EVERYDAY With PRACTICAL ELECTRONICS

APRIL 1995

INCORPORATING ELECTRONICS MONTHLY

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NATIONAL LOTTERY PREDICTOR

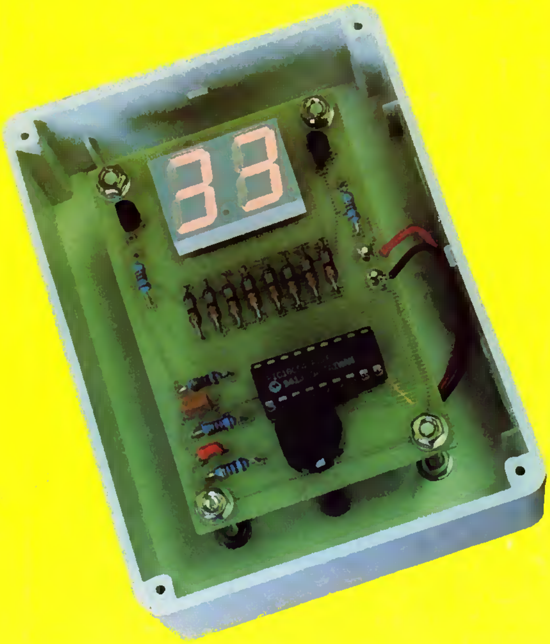
Generates numbers for your entry using a PIC Microcontroller

Plus *Three more projects for last month's FREE p.c.b.*

CONTINUITY TESTER

LIGHT ACTIVATED SWITCH

SWITCH ON/OFF TIMER



THE NO. 1 INDEPENDENT MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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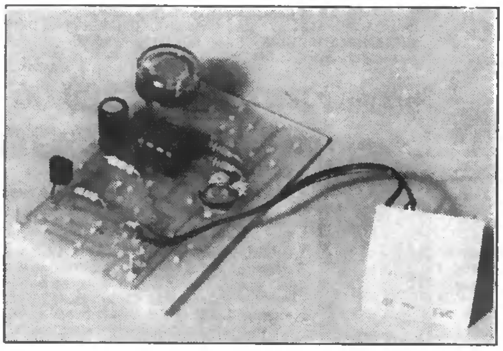
ISSN 0262 3617
PROJECTS . . . THEORY . . . NEWS . . .
COMMENT . . . POPULAR FEATURES . . .

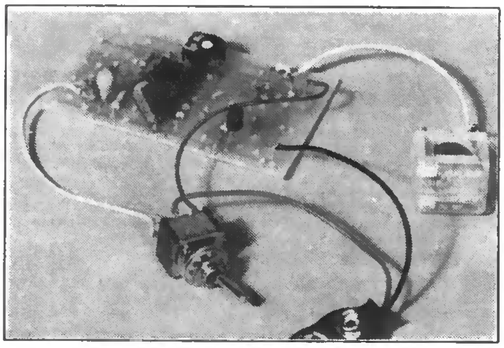
VOL. 24 No. 4 APRIL 1995

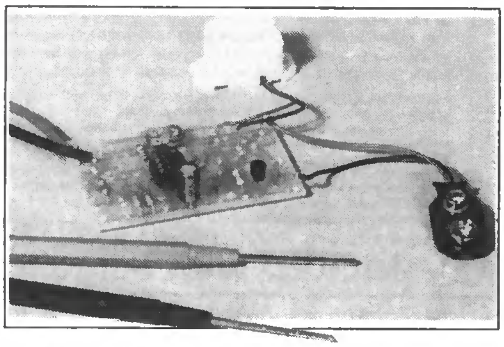
EVERYDAY With PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

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







Our May '95 Issue will be published on Friday, 7 April 1995. See page 255 for details.

Projects

Series

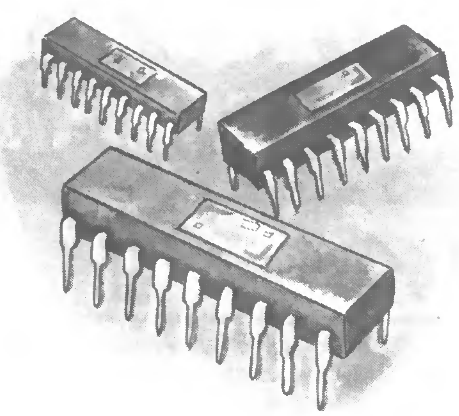
Features

NEXT MONTH

PIC-DATS PIC Development and Training System

PIC-DATS enables in-circuit emulation of the PIC 16C5X family of microcontrollers. For educational purposes the system can be used as a classroom training aid

- ★ *Enables real time emulation so the target system can be run and modified*
- ★ *Cross-assembler, communications program and editor in integrated software package*
- ★ *Simulator allows programs to be checked before using the hardware emulator*
- ★ *Uses a 16C55 microcontroller running at 4MHz*
- ★ *I/O and control lines accessed via 40-pin IDC connector*
- ★ *RS232 port*
- ★ *On board voltage regulation*



RF Signal Generator

A sophisticated design which can be calibrated to 2% accuracy and built for about one third of the price of an equivalent commercial generator. Covers 1·2MHz to 30MHz in three ranges with switched external or internal 30% modulation.

Midi Pedal

Midi Pedal units are often quite expensive and sophisticated, this basic design can be set up as a sustain, portamento or soft pedal and is relatively inexpensive and easy to build.

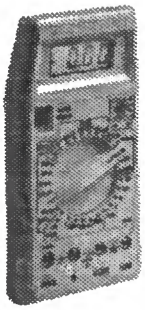
DON'T MISS THIS IMPORTANT "FIRST" FOR AN ELECTRONICS MAGAZINE!

EVERYDAY *With* PRACTICAL ELECTRONICS

MAY '95 ISSUE ON SALE FRIDAY, APRIL 7

A SELECTION OF SURPLUS FROM OUR LISTS

DIGITAL MULTIMETER



- Input Imp. 10MΩ
- 3½ digit 15mm LCD display
- 32 ranges including 20A ac/dc
- Transistor and diode test
- Continuity test with buzzer and LED
- Rugged yellow case
- Test leads with shrouded 4mm plugs
- Carrying case
- Fuse Protection
- Automatic polarity and zero

Battery and instruction manual included

Usually £36.95

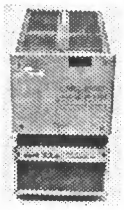
£29.95

AC volts	0-200m-2-20-200-750Vac±0.8%
DC volts	0-200m-2-20-200-1000Vdc±0.5%
AC current	0-20µ-200µ-2m-20m-200m-2A-20Aac±1.0%
CD current	0-20µ-200µ-2m-20m-200m-2A-20Adc±0.5%
Resistance	0-200-2k-20k-200k-2M-20MΩ±0.5%
Transistor h FE	0-1000 NPN/PNP
Dims	176x88x36mm

Order Code M3800

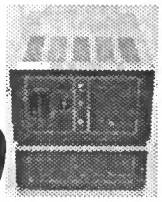
UNINTERRUPTIBLE POWER SUPPLIES

These are all in good working order, offered at a fraction of their original cost. Please note carriage is extra on these items only and will vary with distance; ring for details.



Z9298 Made by Sola, this UPS is rated 600VA and comes with a separately cased sealed lead acid battery of 36 cells.

£400



Z9297 Rated 1000VA, this UPS is made by Sola and is supplied with a separately cased sealed lead acid battery of 36 cells.

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BACK IN STOCK - MINIATURE DRILL PACKS!

REDUCED SHANKTUNGSTEN CARBIDE

These were very popular when last advertised and sold out quite quickly. Don't miss out this time although we have plenty of 0.95mm, the other sizes are in short supply.

All have 3.15mm shank. They normally cost around £3 each

Available in the following packs:

K901 8 drills - 0.35, 0.85, 4 x 0.95, 1.10 and 1.15mm for **£5.95**

These sizes **only** available separately:

Z3233 0.95mm **75p**; 25+ 0.40; 100+ 0.30

Z3234 1.10mm **£1.00**; 25+ 0.50; 100+ 0.40

ANOTHER SUPER DISK DEAL!

X6043 Star LC24-30/LC24-300 printer driver disk, individually packaged. There's also 15 TrueType Fonts for use with Windows 3.1, but we're just selling this for the media value - the software is free!. It's a 3.5" 1.44M formatted high density disk.

10 for £3.95
100 for £30

VOLTAGE TESTER

YO238A Dual function screwdriver type circuit tester. Used as an inductance tester. It will detect buried live cables, breaks in cables etc. Touching a live part with the tip will indicate the voltage level on the LCD screen. AC or DC up to 250V max.

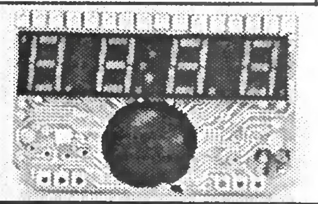
£3.50

FANS

Some ex-equip axial flow fans, all in good working order at substantial savings over new models.

Z3855 Smallest fan we've seen! 42x42 by just 10mm thick! Made by Nitev, model TA150DC. Rated 12V DC 0.11A. **Only £3.00**

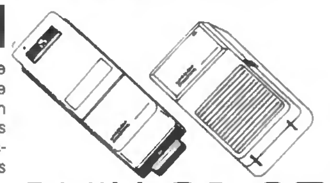
X6015 Papst (mostly) 612L 60x60x25mm 12V DC (6-15V) 0.7W fans. List is 27.47. Our Price £3.00



99P CLOCK

Z3873 Super Offer! A complete clock in a 40x25mm module. 9V operation with sleep & snooze, 24hr alarm, PM, colon and alarm indicators. Simple fast/slow setting controls. 5 display modes, 12/24hr selectable, display brightness control. Full info supplied. **All this for 99p!**

Wireless Doorbell

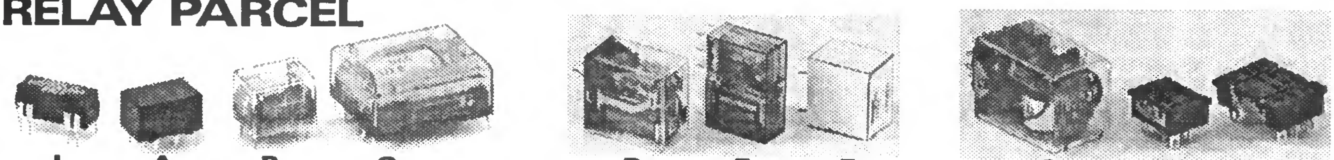


T071D Two part wireless doorbell. The transmitter is mounted by the front door and the receiver can be mounted or carried up to 16m (50 feet) away. Provided with self-adhesive pads and screws for mounting (if required). Transmitter requires a PP3 battery, receiver requires two AA batteries.

Dims:	112x40x30mm
Transmitter	93x70x30mm

ONLY **£8.95**
SEEN ELSEWHERE FOR £14.95

RELAY PARCEL



J A B C D E F G H I

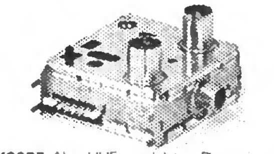
Code	Man & Type	Size	V	R	Contacts	Pic	Qty	DP	Price	100+
Z3877	Omron G5A 234P-53/1	16x10x8	4.5	101R	DPCO 1A	A	2000	3.56	**1.00**	0.65
Z3899	Hamlin HE721A5262	19x6.5x7	5	500R	SPM	J	2500	2.55	**1.00**	0.65
Z3878	211NC D009-P	16x11x10	9	390R	SPCO	B	2600		**1.00**	0.65
Z3879	NEC MR24-12S	30x24x10	12	330R	4PCO	C	800	7.97	**2.00**	1.20
Z3880	KV23/9 PW	30x24x18	12	550R	DPCO	D	800	5.98	**1.50**	0.90
Z3881	National NF4-24	30x24x10	24	1200R	4PCO	C	100	7.97	**2.00**	1.20
Z3882	KV 1002-027	28x24x12	24	820R	DPCO 2A	E	300		**1.00**	0.65
Z3883	Omron LC1M-US	22x21x16	24	1500R	SPCO 10A	F	200	1.79	**1.00**	0.65
Z3884	AMF KAP14 DG	53x34x34	24	450R	3PCO 6A	G	900	5.86	**2.00**	1.20
Z3885	Omron PT08 (FOR LY2)	29x22x12	8 PIN	BASE	2PCO	H	300	1.48	**0.60**	0.35
Z3886	Omron PT14 (FOR LY4)	42x29x12	14 PIN	BASE	4PCO	I	800	1.73	**0.80**	0.50

MINIATURE SWITCHES

X3070 X3071 X3072 X3073 X3074

Code	Type	Size	Contacts	Pos	Mntg	Qty	Price	100+
X3070	A13HAO	13x10x7	SPCO	NB	PCBH	1150	**3/£1.00**	0.15
X3071	A12GVAO	13x10x7	SPCO	NN	PCBH	1000	**3/£1.00**	0.15
X3072	A14SAO	13x10x7	SPCO	Push	PCBV	900	**3/£1.00**	0.15
X3073	A24AO	13x10x12	DPCO	NFN	ST	3600	**5/£2.00**	0.20
X3074	A22TSAO	13x10x12	DPCO	NN	PCBV	250	**5/£2.00**	0.20

UHF MODULATOR



X6035 Alps UHF modulator. Phono input, co-ax output, also switchable between co-ax input and output. £2.50

HEADPHONE OFFER

CD04 - Neat rectangular style CD Headphones, compact design with extremely good sound. These retail for up to £19.95 (depending on how posy the store is!) Spec: 16-22,000Hz Somarium cobalt transducers. Gold plated 3.5mm plug & adaptor. 32R impedance.

SUPER PRICE **£4.95**

MDR20 - Personal stereo headphones. Again top quality using somarium cobalt transducers. Spec as CD04 alongside. Attractively packaged with spare covers.

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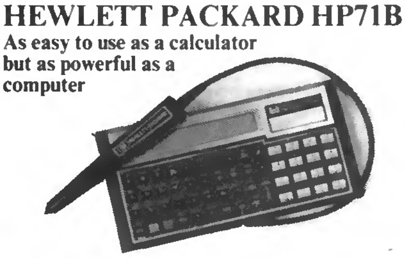

BARCODE READER
Smart wand

– Automatically recognises and decodes all major bar-code standards.

- A powerful set of basic functions, statements, and operators – over 230 in all – many larger computers don't have a set of basic instructions this complete.
- Advanced statistics functions enabling computations on up to 15 independent variables.
- Recursive subprograms and user defined functions.
- An advanced internal file system for storing programs and data – The HP71 has continuous memory – when you turn the computer off it retains programs and data.
- A keyboard that can be easily customised for your specific application.
- HP-1L Interface pre-installed to create a system that can print, plot, store, retrieve and display information. Control or read instruments or speak to other computers, 5000 bytes/sec.

Built in ROM includes 46 separate commands, Interface to HP-1L, HP-1B, RS232C, GPIO or series 80. Includes connection cables.

These are second users systems, ex NHS, are fully tested and working but have no programming (THAT IS UP TO YOU).

HP71B	**£29.95**
Bar-code Reader	**£12.95**
A.C. Power Supply (Works from batteries normally)	**£4.95**
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(Unkown Program – Memory Modules (2 different types) (Limited quantities)	**£3.00**
Complete kit of HP71B, Bar-code Reader and power supply	**£39.50**

(Prices include VAT – Delivery Next day **£3.00**)
(Currently selling in US for over **£500!**)

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Please rush me
- ☐ HP71B Powerful Calc/Computer @ **£29.95**
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- ☐ Memory module @ **£3.00**
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A new range of high quality project kits from **QUASAR ELECTRONICS** *that offer exceptional value for money. Supplied complete with all components, screen printed, solder resist tinned fibre glass PCB's & comprehensive instructions (not just assembly notes!). The detailed explanation of circuit theory & operation, together with schematic circuit diagrams, really help you to understand how each circuit works.*

SURVEILLANCE KITS

Don't be mislead by the low price of our surveillance kits. They perform as well, if not better, than many we have seen that cost over twice the price! Transmitters can be received on an ordinary VHF FM radio.

KIT 7. 3V FM TRANSMITTER The most powerful 'bug' available for its size, 3V supply & number of components. Guaranteed to transmit over 100 metres within buildings & to 500 metres in the open. Easily tuneable in FM band. Greater range at higher voltage and better aerial. **£4.95**

KIT 13. SOUND ACTIVATED TAPE RECORDER SWITCH Used to turn on your tape recorder through its REMOTE plug. Has feedback and delay circuit for robust operation. Very sensitive. Proven circuit. Needs 6V plug pack for most stable operation. **£7.95**

KIT 16. FM TELEPHONE TRANSMITTER Miniature transmitter which attaches in series to one of the two lines of "your" phone. Transmits over 200 metres to an ordinary FM receiver & further if the receiver is near phone line. Tune with ceramic trim cap. Uses phone line as an aerial and power source. Not for illegal use. **£4.95**

KIT 18. 9V MINIATURE FM ROOM TRANSMITTER More powerful FM transmitter 'bug' than KIT 7. Tank oscillator coil built into the circuit board. Can be tuned anywhere in the FM band. 9V battery operation. Over 500 metre range in the open depending on aerial used. **£5.95**

KIT 28. SOUND ACTIVATED TRANSMITTER A sound activated switch and an FM transmitter joined together to make a sound activated FM TX. Set the level of sound that it will respond to. 2 stage transmitter needs tuning for best results. Tuning kit & instructions enclosed. Transmits up to 1 km in the open depending on aerial used. **£8.95**

KIT 32. TWO STAGE FM TRANSMITTER Our most powerful FM 'bug' to date. Two stage FM transmitter with an RF transistor (2N3563 or ZTX320) in its output stage 9V operation. On/off switch mounted on PCB. **£6.95**

KIT 33. LOW VOLTAGE TAPE RECORDER SWITCH This is our new improved tape recorder switch which uses an FET to switch low voltage tape recorders as low as 1.5V. Tape recorder will turn on when the phone is used. Plugs into REMOTE & MIC sockets of recorder. **£6.25**

OTHER KITS FROM THE RANGE

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KIT 24. LOGIC PROBE This is the most important piece of equipment for testing and measuring digital equipment. It is usually used in fault finding and testing but can also assist in design work and to find out how digital equipment works. Switch for either TTL or CMOS. This modern design using a PUT. Includes detection circuit for very fast pulses. Gives visual (3 LED's) & audio (piezo buzzer) response. **£9.25**

KIT 29. COMBINATION LOCK An introduction to a basic but fully working combination lock. Separate touch pad with 9 pads. Lock is reset if an incorrect digit is pressed. Relay capable of switching 240V supplied. 12V operation. Robust and versatile **£11.50**

KIT 48. INTRODUCTION TO CLASS AB AMPLIFIERS Using amplifier modules is modern, quick and easy but teaches nothing about how they work. Here is a Class AB amplifier made from individual components which will deliver several watts of power into an ordinary 8 ohm speaker. Gives hands-on learning about cross-over distortion, bootstrapping, complementary pairs, and push-pull. Detailed explanation given. **£10.95**

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These are sold for the **dismantling** of the exceptional quality components. Regret no Circuits available.
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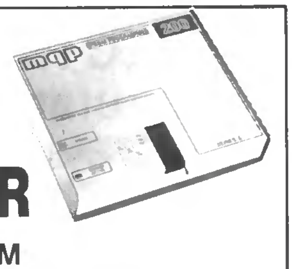
SYSTEM 200 DEVICE PROGRAMMER



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Expandable to cover virtually any programmable part including serial E², PALS, GALS, EPLD's and microcontrollers from all manufacturers.

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Not a plug in card but connects to the PC serial or parallel port; it comes complete with powerful yet easy to control software, cable and manual.

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NEW SERVICE

I quite often use this space to "plug" some of our forthcoming projects and articles. I am going to do that again this month but I also want to plug a new publication which is "hot off the press" – the new item is our *Electronics Service Manual*.

We are often asked by a wide variety of readers – everyone from novice hobbyists to university lecturers – if there is a publication which will show them how to go about repairing various items of electronic equipment. There used to be such a book: it was the *Electronics Repair Manual* published by WEKA Publishing before they closed their UK operation a few years ago.

When we bought the *Modern Electronics Manual* from them we also had the opportunity to buy the *Electronics Repair Manual* but we were not impressed with much of the original material in the Repair Manual and decided not to buy the title. However, we knew there was a strong demand for this type of information so, about a year ago, we set about producing our own entirely new *Electronics Service Manual*.

The new Manual has been written for us by Mike Tooley (who will be well known to *EPE* readers) so it comes from one of the best authors in the field, and we are proud of the finished product – which should be coming "off the press" as you read this. If you are interested in this fascinating and rewarding field of technology then see the centre pages in this issue for full details of this new Manual.

PROJECTS

Once again I believe we have a very exciting range of articles lined up for the next few months. These include a PIC Development and Training System which will enable students and hobbyists to develop PIC software, allowing the production of your own dedicated PIC Microcontroller projects. The system also forms an excellent classroom training aid and we believe it is another "first" in an electronics magazine.

In addition we will soon bring you an exciting and reasonably priced valve hi-fi amplifier design which is unlike anything ever published before; this will hopefully feature in our June issue. We also have a couple of Barry Fox features lined up for the next two issues, one of which is all about Smart Cards. Don't miss out!

Mike Kenward

READERS' ENQUIRIES

We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply *must* be accompanied by a **stamped self-addressed envelope or a self-addressed envelope and international reply coupons. Due to the cost we cannot reply to queries by Fax.**

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.

COMPONENT SUPPLIES

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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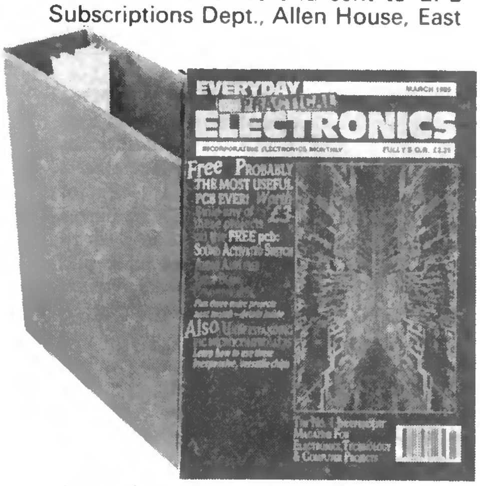

BINDERS

Binders to hold one volume (12 issues) are now available from the above address. These are finished in blue p.v.c., printed with the magazine logo in gold on the spine. Price £5.95 plus £3.50 post and packing (for overseas readers the postage is £6.00 to everywhere except Australia and Papua New Guinea which cost £10.50). *Normally sent within seven days but please allow 28 days for delivery – more for overseas orders.*

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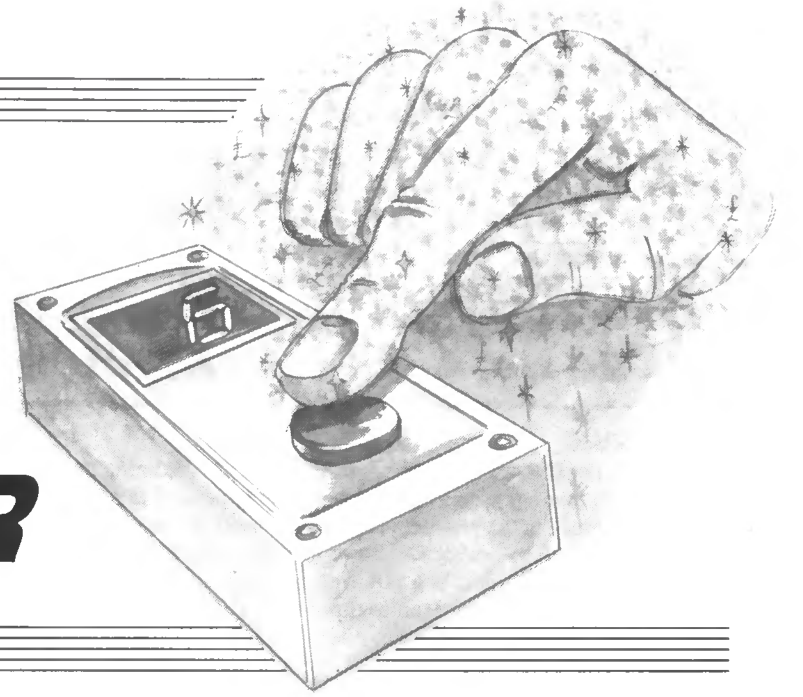
Constructional Project



NATIONAL LOTTERY PREDICTOR

JULYAN ILETT

A simple PIC Microcontroller project that could make your fortune. This pocket-sized random number cruncher won't guarantee you win the National Lottery, but it is great fun to build – Who knows "it could be you!"

SINCE the introduction of the National Lottery back in November, a small number of people have become very rich. The rest of us, however, must have realised by now, what odds of "14 million-to-1 against" actually mean. So can anything be done to improve ones chances of winning?

The idea of accurately modelling the machine used by the lottery organisers is simply out of the question. The behaviour of a single ball, bouncing around inside a Perspex sphere, would be practically impossible to predict. The paths of forty nine balls, all colliding with each other, can be considered utterly random.

Would it be possible, then, to predict the next draw from analysis of previous draws? The mathematics of chance say not! The likelihood of any particular combination of numbers being drawn is precisely the same as all other combinations, and is not influenced in any way by any previous event.

PSYCHOLOGICAL FACTORS

So although it isn't possible to increase the chances of winning, it is possible to increase your share of the prize, if your numbers come up. The idea is to avoid combinations that other people are likely to select.

Choosing numbers in any other way than completely at random, will inevitably be affected by various psychological factors. A winning combination, for example, which consisted of four or more numbers greater than 31, would completely eliminate anyone who used birth dates to make their selection!

A random number generator is therefore essential, and if nothing else, it gives the electronics enthusiast a good excuse to get started on an interesting new gadget! The unit presented here, generates numbers between one and 49 in a random sequence, and displays them on a two digit, 7-segment l.e.d. display. A single pushbutton is used to switch the unit on, display all the numbers, and reset the device, ready for a new number combination.

Reg No. (Hex)	Bit position 0	1	2	3	4	5	6	7
10	1	2	3	4	5	6	7	8
11	9	10	11	12	13	14	15	16
12	17	18	19	20	21	22	23	24
13	25	26	27	28	29	30	31	32
14	33	34	35	36	37	38	39	40
15	41	42	43	44	45	46	47	48
16	49							

Fig. 1. Grid layout for the lottery numbers.

PRACTICAL DEVICE

One serious aim of this project is to demonstrate the design of a practical device using a PIC microcontroller. (See last month's feature *Understanding PIC Microcontrollers.*). Information is given about the software used, including a flowchart, and an example of how this is converted into actual assembly language instructions.

The microcontroller used is the Arizona Microchip PIC16C54, which is the smallest and simplest device in their current range. Even so, it still has a very impressive specification.

This remarkable 18-pin integrated circuit contains 512 bytes of ROM, 32 bytes of RAM, a real time counter, watchdog timer, code protection and more. It has a RISC architecture and is capable of operating at 20MHz, although in this design, it runs a good deal slower than that! It also has the ability to enter a very low power "sleep" mode, so this project needs no on/off switch.

Traditionally, the problem with designing microprocessor based projects has been software development. The microprocessor chip may only cost a few pounds, but the cost of all the development hardware and software can be considerable. A text editor, assembler, target development system, EPROM programmer and EPROM eraser are all essential tools, and if you want an in-circuit emulator and logic analyser, you'll need to win the lottery to pay for them! *(We expect to publish a PIC Development and Training System as a project in the May issue – Ed.)*.

The PIC microcontrollers are supported by a realistically priced development system called PICSTART. This comprises assembler and simulator software, a neat little programmer unit and a stack of manuals. The system is readily available and costs under £200, but you do need to provide a PC compatible computer and an EPROM eraser. The software for the Predictor was developed on this system.

If you're not yet ready to rush out and buy the PICSTART development system, the author is able to supply a pre-programmed PIC16C54RC/P microcontroller for the project for £7. A floppy disk containing the complete source code and other related files is also available for £1. For details, see *ShopTalk* page.

DESIGN BEGINNINGS

Generating a random number and displaying it as two 7-segment digits could be achieved using a handful of CMOS logic i.c.s. A complication arises, however, with the requirement that the National Lottery Predictor must not display any number more than once. This function can only be achieved by marking off the numbers that have been used, in an array, or grid.

This is where the logic circuit gets rather complicated, requiring an additional memory chip. The microcontroller has a small number of RAM locations or "registers" which can be used to form the array. Each element in the array only needs to indicate whether or not a certain number has been used, and can therefore be represented by a single bit.

Forty nine bits occupy just 7-bytes of memory (actually 6-bytes and 1-bit), which is just as well, as the microcontroller has a very limited number of registers, 32 in total, seven of which are reserved for special purposes. The arrangement of lottery numbers in the 7-byte grid is detailed in Fig. 1. For example, lottery number one is positioned in the first byte (register 10) in bit position zero.

To begin the design process, the operational requirements of the unit must be defined. Pressing the pushbutton for the first time, switches the National Lottery Predictor on. The display initially shows "▬▬", indicating that it is reset, ready to start the number sequence.

Pressing the button again, displays the first random number, and subsequent presses generate further numbers until all 49 numbers have been displayed. With no more numbers available, the display shows "••", although normally, only the first six numbers will be required.

At any time, the pushbutton may be held down for a couple of seconds which will reset the grid ready for a new set of numbers. If the unit is left for more than about 2·5 minutes without the pushbutton being touched, the National Lottery Predictor goes into "sleep mode", effectively switching itself off. All these functions are achieved using just one button.

CIRCUIT DESCRIPTION

With the operational details worked out, the circuit design can begin. The complete circuit of the National Lottery Predictor is shown in Fig. 2. The PIC16C54 microcontroller IC1 is driven by a very simple clock circuit consisting of just one resistor and one capacitor, R3 and C2. The frequency of oscillation is about 800kHz using the values shown. The components R1, C1 and R2 generate the reset, and wake-up-from-sleep pulses.

There are two I/O (Input/Output) ports, one 8-bit and the other 4-bit. The 8-bit port, port B, is connected to the eight segments (seven plus decimal point) of both digits of the dual display, via resistors R6 to R13. Port A, the 4-bit port, is divided into one input bit and three output bits.

Outputs A1 and A0, pins 18, 17 are connected to the bases (b) of two *pnp* transistors, TR1 and TR2, via resistors R4 and R5. The display is a common anode type, which requires that current is sourced through the common anode connection, and sinked via each individual cathode segment connection.

The pushbutton switch S1 is read by the microcontroller by first taking output A2, pin1, *low*. Then, input A3, pin 2, is read, after which A2 is taken *high* again. In this way, capacitor C1 is not discharged when the pushbutton is read, since output A2, does not go low for long enough.

When the microcontroller is in sleep mode, however, output A2 is left permanently low. Now, when the pushbutton is pressed, C1 discharges through resistor R1 and the microcontroller is reset, which wakes it up.

Much of the circuit design, in particular the clock, reset and wake-up circuitry, is taken straight from the applications handbook supplied with the PICSTART system. Details are also given on driving multiplexed displays and reading key switches.

SOFTWARE DESIGN

Software design is a very personal thing. Different people achieve the same result in different ways. The software developed for the National Lottery Predictor demonstrates just one method of providing the necessary functions, there are doubtless many others.

