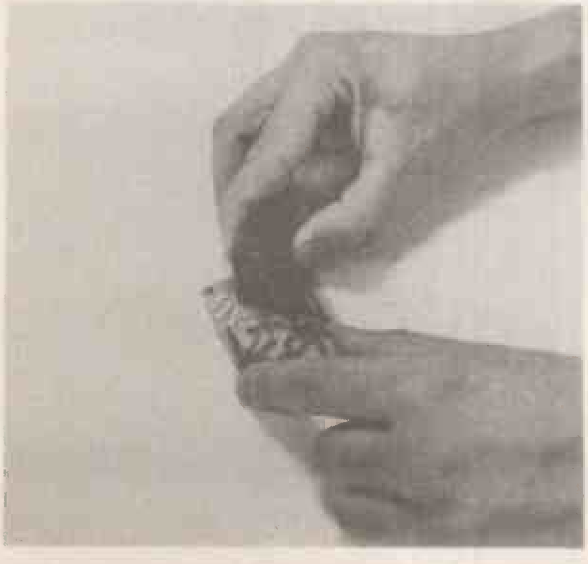
Cleaning Up

Having successfully etched the board, see Fig. 8, the next stage is to

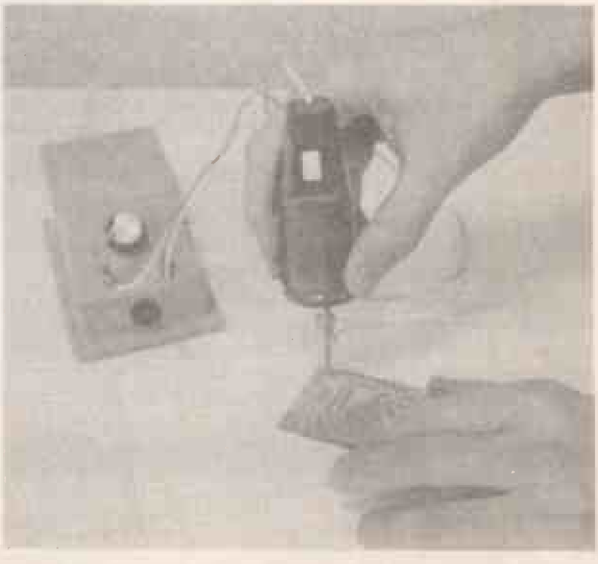
Materials for etching printed circuit boards: plastic trays, Ferric Chloride crystals, plastic tongs, goggles and disposable gloves.



Removing the p.c.b. from the etching solution. Gloves and goggles are sensible precautions.



The etched board is rinsed with clean water and then the Alfac tranfers can be removed with the cleaner block.



Drilling the board with a low-voltage mini drill; note the mains adaptor.

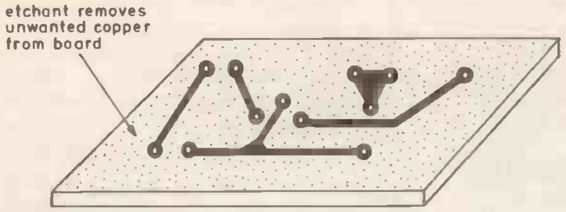


Fig. 8. The board, with etch-resist transfers applied, is placed into a corrosive liquid (Ferric Chloride) which removes all the copper except that protected by the resist. Notice the layer of copper foil has disappeared from the cross-sectional view (compare against (Fig. 6).

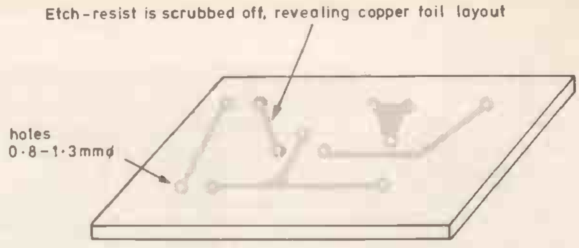


Fig. 9. After etching is completed, the resistant transfers are removed to expose the copper tracks underneath. Holes are drilled with a mini-drill to accommodate component leads and the completed p.c.b. can be protected with a coat of spray-on lacquer.

remove the etch-resist transfers in order to expose the copper track pattern underneath (compare Fig. 8 with Fig. 9). Do this by rubbing the board with the abrasive cleaning block.

Remove any etch-resist ink with acetone (e.g. nail varnish remover) on a cotton wool swab. Solvents can also be used instead of the abrasive block to clean off the transfers.

The Right Drill

The final step to making your printed circuit board is to drill out the copper islands or pads to permit the components to be fitted, see Fig. 9. The following table summarises the generally-used diameters of holes required for particular components:-

DRILLING DIAMETER	*TYPICAL COMPONENTS*
0.8mm	general discrete components including smaller resistors, capacitors, transistors, i.c. pins/sockets, miniature trimmer resistors etc.
1.0mm	larger electrolytic capacitors, trimmer resistors and potentiometers, flying leads, bridge rectifiers etc.
1.3mm	larger trimmer resistors, p.c.b. mounting transformers, fuseholders, screw terminal blocks, large rectifiers (1N5401 etc.), power transistors etc.

As you will see, the diameters are rather small and it is difficult to drill such fine holes accurately with a handheld "gearwheel" drill – and impossible with a standard electric drill!

Mini Drill

Special miniature low-voltage drills are available which have various sizes of collet available which fit into the miniature chuck to hold these twist drills. The drills require an adaptor to operate from the mains because battery operation is not feasible. Often a variable-speed adaptor is used (see the author's Drill Control Unit, EE August 1985 for instance).

It will be found that glassfibre board is very demanding indeed on normal "high speed" twist drill bits, and high-speed tungsten tipped or diamond tipped twist drills are preferable as these offer much longer life.

A miniature drill stand is often available as an accessory to improve accuracy, but these are not strictly necessary. Perfectly good results are obtainable by using a handheld drill with the p.c.b. resting on a block of wood.

Use the central hole in the copper pad to act as a starting point for the twist drill and drill through the board taking about two to three seconds. Check that you have not missed any pads as there is nothing more irritating than discovering an undrilled pad, halfway through soldering the board!

Finally, don't forget to drill holes of appropriate diameter to accept the p.c.b. mounting hardware, if any, after which your printed circuit board is complete and ready for soldering.

Etching Kit

The reader may by now have reckoned that etching your own printed circuit boards in an open tray could be fraught with potential problems, although the system is certainly safe enough provided that due care is taken.

One excellent alternative which has been available for many years is the unique Seno GS sealed system for etching printed circuit boards, which is available from several suppliers. Although it is more expensive than mixing your own etchant in an open tray, it is strongly recommended by the author because there is no direct contact with etchant and no etching trays are required. It permits safe storage of the hazardous etchant (in an expanded polystyrene box) for an indefinite period and it also contains a neutraliser to render the spent solution harmless, ready for disposal.

The Seno GS system is ideal, therefore, for etching your own boards at home. The basic system is shown in Fig. 10 and consists of a heavy-gauge polythene tube, heat-sealed at one end. The system originally contains dry Ferric Chloride granules at the bottom of the bag, to which 250ml. of water is added. Special slide-in seals are applied to the polythene in the middle and at the open end, and the etchant solution is retained in the "bottom half" of the tube when not in use, being safely and conveniently sealed in.

The one disadvantage with this product is that larger boards cannot be accommodated by the polythene tube, and the maximum size board is about 200mm x 130mm.

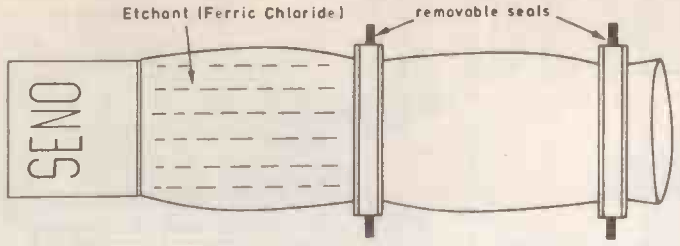
In The Bag

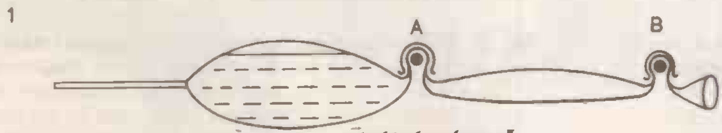
The prepared p.c.b. is placed in the top half of the bag, in between the two slide-in seals. The middle seal is then removed to release the etchant into the rest of the tube and over the p.c.b., which is then etched – there is adequate etchant to process some 1600cm^2 of board.

After etching has been completed, the etchant is drained to the bottom of the bag and it is then safely crimped in again by replacing the middle slide-in seal. The end seal is then opened to gain access to the board, and clean water can be poured in to rinse the board before removal from the tube. The p.c.b. is then cleaned and drilled as normal.

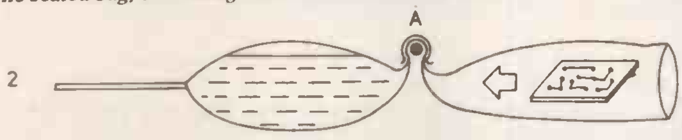
One way to increase the etching speed is to warm the polythene tube with a hair drier (!) to increase the temperature of the etchant. Some other tips: It is essential that the board does not have any sharp corners or burrs which could puncture the polythene, and it is a good idea to place the tube on several sheets of newspaper to act as a cushion. Also, to avoid the polythene from being unduly weakened with use (leading to leakage), apply the slide-in seals at differing positions from time to time instead of using exactly the same place.

The unique Seno GS sealed system for etching boards. The neutraliser powder is added to the exhausted Ferric Chloride and the bag can then be safely thrown away.

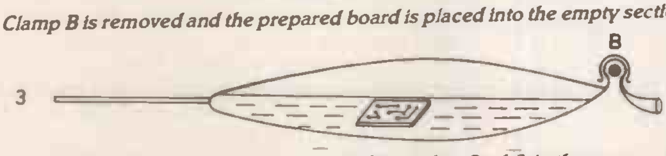




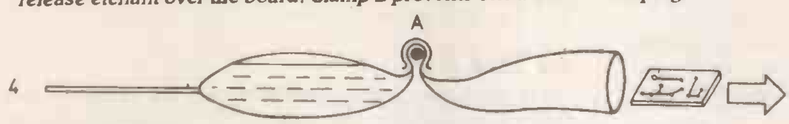
The sealed bag, containing etchant sealed in by clamp A.



Clamp B is removed and the prepared board is placed into the empty section.



Clamp B is replaced to seal the end of the tube. Seal A is then removed, to release etchant over the board. Clamp B prevents etchant from escaping.



After etching (15 minutes), the etchant is moved to the bottom of the tube whilst the p.c.b. is retained near the top. Clamp A is replaced to seal in the etchant once more. B is removed, to gain access to the etched board. Clean water can be poured in to rinse it before it is removed.

With use the Ferric Chloride solution will eventually become laden with iron, slowing down the etching time and when the etchant has finally been exhausted, a neutralising powder (supplied) is added to the solution which is eventually transformed into a solid mass for safe disposal.

Tinning

One further process which the more advanced constructor may wish to use is to "tin" the etched printed circuit board. Commercial boards may be roller-tinned in a bath of molten solder but it is possible to tin a home-made board with a chemical deposition. This lays down a silver-coloured coating onto the copper of the etched p.c.b., which prevents the tracks from oxidising, and also makes the job of soldering quicker and easier.

Several rather expensive compounds exist for the job, including crystals which dissolve into water and others which require the addition of hydrochloric acid – hardly the sort of materials you would use at home!

A tin-plating system is, happily, available to complement the Seno GS system described above and this works in the same way as the Ferric Chloride etchant.

Be Sensitive

Having described the basic method of etching a printed circuit board, *next month* we will be looking in detail at the more advanced processing techniques which utilise ultra-violet light-sensitive chemicals and which offer high-quality results, with the added bonus of letting you retain an artwork "master" so you can make or modify subsequent boards.

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FRIDGE WARNING

T. R. de VAUX BALBIRNIE

Keep an eye on your fridge or freezer temperature

AT THE time of writing, fridge safety is in the news – a proposal that new ones should be fitted with a thermometer. This is because it is essential to maintain the cabinet temperature of a fridge at 5°C and a freezer at −18°C maximum. Above these temperatures dangerous levels of bacteria can form quite rapidly.

The Fridge Warning circuit is a mains-operated electronic thermometer giving a continuous read-out of temperature on a large pointer-on-scale meter. It also gives an audible warning should the temperature rise above a preset level. It has a back-up battery so that the audible warning section will continue to work in the event of mains failure.

A temperature read-out may also be obtained using the back-up battery by means of a pushbutton switch. The battery should last for at least a year if the device has not been required to sound a warning very often.

The main section of the circuit may be mounted any reasonable distance from the fridge – it could monitor in the kitchen the temperature of a fridge or freezer situated in the garage, for example. It is, of course, necessary to have a mains socket close to the position of the main unit.

As described, the meter has a scale covering the range −20°C to +10°C which makes it suitable for both fridges and freezers. However, it would be a simple matter to narrow the scale – for example, 0°C to 10°C for a fridge or −20°C to −10°C for a freezer.

You will need to borrow a glass mercury thermometer accurate to 1°C for setting-up purposes. This should read down to −20°C if the device is to be used with a freezer. Many laboratory thermometers show a minimum of −10°C but the scale may be extended by simple measurement and a temporary extension scale stuck into position.

Apart from the intended use, this circuit could have other applications – for monitoring the temperature inside a greenhouse, for example. By suitable adjustment, the circuit, as described, may be used to display temperatures in any range from −20°C to +40°C.

TEMPERATURE SENSOR

The temperature sensor itself consists of a thermistor probe placed inside the fridge or freezer. This plugs into the main unit using a "power-in" type socket. The interconnecting lead may be of any light-duty twin variety and of any reasonable length – the prototype was tested with wire up to 20 metres long.

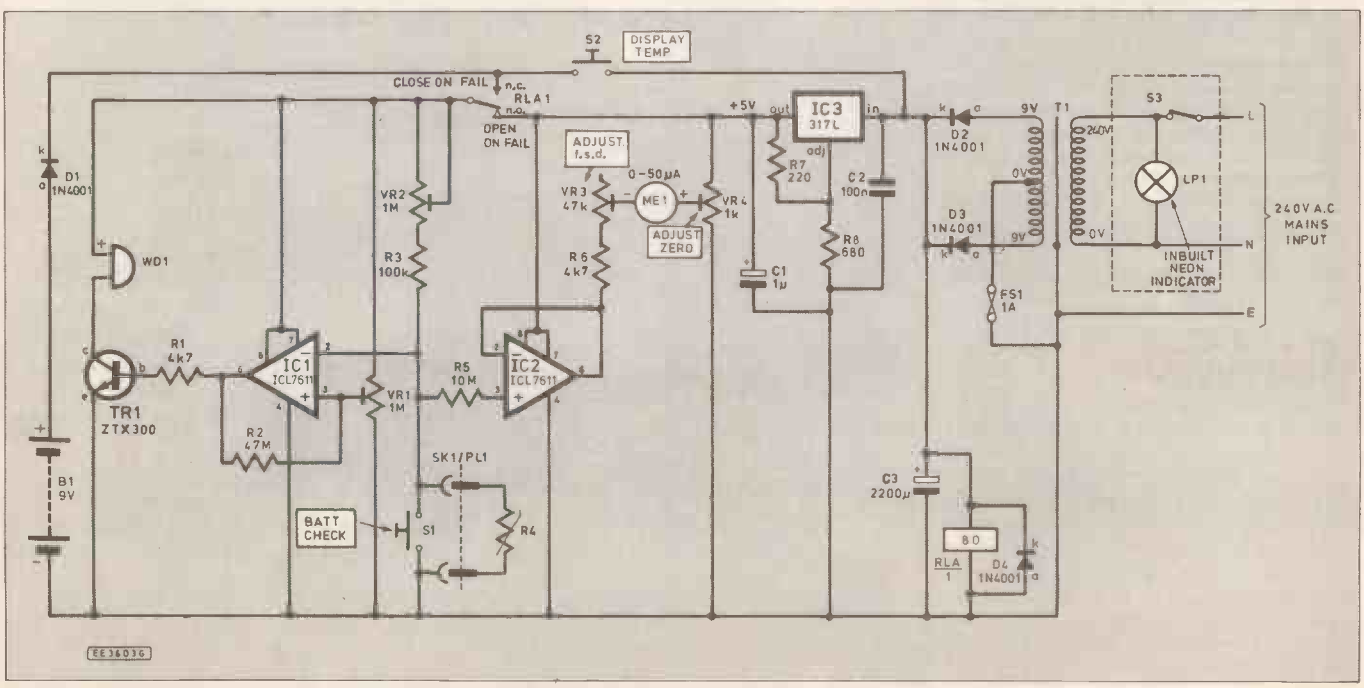
The sensor wires must NOT interfere with proper operation of the fridge door seal. Warm air must not be allowed to enter the cabinet since this would lower the efficiency.

It would be a good idea to check how the sensor wires will be routed into the cabinet before proceeding with construction work. It often happens that pipework passing through to the inside has enough clearance to allow thin wires to be inserted alongside. If this is done, any sealing compound used for gap filling must be pressed back into position again.

The author found a plastic drain plug at the bottom of the cabinet. A hole was drilled in this just large enough to accommodate the wires and this proved to be an excellent way of doing the job.

Note that constructing the Fridge Warning involves making mains connections. *Any*

Fig. 1. Complete circuit diagram for the Fridge Warning. When the supply is switched on the normally open relay contact (n.o.) will be closed, as shown here.



reader who is unsure of being able to make a safe job must consult a qualified electrician. In particular, the main section must be built in an Earthed metal case. The unit is connected to the supply using a fused plug and must not be permanently connected to the mains.

CIRCUIT DESCRIPTION

The complete circuit for the Fridge Warning is shown in Fig.1. The circuit uses two identical low-power CMOS input op-amps, IC1 and IC2. IC1 is concerned with the low-temperature audible warning and its action will be described later. IC2 operates the thermometer display.

Thermistor, R4, is the temperature sensor. This has a negative temperature coefficient – that is, its resistance falls as the temperature rises.

Assume for the moment that the circuit is receiving power with RLA1 contacts closed in the "open on fail" position as shown. Thermistor R4 forms the lower section of a potential divider with the upper limb consisting of fixed resistor, R3, and preset potentiometer, VR2.

This divider arrangement is connected across the supply so, as the temperature rises, the voltage at IC2 pin 3 falls. This voltage will depend on the temperature of R4 and the adjustment of VR2.

By connecting the output of IC2 pin 6 to the inverting input, pin 2, a voltage follower is formed. This means that the voltage applied to the non-inverting input, pin 3, is duplicated at the output, pin 6. Microammeter, ME1, together with fixed resistor, R6 and preset potentiometer VR3, form a type of voltmeter circuit which responds to this voltage.

Resistor R6 and preset potentiometer VR3 control the current passing through the meter ME1 which then flows to preset VR4 sliding contact and hence to the negative supply line. VR4 has little effect on the current whatever the position of its sliding contact because it has a low resistance compared with R6, VR3 and the resistance of ME1 itself. In controlling the current flowing, VR3 sets the full-scale deflection (f.s.d.) of the meter for any given temperature.

The purpose of preset VR4 is to shift the meter zero. In the prototype unit this was −20°C but is freely adjustable. At this temperature IC2 pin 6 will have a certain voltage output which would normally give a reading on ME1. VR4 is connected as a potentiometer across the supply and at the end of construction will be adjusted to provide an equal voltage to that at IC2 output at the temperature at which the meter is required to read zero. Both ends of ME1 will now be at the same voltage and the meter will pass no current – that is, it will read zero. The meter is thus connected in a bridge arrangement.

AUDIBLE WARNING

As well as operating the meter, the potential divider containing the thermistor applies the same voltage to IC1 inverting input, pin 2, as was applied to IC2 pin 3. At the same time, a preset fixed voltage is applied to IC1 non-inverting input, pin 3, by the potential divider action of preset VR1.

As IC1 is connected as a comparator, if the non-inverting (pin 3) input voltage is greater than the inverting one the output, pin 6, will be high (positive supply voltage). In other cases it remains low.

Preset VR1 will be adjusted at the end of construction so that the non-inverting input voltage is just less than the inverting one when the temperature sensed by thermistor R4 is just below the maximum safe level. When it rises above this, the voltage appearing across the thermistor falls and becomes less than that at the non-inverting input.

The op-amp IC1 now switches on and current flows through current-limiting resistor R1 to transistor TR1 base. Audible warning device, WD1, in TR1 collector circuit now sounds. Resistor R2 applies a small amount of positive feedback to IC1 non-inverting input and this results in a sharp switching action at the critical temperature.

POWER SUPPLY

With mains On/Off switch S3 on, the circuit receives power from the mains by a conventional power supply arrangement of step-down transformer, T1, full-wave rectifier diodes, D2/D3, smoothing capacitor, C3 and fuse, FS1. This develops an output of 10V d.c. approximately and is applied to the input of voltage regulator, IC3.

The regulator provides a steady nominal 5V at the output which acts as a supply for IC2 and VR4. This is necessary because absolute voltage levels control the current flowing through ME1 and hence the accuracy of the temperature reading.

The regulator used in the prototype was an adjustable one – the exact voltage output is programmed by fixed resistors R7 and R8. This was found to provide better performance than a fixed 5V regulator.

While a mains supply exists, relay RLA is energized because its coil is connected direct to the supply before stabilisation is applied. The relay's normally-open contact (n.o.), (Open On Fail), will therefore be closed and, providing switch S2 (Display Temp) contacts are open, no current will flow from standby battery, B1.

On mains failure, RLA coil fails to energize and the normally-closed (Close On Fail) contact (n.c.) "makes". Current now flows from the back-up battery, B1, through diode, D1, to the audible warning section centred on IC1. Thus, the low-temperature warning section continues to operate.

Note that IC1 does not normally use a stabilised supply on mains failure. This is acceptable since both op-amp inputs are derived from the same source and, as the battery ages, the voltage at each will fall in like manner. Switching will therefore occur at the same temperature whatever the supply voltage.

This method avoids the continuous quiescent current drain of the regulator and other parts of the circuit. During mains failure conditions IC2 (the meter section) is normally off since RLA1 "open on fail" contacts are open. This saves the back-up battery.

On mains failure, the back-up battery supplies 8μA approximately and this may be regarded as negligible. When the alarm sounds, the current rises to 8mA approximately and the internal battery can provide this for several hours if need be. The battery should be replaced as a matter of routine if it has sounded for a prolonged period and in any case, annually.

If during mains failure a temperature reading is required, pushbutton switch S2 (Display Temp) is operated. This directs current from B1, through D1 to the voltage regulator IC3 input. The relay coil energizes, RLA contacts "make" and the rest of the circuit operates as it would if the mains were connected.

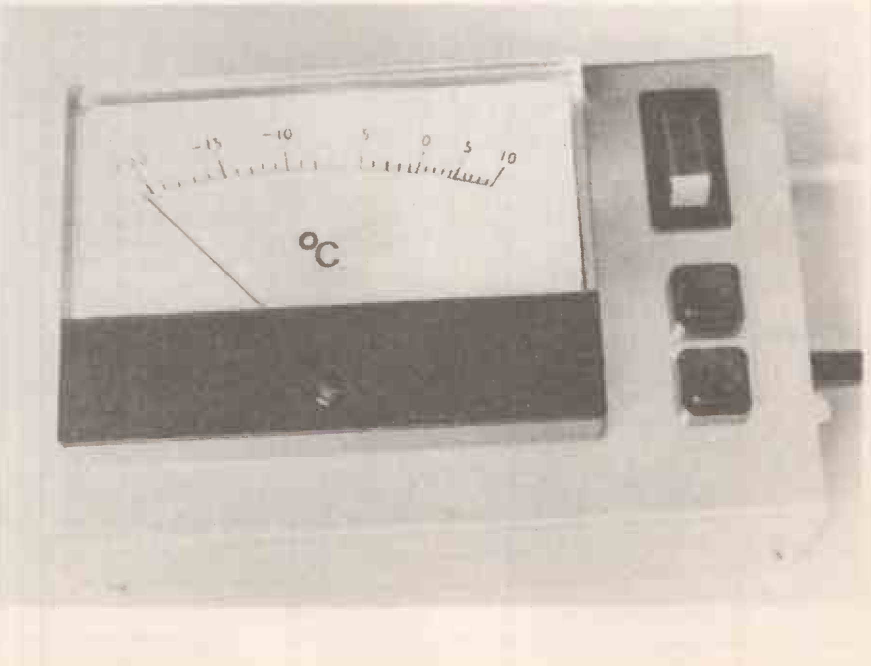
Diode D1 ensures that a reverse current cannot flow into battery B1 if, for example, switch S2 were pressed by accident while a mains supply existed.

Also current from the battery B1 cannot pass back into the transformer secondary windings since diodes D2 and D3 are reverse biased. While providing a temperature reading, the current requirement rises to approximately 80mA so this should only be done briefly and not very often.

Diode D4 by-passes the high-voltage "spike" which occurs when the magnetic field in the relay coil collapses. This could otherwise cause failure of semiconductor components in the circuit.

Switch S1 provides a battery check. When pressed, this connects IC1 inverting input to the negative supply line – that is, to zero volts. This voltage will therefore be less than that at the non-inverting input whatever the temperature sensed by thermistor R4. IC1 therefore switches on and warning buzzer WD1 sounds. This check should be carried out every so often.

The completed unit showing the large meter scale.



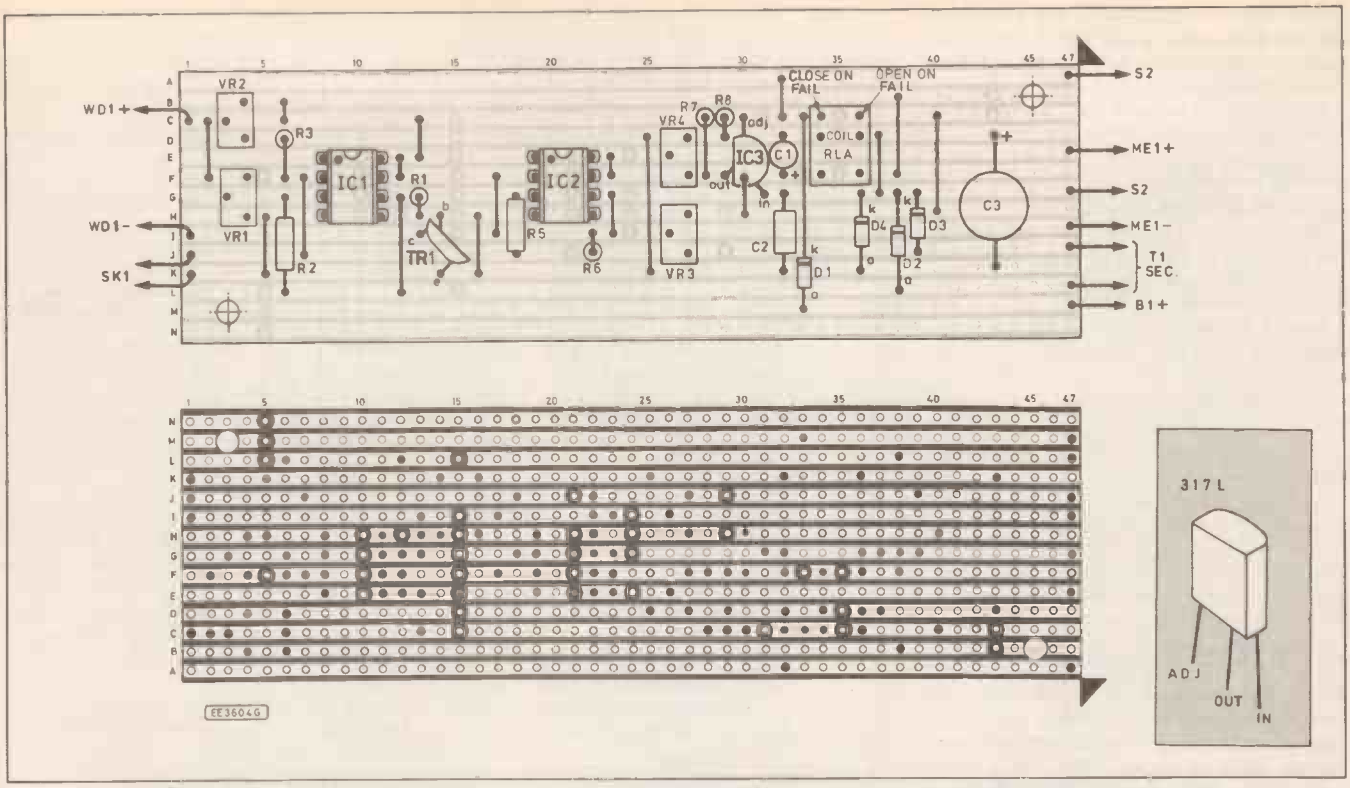


Fig. 2. Stripboard component layout and details of breaks required in the underside copper strips. The leadout details for the voltage regulator IC3 are shown on the right.