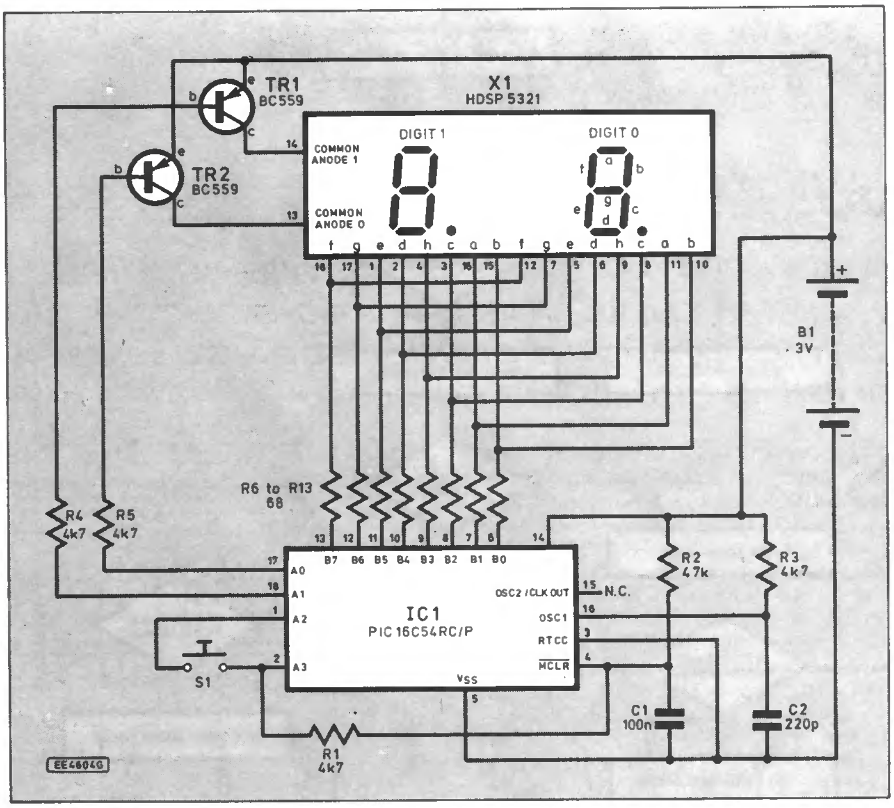
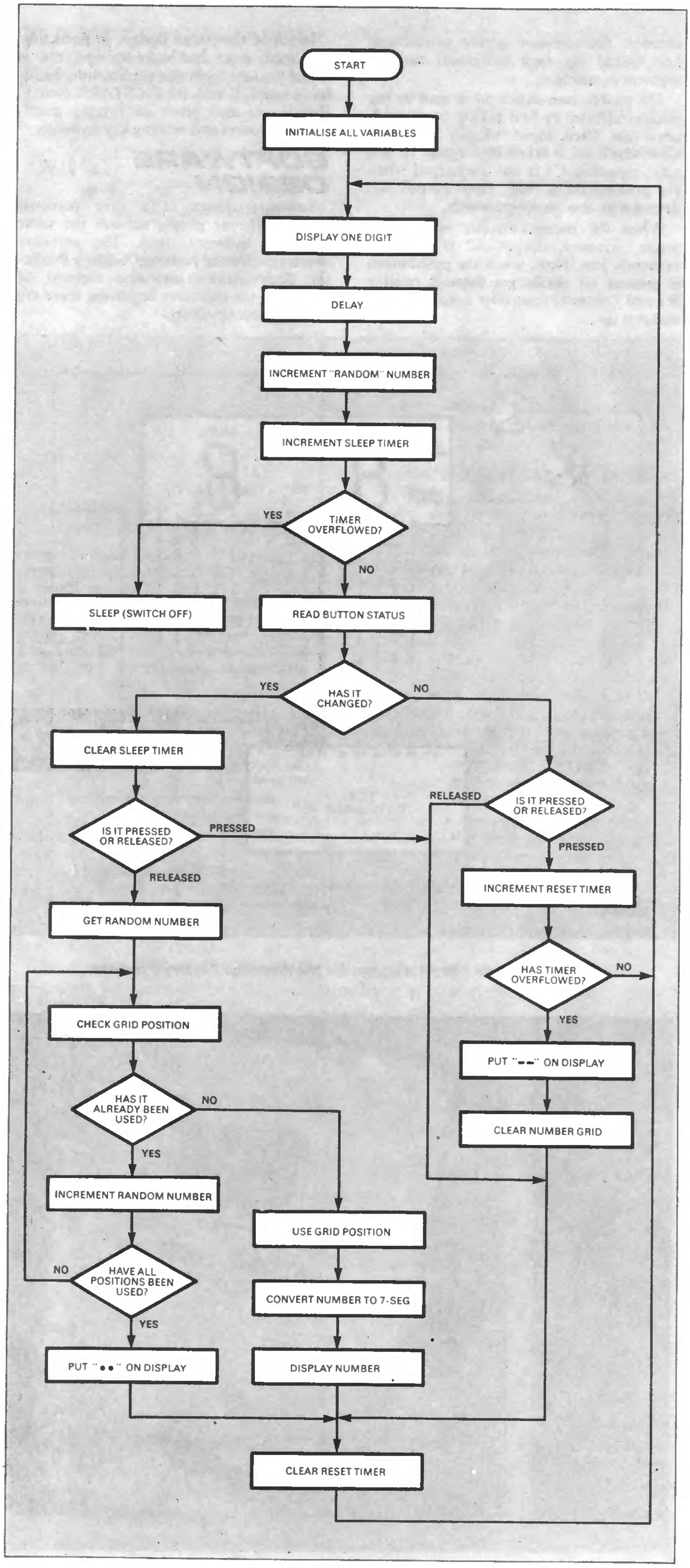


Fig. 2. Complete circuit diagram for the National Lottery Predictor.



In order to provide some insight into the design of this project, a flowchart has been provided, see Fig. 3, and a section of the source code has been reproduced, see Fig. 4.

The program performs several distinct functions, each of which is described below:

Display Multiplexing

Every time the software loop is executed, only one digit is displayed, both digits taking it in turns. The digit whose turn it is to be displayed, is identified by testing one bit in a register. The appropriate data is then taken from either of two digit registers, and the appropriate transistor turned on by lowering either bit 0 or bit 1 of port A.

As long as the software loop keeps running at a fast enough rate, both display digits appear to be lit up simultaneously.

Random Number Generation

The "random number" variable is incremented each time the loop is executed, unless it exceeds 49, whereupon it is set back to one. When the pushbutton is pressed, the current value of this variable is used as the random number.

The random behaviour results from the delay between presses of the pushbutton. The person operating the unit cannot see the value of the counter, so the random numbers cannot be influenced directly, although deliberate rythmic button pushing can result in sequences of similar numbers.

Binary-to-Decimal Conversion

When the random number has been generated, it is converted into two decimal digits by repeatedly subtracting 10 from the number until it underflows (goes negative). Each time the subtraction is carried out, another register is incremented, indicating the number of times 10 has been subtracted. This number becomes the "tens" digit.

When the number does underflow, ten is added back restoring the remainder, which becomes the data for the "units" digit.

Digit Character Generation

Character data for the 7-segment display is taken from a table, indexed by the decimal number to be displayed. The table contains ten items corresponding with the digits 0 to 9.

The table is read twice, once for the "tens" digit and again for the "units" digit. Leading zero suppression is achieved by replacing the "tens" digit with a blank character whenever it is zero.

Number Grid Maintenence

Forty-nine bits of RAM hold the data indicating whether a number has already been used. When a number is displayed, the corresponding bit is set. If the unit attempts to use that number again, it must move on to the next available unused number. Two variables are used to address the grid.

A pointer is used to index one of the seven bytes in the grid, and a mask selects one bit out of the eight in each byte. Each time the random number is incremented, the mask bit is rotated into the next highest significant bit position. If the bit is rotated

Fig. 3. (left) National Lottery Predictor flowchart.

```
reset       movlw   10              ;Subroutine to reset all bits in grid
            movwf   fsr             ;set fsr to point at register 16
            movlw   07
            movwf   gp_counter      ;set gp_counter to 7, 7 registers to clear
clearreg    clrf    ind             ;clear the register
            decf    gp_counter,f    ;decrement gp_counter
            btfsc   status,z        ;test gp_counter for zero
            goto    alldone
            incf    fsr,f           ;point to next register to be cleared
            goto    clearreg
alldone     movlw   40              ;put two dashes on the display
            movwf   digit0
            movwf   digit1
            retlw   0
```

Fig. 4. Example of PIC Microcontroller assembly language.

out of bit seven, it is put back into bit zero and the pointer is incremented. This pair of variables operate like an octal (base-8) counter.

Pushbutton Reading and De-Bounce

The pushbutton has to be read in a special way so that it can also be used to bring the microcontroller out of sleep mode. One side of the button is connected to an input which is pulled high. The other side is connected to an output, see Fig. 2.

If the output is high, pressing the button has no effect. When the pushbutton is to be read, the output is briefly taken low, but only long enough for the read function and no more. This prevents the microcontroller being reset, even if the pushbutton is held down.

When the microcontroller is in sleep mode, however, the output is left at a low level. Pressing the button then causes the capacitor (C1) to discharge.

De-bounce is achieved by reading the pushbutton input at intervals of no less than about two milliseconds. This allows time for the bounce signals to stabilise between one read and the next.

Auto-Sleep Timing

A 16-bit counter increments continuously while the pushbutton remains inactive. When the counter eventually overflows, after about 2·5 minutes, the I/O pins are all put into a condition which uses least power, after which the controller goes to sleep.

When the PIC microcontroller is woken up, the program is executed from the beginning.

Clearing the Grid

All bits in the number grid must be cleared or set to zero when the pushbutton is held for a couple of seconds. The program instructions used to achieve this function are shown in Fig. 4. providing an example of PIC microcontroller assembly language.

The file select register (fsr) is initially set to register 16 (or hexadecimal 10). This is the first register in the number grid. A general purpose counter (gp counter) is then given the value 7, as there are seven registers in the grid that need to be cleared. The indexed grid register is then cleared indirectly using the "fsr" as a pointer.

The counter is then decremented and tested for a zero value. If the counter is not yet zero, the "fsr" is incremented ready for the next grid register to be cleared. When all seven registers have been cleared, a "dash" symbol is put onto both digits of the display.

FUN!

Writing short programs in assembly language can be great fun. Piecing together the various different instructions is a bit like constructing a building out of "Lego" bricks.

There is one important difference, however. While building your multi-storey, luxury apartment block, you always seem to run out of one type of brick while having plenty of the others left over! There may only be 33 different instructions in the PIC assembly language, but you've got an unlimited supply of all of them!

COMPONENTS

Resistors

R1, R3 to R5	4k7 (4 off)
R2	47k
R6 to R13	68 (8 off)

All 0·25W 5% carbon film

See SHOP TALK Page

Capacitors

C1	100n disc ceramic
C2	220p ceramic

Semiconductors

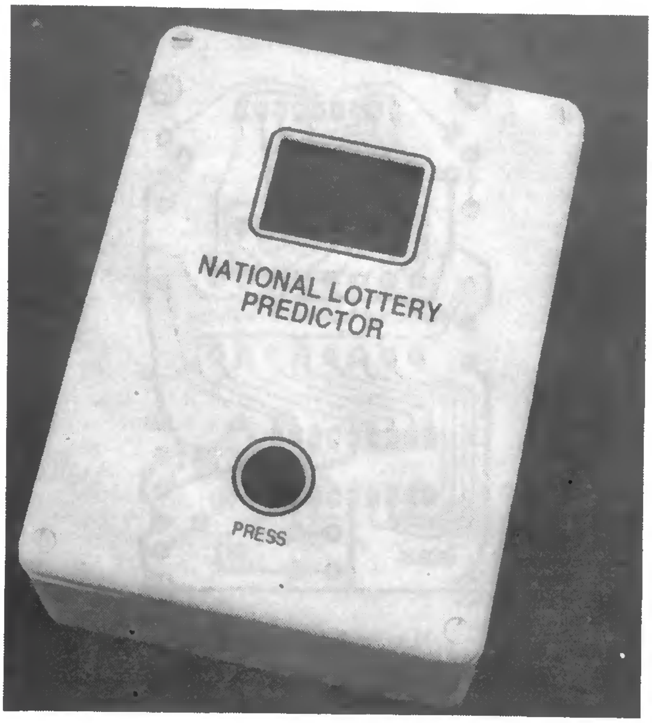
X1	HDSP5321 dual 7-segment display (red), common anode
TR1, TR2	BC559 *pnp* silicon transistor (2 off)
IC1	PIC16C54RC/P ready-programmed microcontroller (see text)

Miscellaneous

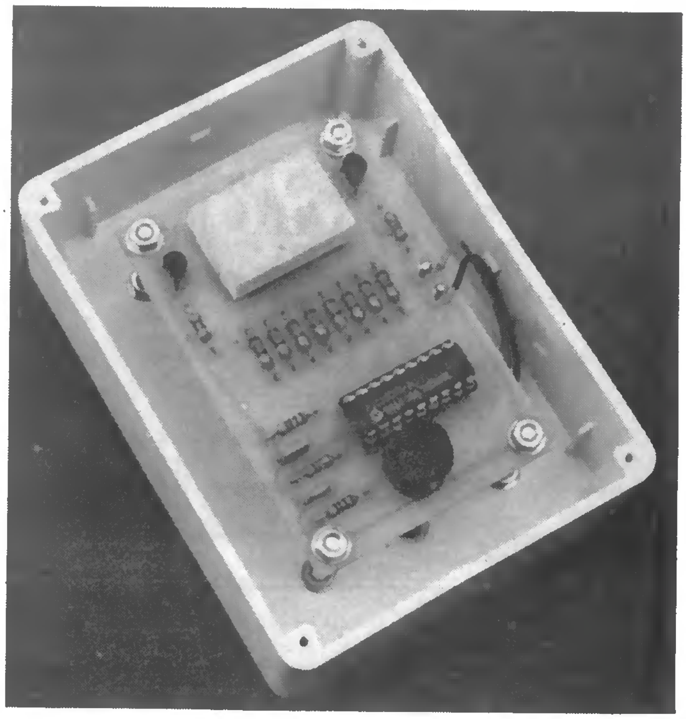
S1	Min. round pushbutton switch (5mm pin spacings)

Printed circuit board available from the *EPE PCB Service,* code 935; plastic ABS box, size 102mm x 76mm x 38mm; red display filter; battery holder (2xAA type); battery clip; 18-pin d.i.l. socket; 1mm p.c.b. pins (2 off); 30mm M3 countersunk bolts; M3 nuts and washers; stick-on rubber feet; Velcro strip or sticky pads; solder etc.

Approx cost guidance only **£19**



Front panel arrangement of the completed unit.



The completed circuit board mounted inside the small box.

CONSTRUCTION

Because the microcontroller integrates all the essential elements of a computer system into one tiny chip, the design of the printed circuit board (p.c.b.) layout is made very simple. All the components mount directly on the small single-sided p.c.b., including the double-digit display and the pushbutton, and there are no wire links.

The topside p.c.b. component layout and full size underside copper foil master pattern are shown in Fig. 5. This board is avaiable from the *EPE PCB Service*, code 935. The battery connector is soldered directly onto two solder pins at the side of the board. Remember, there is no on/off switch.

Construction of the p.c.b. is very straightforward. The components can be fitted in any order, although a socket should be used for the microcontroller IC1, preferably a good quality, turned-pin type. The socket must have a low profile though, so that IC1 does not sit too high on the p.c.b.

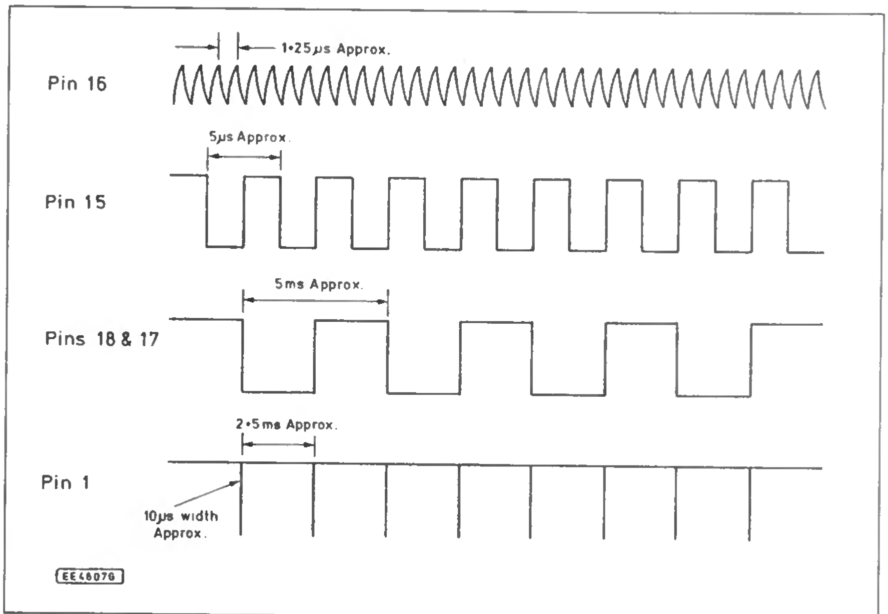
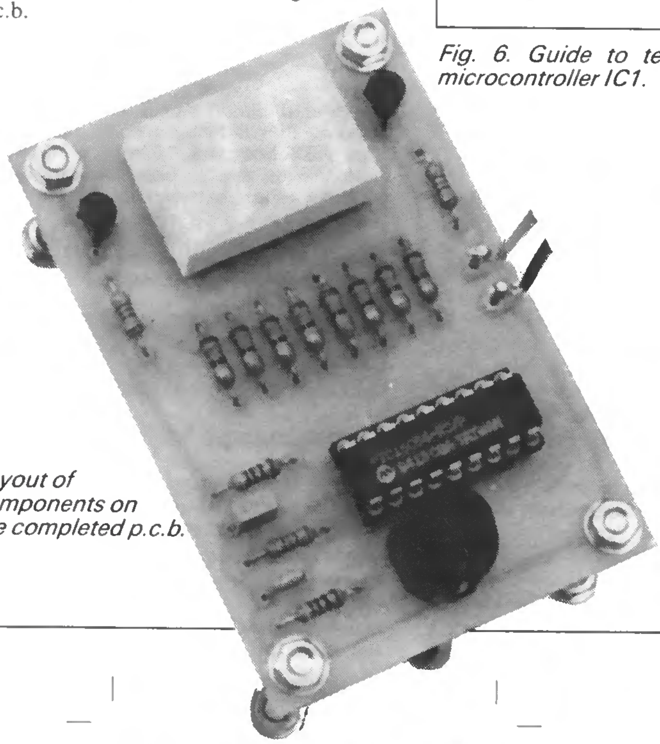


Fig. 6. Guide to test waveforms to be expected at the output pins of the microcontroller IC1.



Layout of components on the completed p.c.b.

TESTING TIME

Testing can be carried out using an oscilloscope if one is available, although a good quality logic probe will be perfectly suitable as an alternative. The waveforms in Fig. 6. should be referred to during the test procedure.

Check the output on pin 15, this should be a square wave of approximately 200kHz frequency (5μs period). On the adjacent pin, pin 16, the frequency should be four times higher and much less square.

The outputs on pins 17 and 18 should both be square waves of approximately 200Hz (5ms period), although one goes high when the other goes low. Finally, the output on pin 1 should show a brief, low going pulse (about 10μs width) at a frequency of approximately 400Hz (2·5ms period).

The logic probe, used to test the prototype unit, was capable of showing high and low logic levels as well as pulse waveforms. In addition, an indication was given of whether the pulse frequency was less than or greater than 100kHz, and whether the waveform was square (50 per cent mark/space ratio) or was mainly high or mainly low. As such, it was an ideal tool with which to perform the tests mentioned above.

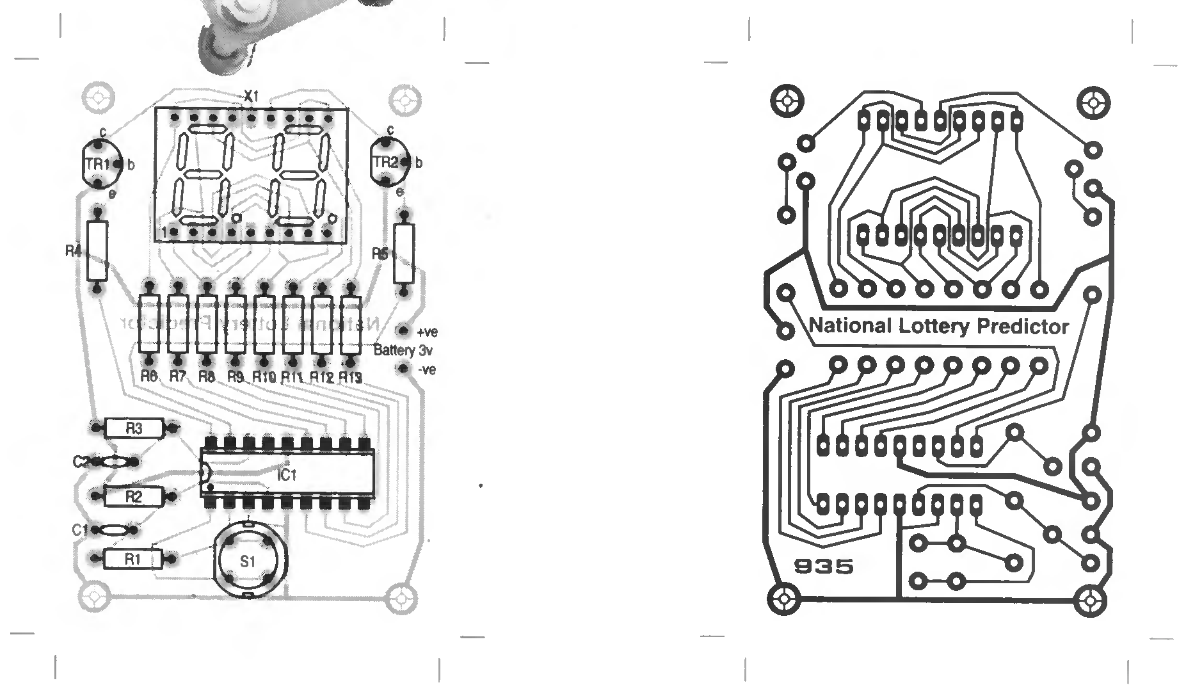


Fig. 5. Printed circuit board component layout and full size copper foil master pattern for the National Lottery Predictor.

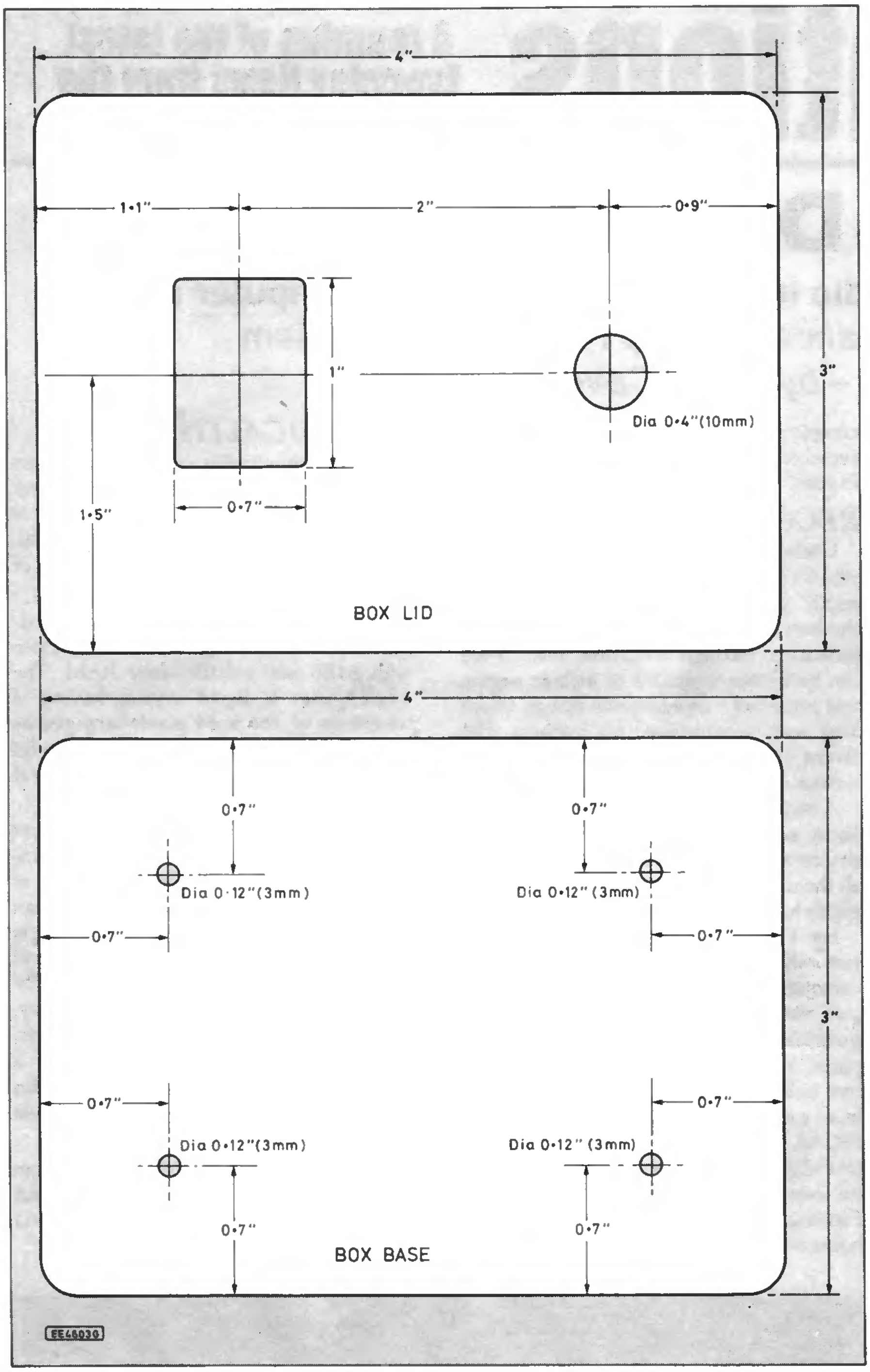
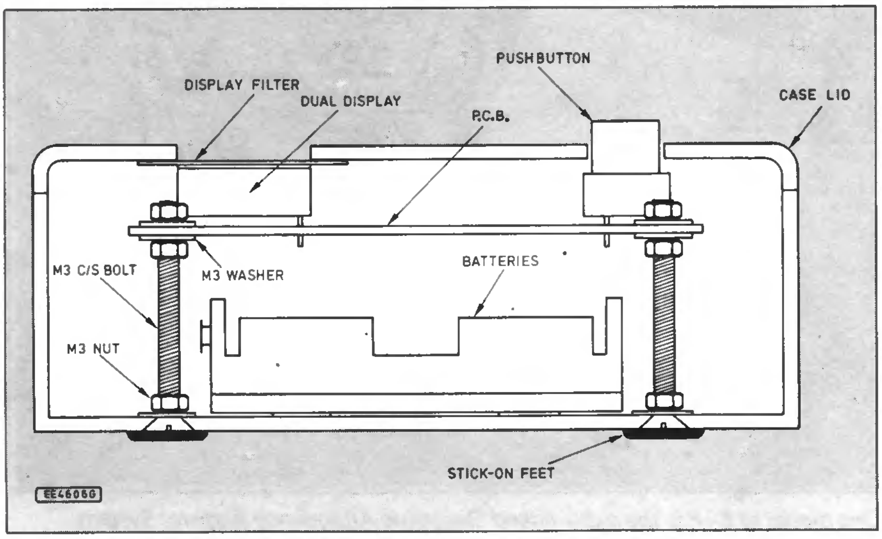


Fig. 7. Case dimensions and drilling details. The p.c.b. is mounted on M3 bolts and locked in position with nuts and washers, once the correct height has been found.



IT COULD BE YOU!

Note that the logic probe may require TTL signals and a supply of around 5V. In this case, a 4·5V supply (three AA cells) may be used during testing, but *avoid* using 6V, as this might overload the microcontroller's outputs. All that remains is simply to confirm that the unit operates as expected.

ON THE CASE

The case, used to house the National Lottery Predictor, requires two cutouts on the front panel (i.e. the lid), and four holes in the base. The dimensions of the cutouts are detailed in Fig. 7. The cutout for the display is rectangular, but can be finished off with rounded corners to improve the appearance.

The p.c.b. is mounted on four countersunk M3 screws using nuts and washers to set it at the correct height. A piece of red transparent plastic filter material is attached to the inside of the case lid and should just touch the front of the display when the case is closed.

The battery holder can be attached to the inside of the case with self adhesive Velcro strips or double-sided sticky pads, and stick-on rubber feet can be attached to the bottom of the case, to cover the screwheads.

IN SUMMARY

The PIC series microcontrollers are proving to be among the most popular devices of their type, and are widely used commercially. The range of devices includes such features as analogue-to-digital conversion and E²PROM non-volatile memory. More complex devices use a 16-bit bus and can make use of interrupts. The range is being added to all the time.

From the electronics hobbyists point of view, these devices represent an even more important innovation than microprocessors, when they became available in the late seventies. Microcontrollers are easier to use, have more flexible power requirements, require much less complex p.c.b layouts and they often need no support logic at all.

If this project inspires you to equip yourself to get involved in this facinating area of micro-electronics, you could be designing minaturised microcontroller devices in no time at all! □

EARS TO DEFEAT SKIVERS

Intelligent key pads, radio interfaces and a central computer register class attendances to help reduce absenteeism

– by Hazel Cavendish

THEY are not going to get away with it any longer! Pupil drop-out days are numbered. "EARS", the £25,000 Electronic Attendance Registration System, works as an electronic register to reduce the administrative load on teachers and claims to save schools so much time that it can add two teaching periods to the school day.

Designed to provide the most advanced and effective system yet devised, the scheme has won numerous awards including the 1994 Educational Technology Gold Award and is already being used by 5,000 teachers not long after its introduction.

The brainchild of Bromcom Computers of Bromley, Kent, the system links key pads the size of a normal piece of A4 paper to a central computer by a two-way radio, modem links or broadband networks. Designed particularly for recording the presence or absence of pupils or college students, it has also been expanded to perform other valuable uses for schools and educational establishments.

KEY LIST

Teachers using the "Ears" system simply key in their name and the form they are about to teach, and it provides a list of names of those who should be attending that day. They can monitor the attendance of any class on a small screen, to see who is genuinely absent or playing hookey. It also records the reason for absence, where this is known, and records the attendance history of a pupil in his or her class.

The previous system most favoured by schools was based on the issue of cards to pupils which had to be inserted in card readers to record attendance. Alternatively, schools relied on specially prepared forms which were completed in the classroom, and subsequently inserted into an "optical mark reader" at a central point, which in turn transferred the information into the school's own system.

Apart from being labour-intensive, both these systems had specific weaknesses. Pupils were able to give their cards to others to register for them, and the "optical mark reader" increased a school's paper work considerably, and wasted staff time be requiring the transfer of records from classroom to school office.

Each teacher's "mobile data collection means" comprises a network of radio transmitters distributed over the area of the school or college premises and connected to a central computer. Radio links have the big advantage that the apparatus is then completely portable, although it is conceded that modem links may be preferred in some cases.

RECORD PERFORMANCE

Usefully, the portable computers can be provided with further software for storing pupils' performance records and provides the basis of a network for exchanging information through electronic mail. They can be further upgraded to include paging and panic-call – an additional feature which may well be welcomed by teachers after recent reports of violent pupils causing serious injuries to staff in the classroom.

A staff member at the Portsmouth Sixth Form college remarked that the paging device would be particularly useful to route all the messages received from parents that pupils had forgotten their sandwiches!

For Colleges and Universities the system will be appreciated as affording greater communication between Tutors and College staff via use of Ears' one-way messaging, particularly in the case of "Split-site" Campuses, and interfaces with the administrative software currently used by most colleges such as SIMS, FEMIS, COVTECH and FECAS. It is anticipated that it will be particularly useful in the production of statistical data required by the Further Education Funding Council and is expected to save hours of administrative time.

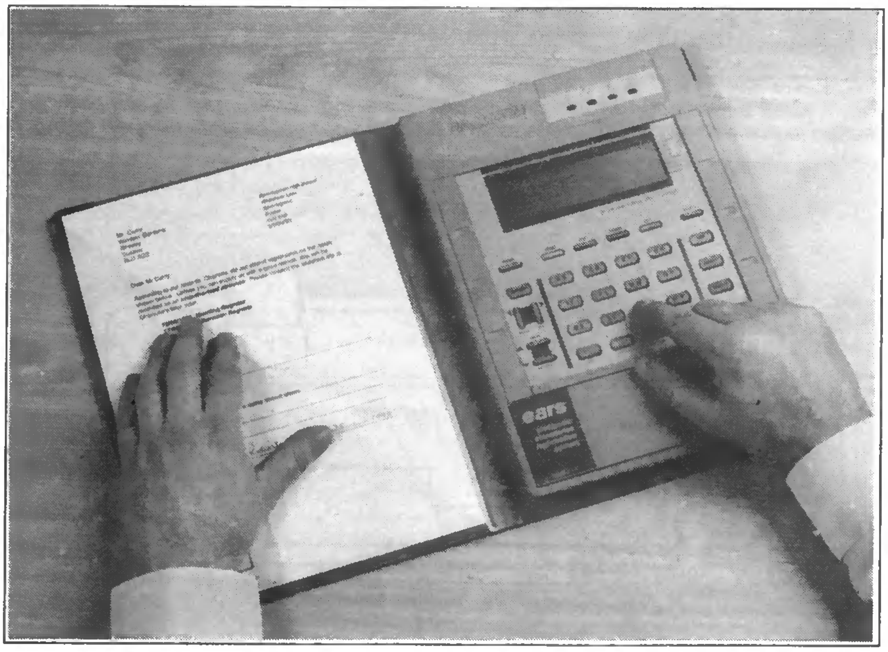
TECHNICALITIES

The system consists of A4-sized folders with a built-in slim-line miniature computer and radio transmitter-receiver. The folder is battery-operated with no need for cables. Battery life is in excess of 120 hours of operation, lasting up to an academic year.

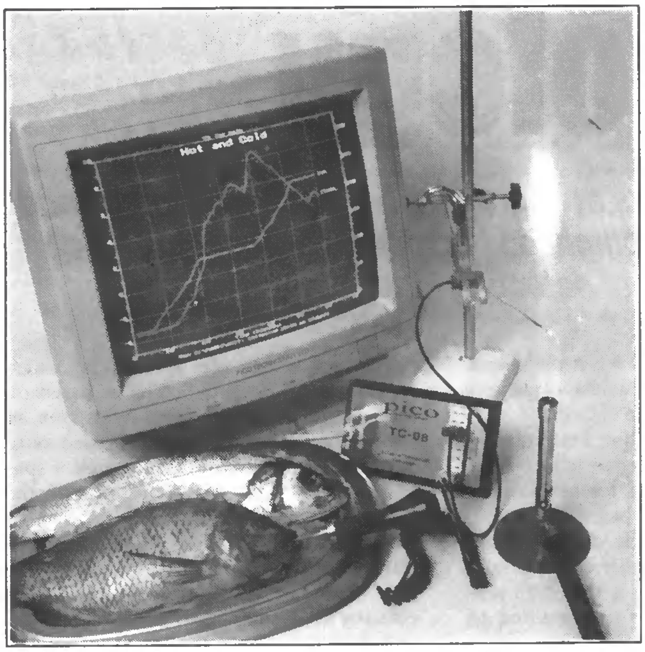
The microprocessor used for the registration folders is a Zilog Z180 6MHz device with 64Kb non-volatile static RAM. The display uses a liquid crystal having a resolution of 256 x 64 pixels arranged as eight lines by 42 characters. The radio transceiver is a MPT1340 UHF unit (licence exempt).

The central processor is a Mini-Tower Bromcom QC486/DX2 using an Intel 82486 microprocessor operating at 66MHz and having a 4Mb cache and an 8Mb RAM. A 540Mb capacity hard disk is used, which has a 15ms access time and 4Mb cache on its controller. The monitor used has a 14 inch SVGA display, and if a modem is preferred a Miracom Courier or equivalent is advised with a baud rate of up to 14,400. The radio transceivers are linked to the system via RS485 and RS232 interfaces.

For further information contact Bromcom Computers PLC, 417/421 Bromley Road, Downham, Bromley, Kent. Tel: 0181 461 3737. Fax: 0181 461 3993.



One model of EARS, the radio-linked Electronic Attendance Register System.



PC THERMOCOUPLING

Pico Technology has introduced an interface which allows thermocouples to be monitored by PC-compatible computers. The TC-08 is supplied with PicoLog datalogging software and is designed to allow simple yet accurate temperature recordings to be made. The interface accepts up to eight thermocouples (B, E, J, K, R, S and T types) and connects via the serial port. It does not require a power supply.

For type K thermocouples, resolution over the −270°C to +1300°C range is better than 0·1°C and accuracy is better than 0·5°C. Cold junction compensation is carried out within the unit and linearisation is carried out by the software.

Samples can be taken as fast as one per second and as slow as one per hour allowing recordings to be made for a few seconds or over several weeks as required. PicoLog offers advanced temperature processing functions including filtering, min/max detection and alarms. Data can be displayed in real time, in either graphical or text format, or printed out after collection.

The TC-08 interface comes complete with the PicoLog software, software drivers and connecting cable, for £199. A range of thermocouples/probes is available.

For further information contact Pico Technology Ltd., Broadway House, 149-151 St Neots Road, Hardwick, Cambridge, CB3 7QJ. Tel: 01954 211716. Fax: 01954 211880.

LOW POWER RADIO COMMS

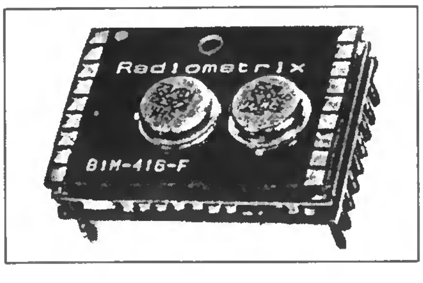
Radio-Tech can help you to tune in to simple and affordable Low Power Radio data communications. The company has been involved in the design and supply of this type of equipment since the allocation of the deregulated radio bands by the DTI back in the mid-1980s.

A choice of over 20 affordable and high performance radio data modules is available off-the-shelf, including the new BIM high speed radio transceiver. Radio-Tech's aim is to make the use of Low Power Radio a viable alternative to cables for data communication applications, ranging from the traditional social and security alarms, through to wire-free EPOS (Electronic Point of Sale) terminals, remote controls, monitoring systems and radio LANs (Local Area Networks).

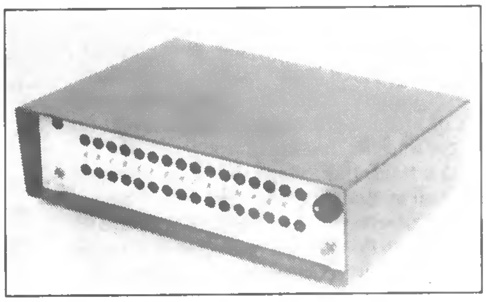
Undoubtedly, there are numerous other uses to which the various transceiving modules available can be put. Low Power Radio at affordable prices is a technology waiting to be explored by professional and hobbyist designers alike.

Manufacturers can also benefit from using one of the many DTI type-approved modules that Radio-Tech can offer. The procedure for obtaining type-approval for a product can be reduced to that of a paper exercise with only a nominal DTI registration fee involved. Exporters can also benefit since Radio-Tech can offer advice on which modules comply with European and other overseas specifications.

For further information, see Radio-Tech's full-page advert elsewhere in this issue, which also contains a FREE £15.00 introductory discount voucher offer. Alternatively, contact Radio-Tech Ltd. at Overbridge House, 41 Weald Hall Lane, Thornwood Common, Epping, CM16 6NB. Tel: 01992 561994. Fax: 01992 561994.



PLANE SPOTTING



Shortwave listeners to the HF Aeronautical frequencies will be interested to know that they can now automatically identify an aircraft's type and registration details. Seldec has introduced a Selcal decoder which, when linked to a suitable receiver tuned to one of the Oceanic Control Centres, will decipher a Selcal as it is transmitted, and present a clear visual display allowing identification of the aircraft by type, nationality, registration and airline.

Housed in a two-tone metal case, the Seldec Decoder displays the decoded Selcal codes on two rows of l.e.d.s correspondingly lettered A to S. Having logged and identified the Selcal, the display remains visible until reset by a pushbutton switch. The unit is then ready to receive and identify the next Selcal tones.

The decoder is compatible with all good quality, general coverage receivers and has been designed without the use of microprocessor technology in order to avoid electrical interference when used with sensitive HF receivers. Audio signals from short wave receivers are simply plugged into the decoder's audio input socket.

For further information contact Seldec, P.O. Box 3, Kidderminster, Worcestershire, DY12 1YZ. Tel: 01299 861372. Fax: 01299 861530.

LIGHT CONVERSION

Texas Instruments has added another member to its family of light-to-frequency converters. These devices combine, on a single chip, photodiodes and a high resolution charge-to-frequency converter. The output is a pulse train having a frequency proportional to the incident light intensity. By counting pulses, or measuring the time between them, light intensity can be measured by a microcontroller without the use of analogue-to-digital converters.

The latest Texas device, the TSL235, is a low-cost precision opto-converter which typically delivers from 0.25Hz in darkness to 500kHz when fully saturated by light. The frequency output is highly linear to within 0.02% up to 100kHz, and the temperature coefficient is typically 100 ppm/°C. Power consumption is only about 5mW and the device can be run from voltages between 2·7V and 6·0V.

For further information contact Texas Instruments Ltd., Manton Lane, Bedford, MK41 7PA. Tel: 0234 270111.

GREEN PIECE

A new Energy Management Controller from Microchip can reduce electricity consumption by up to 30 per cent it is claimed. Their MTE1122 chip is ideal for all residential, commercial and industrial equipment which uses a.c. motors, including refrigerators, freezers, washing machines, dryers, swimming pool pumps, and heating, ventilation and air conditioning equipment.

Integrating Microchip's popular 8-bit RISC-based PIC16/17 microcontroller technology with proprietary power management firmware the new chip allows induction motor applications to be more energy efficient.

The controller operates by digitally monitoring the motor load and controlling power consumption thousands of times per second. Most a.c. induction motors require large currents under light or even no-load situations. The unique algorithm in the controller monitors the a.c. signal and senses when the motor is consuming more power than is required. The device modifies the a.c. signal allowing the motor to continue its rotational speed while consuming less power.

For further information contact Arizona Microchip Technology Ltd., Unit 6, The Courtyard, Furlong Road, Bourne End, Bucks, SL8 5AJ. Tel: 01628 851077.

New Technology Update

Ian Poole looks at upgrading an "old" technology and throws the spotlight on "confocal microscopy," the latest method of detecting faulty wafers.

EMITTER coupled logic has been available for many years and yet it still offers advantages over other types of logic technology. Its chief advantage is that it can offer operating speeds over 1GHz at affordable prices. This makes it a prime choice for a number of applications including the high speed dividers used in a number of radio frequency circuits like frequency synthesizers.

Power Hungry

However, it is hardly surprising that these chips have some disadvantages. The main one is their current consumption. Emitter coupled logic (ECL) is notoriously power hungry, requiring a pull-down resistor of around 470 ohms to sink current on all the outputs that are in use.

As a result these chips sink large amounts of current and become very hot. For example, one programmable divider dissipates as much as ½W. Being packaged in a 16-pin d.i.l. package it is hardly surprising that it becomes very hot after a few minutes operation, and often it is too hot to handle.

Running at temperatures like this there is no chance of it being put into a surface mount package. It also means that the reliability figures obtained for a chip like this are lower than similar devices operating at lower temperatures.

A further problem is that they operate with voltage levels which do not conform to the normal logic standards. The best performance is obtained when they are run from 0V and −5·2V lines i.e. the inverse of standard logic families.

Even then the supplies have to be more accurately maintained than those for other logic families. Fortunately, it is possible to run them from a 0V and +V supply but with a slight reduction in performance.

In addition to this the voltage swing of the output is small (just over 0·6V) and does not swing between both rails. This means that special translators are required to interface between ECL and conventional series of logic families or vice versa.

Active Service

In view of the high speed performance of ECL a number of developments are under way to improve the shortcomings of the technology. One of these involves the use of an active pull-down circuit. This is used to replace the external resistor which is standard on the existing circuits.

The use of the active pull-down circuit together with a.c. coupling between the devices produces significant improvements, allowing each chip to consume less current whilst being able to operate at higher speeds. When the output changes from low to high, the pull-down current is suppressed as it acts against the rising voltage. When the output is falling from high to low, the capacitors help enhance the pull-down current.

This new idea is only the first stage in upgrading ECL technology. Further work is still required. The ideas for new devices still leave a number of problems.

The manufacture of the devices themselves incorporates a number of specialised structures. The main one is that high performance bipolar devices are required to give the speed.

In addition to this special capacitors need to be fabricated onto the chip. Also the additional circuitry required for the active pull-down facility places a number of restrictions on the remainder of the design.

However, with ECL still being deemed an important technology, research is being undertaken into resolving these problems. This should mean that ECL will remain a leading technology in use for many years to come.

Scanning Wafer Defects

As the size and complexity of i.c.s increases it is forcing the semiconductor manufacturers to meet increasingly high standards in their manufacturing processes. In large i.c.s even small defects can have disastrous results.

Previously it would have meant that a *single* chip in a wafer containing a large number of chips would have to be rejected. Now with the number of transistors increased by many orders of magnitude a single defect will make a much larger proportion of the *whole* wafer defective.

The problem is compounded by the fact that i.c. feature sizes are becoming smaller all the time. This means that even very small defects are very important. However, these small defects are very difficult to locate, putting more pressure on the equipment to locate them.

Current detection systems are based on either optical or scanning electron microscopes. These systems suffer from a number of disadvantages. Firstly they do not offer the types of throughput required by large production lines. In addition to this they are normally only used to scan the areas on the chip that are most likely to give defects. As such they do not fulfil all the requirements which are now being placed upon them.

Confocal Microscopy

As existing methods are becoming hard pressed to meet the ever increasing requirements, a company called Ultrapointe in San Jose, California has developed a new laser scanning system which is capable of locating defects which are as small as 0·1μm in diameter.

The new system uses a technique called "Confocal Microscopy". This is based on the use of a point source of light from an argon laser. This is sharply focused onto the wafer and then viewed through a spatial filter which exactly coincides with the illuminated area.

This means that the illuminated and viewing areas are exactly the same. The filter also ensures that any stray light entering the system from outside is rejected and does not reduce the clarity of any of the images produced.

The spot of light and the filter are scanned so that a picture can be built up of the whole of the surface of the wafer. In view of the very small depth of focus and the differences in height of various parts of the wafer, not every area will be in focus. As a result several passes are needed.

The information from each pass is stored and then a complete three dimensional picture is made of the whole of the wafer. The complete picture can then be examined for any defects.

The process can reveal a number of problems. It will show if there are any dimensional defects, unwanted particles, masking defects, and various pits and scratches. Also, in view of the three dimensional capability of the process, it is possible to see any problems below the surface when transparent layers are used. With conventional systems this would not always be easy because of the very narrow depth of focus which has to be used, and the time taken to refocus for each transparent site.

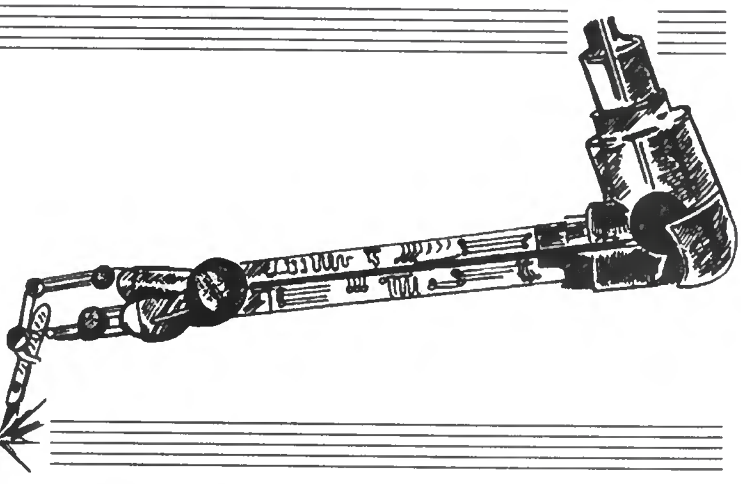
It is very important to be able to examine all of these aspects because some of the defects may reveal process or masking problems. These can then be cured to ensure that future batches do not suffer as well.

There are two main sections to the system: the computer unit with operator console and the laser optics unit. It has been designed so that the operator console can be located away from the optics unit. In this way the console can be kept out of the clean environment allowing for more convenient access to the system. It also means that less people have to enter the clean environment.

Another advantage of having two sections to the system is that it is easier to install the unit into an existing factory. With the extremely high costs of running an i.c. fabrication plant it is essential that down time is kept to a minimum.

In view of the requirements for ever higher yields and better reliability, this new system appears to be another valuable tool for the semiconductor industry. In the future, methods like this for locating defects and resolving problems will become increasingly important in ensuring that yields remain high and quality is maintained.

CIRCUIT SURGERY



ALAN WINSTANLEY

Our monthly round-up of enquiries, hints and tips offers a design for a doorbell which will shed some light on your night-time callers, and also looks at heatsink calculations in more detail.

Doorbell Activated Lamp

SOMETIMES I receive letters from readers asking, what is the point of building things yourself, when you can now buy so many consumer products more cheaply from the shops. It's certainly true that the constructor can no longer compete with mass-produced imported items such as digital clocks, radios or mains adapters, for example – OEMs (Original Equipment Manufacturers) have component purchase prices which we constructors can only dream about!

One of the advantages of being an electronics enthusiast, though, is the fact that you can design and assemble your own custom-made projects and gadgets to perform a specific function, especially useful if there isn't a ready-made solution available in the shops. You can either start from scratch or alternatively adapt existing designs to meet your needs. Not to mention, there's the ultimate satisfaction of building the project from scratch using your skills and your own bare hands.

As if to illustrate the point, from one of our overseas subscribers came this enquiry for a "doorbell with a difference". ***Sumanadasa Namarathna*** of Veyangoda, Sri Lanka writes:

Could you help me with a solution for a system which will help me to see callers who ring my doorbell at night? The idea is that when the doorbell is pressed during the day, the bell rings as normal but at night-time, a nearby outside lamp will illuminate for a few minutes so I can identify who's there. For this project I cannot buy parts from the UK and therefore please use commonly available components if you can.

My initial feeling was that a PIR (passive infra red detector) would fit the bill, detecting the body heat of callers and lighting the way whenever anyone approached, regardless of whether they press the bell or not. Such lamps normally have built-in photocells to disable their operation in the day. (Indeed, my neighbour's cat takes advantage of my patio PIR floodlight to tackle my pond fish at night!) A basic and rather flimsy-looking floodlight fitted with a PIR can be purchased for under £15 here in the UK, but these are functional rather than ornamental, and they also dazzle oncomers.

If you already have an attractive outdoor lamp or a convenient porch light, then Fig. 1 may be of interest to experimenters: it's a circuit which enables your lamp to illuminate with a press of the doorbell pushswitch. It works at night-time only and will power the lamp for a few minutes through a timer circuit. The simple design is readily adaptable for other applications or configurations.

In Fig. 1, S1 is the bell pushswitch which completes the circuit to the solenoid of the existing Doorchime movement. When closed, the switch also triggers the 555 timer monostable built around IC2. This drives a mains relay RLA whose contacts can either be paralleled with an existing light switch, or wired in series with a live mains supply to feed a new lamp. When the switch is closed, the 555 triggers for a period equal to 1·1 VR2.C1 seconds, so the lamp will light for this period.

Let there be light

An electronic audible warning device could be used instead of the bell solenoid, or could be driven in parallel with an existing doorbell to add a second ringer elsewhere in the house. The diode D1 snubs the back e.m.f. generated by the solenoid coil.

In order to prevent the lamp from lighting during daylight hours, a cheap 741 op.amp (IC1) is configured as a Schmitt trigger, which is a circuit that converts a slowly-moving signal into a rapid snap-action edge. PCC1 is an ordinary ORP12-type photoconductive cell (light dependent resistor) forming one half of a potential divider with potentiometer VR1. The photocell is positioned where it can monitor ambient light levels but should be placed so that it will not be adversely affected by street-lights, headlights or light from the porch-lamp itself.

The non-inverting input (pin 3) of the op.amp is clamped at roughly half the supply rail by resistors R1 and R2, whilst a combination of VR1 and PCC1 sets the inverting input (pin 2) voltage. During daytime conditions, the resistance of the photocell is low (say a few hundred ohms) and so the inverting input is pulled down near to 0V.

The output of IC1 is high, and this is inverted by transistor TR1 which saturates hard on. Its collector is

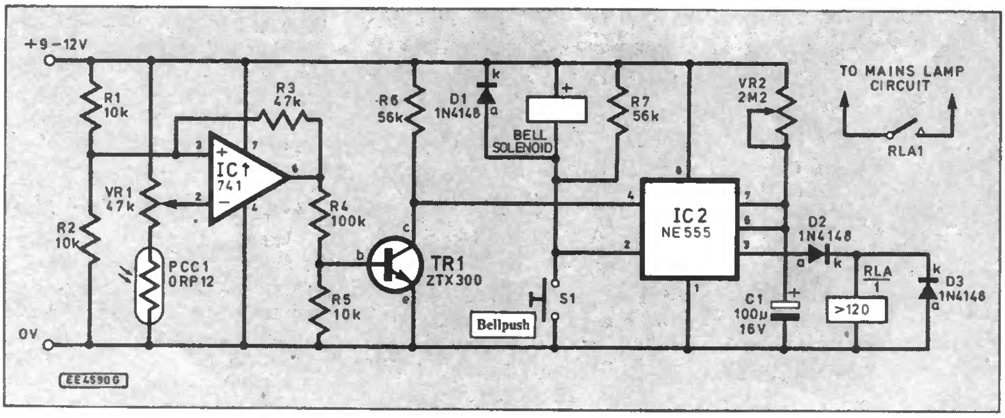


Fig. 1. Circuit diagram for a Doorbell-activated Porch Light.

therefore nearly 0V, which is sufficient to reset the 555 timer at pin 4 and prevent it operating. Adjust VR1 to obtain the desired switch-on level.

Thus, under daylight conditions, the timer is inhibited at pin 4 so the lamp can't illuminate – but the doorbell will still function as usual. Come nightfall, PCC1's resistance increases which pushes up the voltage at the inverting input until the op.amp output switches low and TR1 turns off. Now the 555 (IC2) will trigger when the doorbell is pressed, and the mains lamp will illuminate for a period determined by the setting of VR2.

Mr. Namarathna indicated in his letter that a power supply was available. Battery operation is not really feasible for this circuit due to the quiescent current requirements of the circuit, and no attempt was made to improve upon this using CMOS components. A simple smoothed power supply (approximately 12V) could be used, even a cheap 12V mains adapter might be suitable if it can handle the requirements of the Doorchime or sounder.

Take Note

Some other notes: component values are not at all critical and nearest junk box values will be fine. Similarly the transistor could be almost any *npn* small signal type, and you could try any other op.amp to hand just to see if it works.

The relay must be adequate for the mains loads, and it must have a coil resistance in the low hundreds of ohms or more. You could add an l.e.d. with 680 ohm series resistor to pin 6 of the op.amp, this will then indicate when IC1 is in its day or night setting – useful when initially testing the circuit.

If you have an existing doorbell, check internally that it can be switched from the negative rail, perhaps re-wiring it internally if necessary. Note that an existing bell mains transformer is likely to have an *a.c.* voltage output and *cannot* be used to power this circuit *directly*.

Finally, if you have any doubts or are inexperienced with mains wiring, please do not take risks but refer to a suitably qualified person for advice if needed.

Heatsink values

Last month we investigated regulator power supplies in some depth, noting that an "indestructible" three-terminal variable voltage device is likely to suffer thermal problems when used at extremes. If you dabble with power supplies or other higher power circuits yourself, eventually you will come across the requirement to use a *heatsink* to ensure that the heat produced by a device is removed away from the component quickly enough. Adequate heatsinking ensures that the maximum operating temperature of the device is not exceeded.

Where do you start when trying to calculate the requirements of a heatsink? What follows next might look a bit frightening to non-mathematicians (like myself), but it's actually very straightforward indeed.

There's an enormous variety of sizes and prices available, and often heatsinks are conveniently pre-drilled to accept a particular semiconductor can size, such as TO-3 or TO-220 outlines. Heatsinks are measured in terms of their ***thermal resistance.*** This parameter is specified in Degrees Celsius per Watt (°C/W), and is a very simple indication of how much the heatsink's temperature will rise for a given power "throughput".

In other words, an expensive heatsink with a very low thermal resistance (say 1°C/W) will hardly rise in temperature per watt of throughput, so it's very efficient at transferring heat to the surrounding fresh air. It's big! By contrast, the temperature rise of a small type (say 20°C/W) will be much higher and therefore they are only suited for lower power, less demanding applications.

The idea is that when a device (e.g. a regulator i.c.) becomes hot, we need to remove this heat away from the semiconductor chip or "junction" to ambient surroundings, otherwise the chip is liable to overheat. Think of a heatsink system as a "conveyor belt" shifting the heat away from the junction to the surrounding air. Anything which impedes the flow of heat from the junction (such as certain electrical insulation materials) is in effect contributing to the thermal resistance of the heatsink system – slowing down the conveyor so that heat builds up undesirably!

case, or heat-conducting grease within the steel case of a TO-3 device perhaps. (*Never* cut open such a device to see, because it may contain toxic materials.)

The thermal resistance from the case to the heatsink is shown as θ_{CS}. This could be an insulating washer or a smear of silicon heat-conductive grease. Finally, θ_{SA} is the thermal resistance between the heatsink and ambient temperature – it's the rating of the heatsink itself.

Heat conveyor

We can start by calculating the maximum allowable total thermal resistance in the system, also considering the ambient temperature likely to exist around the device, since this has a bearing on how efficient the system must be. For example, let's suppose the ambient temperature is likely to be 40° Celsius. (This depends, though, on the general layout of any other components around the heatsink, and how adequate the existing ventilation might be.)

Therefore, the maximum permissible thermal resistance from junction to ambient (θ_{JA}) is (125 – 40)°C/10 Watts = 8·5°C/W, otherwise the chip will overheat.

From Fig. 2, $\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA}$.

Buried in the Manufacturers' Data Sheet is the value of θ_{JC} – this depends

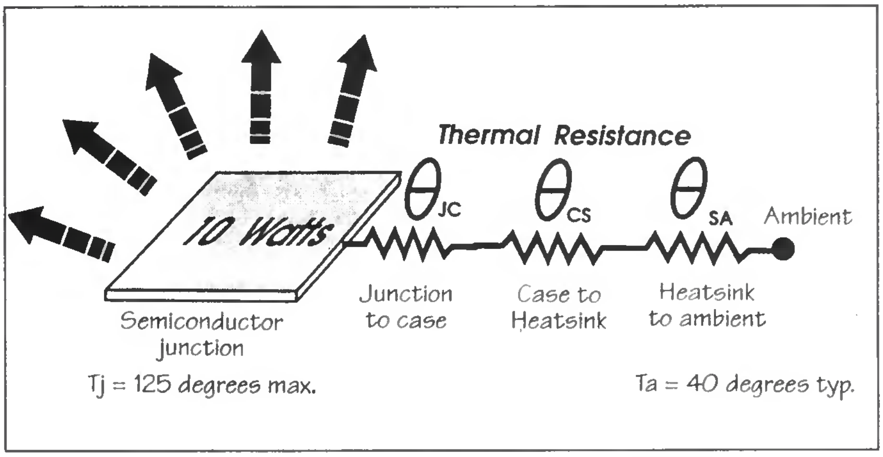


Fig. 2. Thermal resistance present in a heatsink system.

on the type of package. For example, National Semiconductor quote 2·3°C/W for a TO-3 LM317K type, and a somewhat worse 4°C/W for the TO-220 LM317T. Let's assume the latter.

By carefully selecting heatsink ratings, we can ensure that the conveyor moves along at a speed to match the rate at which heat is being produced in the chip. Heat will then be conducted away efficiently, and the chip won't overheat.

A typical heatsink system consists of three "thermally resistive" elements, see Fig. 2. A semiconductor junction such as a transistor die or a regulator chip is embedded within a package. Imagine that the device is dissipating 10 watts and that its Absolute Maximum Temperature (as per its Data Sheet) is given as 125°C – typically for many semiconductors. How do we calculate the required thermal resistance of a heatsink? Firstly, we need to take into account *existing* thermal resistances before deciding upon a suitable heatsink value.

The symbol θ is used to denote thermal resistance. θ_{JC} is the thermal resistance between the semiconductor junction and the case wall of the package. This might represent the plastic resin of a TO-220

Next, if you include an insulating washer with grease, this could introduce an estimated 0·4°C/W thermal resistance between the case and the heatsink (θ_{CS}). You might even choose to ignore this element, since the figure for ambient temperature is already an estimate.

From the above formula, we can say that the heatsink rating θ_{SA} is therefore equal to (8·5 – 4 – 0·4) °C/W = 4·1°C/W. You could use anything lower than this (*a larger heatsink*) if you want. For hobbyist purposes, it's probably not necessary to go into so much detail but the above guide will at least give you a good idea of the sort of rating to go for when choosing a heatsink for your project. Ideally you would design for worse case conditions, though if you need to keep within a budget then a smaller heatsink might be used – the thermal overload protection circuitry of a typical regulator will simply shut the device down at extreme temperature levels.

A brief computer listing written in Microsoft QBasic is offered this month to those who use a PC with MS-DOS. It's simple and you can elaborate upon it as you wish. It will calculate the maximum heatsink thermal resistance allowed, if you input the required data in response to a series of questions.

Power Supplies *(Feb '95)*

Unfortunately several gremlins crept into my Table 1 (Adjustable Voltage Regulators) in the February issue. The L200CV is good for 2A of course, and comes in a TO-220 5-pin style. Also, the "T" suffix in the (National Semiconductor) part numbers given, indicates TO-220 outlines, not TO-3 or TO-202 as printed. Sorry for the confusion.

```
5 CLS
6 PRINT "HEATSINK CALCULATOR"
10 REM HEATSINK CALCULATOR UTILITY - ALAN WINSTANLEY FEB 1995
20 PRINT "MAXIMUM JUNCTION TEMPERATURE (Tj) =";
30 INPUT TJ
40 PRINT "AMBIENT TEMPERATURE (Ta) =";
50 INPUT TA
60 TEMPRISE = TJ - TA
70 PRINT "MAX PERMISSIBLE JUNCTION TEMP RISE OVER AMBIENT ="; TEMPRISE
80 PRINT
90 PRINT "INPUT MAXIMUM POWER DISSIPATED (WATTS)";
100 INPUT PT
110 PRINT "MAXIMUM PERMISSIBLE THERMAL RESISTANCE (Oja) IS ";
115 PRINT TEMPRISE / PT; "deg C per Watt"
120 PRINT
130 PRINT "INPUT THERMAL RESISTANCE Ojc (JUNCTION TO CASE) ";
140 INPUT Tjc
150 PRINT
160 PRINT "INPUT THERMAL RESISTANCE Ocs (CASE TO HEATSINK) ";
170 INPUT Tcs
180 PRINT
190 PRINT "MAXIMUM HEATSINK THERMAL RESISTANCE IS ";
200 PRINT (TEMPRISE / PT) - Tjc - Tcs; "deg C/ Watt"
```

Computer listing for calculating maximum heatsink thermal resistance.