Note that an alkaline PP3 battery is specified for back-up purposes but this is only suitable for light-duty use. Where checks are made frequently or where the alarm may be required to sound for long periods, it would be better to use a larger type of 9V battery. If this cannot be accommodated inside the case, an external battery could be used.

This project justifies a good quality moving coil meter – do not use a small scale or cheap instrument. A meter having a four inch scale was used in the prototype unit and this can be clearly read at a distance.

CONSTRUCTION

Top and underside details of the Fridge Warning circuit panel are shown in Fig.2. This uses a piece of 0.1in. matrix stripboard, size 14 strips x 47 holes.

Drill the two mounting holes and make all track breaks and inter-strip links as indicated. Solder the on-board components into position taking care over the polarity of all four diodes and of electrolytic capacitors C1 and C3.

The high value of R2 specified (47MΩ) can be constructed (near enough) using five 10MΩ resistors connected in series. Alternatively, a single 47MΩ or 50MΩ resistor may be used but these are not always easily available. High value resistors are sometimes described in suppliers' catalogues as "high voltage" resistors and these would be suitable.

Complete construction of the circuit board by soldering 15cm. pieces of light-duty stranded connecting wire to strips *J1* and *K1* on the left-hand side and to strips *A47*, *E47*, *G47* and *I47* along the right-hand side as indicated. Solder the positive wire of the battery connector to strip *M47*. Use of different coloured leads will help greatly in preventing wiring errors.

Connect WD1 positive and negative wires to strips *C* and *I* respectively at the left-hand side. Adjust preset VR1 fully clockwise (as viewed from the edge of the circuit panel) and presets VR2, VR3 and VR4 to approximately mid-track position.

CASE

Prepare the case by making the large circular hole needed for the meter. This is best done by marking its position then drilling a series of holes around the circumference. These are then joined together using a small hacksaw blade and the edge filed smooth.

Drill the holes for meter mounting, switches, transformer, fuseholder, terminal block, power-in socket and for circuit panel fixing. Drill the two holes for WD1 mounting and a larger one between these for the sound to pass through. Drill a hole and fit the rubber grommet which will be used to prevent the metalwork from cutting the mains lead.

Mount all remaining components and complete the internal wiring as shown in Fig.3, shortening any wires as necessary. If socket SK1 is of a type having one terminal

COMPONENTS

Approx cost guidance only **£28**

Resistors

R1, R6	4k7 (2 off)
R2	47M or 50M (or 5 off 10M) – see text
R3	100k
R4	Miniature bead thermistor, resistance 47k at 25°C – see text
R5	10M
R7	220
R8	680

All 0.25W 5% metal film, except R4

See SHOP TALK Page

Potentiometers

VR1, VR2	1M min. enclosed carbon preset (2 off)
VR3	47k min. enclosed carbon preset
VR4	1k min. enclosed carbon preset

Capacitors

C1	1µ radial elect., 16V
C2	100n disc ceramic
C3	2200µ radial elect., 16V

Semiconductors

D1, D2, D3, D4	1N4001 50V 1A rect. diode (4 off)
TR1	ZTX300 *npn* transistor
IC1, IC2	ICL7611 low-power CMOS op.amp (2 off)
IC3	LM317LZ adjustable voltage regulator

Miscellaneous

T1	Miniature mains transformer: 240V primary and 9V-0V-9V secondaries (or twin 9V secondaries); 100mA rating
S1, S2	Miniature push-to-make switch (2 off)
S3	Mains rocker switch, with neon indicator
PL1/SK1	2.1mm power-in plug and matching chassis-mounting socket
RLA	Miniature relay with 6V 80ohm coil and single-pole changeover contacts
FS1	20mm chassis fuseholder and 1A quick-blow fuse
ME1	50µA 100mm scale moving-coil meter – resistance 4300ohms
WD1	High power piezoelectric buzzer, impedance 1k. Operating frequency 3kHz.

Aluminium case, size 152mm x 102mm x 51mm; plastic case for thermistor, size 50mm x 37mm x 24mm; 0.1in. matrix stripboard, size 14 strips x 47 holes; PP3 9V Alkaline battery and connector clip (see test); 3A 2-way screw terminal block (2 off); 2A fuse for mains plug; single-strand connecting wire; 3A mains wire; rubber grommet; strain relief clamp; solder tag; solder etc.

Glass mercury thermometer for calibration – see text connected to the metalwork, this should be the one connected to the solder tag. Note that this terminal is a meeting-point for several wires being connected to "earth".

The mains input lead should be made from a piece of 3-core mains-type wire of 3A rating minimum. This should be passed through the grommet noting that the earth wire (E) is connected to the solder tag at one of the transformer fixings. *Make certain this connection is sound and cannot dislodge in service.* Attach a strain relief clamp so that the wire cannot be pulled free.

Similar mains wire should be used for connecting the illuminated rocker switch S3 to terminal block, TB1. If a type of mains switch other than that specified is used, it is essential to fit a separate neon indicator. Attach a mains plug to the free end of the mains wire and fit it with a 2A fuse.

At this stage you need to check that the case fits together properly. Look out for short-circuits and trapped wires especially at the mains connections. Make any adjustments as necessary then dismantle it again before proceeding.

ADJUSTMENT AND TESTING

Safety Note: All adjustments are made using the back-up battery with the unit unplugged from the mains. When the unit is connected to the mains, the lid of the case must remain on.

You will need plenty of patience during the setting-up stage since the adjustments of the presets are to some extent interdependent. However, VR2 will probably be left with the sliding contact set to mid-track

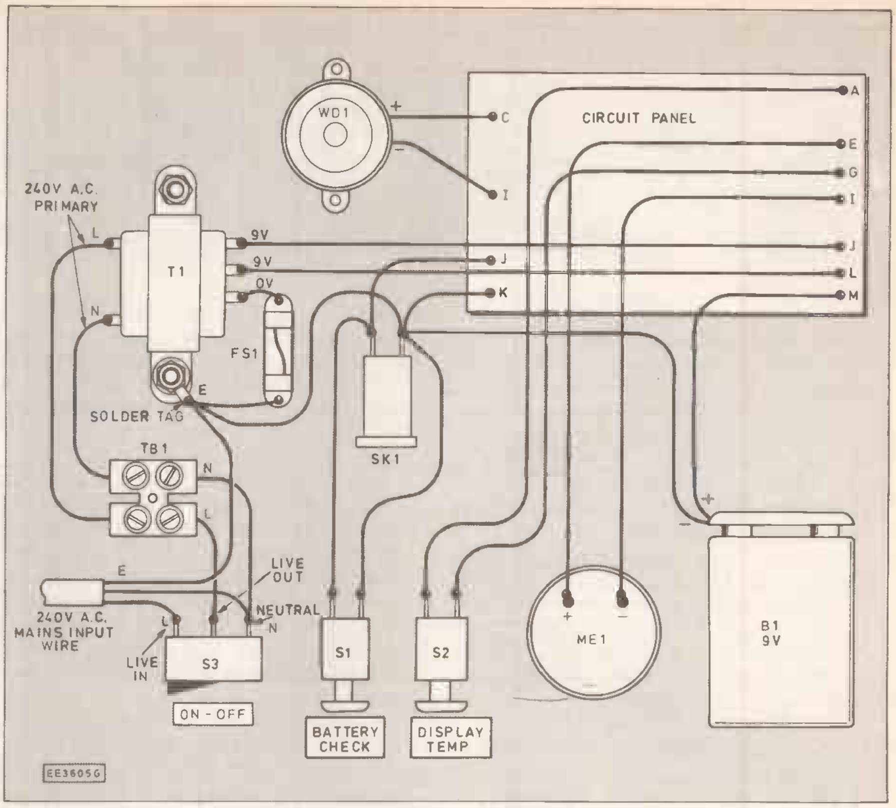
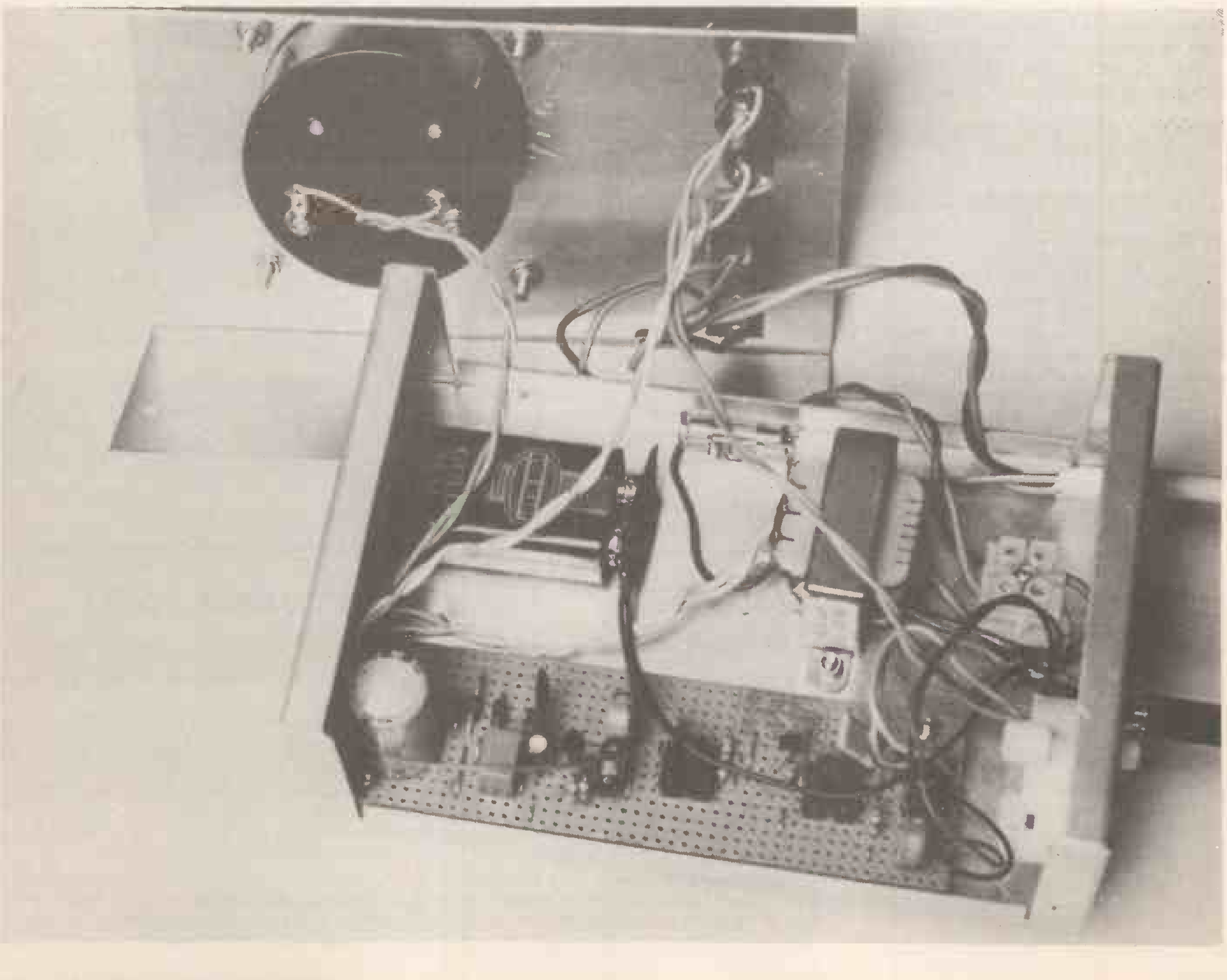
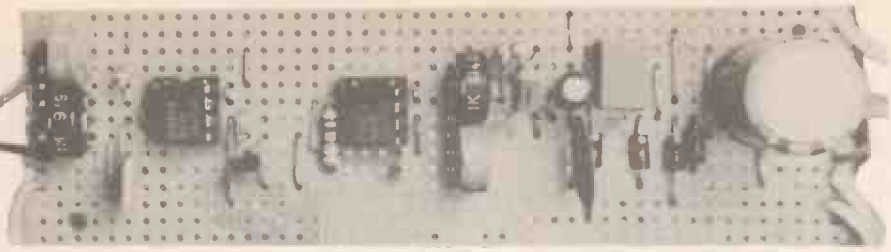


Fig. 3. Interwiring from the circuit board to the case mounted components. Mains 3A wire should be used for connecting the illuminated On/Off switch to the screw terminal block TB1. The completed unit, with cover removed, is shown in the photograph below. The thermistor is housed seperately in a small plastic box.





position unless a different temperature range is being measured.

In addition to the thermometer mentioned earlier, you will need a small drinking glass (100cc approximately) half-filled with cooking oil. You will also need a small piece of bare connecting wire or a crocodile clip with which to short-circuit switch S2. This enables setting-up to be carried out without having to press the button.

Connect a *new* alkaline battery for the back-up supply. An old battery may fail to provide temperature readings which correspond accurately to those obtained under mains conditions. It would be a good idea to connect a larger 9V battery to the circuit temporarily – this would save the back-up battery during prolonged testing.

Connect the thermistor to a short piece of light-duty two-core wire for the moment and solder the power-in plug to the other end. Plug this into the sensor socket SK1.

Place the glass of cooking oil with the thermometer in it in the freezer and wait for the temperature to stabilize. It should fall to −18°C or lower. Remove it and place the thermistor R4 in the oil so that it is fully submerged. Short circuit S2 terminals so that the meter gives a reading.

Stir the oil (which will now be very thick) gently with the thermometer. Assuming the oil is at −18°C, VR4 should be adjusted so that the meter reads 5μA – this is to allow −20°C to be added later.

Now wait as the oil rises in temperature stirring frequently and thoroughly. At 10°C, adjust VR3 to provide full-scale deflection (50μA). You will now have to re-check the zero and re-adjust VR4 if necessary then re-check the full-scale reading.

By a process of back-and-forth checks on the high and low points you will obtain the correct readings. If the pointer moves in reverse – that is, the reading rises as the temperature falls, the meter has been connected the wrong way round and the connections to its terminals should be reversed.

Now comes the job of filling in intermediate points on the scale. This cannot be done by simple measurement because the scale is non-linear – that is, equal steps on the scale do not correspond to equal temperature changes.

In the case of the prototype, this meant that each degree corresponded to 2μA at the low end and 1μA approximately at the high end. Calibration should be carried out at temperatures of −15°C, −10°C, −5°C, 0°C, +5°C and +10°C. The −20°C point will be filled in by common sense at the end.

Start with the oil at freezer temperature again and submerge the thermistor and thermometer bulb in it. Keep stirring with the thermometer and watch the temperature continuously. When it reaches −15°C, note the reading on the scale. Do similarly as the temperature rises to the other calibration temperatures. This procedure should be modified for any other range of temperature required.

In tests on the prototype, temperatures up to 40°C could be accommodated but for such temperatures, VR2 will need to be adjusted fully clockwise (as viewed from the edge of the circuit panel). For measuring high temperatures, it may be an advantage to use a thermistor with a higher resistance – 150kΩ at 25°C for example.

The unit should now be checked on mains operation. *For this, the case must be fully assembled.* If the battery was in good condition, the readings obtained under mains operation should agree closely with those obtained with the battery supply – to within 1°C in the case of the prototype unit.

To make the new meter scale, first remove the meter front cover – this just "snaps" off. Do this with care so that neither the pointer nor the meter movement is damaged in any way.

Now remove the two small fixings securing the old meter scale and, with extreme care, remove it completely. Be particularly careful to avoid bending the pointer.

Mark out a new scale on good quality paper using the old one as a template. For best results, use a fine drawing pen and dry-print lettering. You will be able to fill in the single degree markings and −20°C by common sense.

White-out (Tippex typewriter correction fluid) the old scale lettering before sticking the new scale in place – this will prevent the original numbers showing through. When this has been done, re-attach the scale, again with great care.

AUDIBLE WARNING

Preset VR1 should now be adjusted so that the warning buzzer operates at the correct temperature. It is suggested that for a fridge this should be 8°C approximately and for a freezer, −15°C. Setting the temperatures too close to the operating temperature will mean that the unit sounds unnecessarily – when the fridge door is opened, for example. VR1 is adjusted clockwise (as viewed from the edge of the circuit panel) to raise the operating temperature.

The thermistor R4 now needs to be de-soldered from its temporary connecting wire and mounted in a small plastic box so that it will not be damaged when inside the fridge or freezer. The specified box is large enough to accommodate two sections of a 3A screw terminal block to which the connections are made (see Fig.4).

The box should be drilled with a matrix of holes to allow the free passage of air around the sensor so that the unit responds rapidly to changes in temperature. Apply strain relief to the connecting wire with a cable clamp inside the box.

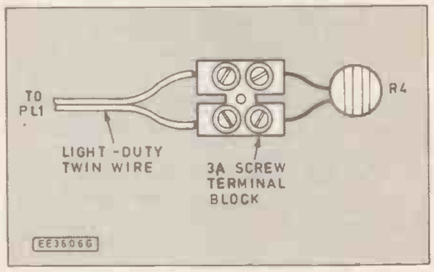


Fig. 4. Suggested method of mounting the thermistor inside a small box using a two-way terminal block.

Long wires between the main unit and the thermistor are sometimes prone to mains pick-up. This shows by the buzzer coming on with a warbling sound.

This is of no consequence but if it proves to be annoying it can be practically eliminated by connecting a 220nF capacitor in parallel with the thermistor. The capacitor can be soldered inside the main unit but it is much easier to connect it to the terminal block inside the thermistor unit.

If failure of the fridge occurs so that the cabinet temperature rises to room temperature (20°C approximately), this will exceed the full-scale reading of the meter. However, this will not cause damage. Note that it is normal for the case to become slightly warm during operation. □

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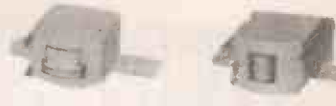

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ACTUALLY DOING IT!

by Robert Penfold

THERE is a famous quotation from Benjamin Franklin which goes "But in this world nothing can be said to be certain except death and taxes". For the electronic project constructor there is a third certainty, and this is the occasional project that fails to work first time! If you are not very diligent at checking over new projects before switching them on, you may well find that the number of failures substantially outnumber the successes.

Fortunately, when a project fails to work first time the solution to the problem is often something very simple. When something goes wrong we would all like to think that it is someone else's fault, but I think it is true to say that most projects which fail to co-operate when you first switch them on have an error which is the fault of the constructor.

When things go wrong you must try to be positive in your approach, and set about finding the mistake (or mistakes) you have made. Telling everyone that it is the fault of the project designer or publisher may be more fun, but it will not get the project working. If a thorough check of the wiring etc. fails to locate a problem, it might then be worthwhile contacting the publisher of the project to see if there is a known problem with the design in question.

CLASSIC MISTAKES

I will not try to give a complete course in project fault finding in this article, which would definitely not be possible in an article of this size. On the other hand, there are some classic errors which we all make from time to time. Experienced project builders know the tell-tale signs, and can often rapidly locate the problem when a finished unit fails to perform. Here are some classic symptoms together with the usual causes.

BACK TO FRONT

A potentiometer control (such as a volume control) works "backwards".

There are three terminals on a potentiometer; the track terminals (the outer two) and the wiper terminal (the middle one). If you get the connections to the track terminals swapped over, the project will still work, but the control will work "backwards" (e.g. advancing a volume control will actually reduce the volume).

ERRATIC

A potentiometer gives erratic operation. For example, a volume control might work after a fashion, but with an odd control characteristic and distortion at low volume levels.

This is often indicative of the wiper and one of the track terminals having been connected the wrong way round. In a volume control application this can provide control of the volume by loading down and virtually short circuiting the output of the preceding stage (hence the distortion!).

A control which uses a dual gang potentiometer works properly at mid settings, but goes completely haywire towards the ends of the adjustment range.

Over the years I have received quite a few readers' letters complaining about this type of thing. It is usually the result of getting the track connections to one gang of the potentiometer connected the wrong way round. At a middle setting this makes no difference. As the control is adjusted away from the mid-point the two gangs go further and further out of balance, and the circuit fails to work properly.

SWITCHED

A project works after a fashion, but (say) none of the ranges of a piece of test gear seems to give sensible results.

In days gone by rotary switches were awkward to use. It was very difficult to tell which wiper tags were grouped with each pole tag. These days it is much easier as the pole (or wiper) tags are normally marked "A", "B", "C", etc., and the connecting tags are marked "1" to "12". With a six-way two-pole switch for example, tag "A" is grouped with tags "1" to "6", and tag "B" is grouped with tags "7" to "12".

Unfortunately, when wiring up these switches it is still very easy to make mistakes, because it is often difficult to see the tag markings. In particular, it is very easy to get all the connections to the outer ring of contacts shifted one tag away from their correct placement.

When wiring up these switches the normal method is to put in the connection to tag "1", and then work your way through to tag "12". If you accidentally make the first connection to the wrong tag, then the subsequent connections will all be wrong as well. There is then no option but to disconnect all the wires and reconnect them to the right tags.

Sometimes a project can seem to be totally inoperative when it is in fact fully operational. It is just that switch positions are the opposite way round to what you are expecting.

For instance, what you think is the *npn* setting of a transistor tester might actually be the *pnp* setting, and vice versa. You would then test transistors with the unit always set to the wrong mode, and it would seem as though the unit was failing to work at all. With switches it is not a bad idea to check them with a continuity tester (see last month's issue) prior to installation, just to make sure that everything is as expected.

HOT AND BOTHERED

The smell of hot components. Most people who pursue project construction as a hobby soon develop a keen sense of smell which will soon detect any hot components.

Except where something should be getting hot, such as a project which uses power semiconductors, always switch off at once when overheating components are discovered. The quicker you get to the on/off switch, the better the chances of the heated components surviving the experience.

When overheating occurs it is usually some of the semiconductors that become heated, and in most cases it is the integrated circuits that are the problem. Surprisingly perhaps, most semiconductors seem to be able to withstand quite high powers for short periods without sustaining damage. Provided you switch off the power before something gets seriously overheated, there may well be no damage to the components.

There are numerous possible causes of overheating, but checking the polarity of the battery or power supply unit is a good starting point. Many integrated circuits place a virtual short circuit on the supply lines if the polarity is reversed, and getting the supply round the wrong way will therefore produce a massive current flow. If just one integrated circuit gets hot, then it is probably fitted the wrong way round.

SOCKET

I am often asked why I (and many others) recommend using sockets for all d.i.l. integrated circuits, regardless of whether they are expensive or static-sensitive. The answer is a very simple one, and one that it is worth mentioning yet again.

It is very easy to inadvertently fit an integrated circuit the wrong way round. If it is fitted in a socket there is no difficulty in gently prising the device free and reinserting it with the correct orientation. Removing a d.i.l. integrated circuit that is soldered direct to a printed circuit board can be very difficult indeed.

Even if you have proper desoldering equipment it can be very difficult to remove integrated circuits which have 14 pins or more. It also pays to bear in mind that a fault could develop at some time, and that it might then be necessary to replace an integrated circuit. This is straightforward if it is in a holder, whereas you risk seriously damaging the circuit board and other components if it is not.

There are a couple of other points worth checking if overheating occurs. With a mains powered project check carefully that the rectifiers are connected the right way round. Getting the rectifiers round the wrong way reverses the polarity of the supply's output. Check for short circuits on the underside of the board caused by solder blobs or splashes. Pay particular attention to the pads of any integrated circuit that is getting heated.

HUM!

Clearly excessive mains "hum" from a mains powered audio project.

Switch off immediately if there is a large amount of "hum" on the output of a mains powered audio project. This often gives early warning of an overload on the power supply, with things about to heat-up (literally).

Apart from making the checks on the integrated circuits, etc. that were mentioned previously, check the large smoothing capacitor in the power supply circuit. Possibly one of the connections to the capacitor is a "dry" joint, but more probably it will be connected with the wrong polarity. Be warned that a smoothing or supply decoupling capacitor connected the wrong way round can quickly overheat and burst open with considerable force.

LIGHTS OUT

One or more l.e.d.s fail to light up when they should.

These components have tended to be troublesome ever since they were first introduced. These days most l.e.d.s have the cathode (k) lead shorter than the anode (a) one. Also, there is usually a "flat" on the cathode side of the body. However, I have encountered l.e.d.s which do things the other way round, and there are some which, rather unhelpfully, seem to be completely symmetrical.

If a l.e.d. fails to work, the most likely explanation is that it is connected round the wrong way. Even if a check of the wiring suggests that an unco-operative l.e.d. is connected correctly, it might still be worthwhile trying the opposite method of connection. It is highly unlikely that getting the polarity of a l.e.d. wrong will do it any harm, so it is quite acceptable to adopt trial and error with these components.

SILENCE

Silence or just "hiss" type noise from an audio project.

When problems with a lack of signal occur with an audio project I usually investigate the plugs and sockets sooner rather than later. If the background "hiss" is present, it is likely that everything is all right on the output side of the circuit.

Getting the connections to an input socket wrong can short circuit the input of the project, giving little or no output. In some cases getting these connections swapped-over will result in a lot of "hum" and general noise (possibly including breakthrough of strong radio transmissions) on the output.

Cables with broken wires are not exactly a rarity. If possible check the input lead using a continuity tester. It is a good idea to check for short circuits between one lead and another, as well as checking for a lack of continuity through each lead.

If there is genuinely no output at all from an audio project, the output socket is the first thing to check. Where the output socket of a power amplifier is an insulated type, such as a two-way DIN loudspeaker socket, it does not matter which way round it is connected. This is not strictly true for a stereo amplifier, where you should ensure that both sockets are connected with the same "polarity" so that the phasing of the loudspeakers is the same.

If an output socket is a non-insulated type (i.e. one tag connects to the chassis of the project), getting the connections round the wrong way will short circuit the output. This is unlikely to do any damage if the project is something like a signal processor which provides a low power output, but it could be disastrous with a project that has a power amplifier at the output.

With any project that provides significant output powers you really must be very careful when adding the output wiring, and should thoroughly check this part of the unit before switching on. Output leads are no more reliable than input cables, so check that the output lead is providing a proper signal path.

TOTAL FAILURE

A project does nothing at all. Here we really do mean absolutely nothing at all (e.g. not even a "click" from the loudspeaker or a brief flash from a l.e.d. at switch-on).

This could be due to a fault on the circuit board or in the wiring, but I would be inclined to investigate the battery and battery clip first. I frequently have problems with battery clips where one press-stud does not make proper contact with its counterpart on the battery. Some careful squeezing of the female connector in some pliers usually clears the problem, but a few combinations of battery and connector seem to have incompatibility problems. There is then no option but to change one or the other.

Some battery clips seem to be perfectly all right when a lead has in fact come adrift from its press-stud. Pulling firmly on one lead and then the other should detach a lead that is not properly connected. You can cut most battery connectors open and repair them quite easily, but it is probably best to reserve this for emergency use. Fitting a replacement will give neater results with no risk of accidental short circuits.

Is the battery in a useable condition? If possible use a battery tester or multimeter to check that it is providing something close to the right voltage. Bear in mind that just because a battery just about manages to power one gadget, it will not necessarily be able to power your latest project.

Some circuits are very tolerant of low supply voltages, and they consume very low currents. These will work with batteries that are what would generally be considered "flat". Other circuits take large supply currents and shut-down if the battery voltage drops more than a few percent below its nominal potential. The old batteries from such devices will often power other units quite happily for many hours. Always try to use reasonably fresh batteries in new projects.

On/off switches are not the most reliable of components. I stopped using slider switches many years ago due to the low quality of many of these components. They worked after a fashion, in that they would go properly into the "on" position if you managed to get the slider knob in just the right place.

More recently I have experienced problems with a number of the smallest size of miniature toggle switch. Some of these switches only seem to work very intermittently, if at all.

Switches are easily checked using a continuity tester. With a mains powered project **remember to unplug the unit from the mains *before* testing the switch.**

The most classic of classic mistakes is to forget to switch on. It may sound ridiculous, but sooner or later everyone seems to somehow convince themselves that a project is switched on when the on/off switch is definitely in the "off" position!

STRIPBOARD

A stripboard based project fails to work.

I used to build large numbers of projects on stripboard, and I have to admit that it was quite a long time before one of them worked first time. In most cases the problem was simply one or two accidental short circuits between adjacent copper strips due to some excess solder. A fair percentage of these solder blobs were so small as to be virtually undetectable visually. Even using an 8X eye lupe did not always reveal the problem.

I found that a continuity tester was the best way of detecting the presence of short circuits. A sharp modelling knife was then used to score between the two offending strips if the solder blob was not visible.

FINALLY

As with most things in life, it is better to work on the basis of prevention is better than cure. I have to admit that I am not very meticulous about checking newly constructed projects prior to switch-on. On the other hand, where the mains supply or high powers are involved, I thoroughly check everything at least *twice*. Not to do so would be fool-hardy.