Next Time: We check out the difference between *conventional current* and *electron* flow – a subject where in electronics, we're somewhat "backwards" compared with the rest of science.

Circuit Surgery is our column catering for feedback from readers. If you've built an *EPE* constructional project and have any tips to pass on to your fellow constructors, why not write in to *Circuit Surgery* and we'll pass them on. Remember, this feature relies **heavily** on **your** input so if you have any comments or suggestions for future topics, or any particularly puzzling problems which you'd like us to investigate, write to me at the usual address: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF., U.K.

Ohm Sweet Ohm

Max Fidling

The Honey Monster

RARE is the minute when the soldering iron's not plugged in and ready for action, with the smell of flux drifting into the workshop and the atmosphere occasionally punctuated by the odd electronic mishap or two. One particular day I was cleaning up a prototype after a small electrolytic capacitor had gone to meet its maker, accompanied by a disproportionately loud explosion of fluff and fumes. I was looking around for a replacement cap. when into the workshop walked one of my neighbours. Bob happened to be the local beekeeper, and as I started to solder in the new capacitor, he recounted a tale of woe.

Beekeeping has many fascinating aspects but the medieval technology associated with apiculture perhaps isn't one of them, not to a boffin like myself, at any rate. It seems that Bob's honey separator had suddenly expired and as he was in the middle of processing a batch of honeycombs, he desperately needed a hand to repair it, given that his electronics expertise was restricted to wiring a three-pin plug. (Which seems reasonable since my knowledge of honey was limited to scoffing it.)

Bob knew I was extremely partial to fresh honey and armed with this psychological weapon he had in the past managed to tempt me into "modernising" his equipment by installing several modest electronic gizmos to help with his honey processing.

Let me explain. When honey is produced within a bee-hive, it's necessary to extract the slurpy syrup from the wax honeycombs. This is effected by the simple technique of spinning the honey frames at full pelt in something resembling a spin-drier. Bob's honey separator was a round stainless steel tank about the size of a Baby Burco boiler, and it held four frames at a time, flinging the honey out of the honeycombs like a centrifuge which could then be drained from a valve at the bottom of the tank. The yummy honey thus produced was then heated in a temperature-controlled warming box to remove any impurities or wax; hence the electronic thermostat I'd built for him some time ago . . . all scientific stuff!

The centrifuge had formerly been hand-powered but you can guess who, in exchange for some jars of fresh honey, had "automated it" by adding an old electric motor and speed controller! Bob explained that the motor had suddenly stopped working and hence he was in dire straits. Armed with my multimeter, Bob, myself and Piddles my feline apprentice walked round to the honey shed – which was in fact an almost derelict garden shack. The honey separator lay inside, silent.

Hurricane Honey

I removed the drive belts and pulleys and eventually tested the electric motor by running it gingerly from the mains. The motor ran perfectly so I guessed the fault lay in the speed controller which I'd constructed for him last season. It was a very simple design, using a very large triac and could probably power a London Underground train judging by the size of it. The theory had been to over-engineer the project a bit by using a 25A triac so I was a bit puzzled why it should fail on a mere quarter-horsepower washing machine motor. Perhaps the fact that the diecast box was full of honey which had leaked into it had some bearing on the matter, I mused.

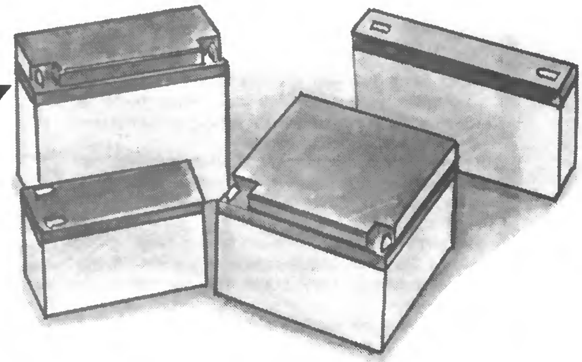
Back at the workshop, I replaced the triac with another spare from the biscuit tin. Piddles assisted by licking out most of the honey from within the diecast box appreciatively, while I rummaged around for the solder. We soon had the controller bolted back into place on the separator and Bob filled the whirling dervish with more dripping honey frames. Clamping the lid down tightly, I plugged in and switched on the controller while Bob looked on. Meantime Piddles had started helping himself to a jar of freshly made honey he'd found open on the bench nearby.

The separator hummed into life and gathered speed like a hurricane mustering strength. Accelerating up to full speed, the steel lid on top started clattering like a milk pan lid about to boil over. The separator whirred at full tilt with me hanging on to it for all I was worth – the vibration rattling the timbers of the ancient shack and almost shaking my fillings out!

Mercifully, delicious liquid honey soon started to trickle out of the valve once more and into a gallon bucket, ready for the warming box. Eventually the separator slowed down to a halt, allowing me to gather my senses and with mission accomplished, a delighted Bob thanked me with more obligatory jars of honey. This job has its perks after all, I thought! Piddles seemed to agree, licking his lips and purring contentedly.

Constructional Project

AUTO BATTERY CHARGER



Terry de Vaux-Balbirnie

On-demand care for lead-acid batteries.

SMALL 12V lead-acid batteries are now used extensively as portable power sources and for back-up supplies. Their main advantage is a larger energy content for a given cost compared with nickel cadmium cells. Also, their self-discharge rate is much less.

The chief disadvantage is that they must be maintained more carefully than nickel-cadmium cells – particularly, to avoid discharging them below a certain level or leaving them in a discharged state. Such practice may cause irreversible damage.

NO DEMANDS

The Auto Battery Charger may be connected to the battery whatever its state of charge and left on continuously if desired. It will switch off automatically when the battery is fully charged.

Whenever the charge becomes less than a preset level (nominally 80 per cent), the unit will switch on again and the process repeat indefinitely – that is, it charges *on demand*. Since it is the mains supply which is switched on and off, the circuit draws current only during the process of charging.

Construction of the Auto Battery Charger is straightforward but you will need access to a digital multitester for setting-up purposes at the end of construction.

DIRTY PLATES

When a nominal 12V lead-acid battery is on charge, its terminal voltage rises and eventually exceeds 14V. When taken off charge, this quickly drops to around 13V. In the absence of an external load it will then fall extremely slowly during the process of natural self-discharge. With a load applied, it falls at a rate dependent on the current drawn. Given time, the voltage would eventually fall to zero. However, allowing this to happen would prove very destructive and serious sulphation of the plates would occur.

In practice, the battery is said to be discharged when its terminal voltage drops below about 11·5V and it should never be allowed to fall much more than this. This charger constantly monitors the terminal voltage and switches on at 12·5V approximately (this corresponds to 80 per cent of maximum charge) and off again at 14·8V.

The design is innovative in that the circuit is powered by the battery itself. This allows the voltage to be monitored while the mains supply is off. Under these conditions, the current requirement of the prototype unit is only 90µA approximately so there is practically no drain on the battery – the natural leakage current being much greater.

The charging current is less than 1A which means that virtually any lead-acid battery can be accommodated without danger of overcharging. The prototype unit has been used successfully with batteries between 1Ah and 8Ah capacity.

This charger could be used as a module in any circuit where a 12V lead-acid battery is used in standby mode – in a burglar alarm system, for example. It may simply be connected up and forgotten. However, it is thought that most readers will wish to use it for cyclic operations where the battery is connected after a period of use and left on until needed again.

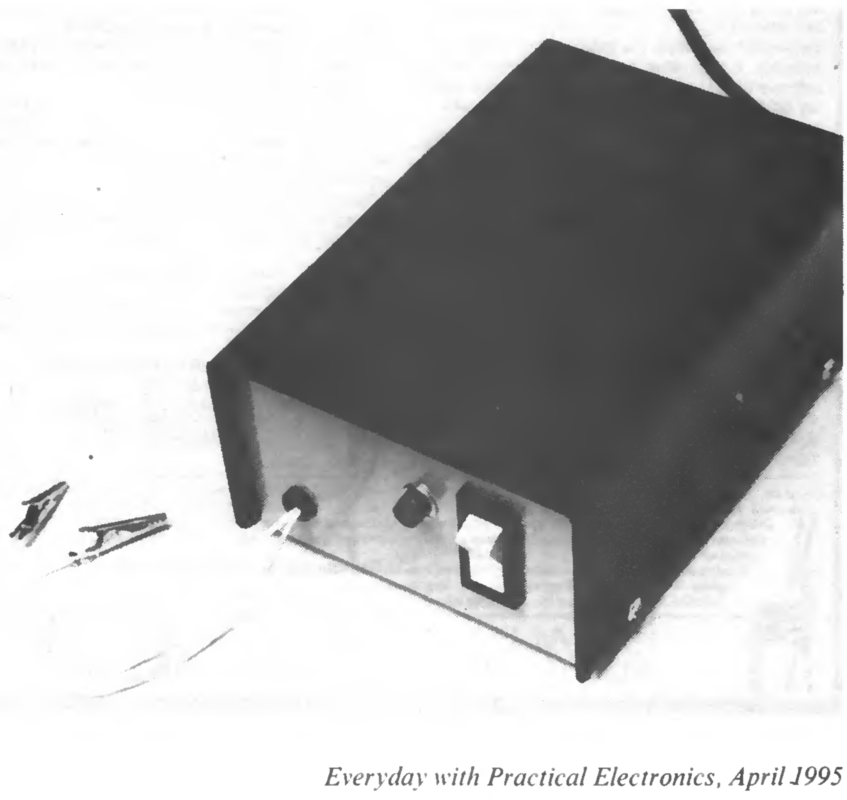
CIRCUIT DESCRIPTION

The complete circuit diagram for the Auto Battery Charger is shown in Fig. 1. While switch S1 is on and relay contacts RLA1 "made", the conventional arrangement of transformer T1, bridge rectifier D1-D4 and smoothing capacitor C1 provide a nominal 16V d.c. supply. Imagine for the moment that the relay contacts are *open* – that is, there is no power supply.

The battery (B1) to be charged is connected to the section of circuit based on the micropower op.amp IC2 and associated components. This op.amp has been specially chosen for its exceptionally low current requirement.

The inverting input, pin 2, of IC2 receives a precise 1·2V from IC1 – a precision reference i.c. Fixed resistor R3 allows a small current to flow through IC1 which is necessary for its operation. The non-inverting input pin 3 receives a proportion of the battery voltage derived from the potential divider consisting of resistors R1 and R2 in conjunction with preset potentiometer VR1.

Ignore the network comprising resistor R4 and preset potentiometer VR2 for the moment. While the battery voltage remains



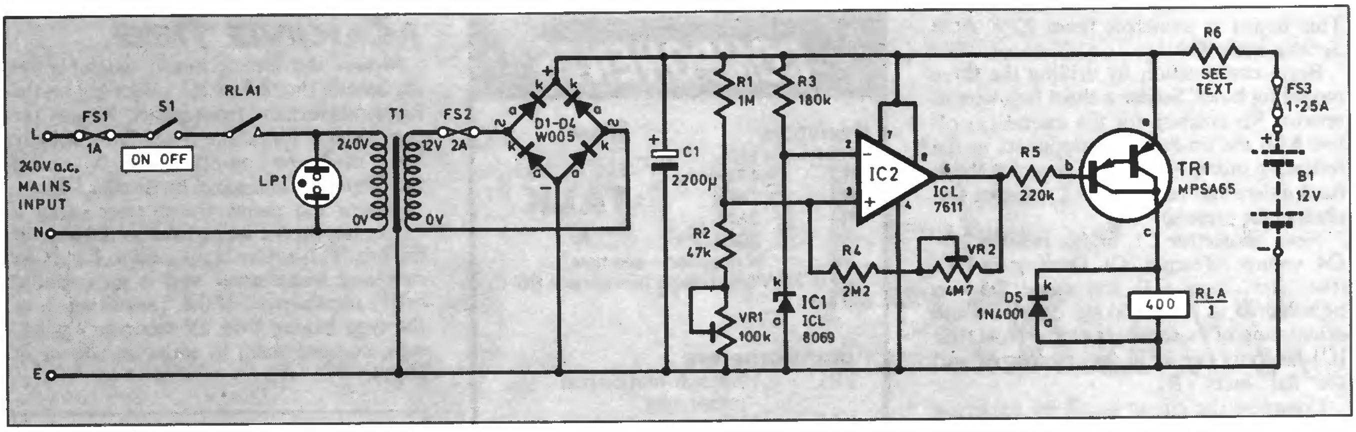


Fig. 1. Complete circuit diagram for the Auto Battery Charger.

above 14·5V, and with VR1 sliding contact at approximately mid-track position, there will be a voltage greater than 1·2V at the non-inverting input of IC2. Under these conditions, the op.amp will be *on* with its output pin 6 *high*.

This high state is applied, via resistor R5, to the base of Darlington transistor TR1. This turns it *off* (since it is a *pnp* transistor rather than the more familiar *npn* type) so no current flows through RLA relay coil. The normally-open contacts, RLA1, are therefore "broken" and the mains supply is *off* as previously supposed.

When the battery partly discharges, the voltage at the non-inverting input will drop below 1·2V. The conditions are now reversed and the voltage appearing at the non-inverting input will be less than that at the inverting one.

The op.amp output now switches *off* with the output becoming *low*. When this state is applied to TR1 base (b), it is switched on and the relay coil in the collector (c) circuit is energized. The relay contacts RLA1 then "make" and establish a supply to the primary winding of transformer T1 and neon indicator LP1.

With a supply provided, the battery charges through resistor R6 and the terminal voltage rises. In fact R6 will probably not be needed. Its purpose, if present, is to limit the charging current to 1A. Its effect on threshold voltage monitoring is negligible.

OVER THE THRESHOLD

Without modification, this circuit would provide only one sharp switching voltage and this is not satisfactory. There need to be two well-defined levels – one for "on" and the other for "off".

This is achieved by introducing positive feedback via resistor R4 and preset potentiometer VR2. This provides Schmitt trigger action so that once off, charging will not re-commence until the voltage has fallen below a certain lower value.

The difference between the "on" and "off" thresholds is set by VR2 adjustment. In the prototype unit, with VR2 sliding contact at mid-track position, the separation between the threshold voltages is approximately 2V. Thus, if the charger were to switch off as the voltage rose to 14·6V, it would need to fall to 12·6V for it to switch on again.

At the end of construction, VR1 will be adjusted to provide the required "on" voltage and VR2 the correct "off" one. Fuses FS1, FS2 and FS3 provide protection to all parts of the circuit.

CONSTRUCTION

Most of the components for the Auto Battery Charger are mounted on a single-sided printed circuit board (p.c.b.) The topside component layout and full-size copper foil pattern are shown in Fig. 2.

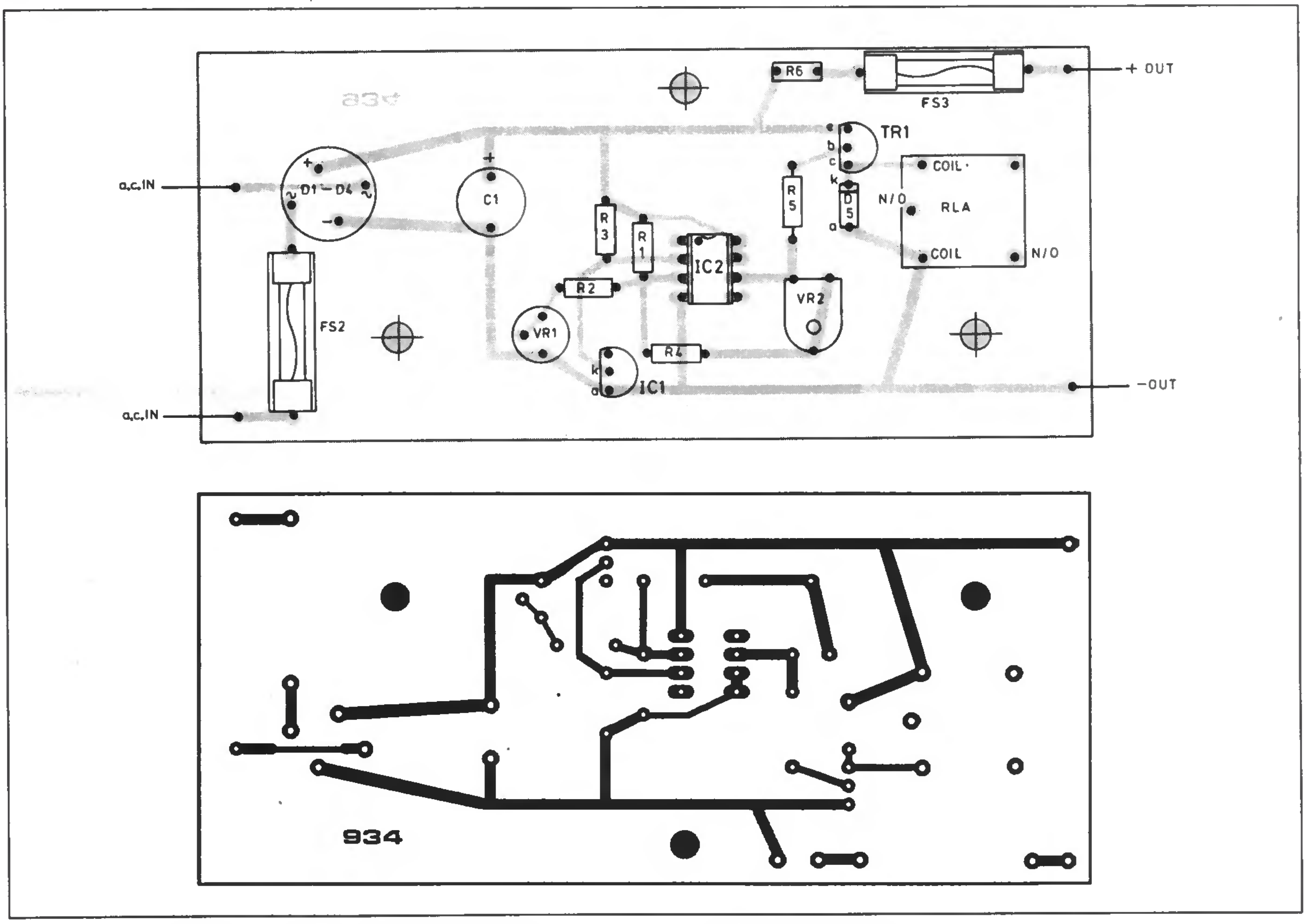


Fig. 2. Printed circuit board component layout and full size copper foil track pattern for the Auto Battery Charger.

This board is available from *EPE PCB Service*, code 934.

Begin construction by drilling the three mounting holes. Solder a short link wire in resistor R6 position for the moment. Follow with the on-board components in the following order. Firstly the i.c. socket, both fuseholders and relay then all resistors (including the presets).

Next, capacitor C1, bridge rectifier D1-D4, voltage reference IC1, Darlington TR1 (the "flat" faces C1) and diode D5 can be soldered in place, taking care over the orientation of these components. Note that IC1 has only two of its legs connected and the "flat" faces VR1.

Complete the circuit panel by soldering 15cm pieces of stranded connecting wire to the points marked "a.c. in" and " –out". Solder a piece of similar wire 25cm long and red in colour to the point labelled "+out".

Finally, solder 15cm pieces of 3A mains-type wire *direct* to the relay normally-open contacts on the underside of the board. Check that these connections are secure – ***this is essential for safety reasons.*** Adjust preset VR1 sliding contact fully anti-clockwise (as viewed from the relay) and VR2 to approximately mid-track position.

Note that an *aluminium or metal* case of the size stated in the parts list (or larger) *MUST be used – a plastic enclosure is not suitable for this project.* Drill holes in the front panel for ON-OFF switch S1, neon indicator LP1 and for the rubber grommet through which the output leads will be passed.

Make holes in the rear panel for fuseholder FS1 and for the strain relief bush to be used on the mains input lead. Note that a strain relief bush is essential here to prevent the wires pulling free which could be dangerous.

The printed circuit board is mounted on an aluminium panel cut and bent to the form shown in Fig. 3. Drill holes to correspond with those in the p.c.b. and one for the wires leading from the relay contacts to pass through – fit this latter one with a rubber grommet. Drill a further two holes to attach the aluminium panel to the base of the box.

Pass the relay wires through the grommeted hole and attach the circuit board to the aluminium panel using plastic stand-off insulators on the bolt shanks. These must maintain a minimum clearance of 5mm between the soldered joints on the reverse side of the p.c.b. and the metalwork. *Place a piece of plastic under the circuit panel in the region of the relay connections as an additional precaution.*

COMPONENTS

Resistors

See SHOP TALK Page

R1	1M
R2	47k
R3	180k
R4	2M2
R5	220k
R6	If required – see text.

All 0·25W 5% carbon film except R6 – see text.

Potentiometers

VR1	100k sub-min carbon preset, vert.
VR2	4M7 sub-min carbon preset, horiz.

Capacitor

C1	2200µ radial elect. 35V

Semiconductors

D1-D4	W005 50V 1·5A bridge rectifier
TR1	MPSA65 *pnp* Darlington transistor.
IC1	ICL8069CCZR 1·2V voltage reference i.c.
IC2	ICL7611 micropower op.amp.

Miscellaneous

T1	Mains transformer with 12V (or twin 6V secondaries) rated at 1A (12VA)
RLA	Miniature 12V 400ohm coil relay, with "make" contacts rated at 3A
S1	Mains rocker switch – 1A rating minimum
FS1	1A 20mm ceramic mains-type fuse and panel fuseholder
FS2	2A 20mm fuse and chassis fuseholder
FS3	1·25A 20mm fuse and chassis fuseholder
LP1	Mains neon indicator

Printed circuit board available from the *EPE PCB Service*, code 934; 8-pin d.i.l. socket; aluminum box, size 150mm x 100mm x 60mm minimum; crocodile clips (or spade-type connectors) (2 off); solder tags; 12V bulb, lampholder and crocodile clips for testing – see text; sheet aluminium for p.c.b. mounting; small fixings; strain-relief bush; rubber grommet; stand-off insulators (3 off); multistrand connecting wire; solder etc.

Approx cost guidance only **£27**

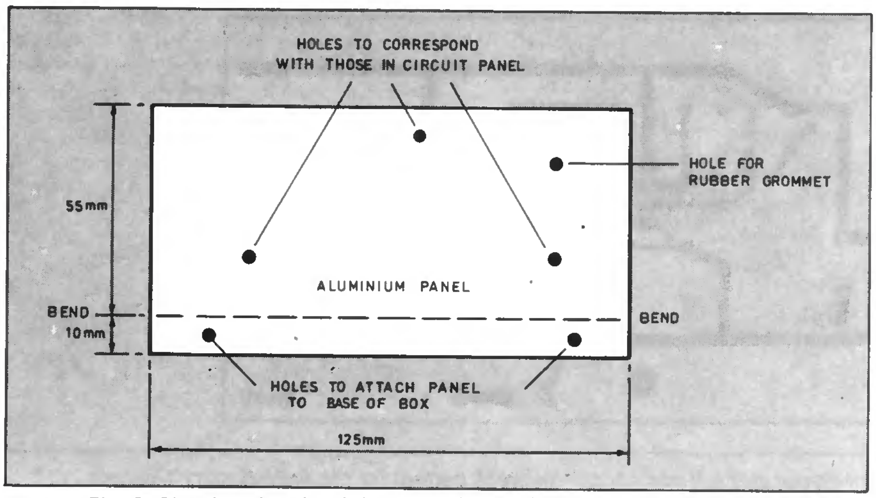


Fig. 3. Shaping the aluminium panel to which the p.c.b. is mounted.

MAKING TIES

Mount the circuit board assembly on the base of the box with a solder tag on the fixing nearest the front panel. Mount the components for which holes have already been made i.e. on-off switch S1, neon indicator LP1 and panel fuseholder FS1.

Mount the mains transformer using a solder tag on the fixing nearest the rear of the box. This solder tag is used to Earth the case and transformer and is an essential safety requirement. If the transformer is of the type having twin 6V secondary windings, connect them in series as shown in Fig. 4.

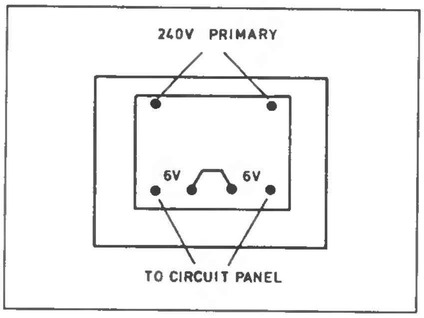


Fig. 4. Connections for transformer having twin 6V secondary windings.

Refer to Fig. 5, mount all remaining components and complete the interwiring shortening any wires as necessary. The use of small cable ties will keep the wiring neat.

Make up the input lead using three-core ***mains-type*** wire of 3A rating minimum. Secure the outer sheath using the strain relief bush and solder the wires as shown. Leave a little slack on the inside. Note that the Earth wire is soldered directly to the solder tag at the transformer. If the plug is of the standard UK type, fit a 2A or 3A fuse.

Cut a piece of *black* stranded wire similar in type to the existing red positive output lead and about 6cm longer. Solder one end to the solder tag at the aluminium panel together with the existing one. Secure the positive and negative output wires together, using a cable clamp pass them through the grommet checking that a little slack is left when they are pulled. Cut them to the same length and fit the ends with crocodile clips or spade-type connectors.

Insert a 20mm 1A *mains ceramic* fuse in FS1 fuseholder, a 2A fuse in FS2 and a 1·25A one in FS3 – these latter two may be of the glass type. Leave the lid of the case removed for the moment.

IMPORTANT WARNING

Make an insulating shield to cover the box on the transformer side of the circuit panel so that it is absolutely impossible to touch any mains connection when the lid of the case is removed. The photograph was taken with the shield removed to show internal components.

TESTING

You will need a 12V bulb to help with testing of the Charger – a 5W car sidelight type for a small battery or the 21W flashing indicator variety for a larger one. This will be used as a load. It should be placed in a lampholder and short wires attached with a crocodile clip on the end of each. Begin testing with the battery substantially discharged – check that the terminal voltage lies between 11·5V and 12V.

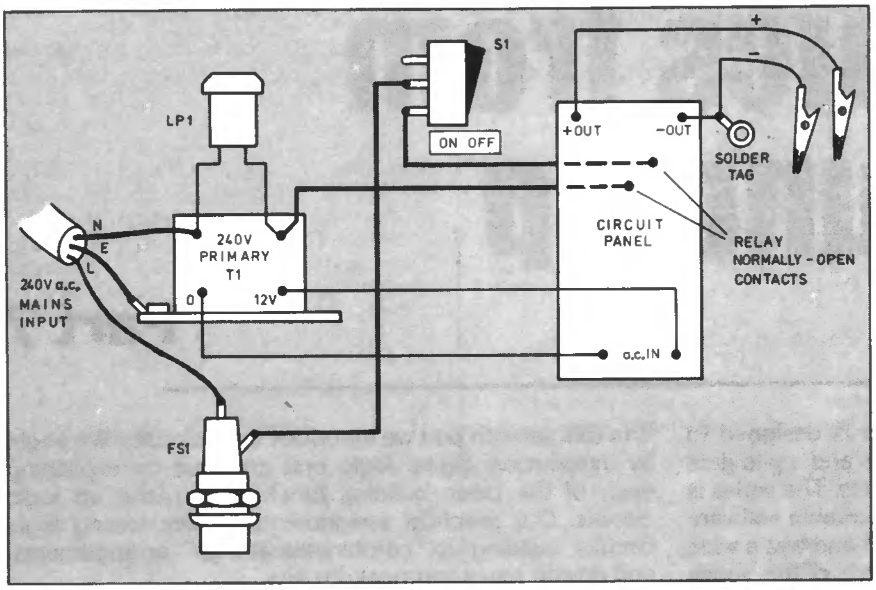


Fig. 5. Details of interwiring between the p.c.b. and other components.

When the reading is about to touch 14·8V, rotate VR1 sliding contact *slowly* clockwise to the point where the relay clicks and the neon indicator goes off. The reading will now quickly fall to around 13V. If you miss the setting, partially discharge the battery and start again – put it down to experience!

Leaving the circuit as it is, connect the "test" bulb directly to the battery terminals so that it partially discharges the battery. Note the point at which the relay clicks-in and the neon lights which indicates that the mains supply has switched on again. This should happen somewhere around 12·5V.

At this point, the bulb should be disconnected and the battery allowed to charge again. It should switch off at the voltage set previously (between 14·6V and 15V is satisfactory). If a satisfactory low point was not reached (between 12V and 12·5V), preset VR2 may be adjusted slightly (clockwise rotation reduces the voltage and *vice-versa*) and the procedure repeated.

Unfortunately, as stated earlier, VR1 and VR2 settings are somewhat interdependent so that when one is adjusted, the other may need attention too. You may therefore need to work in a series of small steps going from one to the other. Trying to speed matters up by using a higher-powered bulb could result in false voltage levels being set.

Set the digital multitester to a suitable current range and include it in the circuit as shown in Fig. 6. Take care to observe the polarity of the battery. Do not be surprised when the relay clicks as it should.

Keep the crocodile clips separated so that they cannot touch and plug the unit into the mains. The neon indicator should light. Check the current flowing into the battery – it is likely to be around 800mA.

If it is greater than 1A, fuse FS3 may blow and you will need a resistor in R6 position. This should have a power rating of ***3W minimum*** – a suitable value to begin with would be one ohm. To do this, snip through the link wire and solder the resistor to the free ends. Its value should be increased to reduce the current if necessary. With this test complete, switch off.

GIVING ATTENTION

You will need a trimming tool or very small screwdriver to enable quick and easy adjustment to preset VR1. Check that this is possible before continuing.

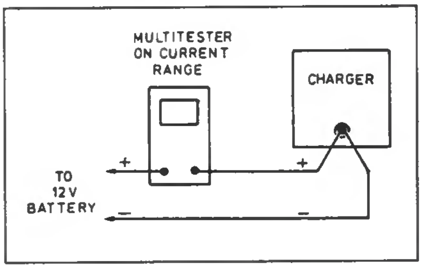


Fig. 6. Checking the current flow into a battery.

Remove the multitester and adjust it to a suitable voltage range. Connect is directly across the battery terminals as shown in Fig. 7. Switch on and observe the reading at intervals. It should be seen that the voltage rises very slowly.

For the 6Ah battery used with the prototype unit this was about 0·3V per hour. This rate increases towards the end point so be particularly watchful after about 13·8V has been reached and have the trimming tool ready.