FOR YOUR ENTERTAINMENT

by Barry Fox

CELLPHONE CAPACITY

At the end of 1989 subscribers to both BT's Cellnet and Racal's Vodafone cellphone services were complaining about failed calls. Too many people were trying to use too few frequencies at the same time. Because all available frequencies have been allocated, the only answer is to re-use the same frequencies more efficiently, splitting existing cells into smaller cells, either by building extra transmitters or making the beam coverage of existing transmitters more directional.

Cellnet believes that the best way to measure system capacity is to compare the number of subscribers round the country with the number of channels created by frequency re-use. Cellnet's average at November 1989 was 35 subscribers per channel. After spending £200 million on modifying and adding transmitter sites (to a total of around nearly 800) Cellnet now claims just 17 customers per channel. But in this respect any cellular service is a victim of its own success, and temporarily benefits from a degree of failure. A few years ago Cellnet was earning a reputation for failed calls, which is one reason why Cellnet now has around a hundred thousand subscribers less than Vodafone.

There is currently a 20 percent "churn" of people who start using a cellphone because it is cheap and then discover how expensive it is to use. Cellphones that used to cost over £2,000 can now be had for a few hundred pounds or even free. This is because the service providers or "wholesalers" who sell the phones, also buy air time from the cellular networks and sell it on to the customer at a profit. Also both networks pay a connection bonus of between £200 and £250 to the service provider for every subscriber signed on.

CHARGES

Cellnet charges a one-off connection fee of £50 for every subscriber signed onto the network. The SP can charge the subscriber what he likes. Sometimes this is the flat £50, other times £60. The monthly connection fee is £25 a month, again the SP can charge what he likes. Some charge £30 a month.

Call rates at peak times are 33p a minute inside the M25 ring, and 25p outside the ring. Off-peak all calls are 10p a minute. Again the service providers can charge what they like; British Telecom's own subsidiary, BTMC, charges 27p and 35p. Also the subscriber can break up the minute in any way he wants, for instance so that a 61 second call is billed at two minutes.

Cellnet just gives the service provider a data tape, showing each subscriber's usage and the SP collects the money, usually with a 20 per cent or 25 per cent mark-up. This explains why so many firms are now selling cellphones so cheaply. It's the old, give away the razors and make money on the blades, ploy.

Vodafone does not set so much store on the customers-per-channel rule of thumb, arguing that what really matters is getting enough channels in the right place, for instance the M25 where people make calls from a traffic jam. Vodafone's current average however is around 22 per channel, with 1991's investment £130 million.

Vodafone also makes the interesting point that at the moment network capacity is not a problem for anyone. The recession has slowed subscriber growth, but the infrastructure has kept on growing, like a supertanker that takes miles to slow down. Vodafone reckons that at the moment system capacity is 25 per cent or 30 per cent above customer needs.

The big question for the future is how much further can the network expand, i.e. how small can the cells be split to accommodate more subscribers? Cellnet believes that its current network can cope with one million subscribers,

VIRUS TRAP

Most publishers, of books and magazines, now use an electronic editing system. They then send discs of edited copy to the printers. To save time on copy-keying, the publishers ask contributors to send in their text on floppy disc. The discs are then returned after use.

Recently things took a new and nasty turn. I got a call from a publisher (not the one responsible for this magazine) to whom I submit copy on disc. The whole company had been shut down by a computer virus which had got into its system.

"Be careful with the discs we have returned to you" warned the publisher "we think the virus got into our system from discs which the printers returned to us. They had been infected from discs sent by another magazine. One of those discs may have been yours. So it has been sent on to you".

So far viruses have infected a PC by waiting for the owner to switch on with a disc already in the floppy drive. The PC tries to boot up from the floppy and fails, displaying an error message like "not a system disc". By this time the virus program has run and transferred a copy of itself to the Paritition table of any hard disc in the PC. From then on the virus transfers itself to any floppy as soon as the PC reads its directory. On a preset date (like Michelangelo's birthday for the Michelangelo virus) the virus overwrites the hard disc with random data. The hard disc must then be re-formatted and all programs and data re-loaded from backups.

Any full disc "image" backup of the hard disc will also be infected. Only separate data file backups are safe.

The publisher warned that the virus he had suffered worked in an even more sneaky way. Once the infected floppy was put into a computer, e.g. to delete old files and save new ones, it transferred to the hard disc. In theory, this should be impossible. In practice I would not want to rely on it.

Virus check programs exist, but there is no guarantee that they will check for a new virus which has been designed to fool a checker. Michelangelo can, for instance, get past Version 1 of Norton's Antivirus. Only Version 2 traps it. Who knows what the next virus will be and what tricks it can play.

So what can people do when they are returned used discs, other than destroy them? I reckon the following is a foolproof plan. Can anyone see any loopholes?

Every time a used disc is returned to me, I now re-format it. But I do not use my workhorse PC, which has a hard disk because I fear there may one day be a virus that can infect before it is wiped out by formatting. Instead I use a cheap portable PC that has only one floppy disc drive and no hard disk; its DOS operating system is permanently stored in ROM. I format the disc and then cold start (Cntrl;Alt;Del) or switch off to clear everything from RAM. So there is nowhere for the virus to hide, and the newly formatted disc is guaranteed clean. So I know I am safe to save to the disc and anyone who takes the disc knows it is safe to read.

If everyone went through this procedure, before exchanging discs, there could be no exchange of viruses – assuming of course that their own workhorse system is clean at the start.

Or am I missing something?

with possible further expansion to 1.5 million, still using only existing frequencies.

DIGITAL EUROPEAN

The grand plan was originally that by the mid-90s both networks would be turning to the new all-digital GSM service for which frequencies in the 900MHz band have already been allocated. This will be a pan-European service which allows subscribers to carry cellphones round Europe, making calls on the move with billing back home. GSM is also more efficient in frequency use. Although the first generation GSM cellphones will transmit and receive speech at 16Kb/s later models will work at half speed, 8Kb/s. This makes the system up to six times more efficient in its frequency requirements than the existing analogue system.

But there are significant problems with GSM. Systems are now running in Germany and Finland, but only with test phones. Both Vodafone and Cellnet were committed to launching a commercial GSM service by mid 1991, later revised to mid 1992. Vodafone has had service trials running in London since December 1991 but GSM receivers are still large and cost around £2000. Cellnet has now put its GSM service on hold until 1994. In chicken and egg fashion this gives no incentive to provide national cover, which in turn does nothing to create the volume sales of GSM cellphones which will drive down price, size and weight.

Vodafone is pushing harder on GSM than Cellnet, because the company plans to launch a service within a service. MCN, or Microcellular, cellphones will be small hand-portable, built to the GSM all-digital standard and operating on the GSM frequencies. They will work in very small cells, in city areas. So the handsets can transmit at low power, and thus use small batteries. The call tarriff will be lower than for the full Vodafone network, too. In this respect MCN rivals the PCN (Personal Communications Network) system which Mercury and others plan to launch in a year or so. PCN phones will be all-digital, using GSM technology, and rely on small cells. On the face of things it is hard to see any future for PCN. On the face of things, too, Cellnet has missed a trick on MCN.

If GSM/MCN becomes a commercial success, there will be a risk of congestion on the GSM frequencies. Cellnet and Vodafone will then have to start taking blocks of frequencies away from their analogue service and using them for GSM/MCN digital. The long term theory is that both Cellnet and Vodafone will eventually have converted their full 20MHz frequency allocation in the 900MHz band to digital operation.

But all this starts to sound a lot like the long term theory of satellite television, with viewers switching from old PAL to new MAC and later High Defintion MAC. There is an equally good chance that viewers will still be watching PAL well into the next century, perhaps the improved widescreen version, PAL-Plus. The same thing could happen with cellphones, with the analogue systems still running long after the theorists had predicted a fullscale changeover to digital GSM.

EVERYDAY READOUT

REGULAR-RADIATION

Dear Ed.,

I have had *Everyday Electronics* now for a number of years and although I have now retired I still get it regularly and make up some of the circuits.

However, I am interested, and I think a number of your readers would be also be interested, in an article on a circuit to detect any radiation leakage from a microwave oven.

Over the past I cannot remember ever seeing an article for this application.

R. S. Cox
Dudley

Your wish will hopefully be our command, we will ask one of our contributors to investigate and produce a suitable project. We should however warn you that it will be quite a few months before a design will be published.

AUDIO TELESCOPE

Dear Ed.,

I noticed with interest Mr Penfold's article for an *Audio Telescope* in the April issue of *Everyday Electronics*. This is an area of the electronics field which could be very useful to a person in my predicament.

I suffer from a severe loss of hearing in both ears, and as such find it difficult to take part in conversations, debates, etc, the commercial hearing aids available are mostly of little use as they simply pick up the loudest noise in the vicinity which may not be in the immediate company.

I know from speaking to staff at the local hearing aid clinic that the proportion of people affected by this disability is as high as three out of five.

Do you think any of your contributors could come up with something to help us youngish hard of hearing persons to take part in normal conversations?

G. I. Smith
Edinburgh

The Audio Telescope *circuit can be used in this way, simply connect up a couple of extra microphones (repeat the circuit of C1, R1, MIC1, C2) using twin core screened lead – positive, output and 0V screen. Then place each microphone near to the people speaking, in this way you can concentrate on the speech near each microphone. Please let us know how you get on.*

KIT IMPORTERS

Dear Sir,

Upon reading your magazine we notice that you have many advertisers selling electronic kits, plans etc.

We have been offered the opportunity to import and distribute a range of products that do not seem to be catered for in this country. These kits and plans include a very wide range of items, from neon driver systems, Tesla coils, plasma bolts, ultrasonic devices, magnetic cannons, etc.

Could you give us the benefit of your experience as to whether this sort of thing has simply not reached us yet, or whether it is not available because nobody wants it?

Any comments you may have would be very helpful

Brian Cox
Torquay

Over to our readers, please let us know if these types of kits/plans would be of interest, we can then pass on the information.

WRONG ADDRESS

Dear Ed.,

As readers of the *Interface* article are to be encouraged to run some form of control program next month, it would be helpful if the address decoding described in the August '91 issue, page 512 were corrected to:

OUTPUT	ADDRESS	RANGE
0	300h	307h
1	308h	30Fh
2	310h	317h
3	318h	31Fh

There are four errors in the table, two of which could cause the wrong chip enables to be active for a given address, which might just throw beginners.

With beginners in mind, I have placed an advert in your magazine, offering to supply the necessary double sided p.c.b., or completed I/O card, allowing people to program the interfaces described by Mr Penfold in his series over the past few years, and hopefully in detail in the months to come. As many column inches have been used to describe the lack of suitable easily available hardware, I would appreciate a mention if Mr. Penfold considers it appropriate.

Richard Bartlett
Coventry

Mr Bartlett is correct, and the address ranges are as stated in his letter (giving four blocks of eight addresses). Clearly a case of me not knowing my hex from my elbow! Apologies for the careless mistakes in this table. Robert Penfold.

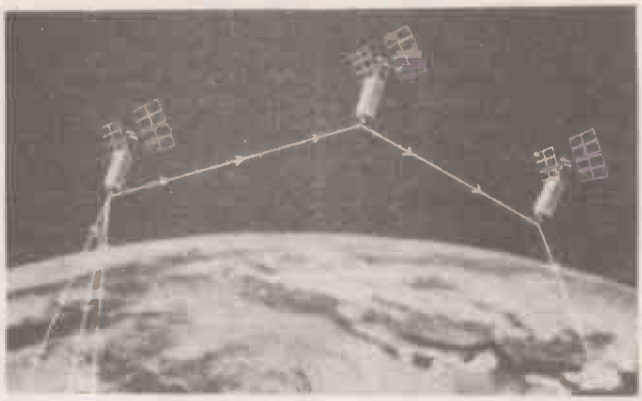
EVERYDAY NEWS

GO-ANYWHERE TELEPHONES

Ian Graham reports on future developments in cellular telephones

The portable telephone has become one of the status symbols of the successful modern business person and an essential communications tool to countless companies. From tree surgeons to stock marketeers, the portable telephone enables them to keep in touch when they're on the move.

Until now, there has been little in the way of standardisation in cellular telephone technology. Take a British phone to Paris, Bonn, Sidney or New York and it probably won't work. But now, two new systems promise to end the portable phone's national exclusivity. One, called GSM (Groupe Special Mobile), will establish a single common cellular telephone standard throughout the sixteen European countries *(see For Your Entertainment for more details – Ed).*



When placing a call on the Motorola Iridium System, the signal is transmitted from the caller's portable cellular phone directly to the nearest overhead satellite, which in turn sends the signal to an earth "gateway" station that verifies the caller as an authorised user. The call is then routed through the constellation of satellites to its destination anywhere on earth.

World wide system

The second system is the subject of a much more ambitious project which aims to establish a *world wide* cellular telephone network. And as it doesn't depend on being within range of a ground-based transceiver at all, the same handset *should* work everywhere from the middle of the Gobi desert to the top of the Sears Tower in Chicago or from a remote village in India to, the developers claim, a space shuttle in orbit! The US manufacturer of the system, Motorola, plans to achieve such universal coverage with its Iridium system by using satellite relays instead of a ground based radio network.

In a conventional cellular system, the operational area is overlaid with a honeycomb of cells, each with its own radio relay station. A telephone anywhere inside the area communicates with the national telephone system through the nearest relay station. If the user walks or drives out of one cell, the call is automatically switched to the next cell. The Motorola system turns this mode of operation on its head. It is the cells created by the orbiting satellites that are constantly on the move.

Communications satellites are normally huge beasts the size of a small house and weighing anything from half a tonne up to 15 tonnes. Motorola plans to use "smart lightsats" weighing no more than 320 kilos. The size and weight are critical because satellites of this size could be launched, both by conventional rocket or space shuttle, but by the Pegasus air-launched rocket system. Pegasus and its payload are launched by being dropped from the wing of a converted B-52 bomber. The Pegasus rocket engine then fires and it soars into orbit. Pegasus has already been test-flown into orbit. It made its first and entirely successful launch to orbit with two experimental satellites on-board in April 1990.

Pegasus Launcher

Ideally, to achieve the system goal of coverage of the whole Earth, a few satellites would be placed in high Earth orbit. But that would put them out of reach of small handheld telephones. The orbits were therefore moved down to enable them to connect with handheld phones, but not so low that they would be pulled out of orbit by atmospheric drag. The orbits also had to be low enough to come within the Pegasus launcher's capabilities. The Iridium design team finally settled for an orbital height of 765 kilometres (413 nautical miles).

Lower Orbit

Lowering the orbits also meant that more satellites were needed. Motorola chose 77 as the ideal number. This gave the system its name, because 77 is the atomic number of the element Iridium. The swarm of 77 satellites will orbit from pole to pole in seven planes of 77 satellites each. Each satellite will generate 37 antenna beams, each beam corresponding to a single telephone cell. Each cell will be approximately 650 kilometres across. The satellites will not only communicate directly with individual telephones on Earth, but also with each other. Each satellite will link up with neighbouring satellites in its own and adjacent planes. The whole system will connect with Earth-based Public Switched Telephone Networks (PSTNs) through a series of gateways, 20 initially.

Iridium will enable any two points on Earth to be connected with a maximum line delay of only 150 milliseconds. This compares very favourably indeed with a telephone call made using satellites in the much higher geostationary orbit (36,000 kilometres). This introduces a delay of 270 milliseconds between any two points within the one-third of the Earth that each satellite covers.

Motorola's schedule for Iridium envisages the launch of two demonstration satellites this year, manufacturing of the production satellites and also the launch of the first operational satellite in 1994, followed by operational status of the whole network by 1996.

Zero Bike

The Zike received plenty of press coverage when it was launched by Sir Clive Sinclair at Cyclex in March, but most of the publicity gave little detail on the technical aspects of the new bicycle.

Production of the Zike represents a number of new solutions to the problems of efficiency, strength, weight and power. The frame is made from high tensile anodised aluminium alloy and Verton, a material which combines long fibre glass and nylon to form an immensely strong and tough structure, Verton was invented and is made by ICI.

Power for the Zike is derived from a pack of nickel cadmium cells which can be recharged in an hour, these feed a lightweight (850gms) motor through an electronic controller. The motor uses a newly developed magnet made, by a recent UK process breakthrough, from neodymium-iron-boron. The use of this material results in the lightweight motor which offers a high level of efficiency over a wide range of speeds and loads.

The controller is a newly developed switching type, on which Sinclair Research have filed for patents, it restricts the maximum starting current to the motor via an f.e.t. to 17A and reduces this as the top speed is reached to around 5A, these currents are varied in different control settings. The circuit also provides regenerative braking – recharging the battery from the motor when the Zike is being braked. The motor peak power is around 300W in this circuit and the battery pack is rated at 24V, 4·5Ah.

Both battery and motor are housed inside the central bar of the frame. The controls provide three modes of operation selected by a switch on the handlebars; these modes give full motor power (battery life around 30 minutes), motor power plus light pedelling (battery life around 1½ hours) and rider power plus motor assistance (battery life between 2 and 3 hours).

The total weight of the bike is 11kgs – around the weight of a normal "racing" style bicycle. Zike is being made by Tudor Webasto, better known for car sunroofs, and is priced at £499 including the recharger, VAT and post and packing. Mail order delivery of Zikes should start towards the end of May if everything goes to plan.

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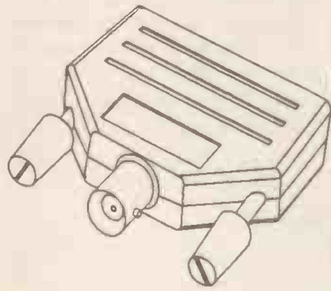

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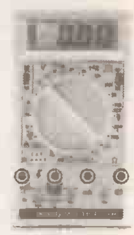

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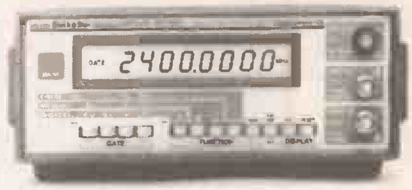

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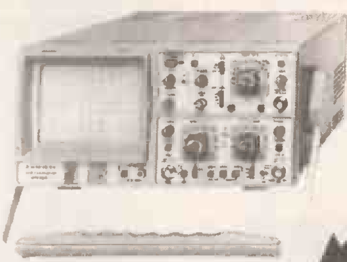

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INTERFACE

Robert Penfold

THIS month we will consider some PC software topics. First I must apologise for the absence of the train controller program which was promised last month. Due to problems in reading the PC keyboard in the desired fashion, the completion of this program has been delayed. It should be ready for the next Interface article though.

PC Languages

In the past, most computer add-on enthusiasts simply settled for writing software in whatever language was supplied with their computer. This usually meant some form of BASIC. Machine code or assembly language routines could be added into BASIC programs when high operating speed was needed.

It is still possible to adopt this approach with the current 16 and 32 bit computers such as the PCs, but there are now numerous other languages available for these computers. These each have their own sets of advantages and drawbacks, and some are better suited than others to the direct control of add-ons in the input/output map.

PD and shareware software is now big business, and there is probably more software of this type for the PCs than for any other computer. There are a substantial number of shareware and PD computer languages available for the PCs. You do not have to delve into this type of software for long before you realise that the quality varies greatly. Some of the languages supplied in this way are decidedly ropy, old fashioned, and difficult to use. At the other extreme, the best can approach the quality of commercial products.

FS Modula-2

FST Modula-2 is one of the better efforts. It has an editor integrated with the compiler, a "make" program which automates the process of compiling and linking, a makefile generator for use with this, and a linker. There is even a simple execution profiler, to tell you which parts of your program are most used, and where, therefore, optimisation will be of most benefit. Unfortunately, there is as yet no source code debugger.

Modula-2 was Niclaus Wirth's attempt to improve and extend his Pascal language. As the name suggests, it allows programs to be written in the form of separately-compilable modules. Compiled modules can be linked into many programs, thus allowing code re-use. A number of pre-compiled library modules are supplied with the compiler. There is also a form of multi-tasking, in that, within a program, several processes can run concurrently. The language version supported by this compiler is described in *Programming in Modula-2*, 3rd. edition, by Niclaus Wirth.

The compiler incorporates an in-line assembler. This accepts all 8086/8087 instructions, and is useful for such things as port addressing (not provided in the standard language) as well as for speeding up parts of programs. It is also possible to use "foreign" modules written in other languages in FST MODULA-2 programs. This is not necessarily easy, but it can be done.

Producing an .EXE file with most languages is a two-stage process. The compiler compiles the source code into object files, and these are then linked into an executable file by a program called a linker. A problem with many shareware compilers is that they do not provide a linker. Microsoft's Link program used to be supplied with MS-DOS, but this is now rarely done. Fortunately, FST Modula-2 is supplied with its own linker.

FST Modula-2 normally produces object files in its own format, with a .M2O file extension, but it is also capable of producing standard Intel format .OBJ files. The supplied linker can handle both formats, so MS-LINK is not needed.

It is possible to use this compiler on a twin-floppy system with 512K of memory, but, as always with languages, it is much better to have the full 640K RAM. A hard disk is also virtually a necessity. All the stages of compiling and linking can be slow and tedious without it, and may need a lot of disk swapping.

Editor

The integrated editor can handle multiple files in multiple windows on screen, the number being limited only by the available memory. Cut and Paste between files is possible. One problem is that it is possible to load one file into two windows at the same time, but the editor is unaware of this and will regard them as two separate files. The compiler and "make" programs can be invoked directly from the editor.

If an error occurs during compiling it is flagged and the editor is invoked when compilation is complete (or when more than 20 errors have occurred). You can then move quickly between the errors to correct them. Run-time errors are less well handled. You have to use a map file (a utility is provided to generate this) and the address provided by the run-time error handling code to find the line which caused the error. No kind of source code debugging (single stepping, tracing, variable monitoring) is provided.

Unusually for shareware, the documentation is good, but you need to read the DEF files of the library modules to find what they contain and how to use them. There is little instructional material, however, though there are a few example programs. A newcomer to Modula-2 would need a book or two to get started.

This is undoubtedly one of the best shareware languages, and is one that can be strongly recommended. Registration is US$49.00, which is reasonable, but credit cards do not appear to be accepted, so bank charges would bump this up quite a bit. Registered users get an extra disk, which includes full source for the library modules.

Port Control

There is a potential problem when trying to use PC languages with your add-ons, and this is simply that not all PC languages give you direct access to the input/output map. It is possible in most cases though, and the simple programs shown here demonstrate direct port addressing. The ports used are those concerned with speaker control. These are used because they present little risk of doing damage, always a consideration in working directly with ports, and because they provide a tangible result without needing additional hardware.

The four programs presented here all do the same thing. They produce a series of descending notes from the computer speaker. Note that these programs are for IBM PCs and true compatibles. On other machines the port addresses are likely to differ from those used here. The speaker is controlled by using two ports. Port 61H is the control port. Toggling bits 0 and 1 of this port turns the speaker on and off. Port 42H is a timer, which controls the pitch of the sound from the speaker.

Turning the speaker on consists of setting bits 0 and 1 of port 61H without disturbing the setting of the other bits. This is a three-step process. Firstly, the current value of the port must be read into a variable or register, secondly, this value must be bitwise ORed with 00000011 binary (3 hex), and thirdly, this value must be written back to the port. This forms the first part of each program.

The central part of each program consists of two nested loops. The outer loop counts through values from 0 to 50, setting these values to port 42H. The higher the value written to this port, the lower the note produced, so this loop produces a series of descending tones. To produce ascending tones, you would just have to alter the loop to count down from 50 to 0.

The inner loop is a crude delay loop. These programs were developed on a venerable Amstrad PC1512, largely for the benefit of its volume control! This is a slow machine by modern standards. To appreciate the full melodious charm of these programs, you may need to increase the number of times round the loop for faster machines.

The final part of the program turns the speaker off. This is essential. The sound will not stop at the end of the program if this is not done. The method is similar to turning the speaker on, except that the value read from the port is this time ANDed with the one's complement of 00000011 binary. This is obtained with the NOT function in assembler, Pascal and Basic. C has a one's complement operator, the tilde.

The assembler listing is commented, but the others are not, as it should be possible to follow them from the description above. These programs were written using Microsoft languages. I used Quick Assembler, Quick C, Quick Pascal and the QBasic interpreter supplied with MS-DOS 5.0. The Basic listing should also be usable with Quick Basic. The Pascal listing should be usable with Turbo Pascal, as Quick Pascal follows this standard.

The C listing may be usable with other versions, as C tends to be well standardised now. Points to check are the syntax and variable types in the inp and outp functions, the header file needed to use them, and whether a pragma is required. The assembler listing should be usable with MASM and with other assemblers which follow this standard.

SOUND PROGRAMS

```
;SOUNDS.ASM in/out demo program
   .MODEL tiny
   .DATA
control  EQU  61H            ; Port to turn speaker on/off
pitch    EQU  42 H           ; Timer port controlling pitch
on       EQU  00000011b      ; Bits 0 and 1 turn sound on
   .CODE
   .STARTUP
   in     al,control         ; get current setting
   or     al,on              ; to turn speaker on
   out    control,al         ; write value to port
   mov    al,0               ; start at a high pitch
beep:  out  pitch,al         ; send byte to timer
   mov    cx,5000            ; crude delay loop
delay:  loop  delay
   inc    al                 ; reduce the pitch
   cmp    al,50              ; arbitrary ending pitch
   jne       beep            ; loop for next pitch
   in     al,control         ; read value from port
   and    al, NOT on         ; to turn the speaker off
   out    control,al         ; write value to port
   .EXIT                     ; generates exit code
   END
```

```
'SOUNDS.BAS direct port access demo program
CONST control = &H61
CONST pitch = &H42
CONST turnon = &H3
DEFINT A-Z
portval = INP(control)
portval = portval OR turnon
OUT control, portval
FOR note = 0 TO 50
    OUT pitch, note
    FOR delay = 1 TO 1000
    NEXT delay
NEXT note
portval = INP(control)
portval = portval AND NOT turnon
OUT control, portval
```

```
/* sounds.c */
/* ports demo program */
#include <CONIO.H>
#define control 0x061u
#define pitch 0x042u
#define on    0x03u
void main()
{
int portval;
int counter;
int note;
  portval = inp( control );
  portval |= on;
  outp( control, portval );
  for( note = 0; note < 50; note++ )
  {
     outp( pitch, note);
     for( counter = 0; counter < 1000; counter++ );
  }
  portval = inp( control );
  portval &= ~on;
  outp( control, portval );
}
```

```
program sounds;
{ Demonstrates direct port access. For QuickPascal 1.0 and
 Turbo Pascal 5.0 and later (may work on other versions) }
const
  control = $61;
  pitch   = $42;
  on      = $03;
var
  counter : integer;
  note : integer;
  portval : byte;
begin
  portval := Port[ control ];
  portval := portval OR on;
  Port[ control ] := portval;
  for note := 0 to 50 do
     begin
     Port[ pitch ] := note;
     for counter := 0 to 1000 do {nothing};
     end;
  portval := Port[ control ];
  portval := portval AND NOT on;
  Port[ control ] := portval;
end.
```

CORDLESS DRILL CHARGER/PSU

MARK DANIELS

This unit allows cordless electric drills to be recharged from, or used with, a 12V d.c supply, e.g. a car battery.

RECHARGEABLE cordless drills are extremely useful where no mains power is available. They do however suffer from one serious drawback – a fully charged battery will only give a few minutes drilling power.

With most of the professional models it is possible to remove the battery pack and fit a second fully charged one in its place in order to extend the working time. However, many of the DIY versions such as the popular Black and Decker SC522R have the battery pack built into the machine and exchanging the discharged pack for a fully charged one is not really possible.

OPERATION

The circuit described here is used to temporarily replace the existing mains charging unit and also to eliminate the built-in battery pack of the cordless tool. Operation of the unit is from any stable external 12V d.c. source (e.g. car battery).

When the drill is in use with the unit connected power for the motor is drawn from the external power source and the voltage dropped to an average level suitable for the motor. Under these conditions no power is drawn from the internal battery pack by the drill.

The circuit also provides for recharging of the drill's battery pack from the car battery, at a trickle rate of around 50mA. Although the charger is not a true constant current source and its output may vary somewhat in use it is sufficiently close to this for the present needs, when used with a battery pack not exceeding 7.2V (six cells).

The drill may be kept on constant charge from the car battery and ready for use any time and anywhere. It is especially useful for anyone whose car is kept some distance from the house or anywhere else an extension cable for mains powered tools is not practical.

SWITCH MODE

The complete circuit diagram for the Cordless Drill Charger/PSU is shown in Fig. 1. The circuit is best described in two separate parts – the "chopper circuit" and the "charging circuit" which is enclosed by dotted lines.

The chopper circuit, which could be likened to a very simple form of switch-mode power supply (but without the output inductor), is based around a variable pulse width astable multivibrator, the heart of which is the 555 timer, IC1. The 555 in its astable mode is normally set up to give an almost equal mark-space ratio, see Fig. 2a.