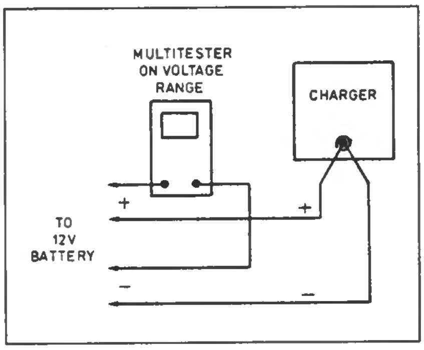


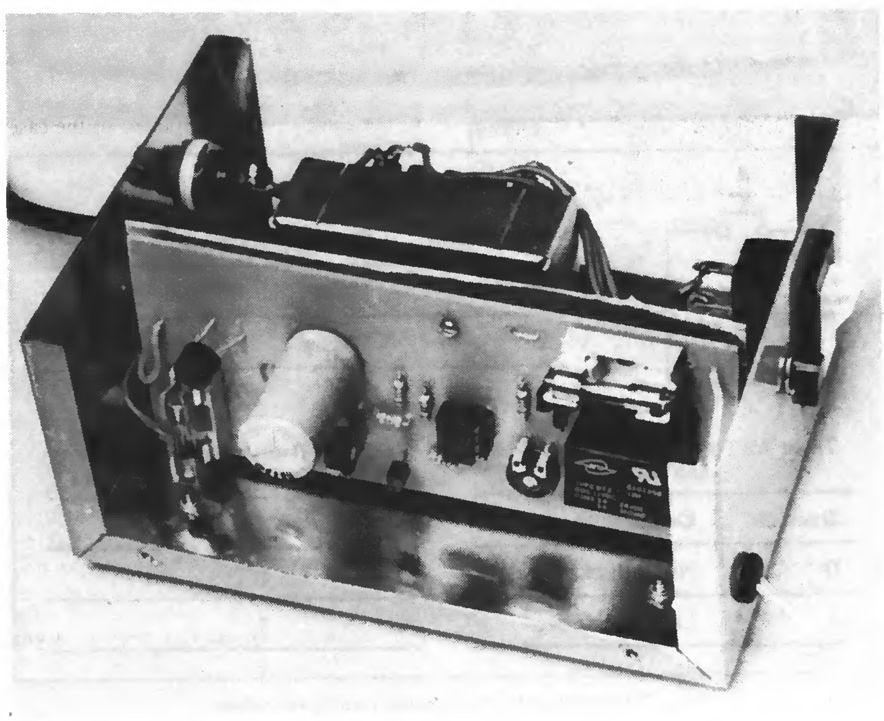
Fig. 7. Checking the actual voltage delivered to a battery.

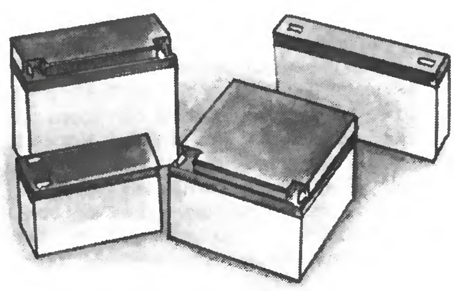
ALL CHARGED UP

With adjustments complete, test the charger under working conditions. The crocodile clips should always be connected to the battery *before* switching on the mains. If this precaution is not observed and they touch, a short-circuit will be caused and fuse FS3 may blow. Note also that if the battery is excessively discharged, either the mains will fail to switch on at all or FS3 may blow.

It is normal for the case to become warm with prolonged use. If there is a short interruption to the supply while charging is taking place, the lower threshold level will have to be reached before charging resumes.

When everything works correctly, the project may be put into permanent service. □





Electronics from the Ground Up

Mike Tooley, BA

Part 7

ELECTRONICS from the Ground Up is designed to provide you with a comprehensive and up-to-date introduction to the world of electronics. The series is based on *Electronics Workbench,* a remarkable software package that lets you use your PC to build and test a wide range of circuits. Back issues of earlier parts of this series are available – see *Back Issues* page.

In this seventh part we introduce logic circuits. We begin by introducing digital logic and continue by explaining each of the basic building blocks that make up logic circuits. Our practical assignments involve testing logic circuits, building up "combinational logic" arrangements, and driving seven-segment displays.

LOGIC

A basic requirement of many electronic circuits is that they should be able to make simple decisions based on a set of given conditions. Decisions are made on the basis of simple logical statements like:

If dark then put on the light

and

If temperature is less then 24°C then connect supply to the heater

and

If "hour" is greater than 11 and "24 hour clock" is not selected then display message "pm".

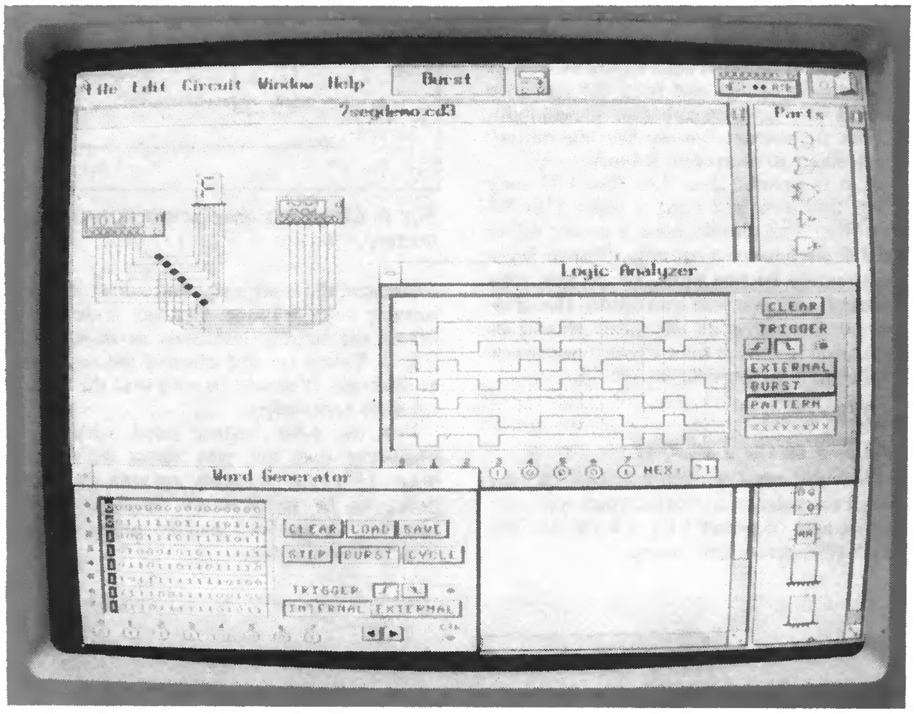
All of these statements are similar in form. The first two are essentially:

If {condition} *then* {action}.

whilst the third is a compound statement of the form:

If {condition 1} *and not* {condition 2} *then* { action}.

All three of these statements can be readily implemented using straightforward electronic circuitry. Because this circuitry is based on discrete states and since the behaviour of the circuits can be described by a set of logical statements, the circuits that perform such tasks are referred to as "digital logic".



SWITCHES AND LAMPS

To put this into context, let's take a very simple example. Consider the circuit shown in Fig. 7.1 in which a battery is connected to a lamp via a switch. There are two possible states for the switch, *open* and *closed.* It should be obvious that the lamp will only operate when the switch is closed. We can summarise the operation of the circuit using a simple table as in Table 7.1.

Since the switch can only be in one of the two states (i.e., open or closed) at any given time, the open and closed conditions are mutually exclusive. Furthermore, since the switch cannot exist in any other state than completely open or completely closed (i.e., there is no intermediate or half-way state) the circuit is said to use binary or "two-state" logic. We can represent the logical state of the switch using the binary digits, 0

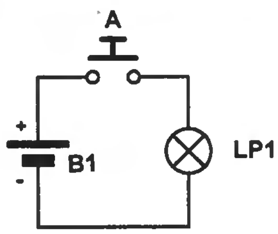


Table 7.1 Simple switching and logic

Condition	Switch	Comment
1	Open	No light produced
2	Closed	Light produced

Table 7.2 Truth table for the switch and lamp

Switch	Comment
0	No light produced
1	Light produced

Table 7.3 Truth table for the switch and lamp written in binary states

Input	Output
0	0
1	1

Fig. 7.1 Switch and lamp circuit, with truth tables.

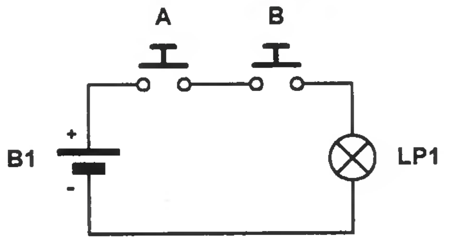


Table 7.5 Truth table for AND switching logic

Switch A	Switch B	Comment
0	0	No light produced
0	1	No light produced
1	0	No light produced
1	1	Light produced

Table 7.4 Simple AND switching logic

Condition	Switch A	Switch B	Comment
1	Open	Open	No light produced
2	Open	Closed	No light produced
3	Closed	Open	No light produced
4	Closed	Closed	Light produced

Table 7.6 Truth table for the AND function in terms of binary states

Input A	Input B	Output
0	0	0
0	1	0
1	0	0
1	1	1

Fig. 7.2 AND switching logic with truth tables.

and 1. We shall assume that a logical 0 is synonymous with open (or "off") and logical 1 is synonymous with closed (or "on"). Hence:

Switch open (off) = 0
Switch closed (on) = 1

We can now re-write the truth table in terms of the binary states as shown in Table 7.2.

We can take this process one stage further by re-writing the table in terms of the binary state of the circuit's "input" and "output" (see Table 7.3). We shall describe the binary state of the output by assuming that light corresponds to a logical 1 and no light corresponds to a logical 0. Hence:

No light (off) = 0
Light (on) = 1

AND LOGIC

Now consider the circuit with two switches shown in Fig. 7.2. Here the lamp will only operate when switch A is closed *AND* switch B is closed. However, let's look at the operation of the circuit in a little more detail. Since there are two switches (A and B) and there are two possible states for each switch (open or closed), there is a total of four possible conditions for the circuit. We can summarise these conditions in another table (see Table 7.4).

Since each switch can only be in one of the two states (i.e., open or closed) at any given time, the open and closed conditions are mutually exclusive. Furthermore, since the switches cannot exist in any other state than completely open or completely closed (i.e., there are no intermediate states) the circuit uses "binary logic". We can thus represent the logical states of the two switches by the binary digits, 0 and 1.

Once again, if we adopt the obvious convention that an open switch can be represented by 0 and a closed switch by 1, we can re-write the truth table in terms of the binary states shown in Table 7.5 or in terms of inputs and outputs, as in Table 7.6.

OR LOGIC

Another circuit with two switches is shown in Fig. 7.3. This circuit differs from that shown in Fig. 7.2 by virtue of the fact that the two switches are connected in

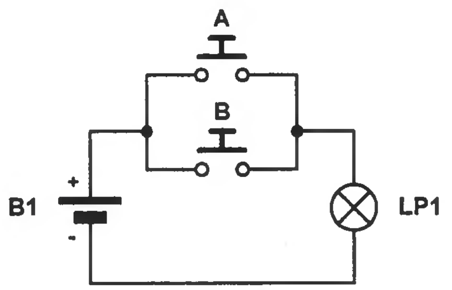


Table 7.8 Truth table for OR switching logic

Switch A	Switch B	Comment
0	0	No light produced
0	1	Light produced
1	0	Light produced
1	1	Light produced

Table 7.7 Simple OR switching logic

Condition	Switch A	Switch B	Comment
1	Open	Open	No light produced
2	Open	Closed	Light produced
3	Closed	Open	Light produced
4	Closed	Closed	Light produced

Table 7.9 Truth table for the OR function in terms of binary states

Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	1

Fig. 7.3 OR switching logic with truth tables.

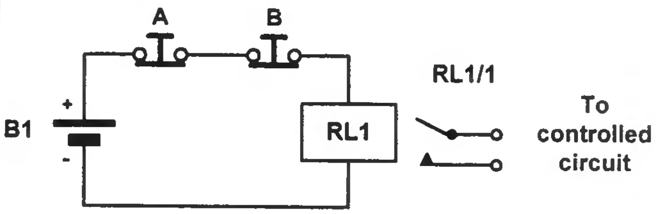


Table 7.11 Truth table for the simple intruder alarm

Door switch	Window switch	Alarm
0	0	1
0	1	1
1	0	1
1	1	0

Table 7.10 Operation of the simple intruder alarm

Door switch	Window switch	Relay coil	Alarm
open	open	not energised	sounding
open	closed	not energised	sounding
closed	open	not energised	sounding
closed	closed	energised	not sounding

Fig. 7.4 Intruder alarm based on normally-closed switches and its truth tables.

parallel rather than in series. In this case the lamp will operate when either of the two switches is closed, i.e. if switch A *OR* switch B is closed. As before, there is a total of four possible conditions for the circuit. We can summarise these conditions in another table, Table 7.7.

Once again, adopting the convention that an open switch can be represented by 0 and a closed switch by 1, we can re-write the truth table in terms of the binary states or in terms of input and output states as shown in Table 7.8 and Table 7.9 respectively.

AND INVERSION

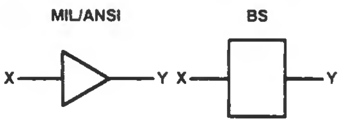
Now let's consider another situation. The circuit shown in Fig. 7.4 is a simple intruder alarm in which both door and a window switches are normally closed. The two switches are wired in series with a relay coil and battery. As long as switch A *AND* switch B remain closed, the relay will operate and its contacts will remain open. When a door or window is opened, its respective switch will open. This, in turn, causes the circuit to be broken and the relay will cease to be energised. The relay contacts will then close and the alarm will sound (see Table 7.10).

Assuming the same logical convention as before (i.e., switch closed = 1, alarm sounding = 1), the truth table for the system is shown in Table 7.11.

It is worth comparing Table 7.11 with Table 7.6. The output column of each truth table is the same except for the fact that all the 0s have been replaced by 1s and vice versa. The logical function is thus the opposite (or "inverse") of *AND*. We call this function *NAND* (standing for *NOT-AND*).

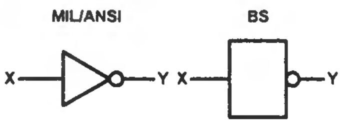
BASIC LOGIC FUNCTIONS

To simplify the task of designing and building logic circuits, a range of standard devices is available to provide the basic logic functions, AND, OR, NAND,



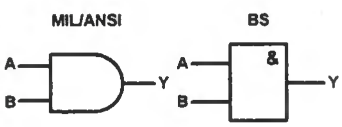
X	Y
0	0
1	1

Fig. 7.5 Symbols and truth table for a buffer.



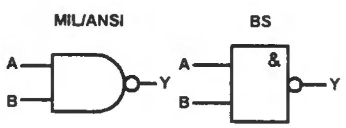
X	Y
0	1
1	0

Fig. 7.6 Symbols and truth table for an inverter.



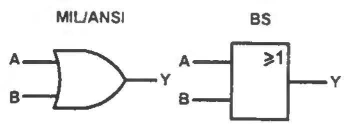
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Fig. 7.7 Symbols and truth table for a two-input AND gate.



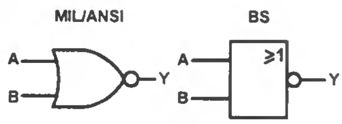
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Fig. 7.8 Symbols and truth table for a two-input NAND gate.



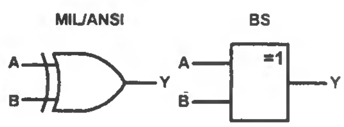
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Fig. 7.9 Symbols and truth table for a two-input OR gate.



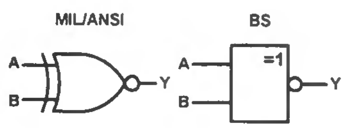
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Fig. 7.10 Symbols and truth table for a two-input NOR gate.



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Fig. 7.11 Symbols and truth table for a two-input exclusive-OR gate.



A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

Fig. 7.12 Symbols and truth table for a two-input exclusive-NOR gate.

NOR (inverted *OR* or *NOT-OR*), etc. These devices are commonly referred to as logic gates and are represented by symbols conforming to either British/European or MIL/ANSI standards. We shall briefly consider the action of each of the basic logic gates in turn (strictly speaking, buffers and inverters are not actually gates, although they are often assigned to this category). In each case, we have shown the BS and MIL/ANSI symbols side-by-side together with the truth table. (Note that *Electronics Workbench* supports both sets of symbols and you can choose which set you want to work with!). (*Note also that EPE conventionally uses the MIL/ANSI symbols. Ed.*).

Buffers

Buffers (see Fig. 7.5) don't actually affect the logical state of a digital signal (i.e., a logic 1 input results in a logic 1 output whereas a logic 0 input results in a logic 0 output). Despite this, they still have a useful function since they can be instrumental in regularising the logic levels at an interface or providing extra current drive to a load.

Inverters

Inverters (see Fig. 7.6) are used to complement the logic state (i.e., a logic 1 input results in a logic 0 output and vice versa). Inverters also provide extra current drive and, like buffers, are used in interfacing applications where they provide a means of regularising logic levels present at the input or output of a digital system. The circle shown at the output denotes the inversion function. (You may sometimes come across an inverter referred to as a NOT gate.).

AND gates

AND gates (see Fig. 7.7) will only produce a logic 1 output when all inputs are simultaneously at logic 1. Any other input combination results in a logic 0 output.

NAND gates

NAND gates (see Fig. 7.8) will only produce a logic 0 output when all inputs are simultaneously at logic 1. Any other input combination will produce a logic 1 output. A NAND gate, therefore, is nothing more than an AND gate with its output inverted! The circle shown at the output denotes this inversion.

OR gates

OR gates (see Fig. 7.9) will produce a logic 1 output whenever any one, or more, inputs are at logic 1. Putting this another way, an OR gate will only produce a logic 0 output whenever all of its inputs are simultaneously at logic 0.

NOR gates

NOR gates (see Fig. 7.10) will only produce a logic 1 output when all inputs are simultaneously at logic 0. Any other input combination will produce a logic 0 output. A NOR gate, therefore, is simply an OR gate with its output inverted. A circle is again used to indicate inversion.

Exclusive-OR gates

Exclusive-OR gates (see Fig. 7.11) will produce a logic 1 output whenever either one of the inputs is at logic 1 and the other is at logic 0. Exclusive-OR gates produce a logic 0 output whenever both inputs have the same logical state (i.e., when both are at logic 0 or both are at logic 1).

Exclusive-NOR gates

Exclusive-NOR gates (see Fig. 7.12) will produce a logic 0 output whenever either one of the inputs is at logic 0 and the other is at logic 1. Exclusive-NOR gates produce a logic 1 output whenever both inputs have the same logical state (i.e., when both are at logic 0 or both are at logic 1). Once more a circle is used to indicate the inversion function. An exclusive-NOR gate is thus an exclusive-OR gate with its output inverted.

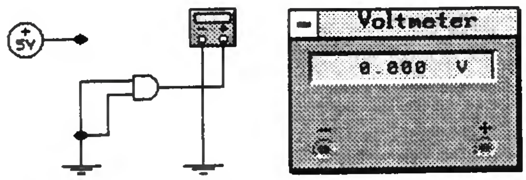
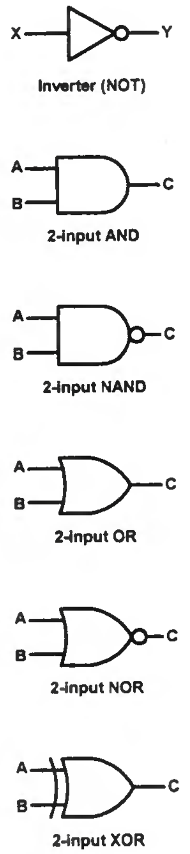


Fig. 7.13 Circuit for Assignment 7.1. Initial input connections (both A and B at logic 0).



X	Y
0	
1	

A	B	Y
0	0	
0	1	
1	0	
1	1	

A	B	Y
0	0	
0	1	
1	0	
1	1	

A	B	Y
0	0	
0	1	
1	0	
1	1	

A	B	Y
0	0	
0	1	
1	0	
1	1	

A	B	Y
0	0	
0	1	
1	0	
1	1	

Fig. 7.14 Results for Assignment 7.1.

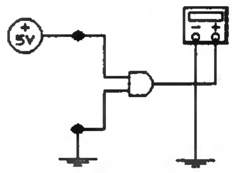


Fig. 7.15 Input connections for Assignment 7.1, A = 0 and B = 1.

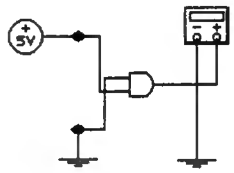


Fig. 7.16 Input connections for Assignment 7.1, A = 1 and B = 0.

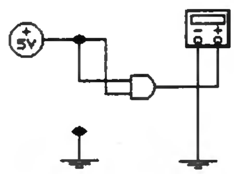


Fig. 7.17 Input connections for Assignment 7.1, A = 1 and B = 1.

Practical assignment 7.1:
Logic gates

In this practical assignment, and using the *Electronics Workbench* software, you will investigate the action of a variety of the most common types of logic gate.

Objectives:

7.1.1 To investigate the behaviour of each of the following types of logic gate:
(a) two-input AND
(b) two-input OR
(c) inverter (NOT gate)
(d) two-input NAND gate
(e) two-input NOR gate

7.1.2 To construct a truth table for each of the gates listed in 7.1.1.

7.1.3 To use a d.c. voltmeter to measure logic levels.

Instructions:

1. Select the two-input AND gate and connect the circuit shown in Fig. 7.13. The voltmeter is to be used to measure and display the voltage produced at the output of the gate. The +5V sources and two ground connections are used to produce the input voltages for the gate.
2. With both of the inputs connected to ground (logic 0), as shown in Fig. 7.13, switch on the power to the circuit and note the output voltage indicated by the voltmeter. Convert this output to a logic state (either 0 or 1). Note that the voltmeter will read 0V for logic 0 and +5V for logic 1. Record the indication produced in the appropriate truth table in Fig. 7.14.
3. Repeat step 2 using each of the connections shown in Figs. 7.15, 7.16, and 7.17. For each circuit, record the logical state of the gate's output in the corresponding truth table in Fig. 7.14.
4. Repeat steps 1 to 3 for each of the logic gates provided.

Conclusions:

To what extent have the objectives for this assignment been met? Check that each truth table is correct for the particular type of gate under investigation, referring back earlier in the text if you are not entirely sure.

LOGIC FAMILIES

The integrated circuits (i.c.s) that provide the logic gate functions in modern digital circuitry are classified according to the semiconductor technology used in their fabrication. Indeed, the technology used is instrumental in determining the operational characteristics (such as power consumption, speed, and immunity to noise) of a device. The two basic logic families are CMOS (Complementary Metal Oxide Semiconductor) and TTL (Transistor Transistor Logic). Each of these principal families is then further divided into sub-families.

74-series TTL

The most common family of TTL logic devices is known as the 74-series. Devices from this family are coded with the prefix number 74. Variants within the family are identified by letters which follow the initial 74 prefix, as follows:

Infix	Meaning
None	Standard TTL device
ABT	Advanced bus interface logic
AC	Advanced CMOS
ACT	Advanced CMOS with TTL compatible inputs
ACTQ	Advanced CMOS with TTL compatible inputs
ALS	Advanced low-power Schottky
AS	Advanced Schotty TTL
BCT	Octal buffers/drivers
C	CMOS version of a TTL device
CBT	Crossbar technology
F	"Fast" – a high speed version of the device
FCT	High speed high output
GTL	Gunning transceiver logic
H	High speed version
HC	High speed CMOS version (CMOS compatible inputs)
HCT	High speed CMOS version (TTL compatible inputs)
LS	Low-power Schottky
LV	Low voltage high speed CMOS
LVC	Low voltage CMOS
LVT	Low voltage technology
S	Schottky input configuration (improved speed and noise immunity).

4000-series CMOS

The most common family of CMOS devices is known as the 4000-series. Variants within the family are identified by suffix letters as follows:

Suffix	Meaning
None	Standard CMOS device.
A	Standard (unbuffered) CMOS device.
B, BE	Improved (buffered) CMOS device.
UB, UBE	Improved (unbuffered) CMOS device.

Examples

Fig. 7.18 shows the outlines of two digital integrated circuits. The device shown first in Fig. 7.18, coded 4001UBE, is an improved (unbuffered) version of a CMOS 4001 device whilst the chip shown second in Fig. 7.18, coded 74LS00, is the low-power Schottky version of a TTL 7400 device. Inside both chips there are four separate two-input gates, NOR in the case of the 4001UBE and NAND in the case of the 74LS00, as schematically shown in Fig. 7.19.

ELECTRICAL CHARACTERISTICS

In Assignment 7.1 you found that a logic 0 was represented by 0V whilst a logic 1 was represented by +5V. These voltages are idealised and, in practice, a range of voltages is used to represent the logic states 0 and 1. The logic levels for CMOS differ markedly from those associated with TTL. In particular, CMOS logic levels are relative to the supply voltage used whilst the logic levels associated with TTL devices tend to be absolute. Table 7.12 shows the logic levels for standard CMOS and TTL devices.

Table 7.12 Logic levels for standard CMOS and TTL devices

Logic level	CMOS	TTL
Logic 1	more than 2/3 V_{DD}	more than 2V
Logic 0	less than 1/3 V_{DD}	less than 0·8V
Indeterminate	between 1/3 V_{DD} and 2/3 V_{DD}	between 0·8V and 2V

(Note: V_{DD} is the positive supply associated with standard CMOS devices, this is often +5V but may take any value between +3V and +18V).

Table 7.13 Comparison of LS TTL and BE-series CMOS devices

Characteristic	Logic family 74LS	40BE
Maximum permissible supply voltage	5·25V	18V
Minimum permissible supply voltage	4·75V	3V
Quiescent power dissipation (per gate)	2mW	negligible
Dynamic power dissipation (per gate at 100kHz)	2mW	100µW
Typical delay experienced by a pulse passing through the gate	10ns	100ns
Maximum switching frequency	50MHz	12MHz
Minimum output current (V_O = 0.4V)	8mA	1·6mA
Number of LS-TTL loads that can be driven from a single output	20	4
Maximum input current (at V_I = 0·4V)	−0·4mA	−1µA

NOISE MARGIN

The noise margin of a logic device is a measure of its ability to reject noise; the larger the noise margin the better is its ability to perform in an environment in which noise is present. Noise margin is defined as the difference between the minimum values of high state output and high state input voltage, and the maximum values of low state output and low state input voltage. Hence:

$$\text{Noise margin} = V_{OH(MIN)} - V_{IH(MIN)}$$
$$\text{or Noise margin} = V_{OL(MAX)} - V_{IL(MAX)}$$

where $V_{OH(MIN)}$ is the minimum value of high state (logic 1) output voltage, $V_{IH(MIN)}$ is the minimum value of high state (logic 1) input voltage, $V_{OL(MAX)}$ is the maximum value of low state (logic 0) output voltage, and $V_{IL(MIN)}$ is the minimum value of low state (logic 0) input voltage.

The noise margin for standard 7400 series TTL is typically 400mV whilst that for CMOS is 1/3 V_{DD}, as shown comparatively in Fig. 7.20.

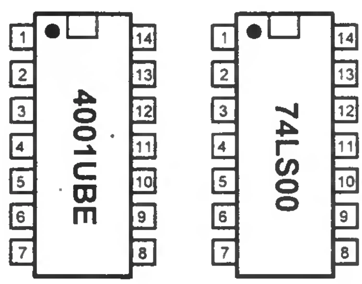


Fig. 7.18 Example of markings on digital integrated circuits.

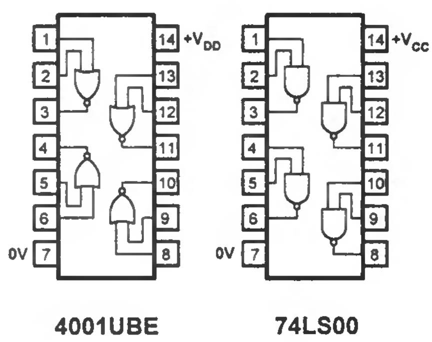


Fig. 7.19 Logic gates available within the chips shown in Fig. 7.18.

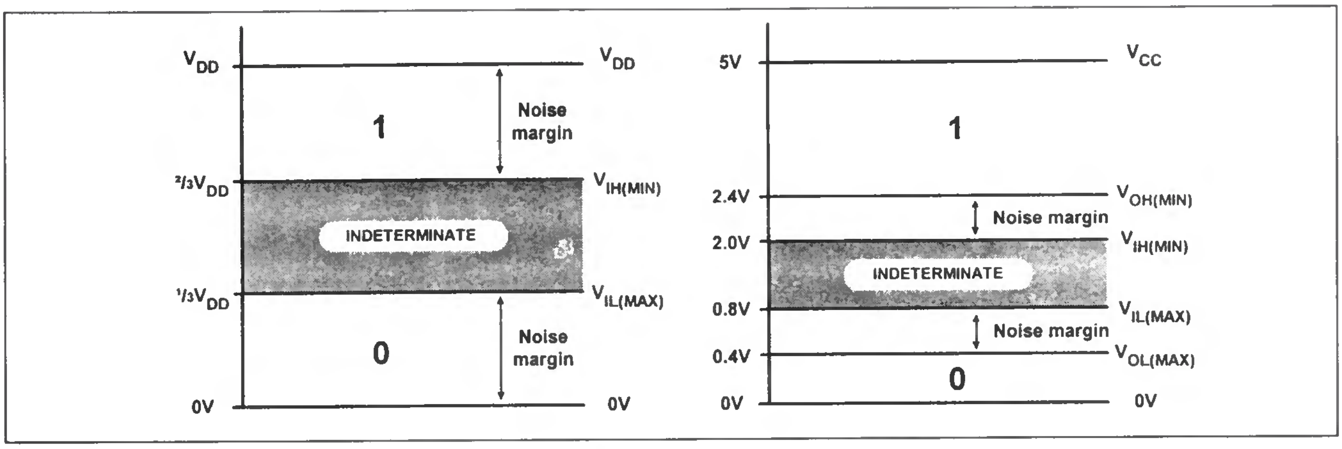


Fig. 7.20 Logic levels and noise margins for TTL and CMOS devices.

Table 7.13 compares the more important characteristics of the LS-TTL family with modern buffered CMOS logic. It is well worth taking a little time to study this table and decide which type of logic may be best suited to a particular application. For example, CMOS logic is ideal for use in battery operated low-power applications.

Practical assignment 7.2: Combinational logic

In this practical assignment you will construct and test a variety of logic circuits based on standard logic gates.

Objectives:

7.2.1 To show how multiple-input AND and OR gates can be built using a number of two-input AND and OR gates, respectively.

7.2.2 To show how inverting the output of NAND and NOR gates produces AND and OR functions, respectively.

7.2.3 To show how inverting both of the inputs of a NAND gate produces an OR function.

7.2.4 To show how inverting both of the inputs of a NOR gate produces an AND function.

7.2.5 To show how an exclusive-OR gate can be built using basic logic gates.

Instructions:

1. Connect the circuit shown in Fig. 7.21. The output of the circuit is connected to a logic level indicator whilst the four inputs are derived from +5V and ground points. Switch on the power and test the circuit by constructing its truth table. Confirm that the circuit provides a four-input AND function.
2. Connect the circuit shown in Fig. 7.22. The output of the circuit is connected to a logic level indicator whilst the four inputs are derived from +5V and ground points. Switch on the power and test the circuit by constructing its truth table.
3. Connect the circuit shown in Fig. 7.23. The output of the circuit is connected to a logic level indicator whilst the two inputs are derived from +5V and ground points. Switch on the power and test the circuit by constructing its truth table.
4. Connect the circuit shown in Fig. 7.24. The output of the circuit is connected to a logic level indicator whilst the two inputs are derived from +5V and ground points. Switch on the power and test the circuit by constructing its truth table.
5. Connect the circuit shown in Fig. 7.25. The output of the circuit is connected to a logic level indicator whilst the two inputs are derived from +5V and ground points. Switch on the power and test the circuit by constructing its truth table.
6. Connect the circuit shown in Fig. 7.26. The output of the circuit is connected to a logic level indicator whilst the two inputs are derived from +5V and ground points. Switch on the power and test the circuit by constructing its truth table.
7. Connect the circuit shown in Fig. 7.27. The output of the circuit is connected to a logic level indicator whilst the two inputs are derived from +5V and ground points. Switch on the power and test the circuit by constructing its truth table.

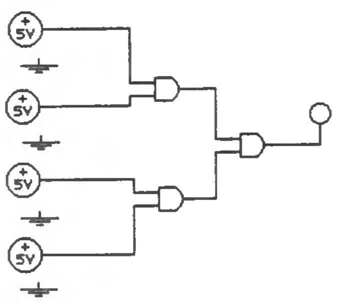


Fig. 7.21 Multiple-input AND gate (Assignment 7.2).

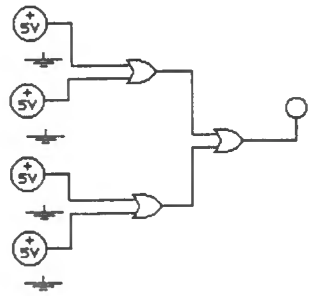


Fig. 7.22 Multiple-input OR gate (Assignment 7.2).

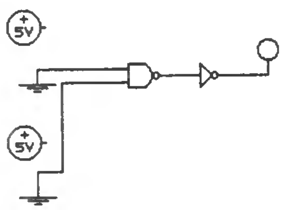


Fig. 7.23 NAND gate with inverted output (Assignment 7.2).

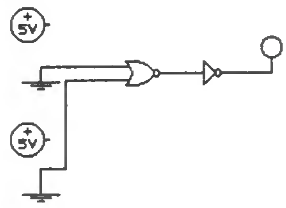


Fig. 7.24 NOR gate with inverted output (Assignment 7.2).

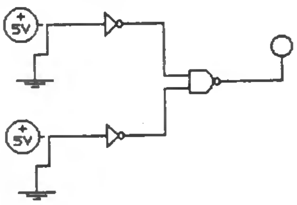


Fig. 7.25 NAND gate with inverted inputs (Assignment 7.2).

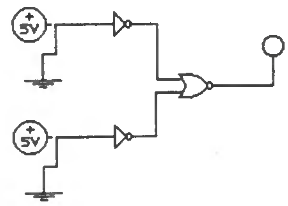


Fig. 7.26 NOR gate with inverted inputs (Assignment 7.2).

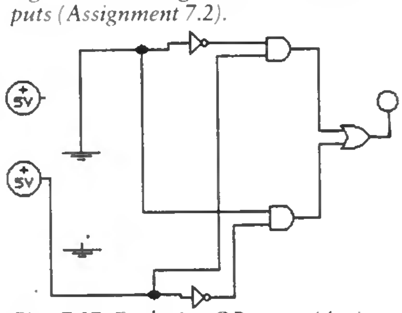


Fig. 7.27 Exclusive-OR gate (Assignment 7.2).

Conclusions:

To what extent have the objectives for this assignment been met? With reference to the truth tables, state the logical function for each logic symbol gate arrangement and identify the single gate symbol that can replace each combination.

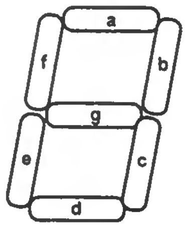


Fig. 7.28 Segment numbers for a seven-segment display.

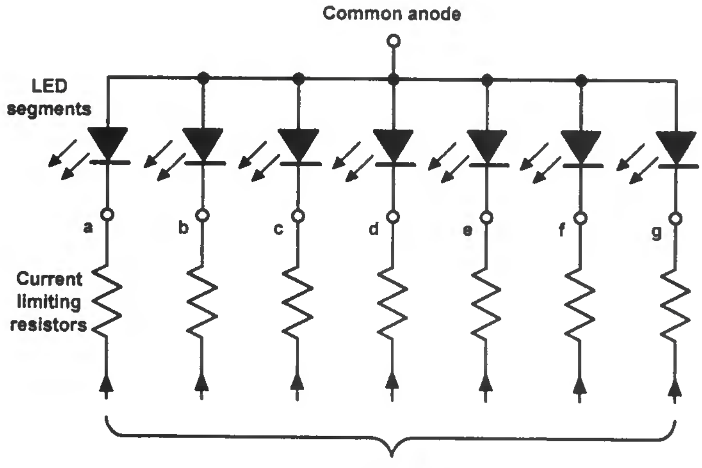


Fig. 7.29 Typical arrangement for a common-anode seven-segment display.

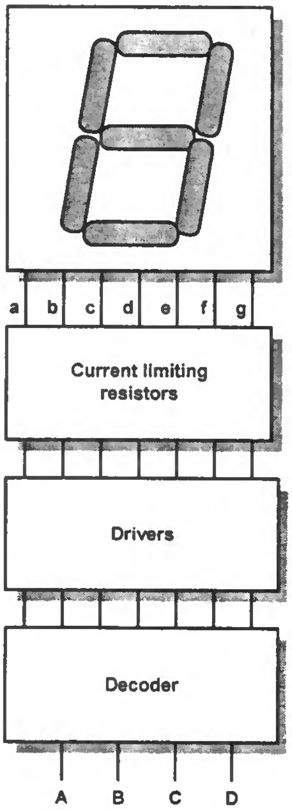


Fig. 7.30 Decoded seven-segment display showing binary-coded decimal (BCD) input (labelled A to D).

SEVEN-SEGMENT DISPLAYS

Seven-segment displays provide a means of displaying numbers (0 to 9) and some letters (e.g., A, b, C, d, E, F, H, etc.). Several different types of display are in common use but one of the most common is based on light emitting diodes (l.e.d.s). The arrangement of the segments in a typical seven-segment l.e.d. display is shown in Fig. 7.28.

Each of the segments is identified by a letter, *a* to *g*. In practice, two configurations are available; common-anode and common-cathode depending upon which of the segment connections is taken to a common point. Fig. 7.29 shows the connections to a common-anode display (note that, in practice the display would probably also be fitted with a decimal point). The seven fixed resistors in series with the segments are included to limit the current (usually in the region 5mA to 20mA per segment).

The problem of illuminating the correct segments of an l.e.d. display is greatly simplified by adding a decoder circuit, as shown in Fig. 7.30. This arrangement accepts a 4-bit binary code as its input (lines A to D) and it contains the necessary logic gate arrangements to ensure that the correct segments (*a* to *g*) are illuminated for each input code. You will investigate this arrangement in the next practical assignment.

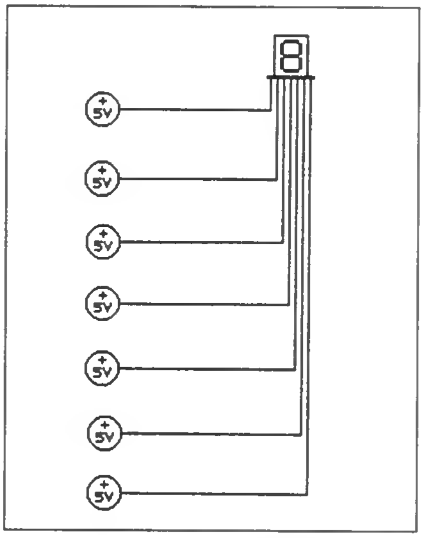


Fig. 7.31 Circuit for Assignment 7.3.

	a	b	c	d	e	f	g
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
A							
B							
C							
D							
E							
F							

Fig. 7.32 Results table for Assignment 7.3.

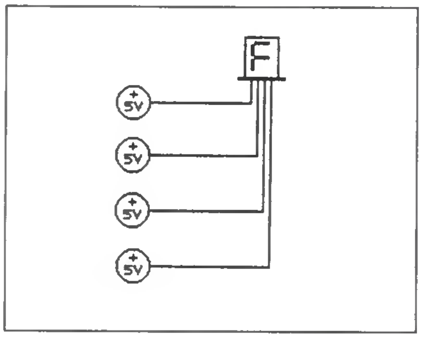


Fig. 7.33 Circuit for Assignment 7.3 (decoded display).

Practical assignment 7.3: Seven-segment displays

In this practical assignment you will investigate the behaviour of seven-segment displays.

Objectives:

7.3.1 To investigate the behaviour of a seven-segment display.
7.3.2 To investigate the behaviour of a decoded seven-segment display.

Instructions:

1. Connect the circuit shown in Fig. 7.31.
2. Using Fig. 7.28, determine the segments that should be illuminated in order to produce the digits 0 to 9 and letters A to F (see Fig. 7.32).
3. Connect each arrangement in turn and check the display produced. Complete the truth table shown in Fig. 7.32.
4. Connect the circuit shown in Fig. 7.33. For each input combination (lines A to D) shade in the illuminated segments in Fig. 7.34. Hence determine the truth table for the decoded seven-segment display. Check that this conforms to standard binary-coded decimal.

Conclusions:

To what extent have the objectives for this assignment been met? How effective is

A B C D	DISPLAY	A B C D	DISPLAY
0 0 0 0		1 0 0 0	
0 0 0 1		1 0 0 1	
0 0 1 0		1 0 1 0	
0 0 1 1		1 0 1 1	
0 1 0 0		1 1 0 0	
0 1 0 1		1 1 0 1	
0 1 1 0		1 1 1 0	
0 1 1 1		1 1 1 1	

Fig. 7.34 Results for Assignment 7.3 (decoded display).

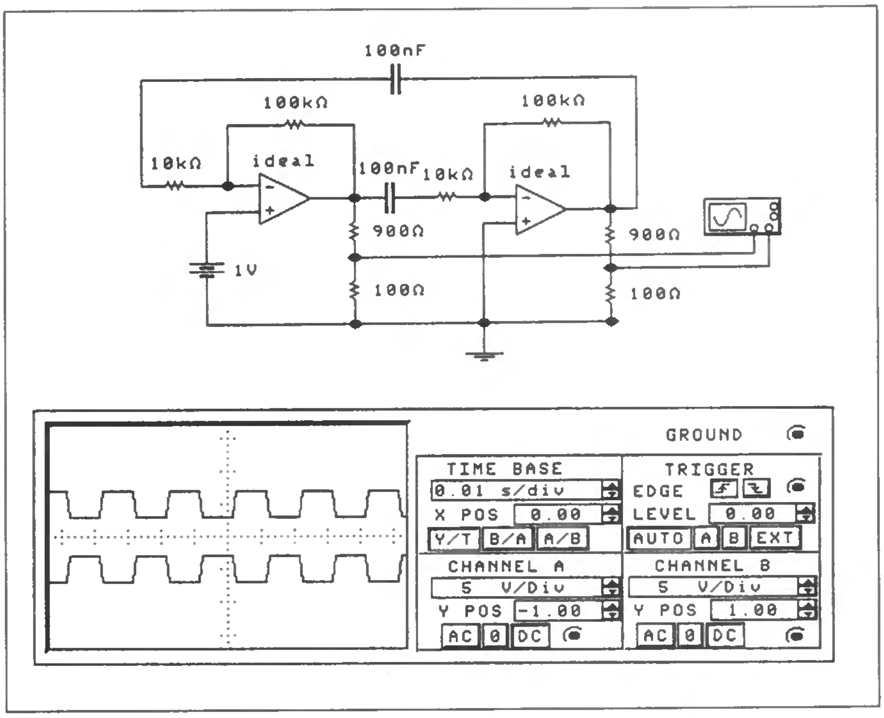


Fig. 7.35 Solution to last month's Brain Teaser.

the seven-segment display at displaying alphanumeric characters? What are the advantages and disadvantages of a display which accepts binary-coded decimal? Can you suggest what the logic inside the decoder might look like? (Hint: consider what logic would be required to operate a single segment, e.g., segment *a*).

BRAIN TEASER

This month's challenge for those of you who are using the full *Electronics Workbench* package is to design a logic arrangement with three inputs that will provide a "majority vote" (i.e., a logic 1 will be produced at the output provided that any two, or more, of the inputs are at logic 1. Build and test this circuit using *Electronics Workbench*.

Answer to last month's Brain Teaser

Last month's Brain Teaser involved the design of a circuit that produces complementary square wave outputs with an amplitude of 1V and a frequency of 50Hz. Fig. 7.35 shows one solution arrived at using the full version of *Electronics Workbench*.

FOX REPORT

by Barry Fox

MAC Grounded

Once Sky's budget PAL satellite service had killed off BSB's higher priced MAC service, the writing was on the wall. MAC was doomed, not just in the UK but the rest of Europe as well. There are still a few MAC services in Scandinavia, France and Germany but the transmission technology is used mainly for the encryption and widescreen distribution it offers.

To all intents and purposes, MAC is dead. So HD-MAC, the high definition upgrade which was due for commerical launch this year, is dead too.

This has turned out to be a blessing in disguise. Europe, and especially the UK, is now free to follow an all-digital route to future TV.

Digital TV

You will be hearing a lot about digital TV over the next few months, so it will help to have some hard facts on record. The situation changes almost daily but this was how it stood in early February.

In September 1993 manufacturers and broadcasters from all across Europe formed the voluntary DVB, Digital Video Broadcast group, to set agreed standards for digital satellite, cable or terrestrial TV. There are now over 150 members from all European countries. DVB gets no official funding.

The DVB drafts its standards and then passes them to ETSI, the European Telecommunications Standards Institute for rubber-stamping. But manufacturers feel free to start designing and building equipment once the DVB group has signed the standard off.

There are three main groups of standards, for cable, satellite and terrestrial TV. All are based on MPEG-2 coding. The differences are in the modulation.

The satellite system uses QPSK (Quadrature Phase Shift Keying) with guideline bit rate variable from 18·4Mbit/s to 48·4Mbit/s, and likely also to cover BPSK (Binary or two phase PSK) with guideline bit rate variable from 9·2Mbits to 24·3Mbit/s. The standard for cable distribution is 64 QAM (Quadrature Amplitude Modulation) with guideline bit rate variable from 9·6Mbit/s to 38·4Mbit/s.

Both these standards were agreed by January 1994 and ratified by ETSI exactly a year later.

The standard for terrestrial broadcasting (with COFDM, Coded Orthogonal Frequency Division Multiplex) should be agreed by the end of 1995, with ratificaton by end of 1996. COFDM has been chosen because it provides resistance to multipath interference, and allows transmitters across the country to share a single frequency for a single network. Also a COFDM signal has a distribution of energy which makes any interference it causes look like analogue snow noise.

Split Decision

There is however an important split on the way COFDM will be implemented, and this split is between the BBC and NTL, National Transcommunications Ltd, the privatised company which provides transmitters for the UK's commercial TV stations.

Both agree that Europe's 8MHz PAL channels can carry a net data rate of around 20Mbit/s, which will convey four or five programmes (depending on content and quality requirements). The BBC plans to split the 8MHz channel into 8000 discrete carriers. NTL argues that this triples the area of silicon, and relies on 0·35 micron technology.

Also if each transmitter is to use the same transmisison frequency, all transmitters must carry exactly the same data stream, tightly synchronised to the others. This is technically difficult and it also blocks regional programme variations e.g. local news on a national network.

NTL's proposal is for uncorrelated transmission, with the data spread over 2000 carriers. Synchronisation is not necessary, so regional programme variations are possible. As long as the viewer's aerial can provide a 16dB difference between wanted and unwanted signal, decoding is error-free.

Conditional Access

The DVB is also working on encryption and conditional access. During 1994 the Group agreed on a common scrambling system for MPEG-2 video signals. With this, broadcasters can use their own chosen conditional access control system.

One option is for each programme service (e.g. Sky, the BBC, Eutelsat etc) to require viewers to buy a dedicated reciever. The other option is to agree a common interface for conditional access. This would be built into all receivers and have slots for control modules. A single receiver could then have several slots which could be used to decode a wide range of programmes, broadcast with different conditional access requirements.

The hidden benefit is that if any one encryption system is hacked by pirates, the broadcaster can swap it out by giving all subscribers a new plug in module for a new system.

This is an important consideration. After a few years of assurances that Videocrypt was pirate-proof, Sky had to go to court to stop pirates selling counterfeit smart cards that defeated the system.

First Broadcasts

So who will be first to the market with digital TV?

A special situation exists in the UK. Two frequencies in the middle of the UHF band (Channel 35 and 37) remain unused for broadcasting.

The UK government has now ordered that one of the two unused frequencies (Channel 35) be reserved for digital TV. The BBC hopes to use this frequency, along with some of the taboo channels between analogue broadcasts, for a new all-digital service to start by late 1997.

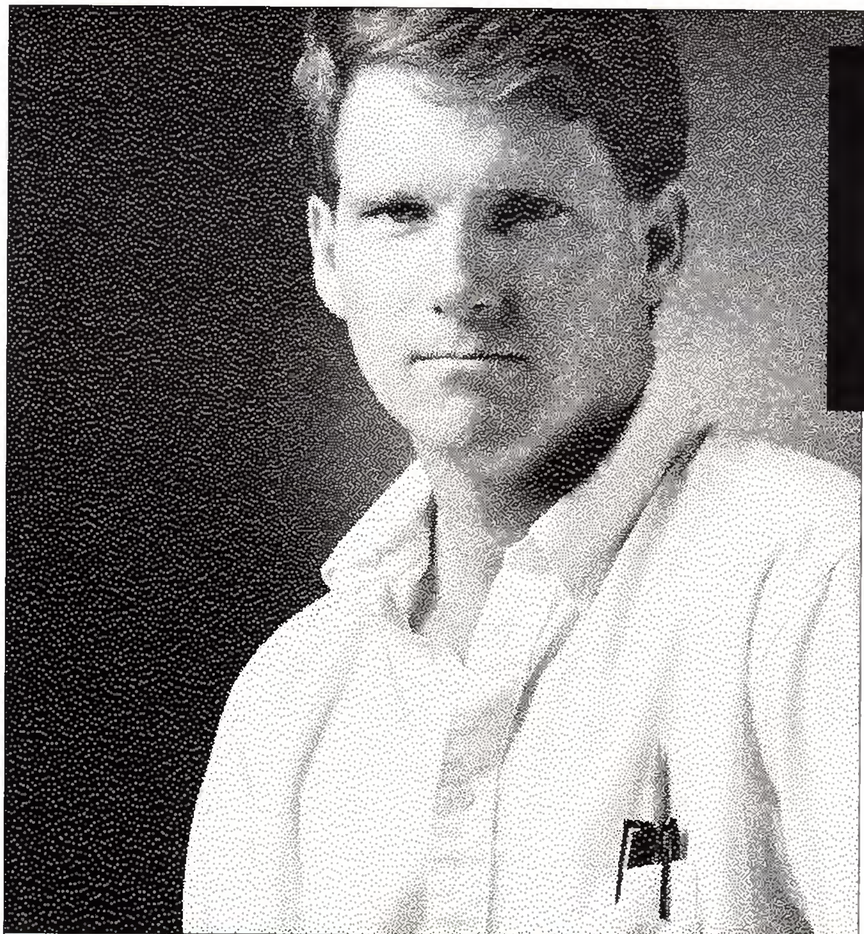
France has just launched six new analogue services, and only has one frequency that could perhaps be used for a digital service. Scandinavia has spare frequencies and wants to use them for terrestrial TV. Ostensibly, Germany has no spare frequencies. But there is talk of the military relinquishing its claim on UHF channels 61-68, to create some space for digital TV.

Continental subscriber TV stations Canal+ (for France) and Kinnevik (Scandinavia) look likely to be the first to use DVB standard systems for working services on air. Astra will soon launch extra satellites which are designed for digital transmission.

The Eutelsat organisation has already demonstrated that it is possible to split its 36MHz transmission channels into two halves, one 27MHz wide and carrying analogue pictures of similar quality to Astra, the other 9MHz wide and carrying a digital TV data stream running at 8 MBit/second.

The half-channels can either carry the same programme, or two quite different programmes. Eutelsat is also in the process of launching higher powered "Hot Birds" which will bring dish size down to match Astra.

Giuliano Berretta, Eutelsat's Commercial Director, predicts that 1997 will be the year when Digital TV becomes accessible and affordable.



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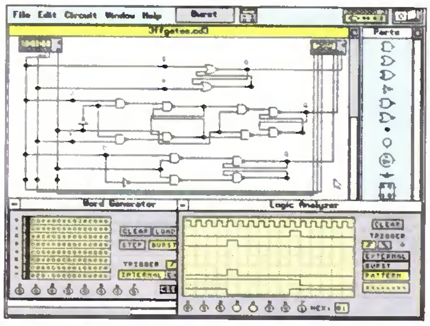
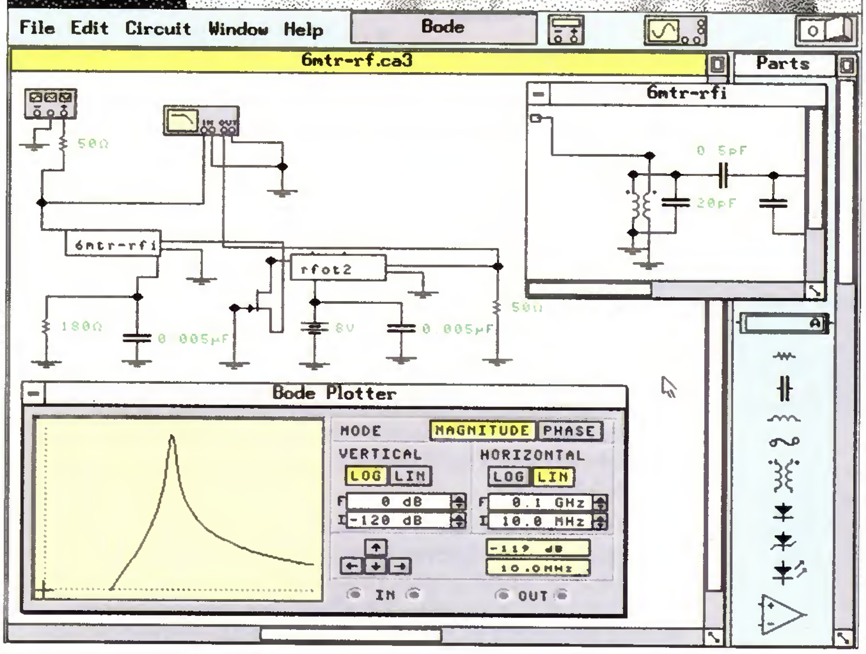


Digital Module: Analyzing a logic circuit.



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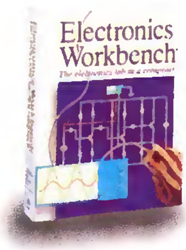

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FEATURES • Velleman View • Electronics Principles, Special Software Supplement.

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FEATURES • Safety First, Part 1 • Index for Volume 22.

JAN. '94

PROJECTS • Autolight (automatic nightlight) • Timer and NiCad Capacity Checker • 250W/600W Inverter and Uninterruptable Power Supply, Part 2 • Multi-Purpose Audio System, Part 4 • Pond Heater Thermostat.
FEATURES • Safety First, Part 2 • Calculation Corner, Part 1 • Electronics Testing and Fault Diagnosis, Course Review.

FEB. '94

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FEATURES • Calculation Corner, Part 2 • Safety First, Part 3 • European International Audio & Video Fair.

MARCH '94

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MAY '94

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JUNE '94

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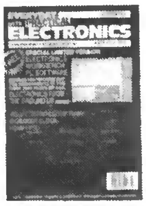

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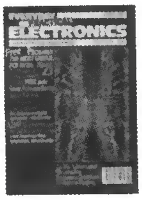

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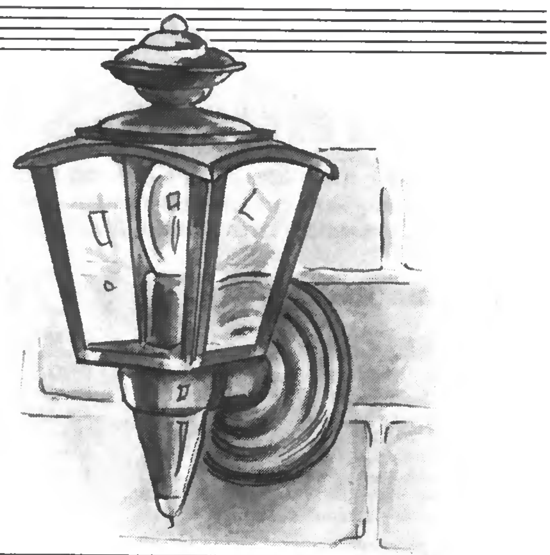
M4/95

Constructional Project



LIGHT ACTIVATED SWITCH

ROBERT PENFOLD

A light-sensitive switch that will find many uses in and around the home. An ideal project for the Multi-Project PCB.

THIS "light activated" circuit will automatically switch on a piece of electrical equipment when the detected light intensity falls below a preset threshold level. Alternatively, and by simply using the relay contacts in a different manner, it will switch on the controlled equipment when the detected light intensity goes above the preset threshold level.

Devices of this type are mainly used in automatic lighting applications. In particular, they are often used as a burglar deterrent.

By automatically operating a light the unit will give the appearance that a house, boat, or caravan is occupied, which is sufficient to deter most would-be intruders. No doubt there are other possible uses for an automatic switch of this type.

CIRCUIT OPERATION

The complete circuit diagram for the Light Activated Switch appears in Fig. 1. Operational amplifier IC1 is used in a simple trigger circuit.

Resistors R2 and R3 provide a reference potential of half the supply voltage to the non-inverting input (+), pin 3 of IC1. The inverting input (−), pin 2, is fed from a potential divider that has preset VR1 and resistor R1 as the upper arm, and R6, a light dependent resistor (l.d.r.) or photo conductive cell, as the lower arm.

The light sensor, R6, is an ORP12 cadmium sulphide photo-resistor. Its resistance is very high in total darkness, and the minimum dark resistance for the ORP12 is actually one megohm.

Higher light intensity produces reduced resistance, and in very bright conditions the ORP12 can exhibit a resistance of under 100 ohms. In an averagely lit room its resistance is typically a few kilohms.

With the l.d.r. in fairly bright conditions, the voltage fed to IC1's inverting input is lower than the reference voltage at the non-inverting input. This results in the output of IC1 going high, which biases transistor TR1 into conduction and switches on the relay.

The voltage fed to IC1's inverting input is relatively high if R6 is subjected to a very low light level. In fact it will be higher than the reference voltage at the non-inverting input. This results in IC1's output going low, which switches off transistor TR1 and the relay RLA.

The relay is therefore switched on if the detected light level is above a certain threshold level. This threshold level is controlled using a preset potentiometer VR1. The higher the resistance of VR1/R1, the lower the threshold level.

With the specified values for VR1 and R1 the unit covers a fairly low range of light levels. The range can be shifted higher by reducing the values of VR1 and R1 to 22 kilohms and 470 ohms respectively.

POSITIVE ACTION

Resistor R4 provides positive feedback over IC1 so that it triggers reliably from one state to the other, and does not tend to hover in an intermediate state when the light level is near the threshold level. It also introduces a small amount of hysteresis, which is a slight reluctance to change back again once the output of IC1 has switched from one state to the other.

The hysteresis occurs because resistor R4 tends to pull the reference voltage slightly below half the supply voltage when IC1's output is low, because it is effectively shunted across resistor R3. When IC1's output is high the reference voltage is pulled slightly above half the supply voltage, because R4 is then effectively in parallel with R2. The threshold level at which the relay switches on is slightly higher than that at which it switches off.

The purpose of the hysteresis is to prevent erratic operation when the light level nears the changeover point. Without the hysteresis it is virtually certain that the relay would switch on and off at a high rate when the light intensity was anywhere near the threshold level.

Even with the small amount of hysteresis provided by R4 the relay should switch "cleanly", but if necessary the amount of hysteresis can be increased by using a slightly lower value for R4. A protection diode D1 suppresses the high reverse voltage that would otherwise be produced across the relay coil each time it switched off.

POWER NEEDS

The current consumption of the circuit is only about 2mA when the relay is switched off, but it is approximately 30mA higher than this when the relay is switched on. The unit can be powered from batteries, such as eight HP7 size cells in a holder, but this is likely to prove rather expensive.

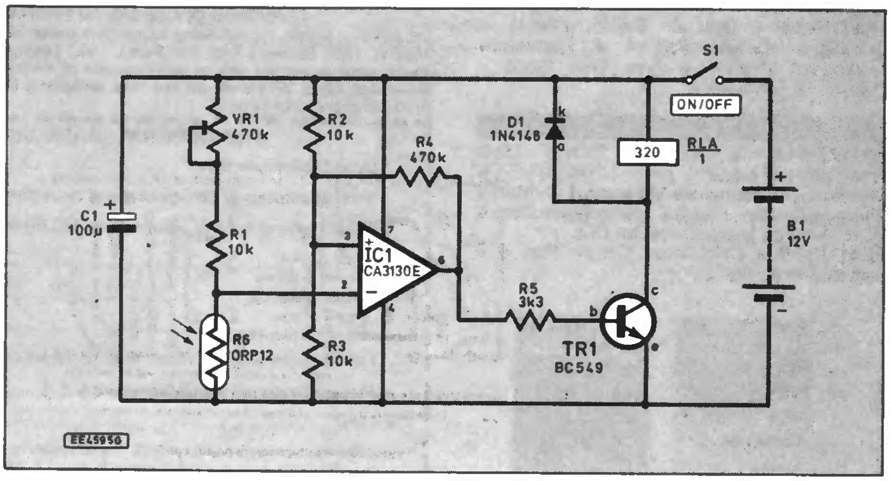


Fig. 1. Circuit diagram for the Light Activated Switch.

If the unit is used in a boat or motor vehicle which has a 12V battery supply, there should be no difficulty in powering it from this supply. The additional current consumption of the Light Activated Switch is likely to be insignificant in comparison to the very high capacity of a boat or vehicle battery. It is advisable to fit a 100mA fuse in series with the On/Off switch (S1) if the circuit is powered from a very low impedance source such as a car or boat battery.

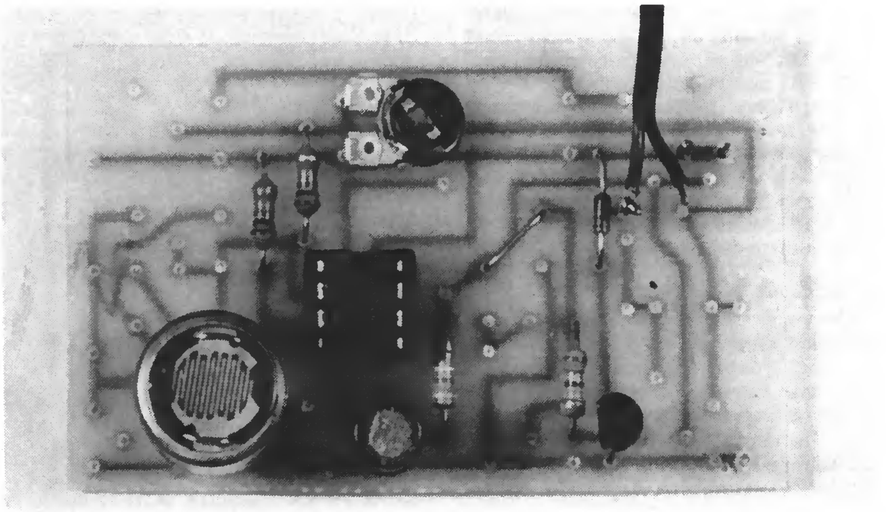
For use in the home a 12V battery eliminator having a current rating of 50mA or more represents an inexpensive means of powering the circuit in the medium and long terms. The eliminator does not need to be a type having a well regulated or low ripple output.