If, for simplicity, we connect a load resistor between the output pin (pin 3) of IC1 and ground (0V), when the output is switched on the load resistor will have a power in it of V^2/R; where V is the voltage across the resistor in volts and R is its resistance in ohms. When the output is switched off V becomes zero and obviously V^2 is also zero thus making the power in the resistor zero.

COMPONENTS

Resistors

R1	22k
R2	15k
R3	220
R4	56 1W metal film

All 0.25W 5% carbon film, except where stated.

See SHOP TALK Page

Potentiometer

VR1	22k sub-min preset, horizontal

Capacitors

C1	100n polyester, 5mm pitch
C2	100n polyester, 5mm pitch
C3	100μ radial elec. 25V
C4	470μ radial elec. 16V

Semiconductors

D1, D4, D5	1N4001 1A rectifier (3 off)
D2, D3	1N4148 signal diode (2 off)
TR1	ZTX750
TR2	2N3055
IC1	555 timer

Miscellaneous

FS1	10A 20mm fuse and p.c.b. mounting fuseholder
PL1	2.5mm standard cable mounting Power Plug
SK1	2.5mm standard chassis mounting Power Socket

Case, size; 129.5mm x 91.5mm x 70mm (Ventilated); TO3 heatsink 4·2°C/W; wire (2 core 2.5mm^2 flex, 2 core 1.5mm^2 flex, single flex); insulated battery charger clips (2 off); p.c.b. pins (3 off); 0.110in. crimp terminals (4 off); solder etc.

Printed circuit boards available from *EE PCB Service*, code EE793, Chopper and Charger boards.

Approx cost guidance only **£12**

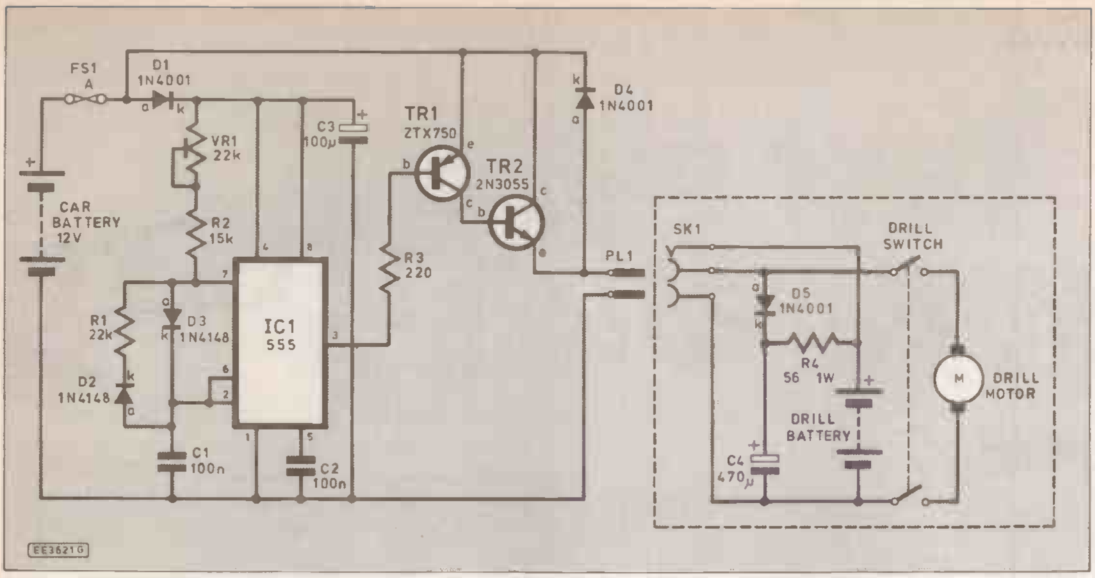
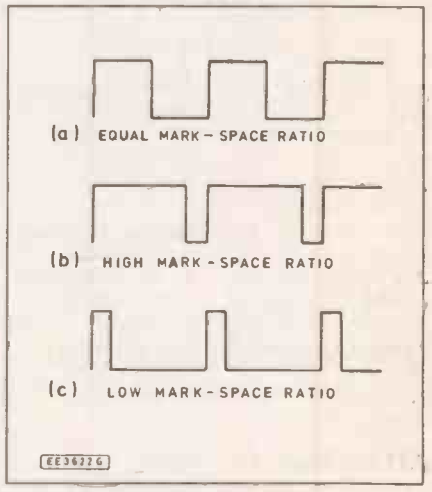


Fig. 1. Circuit diagram of the Cordless Drill Charger/PSU.

Fig. 2 (below). Various mark to space ratios.



The average power dissipation in the load resistor will be ½ × V^2/R if the mark-space ratio is equal. This is therefore equivalent to using a supply voltage of half the input voltage to the chopper.

A circuit of this type has the very significant advantages of low output impedance and low power loss, making it economical and cool running. Referring to Fig. 2 it may be seen that the mark-space ratio does not have to be equal and we may achieve any desired output voltage between zero and the input voltage merely by altering the mark-space ratio. Fig. 2b shows a high mark-space ratio which will give very close to the input voltage, while Fig. 2c shows a very low ratio giving an average output voltage of little more than 0V.

Because no output inductor is used in this circuit, the pulses produced will have a peak voltage very close to the supply voltage and with the addition of a rectifier and a smoothing capacitor to the output it is possible to retrieve the input voltage at the output whatever the mark-space ratio, so long as only small currents are drawn (or a very large capacitor is used).

CIRCUIT DESCRIPTION

The circuit is based on a 555 which is configured to give any desired mark-space ratio, by use of "steering" diodes D2 and D3 in the *RC* timing network. By use of these diodes it is possible to use separate resistors of different values for the charge and discharge of the timing capacitor, C1.

The mark-space ratio is equal to the ratio of (VR1 + R2) to R1. Preset VR1 is included to make the mark-space ratio adjustable in order that the average output voltage may be set to suit the tool being supplied.

The output of IC1 at pin 3 drives the base of the *pnp* transistor TR1, which is configured as a common emitter amplifier stage having both current and voltage gain. Resistor R3 limits TR1 base current to a suitable level.

The collector of TR1 drives the base of the power transistor TR2, which is connected as an emitter follower stage, giving high current gain but only unity voltage gain. Diode D4 gives protection to TR2 against voltage spikes and back e.m.f. from the drill motor.

Diode D1 and fuse FS1 protect the circuit from incorrect supply polarity and overcurrent. Capacitors C2 and C3 are used for decoupling and protect IC1 from false triggering due to spikes.

Diode D5, resistor R4 and capacitor C4 are fitted inside the drill and provide a smooth, current regulated charging supply for the battery pack. D5 prevents the drill motor from taking power from the internal battery pack and also from discharging capacitor C4 which smooths the raw chopped d.c. supply to R4, the current limiting resistor. The switch on the charging socket automatically disconnects the internal battery from the motor when the plug is inserted.

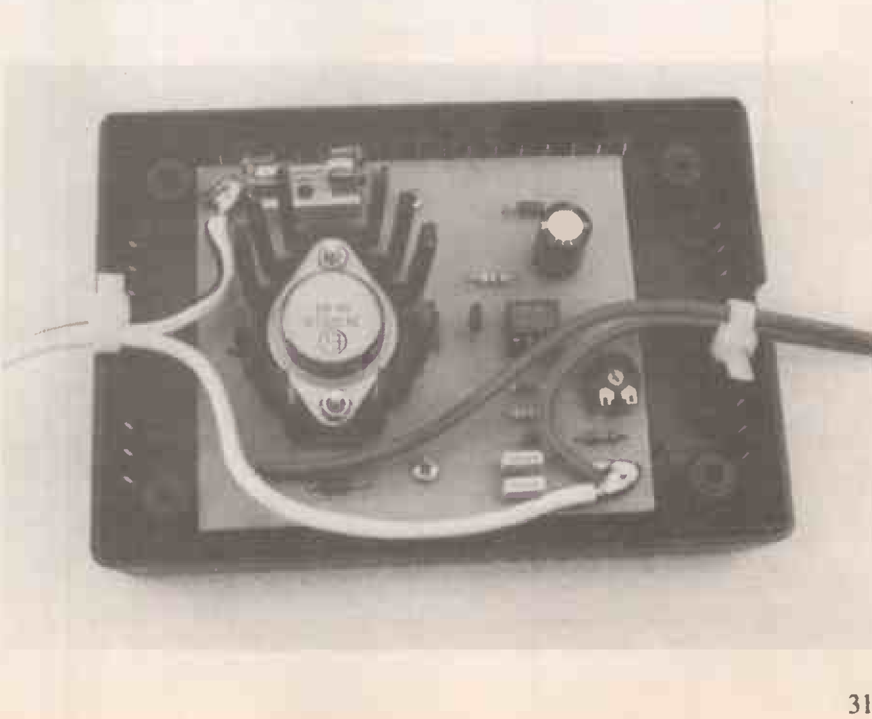
DRILL MODIFICATIONS

Before constructing this project it would be as well to dismantle the cordless power tool to be modified in order to determine whether and where the bits will fit. If the SC522R is being modified, reference to Fig. 3 will show the necessary details, which may also be helpful in connection with other machines.

On this model it is necessary to turn the battery pack around to create the space for mounting the power socket and small charging p.c.b. This may be done by first disconnecting the four leads from the battery pack and lifting it out. Drop it back in place in the new position and mark where the power inlet socket is to go using Fig. 3 as a guide.

Remove the battery pack and place it on one side. Drill the two mounting holes and the hole for the plug, but do not fit the socket at this stage.

Remove the two battery leads from the drill switch by inserting a needle into the wire connector and gently levering the wire gripper to one side (Fig. 4 shows the internal details of this part of the switch),



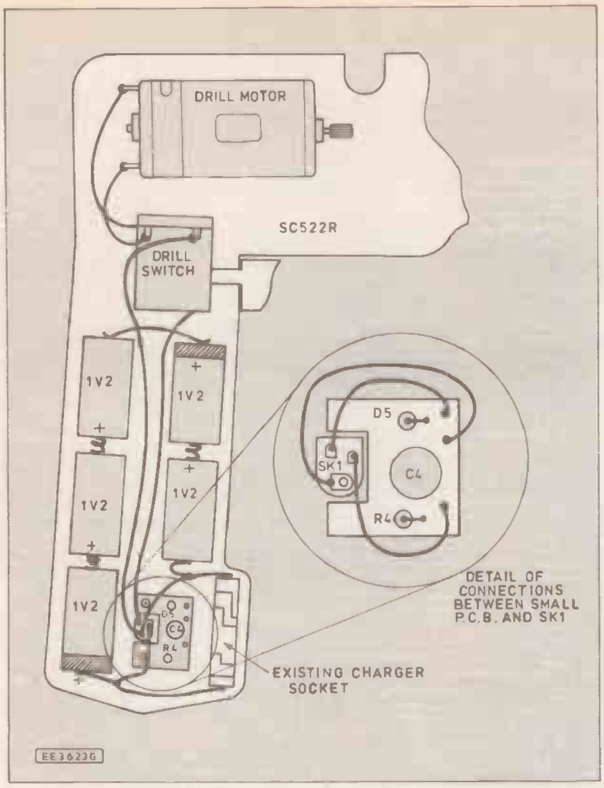


Fig. 3. Modification to the SC522R drill.

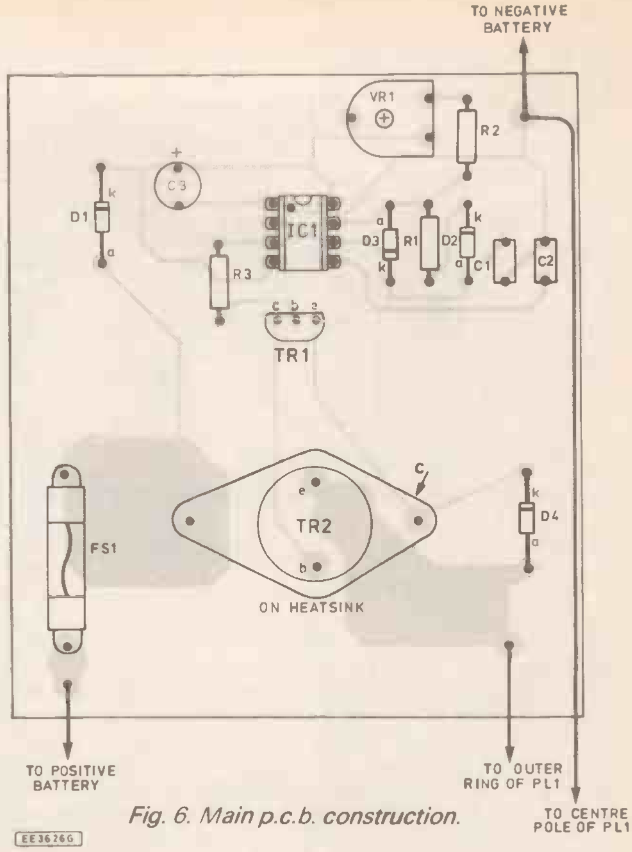
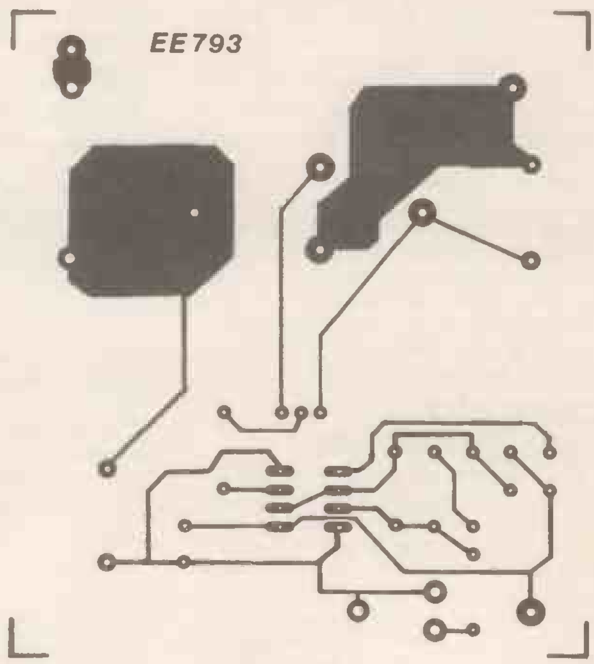


Fig. 6. Main p.c.b. construction.



pulling the wire out. Fit two new longer wires to the switch by solder "tinning" the twisted strands and gently pushing the ends into the switch terminals which will automatically grip the wires.