CONSTRUCTION

If you have not already used last month's Free p.c.b., then this simple Light Activated Switch is another useful project for the specially designed Multi-Project PCB. If you require extra p.c.b.s these are available from the *EPE PCB Service*, code 932.

The printed circuit board component layout, together with details of the hard wiring and full size copper foil master is shown in Fig. 2. IC1 is a CMOS device, and the standard anti-static handling precautions should therefore be observed when dealing with this component. Fit IC1 in a holder, but do not plug it in place until the unit is complete in all other respects.

Do not overlook the link-wire just to the left of diode D1. This can be made from a piece of wire trimmed from a resistor leadout wire. Be careful to fit D1 the right way round, since both transistor TR1 and diode D1 itself could be destroyed if a mistake is made here.



The completed circuit board with the l.d.r. (light sensitive resistor) mounted directly on the p.c.b.

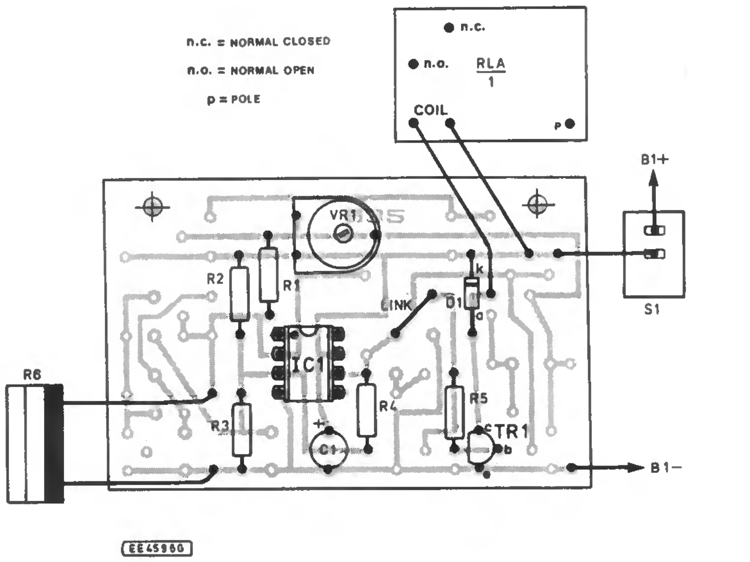
LIGHT SENSOR

In Fig. 2 and the photographs the light dependent resistor R6 is shown as being mounted on the printed circuit board. In practice it will often be necessary to mount this component off-board.

If the l.d.r. is fitted on the main unit, it must be mounted on the outside of the case, or a "window" for it to "look" through must be made at the appropriate position in the front panel of the case. The "window" can be hole about 12mm in diameter with a piece of clear plastic material glued in place behind the hole.

It is probably easier and more effective to mount the l.d.r. on the front panel. Drill a couple of small holes (about 2·5mm in dia.) and spaced 9mm apart to take the leadout wires, and then glue the photocell in place using any good quality general purpose adhesive. If the chosen case has a metal front panel, be careful not to get either leadout wire in contact with the panel.

In some applications it might be necessary to have the l.d.r. R6 located away from the main unit. Bear in mind that the unit might not function properly if it is used to control a light, and light from that source is allowed to shine directly on the surface of the l.d.r. Depending on the method of control used, the system



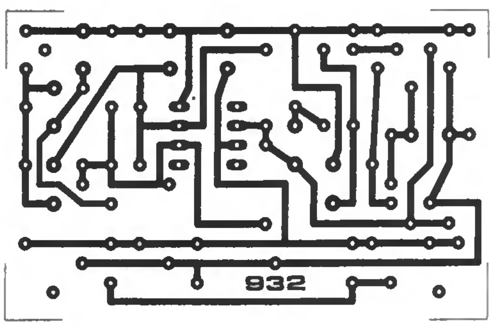


Fig. 2. Light Activated Switch component layout, interwiring and full size p.c.b. copper foil master.

Note: None of the projects in the Multi-Project PCB series use ALL the copper pads on the board, in most cases more than 50 per cent of the holes are left vacant. This makes it essential to double-check the positioning of each component, before soldering in place.

COMPONENTS

See SHOP TALK Page

Resistors

R1, R2, R3	10k (3 off)
R4	470k
R5	3k3
R6	ORP12 light dependent resistor

All 0·25W 5% carbon film, except R6

Potentiometer

VR1	470k min. carbon preset, horizontal

Capacitor

C1	100µ radial elect. 16V

Semiconductors

D1	1N4148 signal diode
TR1	BC549 *npn* silicon transistor
IC1	CA3130E CMOS op.amp

Miscellaneous

S1	On/Off toggle switch
RLA	12V 300 ohm coil (or more) relay, contacts as required (see text)
B1	12V battery pack (8 x HP7 in holder)

Printed circuit board available from the *EPE PCB Service*, code 932 (or Free with last month's issue); case, size and type to choice; 8-pin d.i.l. socket; PP3 type connector; multistrand connecting wire; solder, etc.

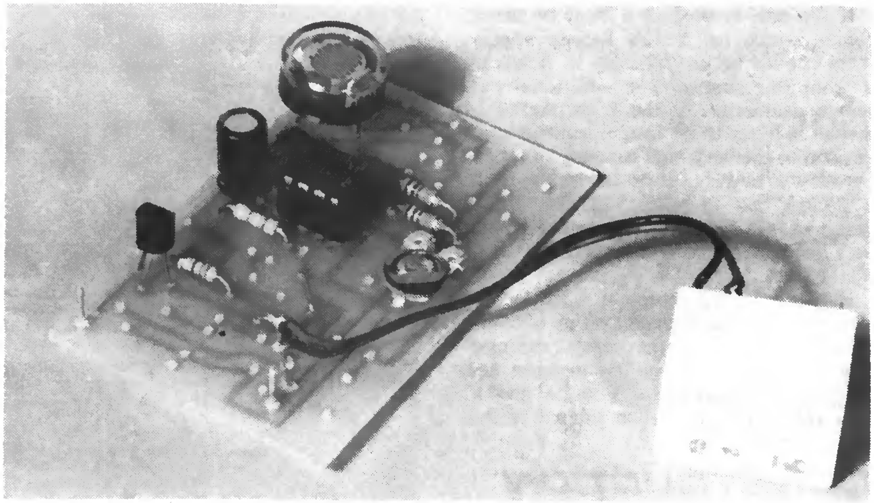
Approx cost guidance only **£10** *excl. Batts* could oscillate, with the light being rapidly switched on and off, or the system could simply latch-up with the light switched on.

The l.d.r. can be connected to the unit via a cable several metres long if necessary, but the cable should be a screened type. An inexpensive screened lead for audio use is perfectly adequate. The outer braiding must carry the connection to the 0V supply rail, with the inner conductor carrying the connection to resistor R1 and IC1 pin 2.

RELAY

The circuit should work properly using any relay which has a 12V coil and a coil resistance of about 300 ohms or more. However, make sure that the relay has adequate contact ratings for your particular application. The connections shown in Fig.2 are correct for a Maplin "10A mains relay". The retailers' literature should provide connection details for other relays.

The specified relay, in common with virtually all modern relays, is only intended for printed circuit mounting. Unfortunately, there is no room for the relay on the circuit board. Probably the easiest way of mounting the relay is to glue it in place, "up-side-down", on the base panel of the case. Use a good quality adhesive such as an epoxy type.



The completed circuit board showing connections to the relay coil. Connection to the relay contacts will depend on application.

The way in which the relay contacts are wired to the controlled equipment depends on whether this equipment must be switched on or off when the light threshold level is exceeded. Fig. 3 provides connection details for both methods of control when using the specified 10A relay.

It is assumed here that the relay will be used to control a 12V d.c. lamp. The relay can control mains powered equipment, but only those who have the requisite experience and expertise should use it in this way. ***Projects that connect to the dangerous mains supply are definitely NOT suitable for beginners.***

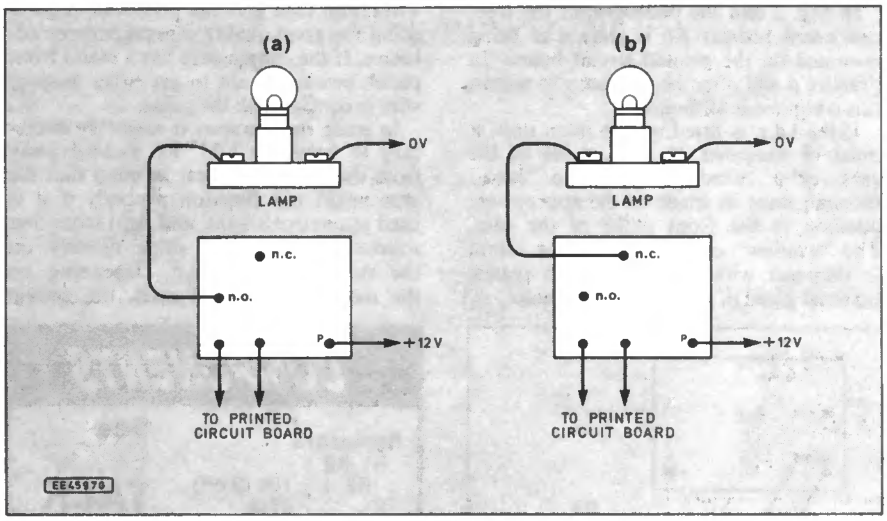


Fig. 3. Contact connection details when using the specified 10A relay. (a) to switch the lamp ON when the light threshold level is exceeded, and (b) to switch if OFF when the threshold level is exceeded.

IN USE

Preset control VR1 must be adjusted to give a suitable light threshold level. The easiest way of doing this is to first subject the l.d.r. to the light level at which the automatic switch on/off is required. Then adjust VR1 to the point where a slight to and fro adjustment results in the relay switching on and off.

If the required threshold brightness can not be reached, even with VR1 at minimum resistance (set fully clockwise), the values of VR1 and R1 must be reduced, as explained previously. □

SWITCH ON/OFF TIMER

ROBERT PENFOLD

A low-cost, one to five minute timer (extendable) that can be wired to switch On or switch Off equipment. A project for last month's Free Multi-Project PCB.

THIS simple timer circuit can be used to automatically switch ON or switch OFF a piece of electronic equipment after a preset delay. For example, it could be used to provide a transistor radio with a "sleep" facility. In other words, it could be used to automatically switch off the radio after a delay of a few minutes.

Using the specified component values the timer provides a delay that is adjustable from just under one minute to about five minutes. As explained later, it is very easy to modify the circuit to cover different time ranges, but times of much more than about 10 minutes are not really practical with a simple *CR* timer circuit such as this.

CIRCUIT OPERATION

The full circuit diagram for the Switch On/Off Timer is shown in Fig. 1. IC1 is an operational amplifier (op.amp) which is used in a basic trigger circuit. Resistors R3 and R4 provide a reference potential to IC1's non-inverting input that is roughly equal to two-thirds of the supply voltage.

The *CR* timing circuit (VR1, R1, and C2) connects to the inverting input, pin 2 of IC1. At switch-on capacitor C2 starts to charge via preset VR1 and resistor R1, and the voltage fed to the inverting input of IC1 steadily increases. The charge on C2 will eventually rise to a potential that is greater than the reference level at the non-inverting input of IC1.

The output of IC1 is high while the inverting input is at a lower voltage than the non-inverting input. Transistor TR1 is a simple common emitter switch that drives the relay coil. With the output of IC1 high, TR1 is switched on, and the relay is therefore switched on or energised as well.

When the voltage at the inverting input starts to go above the reference potential, the output of IC1 swings lower in voltage. A small amount of positive feedback is applied to the circuit by resistor R5. As a result of this, once IC1's output starts to go lower in voltage, it rapidly triggers to the low state. Transistor TR1 and the relay are then switched off.

The time taken for the charge on C2 to reach the reference level is dependent on the values of R1, VR1, and C2. The delay time is approximately equal to 1·1 *CR* seconds, where *C* is the value of capacitor C2 in microfarads, and *R* is the series resistance of R1 and VR1 in megohms.

This gives a theoretical timing range of 51·7 to 294·69 seconds. In practice the tolerances of the components must be taken into account, and these can shift the timing range upwards or downwards by up to about 10 per cent. Also, leakage currents in the circuit are likely to extend the delay times by at least a few per cent.

CHANGING TIMES

This makes it impossible to accurately set a given delay time simply by using the mathematically correct timing component values. Instead, preset VR1 must be trimmed to give the required delay time using trial and error.

For shorter delay times simply make capacitor C2 lower in value. For example, a 30 second delay can be obtained using a value of 10µF, which gives a theoretical timing range of 11 to 62·7 seconds.

Longer delays can be obtained by using a higher value for C2 and (or) R1. In practice there is only limited scope for producing longer times due to the leakage through capacitor C2.

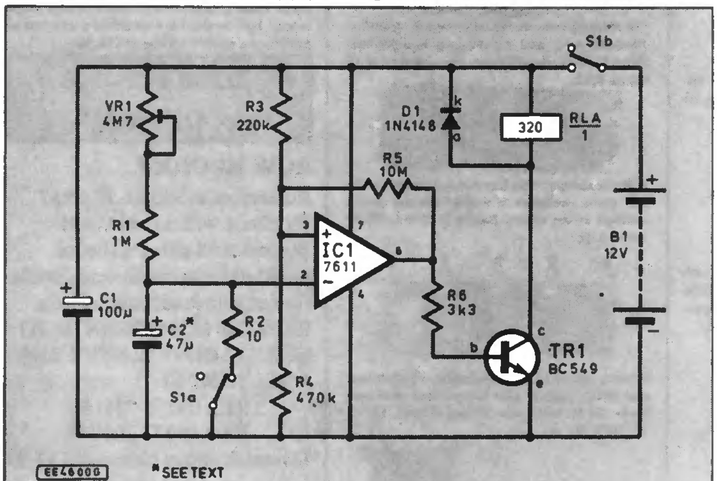
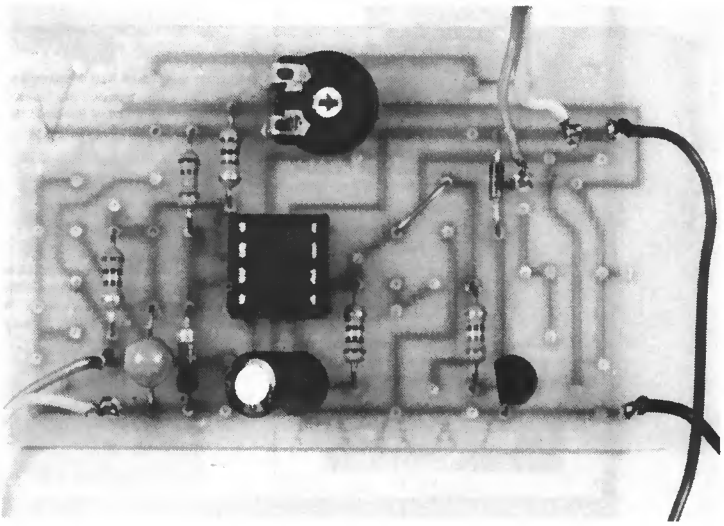


Fig. 1. Circuit diagram for the Switch On/Off Timer. Capacitor C2 must be a tantalum type.



Layout of components on the printed circuit board.

As the circuit stands, the current flow through VR1 and R1 is extremely low, and a small amount of leakage in capacitor C2 would be sufficient to prevent the charge on C2 from reaching the reference voltage. To avoid this it is essential to use a high quality component for C2, but its high value precludes the use of a non-polarised type.

A tantalum bead capacitor will provide good performance, and a superior grade electrolytic might also be suitable. With higher values for C2 it becomes increasingly difficult to obtain satisfactory results. A higher value for resistor R1 reduces the charge current, and also makes it difficult to obtain worthwhile performance. Realistic maximum values for C2 and R1 are 100µF and 10M respectively.

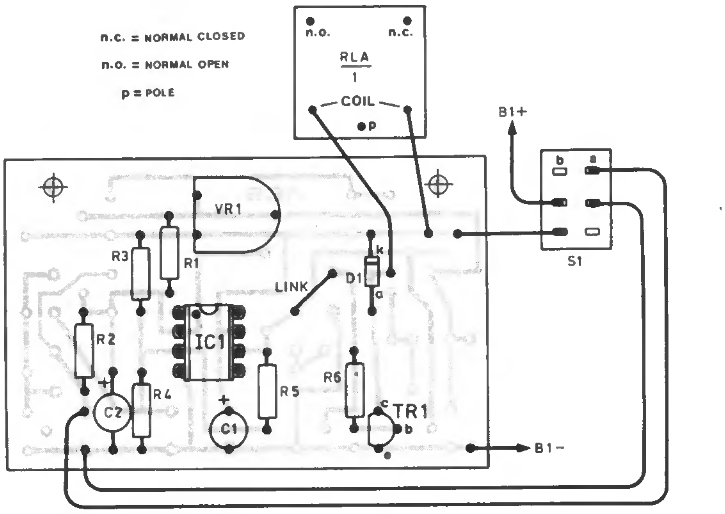
If a variable delay time is needed it is simply necessary to replace preset VR1 with an ordinary rotary potentiometer. This can be fitted with a calibrated scale, but the only way of finding the calibration points is by trial and error.

Switch S1a discharges capacitor C2 when the timer is switched off, so that it is almost instantly ready to start a new timing run again. Resistor R2 provides current limiting when S1a closes.

Without this current limiting there would be a lot of contact sparking, and S1 would soon fail. D1 is a protection diode that suppresses the high reverse voltage spike which would otherwise be generated across the relay coil each time it was switched off.

The low power CMOS op.amp, IC1, has an extremely high input resistance which ensures that the input current drawn from the timing network is far too low to have a significant effect on the charge rate. The current consumption of the circuit is around 30mA to 40mA initially, but this reduces to less than 50 microamps when the relay switches off.

This low current consumption is important, since in some applications the circuit will be left switched on for many hours after the relay has switched off. The HP7 battery pack will not run down significantly even if a current drain of 50 microamps is maintained for many days.



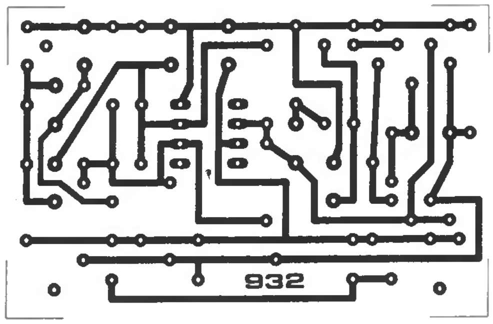


Fig. 2. Circuit board component layout, p.c.b. master and interwiring details for the Switch On/Off Timer.

Note: None of the projects in the Multi-Project PCB series use ALL the copper pads on the board, in most cases more than 50 per cent of the holes are left vacant. This makes it essential to double-check the positioning of each component, before soldering in place.

CONSTRUCTION

Using the Free printed circuit board (p.c.b.) from last month's issue should make construction of the Switch On/Off Timer reasonably trouble free. If you missed last month's issue you can obtain extra p.c.b.s from the *EPE PCB Service*, code 932, for the sum of £3. The component overlay and copper foil master for the printed circuit board plus details of the hard wiring are provided in Fig. 2.

As IC1 is a CMOS device, the normal anti-static handling precautions should be taken when dealing with this component. Use a holder for this device, and do not fit it into place until all other connections have been completed. Do not handle IC1 any more than is really necessary, and try not to touch the pins.

COMPONENTS

Resistors

See SHOP TALK Page

R1	1M
R2	10
R3	220k
R4	470k
R5	10M
R6	3k3

All 0·25W 5% carbon film

Potentiometer

VR1	4M7 min. carbon preset, horizontal

Capacitors

C1	100µ radial elect. 16V
C2	47µ tantalum bead, 16V

Semiconductors

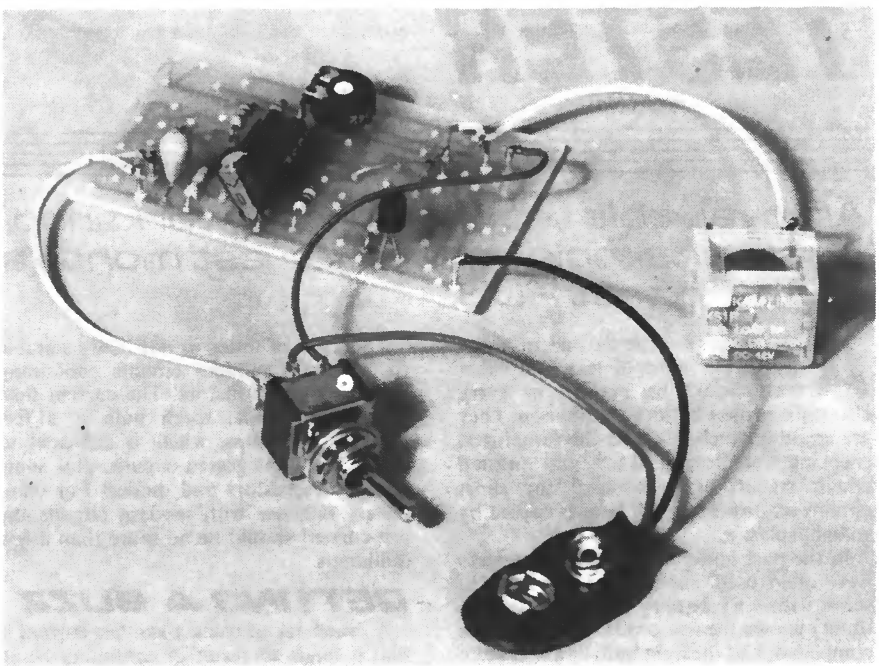
D1	1N4148 signal diode
TR1	BC549 *npn* silicon transistor
IC1	7611 low power op.amp

Miscellaneous

S1	d.p.d.t. min. toggle switch
RLA	12V 300 ohm (or more) coil relay, contacts as required (see text)
B1	12 volt battery pack (8 x HP7 size cells in holder)

Printed circuit board available from the *EPE PCB Service*, code 932 (or Free with last month's issue); case, size to suit; 8-pin d.i.l. socket; PP3 type battery clip; multistrand connecting wire; solder, etc.

Approx cost guidance only **£9** *excl. Batts*



Wiring from the completed p.c.b. to the relay, battery connector and toggle switch.

Be very careful to get diode D1 the right way round as there could be dire consequences for both D1 and transistor TR1 if you get this wrong. Do not overlook the link-wire just to the left of D1.

The polarity of capacitor C2 should be marked by one or more "+" signs on the body of the component, but the markings are likely to be very small, and you may need the aid of a magnifier. The connections to the battery pack are made via an ordinary PP3 type battery clip.

RELAY

The relay can be any type which has a 12V coil with a resistance of about 300 ohms or more, plus suitable contacts for your application. Both the Maplin "10A Mains Relay" and the Electrovalue "Miniature SPDT 3A" types were found to work well. The connections shown in Fig. 2 are correct for the "miniature" 3A type.

There is no room for the relay on the circuit board, and it must therefore be mounted off-board on the case. Most modern relays are only intended for printed circuit mounting, and have no provision for chassis mounting. However, they can be glued in place using a good quality general purpose adhesive such as an epoxy type. Alternatively, it might be possible to fabricate a suitable clamp from a small piece of aluminium.

ON OR OFF

Although the relay switches off at the end of the timing period, the timer can automatically switch the controlled equipment on or off, depending on the way in which the relay's contacts are used. Fig.3 shows the two methods of connection.

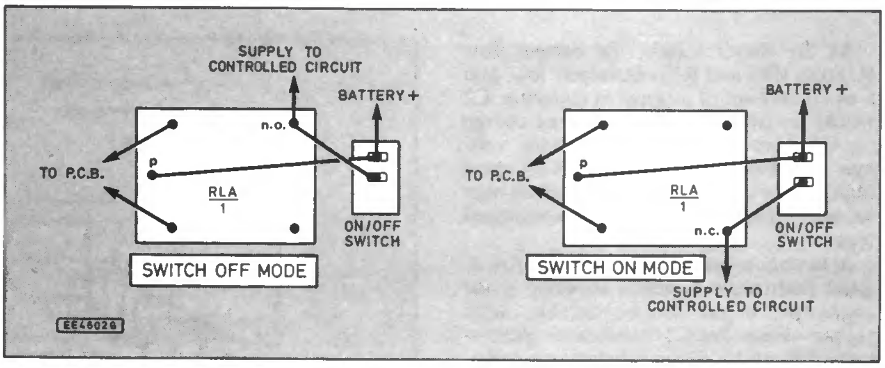


Fig. 3. Two methods of wiring the relay to the existing control equipment on/off switch.

It is assumed here that the relay is the miniature type, and that the unit is to be used with the relay contacts connected in parallel with the existing on/off switch. With the on/off switch set to the "off" position, the timer will then control the main item of equipment.

The exact way in which the unit is used must be varied to suit the prevailing circumstances. It might be necessary to add an s.p.s.t. switch in one lead from the relay to the existing on/off switch, so that the timer does not hold the main equipment switched on at inappropriate times.

This is most likely to be necessary with the switch-on mode, where the main equipment will otherwise be held switched on when the timer is switched off. Alternatively, simply wiring the relay in series with the on/off switch rather than in parallel with it might give the desired result.

The unit can be used to control mains powered equipment, but it should *only* be used in this way by those who have the necessary expertise and experience.

Beginners should only use the unit to control BATTERY POWERED equipment, and should NOT build any projects that involve connections to the dangerous mains supply.

TESTING

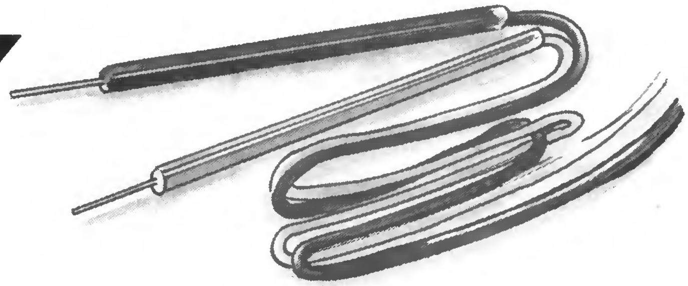
It is advisable to test the unit with preset VR1 initially set for minimum resistance (set fully clockwise). This should give a delay time of roughly one minute. Provided all is well, it is then a matter of trying higher values, and using trial and error to obtain the required delay time.

If the times obtained are much higher than expected, or the relay simply fails to switch off at all, it is likely that the problem is due to leakage through capacitor C2. First check to make quite sure that it is connected with the correct polarity. If it is connected properly, try replacing it with another capacitor.

It is worth emphasising again that the Timer can only work reliably if C2 is a high quality capacitor. □

Constructional Project

CONTINUITY TESTER



An invaluable tester for your workshop. Another simple project for last month's Multi-Project PCB.

A CONTINUITY tester is one of those invaluable items of test equipment that should be present in every electronic project builder's workshop. They are useful for such things as checking fuses, checking for broken leads and printed circuit tracks, and searching for short circuits on printed circuit boards caused by solder "splashes".

In the past quite basic continuity testers were often used, such as a torch bulb in series with a 6V battery. If there was continuity across the test prods the circuit was completed, and the light bulb lit up. If there was not, the lack of continuity was indicated by the bulb remaining switched off.

This type of tester in not really suitable for use with modern circuits containing delicate semiconductors. The current flow through a typical torch bulb is a few hundred milliamps, which is sufficient to "zap" many integrated circuits, plus some discrete transistors and diodes! For completely safe use with modern circuits the test current should be no more than a few milliamps.

GETTING A BUZZ

A drawback of using a low test current is that it tends to result in continuity being indicated even if there is actually a resistance of a hundred ohms or more across the test probes. This can result in a lot of misleading results.

Many continuity testers, even some high current types, are also "fooled" by forward biased semiconductor junctions within the test circuit. These can be provided by diodes, or by diode junctions within transistors and integrated circuits.

Most modern circuits are liberally scattered with these hidden diode junctions. They are a frequent source of misleading results, with short circuits being indicated where none exist.

The Continuity Tester featured here provides an audible "buzz" when electrical continuity is present across the test prods. An audible indication is generally preferred to a visual type, as it avoids the need to keep looking away from the test prods (which tend to slip off the test points each time you look away).

The maximum voltage to be found across the test probes is about 6V, and the short circuit current is approximately 0·3mA. This ensures that the unit can be used safely with circuits that contain delicate semiconductors.

Reliable results are obtained because continuity is only indicated if the resistance across the test prods is no more than a few ohms. Also, the voltage drop across a forward biased silicon junction is sufficient to prevent the unit from being "fooled" into indicating proper continuity.

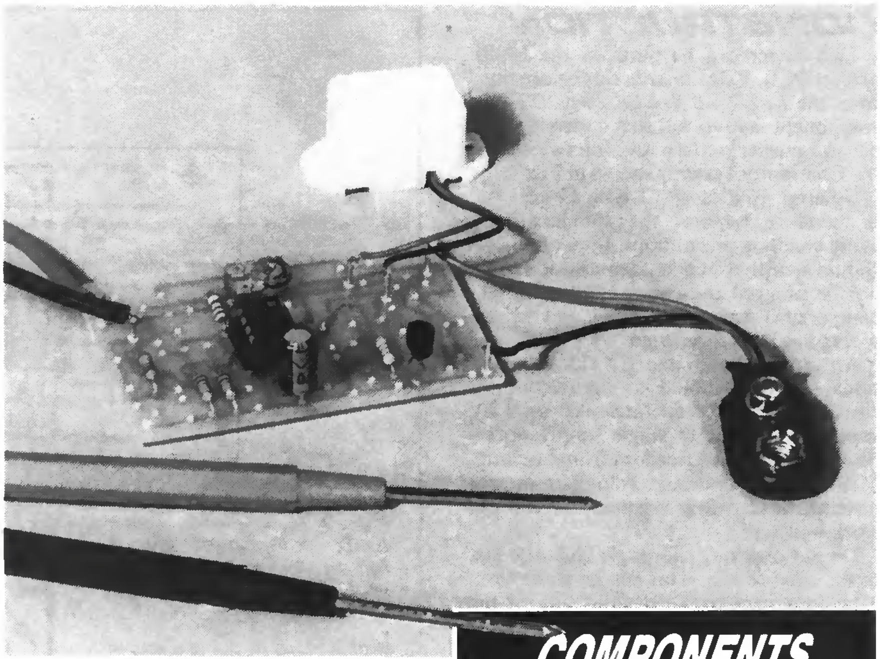
It will not indicate continuity due to germanium junctions or Schottky diodes either. This gives much greater reliability in use, but it does bring the minor drawback that the unit cannot be used to test any type of diode.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Continuity Tester appears in Fig. 1. Operational amplifier IC1 is used here as a voltage comparator.

If the voltage at its inverting input (pin 2) is higher than the potential at its non-inverting input (pin 3), the output goes towards zero volts. Taking the inverting input to a lower voltage than that at the non-inverting input results in the output swinging more positive.

An operational amplifier has a very high open loop voltage gain, and the typical figure for the CA3130E is about 250,000 times. Consequently, only a minute voltage difference is needed across the inputs in order to send the output fully positive or negative.



voltage. Under standby conditions there is an extremely high resistance across the test probes, giving zero volts at IC1's non-inverting input. The inverting input is therefore at the higher voltage, and the output of IC1 is low. This results in transistor TR1 being cut off, and the buzzer (WD1) is switched off.