CONSTRUCTION

The Cordless Drill Charger/PSU is built on two printed circuit boards (p.c.b.s), the smaller one being housed inside the drill handle. These boards are available from the EE PCB Service, code EE793 Chopper and Charger.

Assemble the smaller p.c.b. first, as shown in Fig. 5, fitting diode D5 last. The use of solder pins is strongly recommended for ease of connection between the board and socket when fitted. Fit two M2 × 12 screws through the two small holes drilled in the drill handle and drop the socket onto them, the p.c.b. is then fitted onto these two screws before the washers and nuts are fitted and tightened.

The p.c.b. may be fitted remote from the socket at any convenient point inside the drill if required. It may be necessary to trim the board to fit or even re-design it if space is limited.

Make the connections between the p.c.b. and socket using thin connecting wire as shown inset in Fig. 3. All other connections must be made using wire rated at a *minimum of 10A*. Route all wiring neatly, following the layout diagram of Fig. 3, while taking care to ensure that it will not foul anything when the case is re-assembled.

Connections to the battery pack may be made as originally using crimp terminals or by soldering to the tags on the batteries. *Do NOT solder directly to the batteries as this may easily damage them.*

The drill case may now be re-assembled and the drill checked for normal operation.

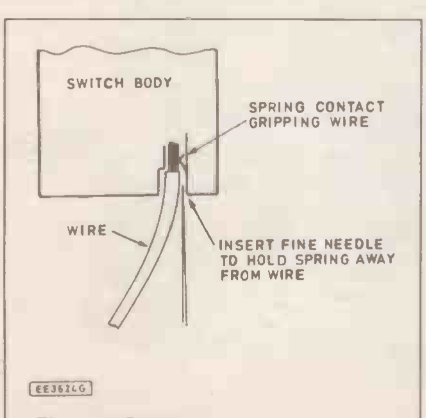


Fig. 4. SC552R switch connection.

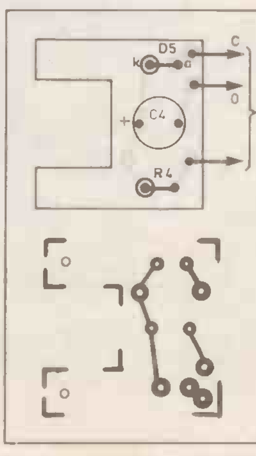


Fig. 5. Construction of the p.c.b. housed in the drill.

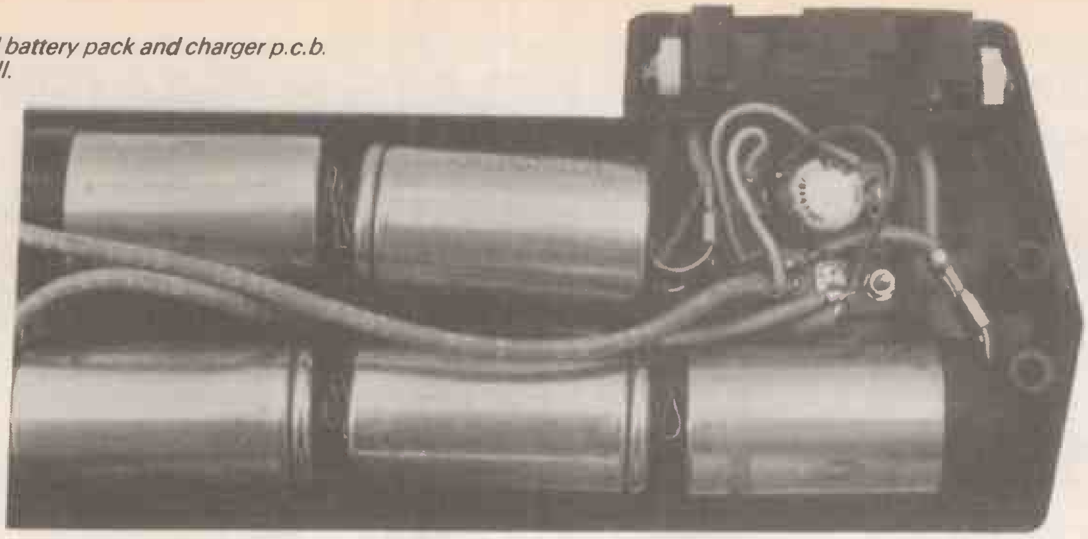
CONVERTER/ CHARGER

All the components for the converter are mounted on a single-sided glass fibre printed circuit board, the component overlay and copper foil pattern for which are shown in Fig. 6.

Fit the three resistors, three capacitors and preset potentiometer to the board followed by the three diodes, TR1 and IC1. A socket should be used for IC1 and will prevent the risk of heat damage to this i.c.

The fuseholder for FS1 may now be fitted followed by the power transistor TR2 and its heatsink. No isolating kit is used here and the transistor is merely bolted to the heatsink and p.c.b. using a small quan-

The modified battery pack and charger p.c.b. inside the drill.



tity of heatsink compound between the transistor and heatsink.

The use of M3 × 12 panhead screws and nuts are recommended with M3 plain washers between the screw heads and p.c.b. Three solder pins are inserted in the board to take leads to the external connections. Solder pins are virtually essential in this application due to the very heavy connecting wires. Fit IC1 into its socket and mount the p.c.b. in its ventilated case.

Twin 2.5mm^2 speaker cable is used for connecting the unit to the car battery via two large crocodile clips. Up to 5 metres of cable may be used. Anything longer than this may cause an unacceptable voltage drop due to cable resistance, unless thicker cable is used.

Between the converter unit and the plug for the drill thinner 1.5mm^2 twin core cable is used and this run must be kept as short as possible, preferably no more than two metres. If the plug PL1 can accommodate thicker flex then the length may, conceivably be extended. Secure the two cables so that they will not pull on the terminal pins when the unit is in use.

TESTING

Connect the converter unit to a car battery observing polarity and measure the output voltage at PL1. Adjusting preset VR1 should cause some variation in the output voltage if an analogue meter is used. A digital meter may be confused by the switched d.c. and not give true readings.

Turn preset VR1 fully anti-clockwise and connect the converter to the cordless drill, which should run when switched on. Adjust VR1 to give the normal operating speed of the drill, (or slightly higher if required). Perform a full operational test with the drill under load to ensure that the torque is adequate and that transistor TR1 does not get too hot.

If the drill does not produce full torque a reduction in operating frequency will most likely cure this, which may be achieved by fitting a larger capacitor in place of C2. Up to about $1\mu F$ should be perfectly all right. If TR1 is getting too hot under load it may be necessary to fit a larger heatsink.

Once everything is working correctly the case may be assembled and labelled up, before putting the unit into full service. □

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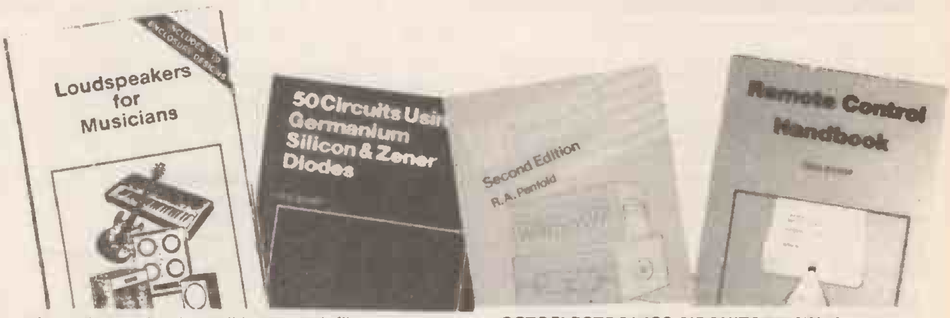

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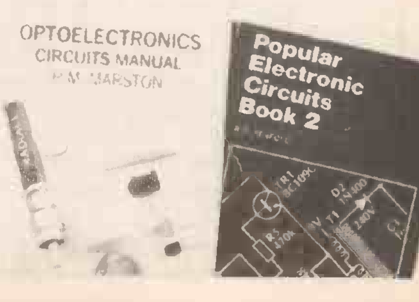

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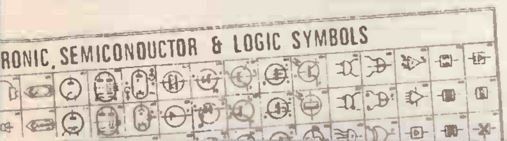

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REPORTING AMATEUR RADIO

Tony Smith G4FAI

BEACON EXPANSION

The Northern California DX Foundation's Beacon net continues to provide useful information on propagation and reception conditions from around the world. Operating 24 hours a day on 14.100MHz (20 metre band), nine stations located in New York, California, Hawaii, Japan, Israel, Finland, Madeira, South Africa and Argentina, transmit sequentially every 10 minutes at varying power levels reducing from 100 to 0.1 watts.

The signals consist of the callsign in Morse followed by four nine-second dashes each one-tenth of the power of the previous dash which, if heard, indicate not only that the band is open to that particular part of the world but the power level necessary to establish communication.

One beacon, W6WX/B in California, now transmits on two further bands. As soon as its 20m transmission is completed the station automatically changes frequency to 21.150MHz (15m), repeats its signals and then changes again to 28.200MHz (10m). Each transmission lasts for 58 seconds with a two second interval between transmissions so rapid band-changing is necessary if it is desired to compare conditions on all three bands!

Unfortunately, in the last couple of years W6WX/B has been stolen and the Japanese transmitter JA2IGY, located on top of an 8,000ft mountain, has also gone missing. Both have been replaced and, as a long term project, NCDXF plans to convert all the beacons to three band operation, thus adding to an already very useful service.

CANDIAN MERGER

Canada has two separate organisations representing the interests of radio amateurs, the Canadian Radio Relay League and the Canadian Amateur Radio Federation, and these have been discussing for some time a possible merger to create a new single body representing all Canadian amateurs.

Discussions are now at an advanced state and, subject to a favourable vote by members of CRRL and CARF, the new organisation, to be known as *Radio Amateurs of/du Canada* (RAC), will come into existence later this year.

G-QRP NOVICES

Dave Gosling, G0NEZ, Novice Manager of the G-QRP Club has written to tell me about the support his club gives to the new novice licence which permits low power operation on limited frequencies, pending the acquisition of a full licence.

The club has over 4000 members, all using QRP (low power up to five watts), so it is well placed to encourage and help the new novices. Dave writes a regular novice column in the club's magazine *Sprat* and offers advice and help on antennas, learning and using Morse, choosing and constructing appropriate projects, etc. He says "I am privileged to have so many active QRP experts at my disposal should I get into difficulty myself!"

SWLs whose receivers cover the amateur bands might like to listen for the G-QRP novices on their adopted calling frequencies, 1960 and 28,360kHz (both CW and phone), and 3570, 21,130, 28,130 (CW only). Their callsigns begin with a "2" followed by E/W/M/J/U/I etc, designating which part of the UK they are located in. 2W0AAI, for instance is located in Wales, while 2E0AAQ and 2E0ABA are in England.

Dave says that a number of new Novices, including those mentioned, are now becoming active on CW (Morse), particularly on 3570, and are beginning to work Dx (long distance) stations on 21,100-21,130kHz. He comments that the 5 w.p.m. Morse test necessary to obtain the h.f. version of the Novice licence is proving to be fairly easy and even those failing first time are happily trying again.

Incidentally, the G-QRP Club has SWL as well as licensed members and full details can be obtained by sending a C5 s.a.e. to Rev. George Dobbs G3RJV, St. Aidan's Vicarage, 498 Manchester Road, Rochdale, OL11 3HE.

AMATEUR RADIO IN LITHUANIA

An interesting account of the past and present problems of radio amateurs in Lithuania was posted recently on a European computer bulletin board by a Lithuanian amateur. It then found its way via amateur radio networks to another bulletin board in America where it was picked up by the *W5YI Report* from which I have extracted and summarised the following information.

The first known Lithuanian amateur wireless message was sent in 1918. Official licences were not issued until 1932, and there were 64 licensees in the country when amateur radio was stopped by the first Soviet occupation of 1940.

During WW2 and the first ten years of the second Soviet occupation the hobby continued to be banned and was then re-introduced, with around 200 licences on issue by the late sixties. It was, however, a long and tedious process getting a licence, even up to the end of perestroika.

Requests were secretly processed by the KGB, taking 6-12 months and, if a licence was granted, amateur conversations on the air were strictly limited to one's name, town, operating conditions and the weather. Giving one's address, phone number, or direct correspondence with a foreign amateur was strictly forbidden.

Contact with any foreigner was banned if the Lithuanian amateur's job involved modern technology or research. Any violation of this rule, even the fact of having an amateur licence, could have a negative influence on an amateur's professional career.

APPEAL FOR HELP

Today's temporary amateur radio licensing rules are still based on those of the former Soviet Union with most of their shortcomings. There continues to be an absence of factory made amateur radio equipment and the Lithuanians are ten to twenty years behind modern technology. Some of today's advanced techniques are being used, but invariably the amateurs concerned build the equipment themselves, including computers.

As a result, most of Lithuania's activity is on CW (Morse) or SSB (phone), and contests, Dxing and award hunting in these modes are very popular. A few use RTTY (radio teletype), less than ten have SSTV (slow scan TV) and only a couple have packet capability.

The author concludes with an appeal for help from the west. "Many of our happy owners of Z80 machines tried to build relatively complicated modems on p.c. boards sent to us by ham friends. But it is impossible to get 7910 chips or 2.4576 MHz quartz crystals here! We are very accurate when copying any foreign circuit, but most of our modems rest on the workbench awaiting their components!

"Maybe some more experienced hams can come up with less complicated circuits for eastern Europe. It is better to show something than to give something sometimes . . . The second largest group of home-brewed computers are built around the 8080 processor chip."

GERMAN CALLS UNITED

The political changes in eastern Europe are affecting amateur radio in various ways. New callsigns are emerging reflecting the individual identities of countries previously part of the Soviet Union. Lithuania, for instance, which was UP in the USSR now has its pre-war prefix of LY.

However, the reverse has happened in Germany following re-unification. Previously there were two separate national radio organisations with representation on the International Amateur Radio Union, but last year the East German Radiosportverband (RSV) was dissolved and the West German Deutscher Amateur Radio Club (DARC) took over all its functions both national and international.

Former East German stations retained their old callsigns, in the prefix series Y2-Y9, but the ITU has now asked Germany to relinquish this series in 1992 for re-allocation to another country. By the end of this year, therefore, all German stations will be identified by callsigns within the original West German series of prefixes, DAA-DRZ.

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