If the test prods are shorted together, the voltage at the non-inverting input of IC1 goes to half the supply voltage, and it is then at a slightly higher potential than

(above) Photograph of the completed unit showing the buzzer connected to the board.

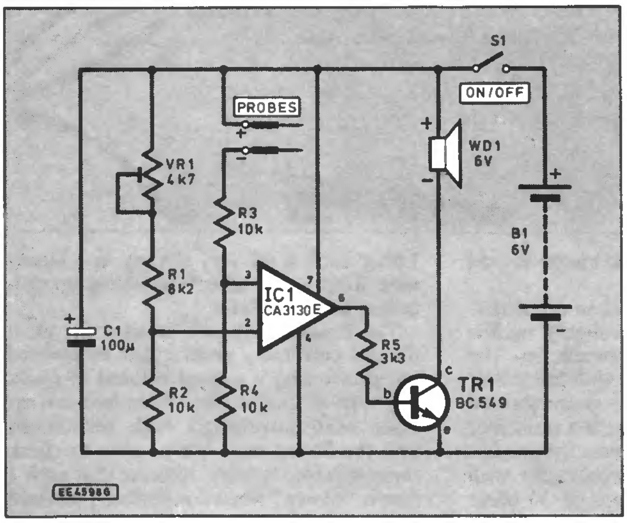


Fig. 1. (left). Circuit diagram for the Continuity Tester. The "test" buzzer is a miniature solid-state type and must be connected in-circuit with the correct polarity.

COMPONENTS

Resistors
R1 8k2
R2, R3,
R4 10k (3 off)
R5 3k3
All 0·25W 5% carbon film

See **SHOP TALK** Page

Potentiometer
VR1 4k7 min. enclosed carbon preset, horizontal

Capacitors
C1 100µ radial elect. 10V

Semiconductors
TR1 BC549 *npn* silicon transistor
IC1 CA3130E CMOS op.amp

Miscellaneous
S1 s.p.s.t. min. toggle switch
B1 6V battery pack (4 x HP7 size cells in holder)
WD1 6V buzzer

Printed circuit board available from the *EPE PCB Service*, code 932 (or Free with last month's issue); case to choice; test probes and leads; 8-pin i.c. socket; PP3 type battery clip; multistrand connecting wire; solder, etc.

Approx cost guidance only **£9** *excl. Batts*

The two inputs of IC1 are fed from separate potential dividers. Preset VR1 and resistors R1 and R2 provide a reference potential to the inverting input, pin 2, and this voltage can be adjusted by means of VR1. Resistors R3 and R4 form the potential divider at the non-inverting input, pin 3, and these provide an output voltage equal to half the supply potential.

However, the test probes are connected in series with R3, and the half supply output voltage is only produced with the prods shorted together. A resistance between the prods, even a relatively low one, will give a slight reduction in the output voltage from R3 and R4.

IN ACTION

In practice preset VR1 is adjusted so that the reference voltage at the inverting input is fractionally lower than half the supply the inverting input. This takes the output of IC1 high, which in turn results in TR1 being biased into conduction and the buzzer being activated.

If there is a small resistance across the test prods the voltage at the non-inverting input will be slightly less than half the supply voltage. This may be sufficient to take the non-inverting input to a higher voltage than the inverting input and activate the buzzer, or it might not.

This depends on the precise setting of VR1, and the resistance across the test probes. With careful adjustment of VR1 the circuit can be made to ignore resistances of less than about five to 10 ohms, which is good enough to avoid the vast majority of erroneous results.

The circuit could be made more sensitive by reducing the value of resistors R3 and R4. For example, using a value of one kilohm would make the circuit ten times more discriminating, so that it would ignore resistances of more than about 0·5 to one ohm. The test current would still be quite low at only about 3mA.

In use it is not necessarily a good idea to have a very high degree of discrimination. It would probably not significantly reduce the number of "false alarms", and it could result in continuity being overlooked due to poor electrical contacts with the test prods. It is left to individual constructor's to select the degree of discrimination they require, but it would be advisable not to make resistors R3 and R4 less than about 560 ohms in value.

The current consumption of the circuit is less than one milliamp, but the consumption rises to about 20mA when the buzzer is activated. This still gives an extremely long life from the four HP7 size batteries.

CONSTRUCTION

This Tester can be built on the Multi-project PCB. Extra boards can be obtained from the *EPE PCB Service*, code 932. The component layout, full size underside copper foil master pattern and interwiring for the Continuity Tester is shown in Fig. 2.

Op.amp IC1 is a CMOS device and it therefore requires the standard anti-static handling precautions. In particular, it should be fitted in a holder, and it should not be plugged into place until the other components have been fitted and all the wiring has been completed.

An alternative to the CA3130E operational amplifier should *not* be used in this circuit. This device operates well on a 6V supply, is capable of single supply operation, and has good freedom from latch-up. Most other operational amplifiers do not have all these characteristics, and will not work well here.

Do not overlook the single link wire just to the right of IC1. This can be made from a leadout wire trimmed from one of the resistors.

The buzzer WD1 must be connected to the board with the correct polarity. The positive (+) and negative (−) leads are respectively identified by their red and black sleeving.

The buzzer requires a rectangular mounting hole in the front panel of the selected case. Probably the easiest way of making this is to first drill a hole of about 12mm in diameter, and then file it to shape and size using a miniature flat file.

The positions of the two small mounting holes can then be marked using the buzzer itself as a sort of template. The use of 8BA fixing bolts and nuts are required, and these are not supplied with the buzzer.

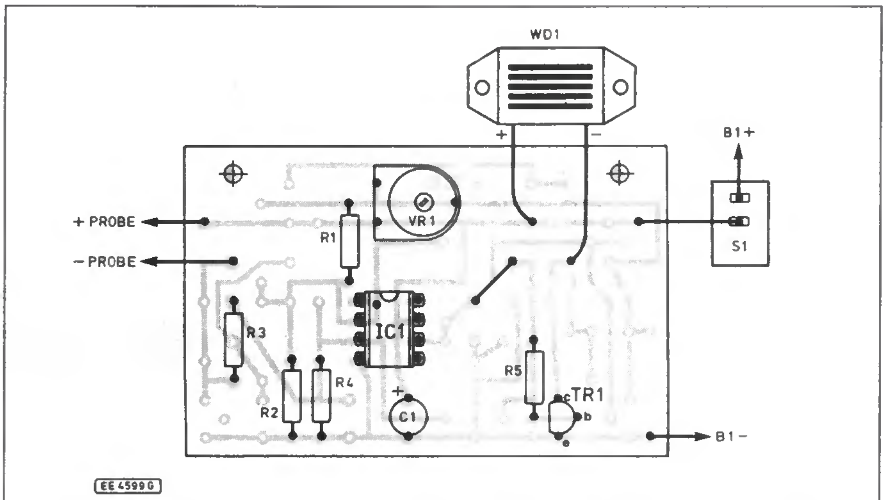
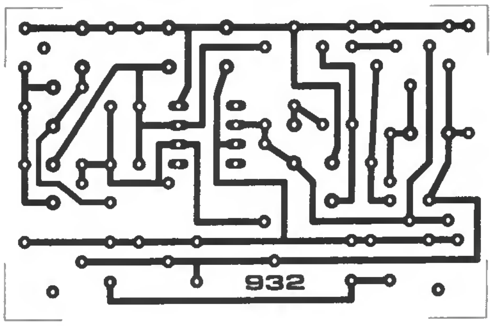
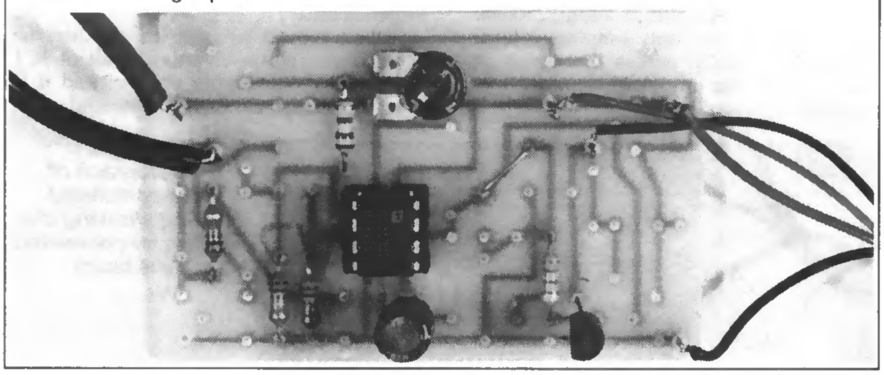


Fig. 2. Continuity Tester p.c.b. component layout, full size copper foil master and (below) photograph of finished board.



Note: None of the projects in the Multi-Project PCB series use ALL the copper pads on the board, in most cases more than 50 per cent of the holes are left vacant. This makes it essential to double-check the positioning of each component, before soldering in place.



PROBES

Test probes are usually supplied complete with leads and plugs. The probes can therefore be connected to the circuit board via a pair of the appropriate sockets mounted on the front panel.

In practice it might be better to remove the plugs from the leads, drill an entrance hole for the leads in the front panel, and then solder the leads direct to the component board. This method ensures that there is always a low resistance connection between each prod and the circuit board, and that reliable results will be obtained.

IN USE

Preset potentiometer VR1 must be carefully adjusted to the correct setting if the Tester is to function well. Start with VR1 set at virtually minimum resistance (set almost fully clockwise). With the two test prods connected together the buzzer should not operate.

If VR1 is steadily adjusted in a counter-clockwise direction, at a roughly middle setting the buzzer should switch on. The unit should then work well, with the buzzer operating when the test prods are shorted together, but not when there is a resistance of more than a few ohms across the prods.

If the circuit indicates continuity with resistances of about 10 ohms to 30 ohms across the prods, preset VR1, has been taken slightly beyond the optimum setting. Either back it off very slightly in a clockwise direction, or repeat the setting up procedure more carefully.

The finished unit can be used for most normal continuity checks, but as pointed out previously, it cannot be used to check any type of diode. Also, some low current fuses have surprisingly high resistances, and the Tester may not be able to check these reliably. It might indicate that such a fuse is "blown" when it is perfectly all right (but not that it is all right when it is "blown"). □

ELECTRONICS SOFTWARE

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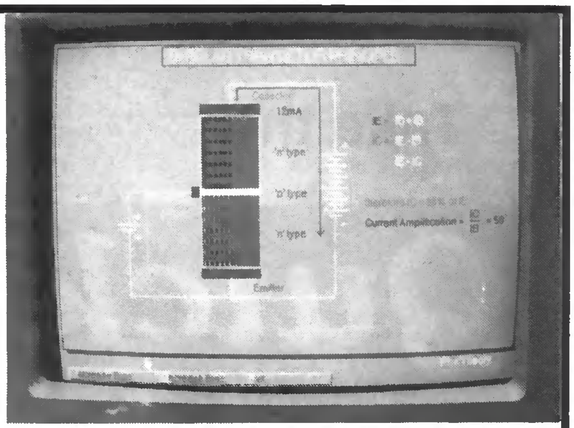

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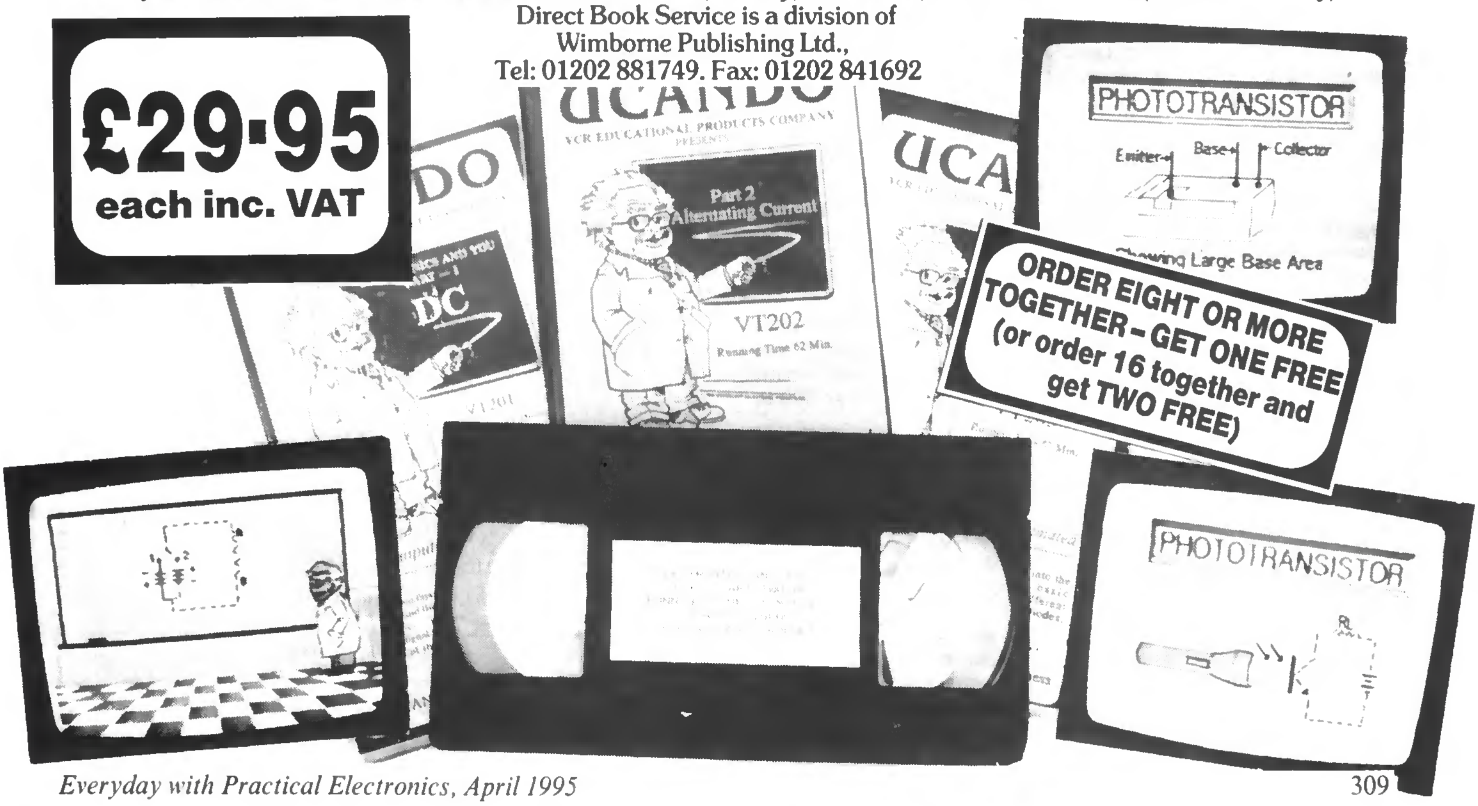


Special Feature

THE HARD CELL

TERRY de VAUX-BALBIRNIE

Are you itching to buy a mobile phone? We look at the technology behind it.

FOR many years, people were content with fixed telephones in their homes and offices. It was a science fiction dream to be able to communicate from any location – perhaps while out walking or in the car.

Although we are still a little way from the comic-strip notion of a commercially-viable watch-strap telephone, most people are at least aware of the technology on offer even if they are confused by it. High Street hype would entice us into the shop and emerge with our new toy.

However, attracted by the price – highly discounted and offered at a fraction of its true value – let the buyer beware! There is a network connection charge, monthly line rental, cost of calls and details such as insurance to consider.

RAPID GROWTH

Mobile telephones constitute one of the most rapidly growing markets in the UK. In 1991 there were fewer than 400,000 units on air. By 1992 this had risen to over 500,000. By 1993 it was almost one million and by the end of 1994 it was expected to have reached 1·5 million – see Fig. 1. Estimates range between seven and 12 million mobile users by the year 2000.

The only way to provide a practical *wire-less* telephone is to use a two-way radio link. The basic techniques have been known for a long time – Marconi demonstrated the use of radio waves for communication purposes a hundred years ago. However, modern technology was needed to turn dreams into practical reality.

It also required a relaxation in the regulations regarding the use of radio transmitters. Traditionally, this has been the prerogative of broadcasting companies, emergency services, taxi operators, ships at sea and so on. General access was denied apart from licensed radio amateurs who needed (and still do) to pass a theory examination. There was some loosening of the rigid line when, in February 1981, the Home Secretary announced that he was willing to provide a Citizens Band service in the UK using the 27MHz band.

BRASS TACS

Early radio telephones were of the "taxi" kind and only able to talk to a base station some relatively short distance away. Messages to the public network had to be relayed by word of mouth. It became clear that, with emerging technology, a radio link could be established not only between mobile users but integrated with the national fixed system.

To this end, in 1982, the Department of Trade and Industry selected two organisations – Racal-Vodafone and Cellnet – to develop analogue networks to the British Standard *Total Access Communications System* (TACS) using the frequency range 890 to 960MHz. Operation began in January 1985.

To operate this service, 1000 duplex (two-way) radio channels were allocated (that is, 1000 frequencies for sending and 1000 for receiving). Each of the rival operators were allocated 300 channels with the remaining 400 reserved for the forthcoming digital pan European network called GSM (Group Systems for Mobile Communication) of which more will be said presently.

One method of use would be for mobile operators to employ high-powered transmitters and communicate with a single distant base station. This could then be patched into the public telephone network. To use this system, a caller would need exclusive use of one communication channel all the time he or she was talking.

With such a small number of possible users at any given time, this would be obviously impractical. A further problem with such an idea is that a fairly low frequency of operation would be needed to provide the necessary long range and such frequencies have long since been allotted to other services.

The problem needed some lateral thinking. Space was available in the u.h.f. (ultra high frequency) region of the radio wave spectrum a little above that used for TV broadcasting (which extends to about 853MHz). Waves in this region behave rather like light and travel best over line-of-sight distances. For this reason, they would seem to be of little use for long-range communication. However, this very drawback gives a clue to their strength.

REPEAT, REPEAT

By exploiting the limited range, a process of *frequency re-use* is made possible. This means that the same frequencies may be employed by others a relatively short distance away without causing interference. In fact, over the entire nation, the same channels may be used many times over.

For a blanket system, therefore, all that is required is a network of very low-powered u.h.f. transmitters grouped in an arrangement

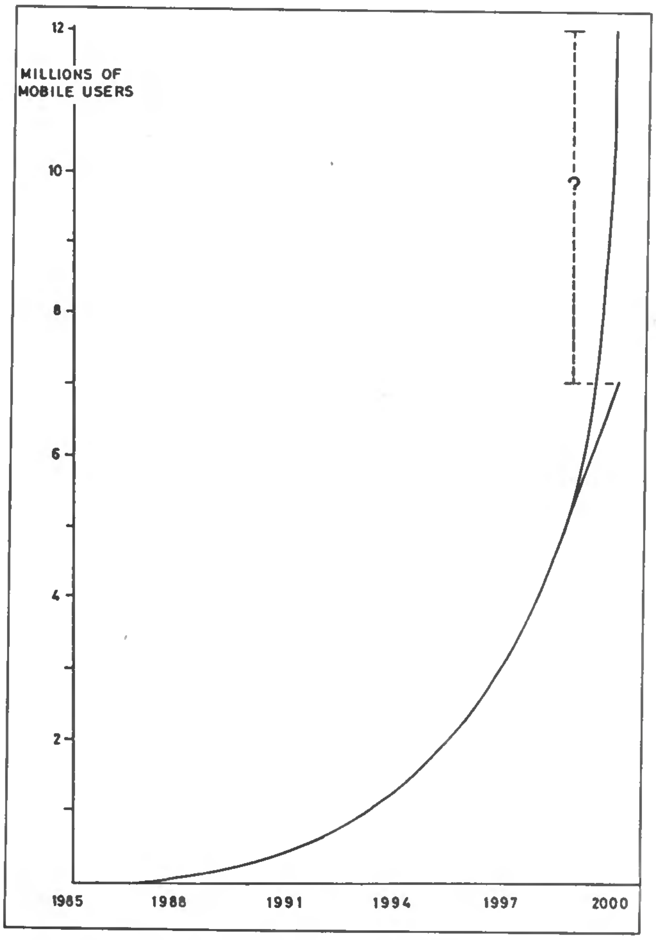


Fig. 1. How the increased use of mobile phones since 1985 is expected to rise by the year 2000.

of cells covering the whole country. As far as practicable, any mobile phone would be within the range of at least one cell. At present more than 98 per cent of the UK population is served by the analogue channels in this way.

In theory, signals should not extend beyond the boundary of the cell in which they are generated. However, this is impossible in practice and there is bound to be some overlap. If adjacent cells used the same frequencies, there would therefore be profound interference problems between them. To overcome this a *cell repeat pattern* is used. Fig. 2 shows one possible arrangement – the seven-cell pattern. Cells are represented by hexagons but this is only for the purpose of illustration.

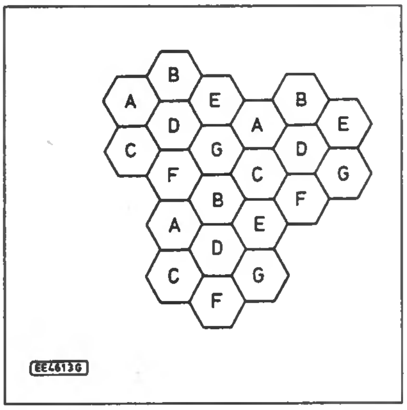


Fig. 2. 7-cell repeat pattern.

Each cell in such a pattern will have at its disposal about 40 channels (i.e. the 300 allocated to the particular operator divided by seven). As a further safeguard against possible interference, adjacent cells do not share adjacent channels. In this way, the total channel allocation is recycled many times over throughout the nation by groups of such cell clusters.

Cells are not all the same size because the distance over which they can effectively operate depends on the terrain. In the city, with tall buildings around, coverage will be small and there will be a need for many closely-spaced cells. Each will have a very low power output, perhaps 1W, and serve a 1km diameter circle. In rural areas, with fewer obstructions, cells will be made larger with a higher-power transmitter, perhaps 15W, serving a 20km circle.

There are twenty-one channels used as *control channels* and each base station will be allocated one of these. Control channels are used to send information to and from the mobile to monitor its status while idle (switched on but not actually in use). These also initiate a call and allocate the voice channel.

Additionally, there are two *guard channels*. These act as buffers between Vodafone and Cellnet frequencies to prevent possible interference. This provides 277 analogue speech channels for each network operator.

BRASS ETACS

More recently, the DTI has issued further frequencies adjoining the TACS allocation to cope with the ever increasing demand for the analogue service. These are called *extended* channels (ETACS). ETACS channels range from 872MHz to TACS at 890MHz (transmit) and 917MHz to TACS at 935MHz (receive). This provides an additional 320 channels for each operator.

ETACS channels are only used in certain urban areas and on major roads where the need for extra capacity is particularly important. Since ETACS is outside the normal TACS range, it can only be accessed by later equipment designed for its use. During the setting-up of a call, ETACS compatible equipment will be allocated an ETACS channel if one is available. If no such channel is free, a TACS one will be given instead. In this way, service is improved for all analogue mobiles.

The spectrum allocation including GSM, TACS and ETACS frequencies is shown in Fig. 3. It will be seen that the lower half of the frequency band is used for mobile to base communication and the top half for base to mobile. There is also a 2MHz gap (915MHz to 917MHz) between base station and mobile frequencies – a further guard against interference.

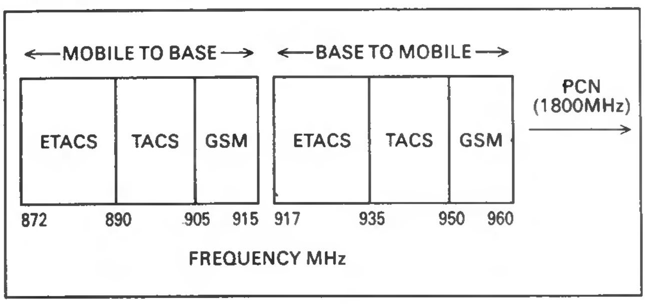
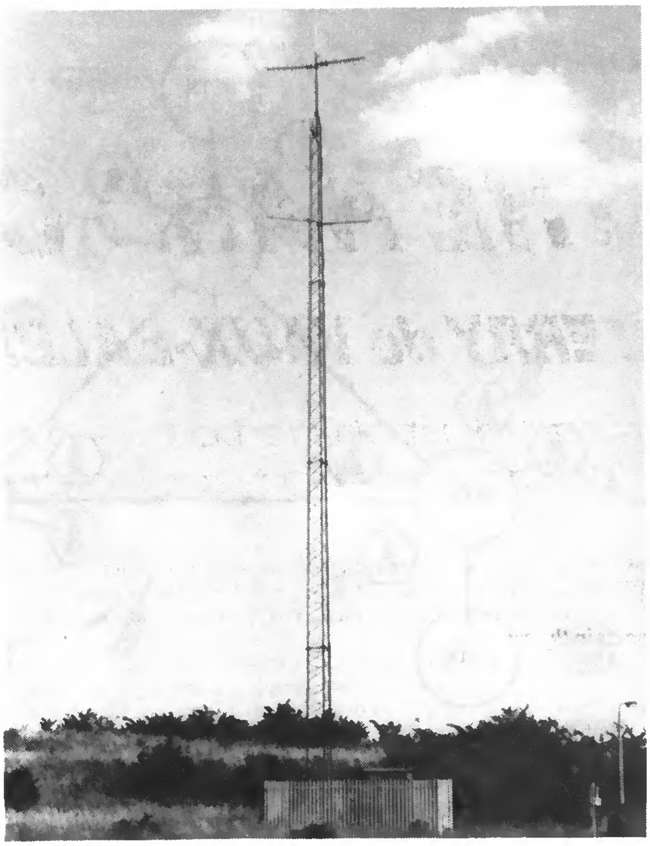


Fig. 3. Allocated frequency spectrum for the full mobile phone network.



Typical antenna mast in a rural area.

BASE STATION

Each base station has a set of aerials (antennas) together with transmitting and receiving equipment. In rural areas, a mast is generally used for the aerials (see photograph) but in towns they will be situated on tall buildings. Since communication is most effective over line-of-sight distances, mounting the aerial high will avoid the effects of intervening objects.

Depending on conditions and the need for selective coverage, some aerials will be omni-directional (covering the full 360 degrees) while others are directional covering perhaps 120 degrees. The transmitting and receiving equipment is sited in a small building or room beneath the aerial mast.

The base station is linked to a mobile telephone exchange (MTX) using conventional copper wire or fibre-optic cable. Although the radio section is *analogue*, this link is a *digital* one and often there will be two separate lines to each base station to guard against the failure of one. The line is provided by British Telecom or Mercury, being the only two fixed link operators.

The MTX is an electronic telephone exchange of the type used in the fixed network. One MTX has control over a number of base stations and all MTXs are interlinked to form a comprehensive grid covering the entire country. It is normal to operate two MTXs in parallel so that one can carry the total load in the event of the other failing.

The MTX sets up and connects calls. It also stores database information such as mobile identification numbers and any special features which the subscriber has paid for. The MTX also routes calls to operators who provide assistance, directory enquiries, etc. A simplified view of the system is shown in Fig. 4.

Each MTX is connected to the PSTN (Public Switched Telephone Network) operated by BT and Mercury. This means that mobiles can communicate with each other or to fixed telephones and vice-versa. One MTX can service many mobiles – for example, each Vodafone exchange can handle 60,000 units and more are added as the demand increases.

Whenever the mobile is switched on, it tunes to the strongest signal provided on a control channel (usually the one from the nearest base station). Before an outgoing call can be made, the MTX must "know" that the mobile is authorised to use it (that is, it is registered, has paid for the service and has not been disconnected for some reason).

This is carried out by two identification numbers. One is the actual telephone mobile number. The other is the ESN (Electronic Serial Number) which, on the analogue system, is a unique number programmed into the circuit.

When a call is made from the mobile, the telephone number to be called is entered on the keypad. The mobile number and ESN

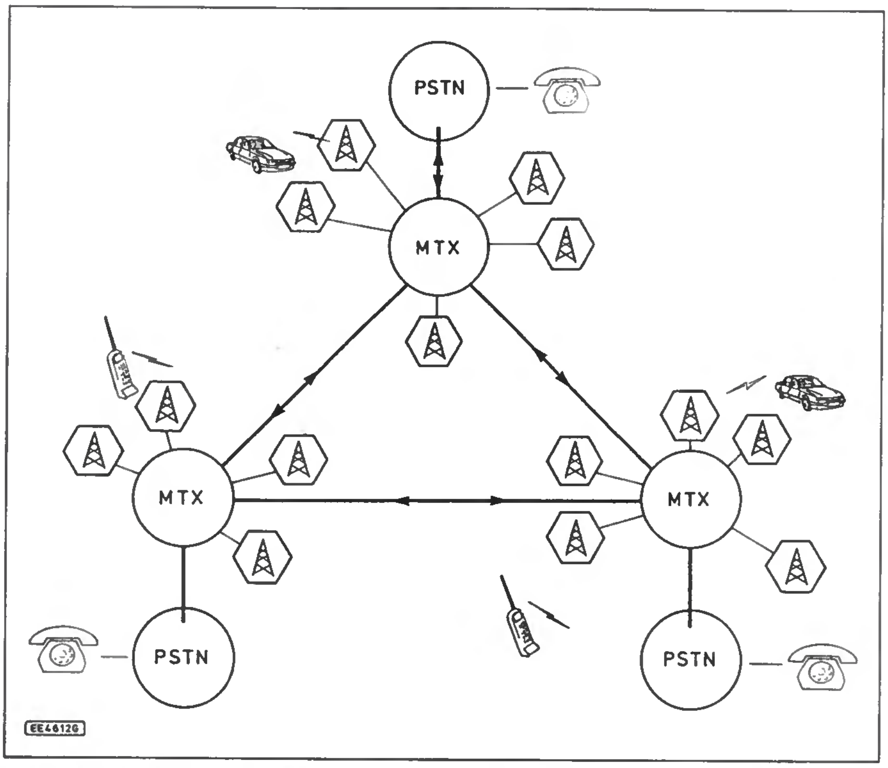


Fig. 4. How mobile telephone exchanges (MTX) are interlinked to form a comprehensive grid.

are automatically sent via the control channel to the MTX. The two numbers are then checked to ensure that they match, this takes about 350ms (a little over one-third of a second). A voice channel is then allocated (i.e. a pair of frequencies) and the call routed either to the PSTN or to another MTX and hence to another mobile.

If a Vodafone user wishes to make a call to a Cellnet subscriber or vice-versa, this was previously done by routing it via the PSTN. However, there is now a direct link between these two operators.

The output power of a mobile is controlled by the network. Each mobile unit has eight power settings and the MTX will select the most appropriate one according to distance and conditions.

THREE CATEGORIES

Whatever the manufacturer, all mobile equipment falls into one of three categories: *Mobile, Transportable* or *Hand Portable*. However, the term *mobile* is often used for any of these. The trend is towards the small hand-held variety and four out of five units now sold are of this type.

These are most versatile and can be carried virtually anywhere (but must not be used on aircraft, in petrol filling stations or in hospitals). Having the phone on the person also reduces the risk of theft. Generally, hand portables may be used hands-free in a car using a special kit.

The power output of a hand portable is generally only about 0·6W *e.r.p.* (effective radiated power) and in marginal signal strength areas the user may need to move around to achieve adequate communication. The prevailing signal strength (i.e.. that received on the control channel) is shown on a display and is consulted before a call is made.

LOCAL GOSSIP

In the course of use, it is possible that the mobile will move from the management of one cell to another. The new cell will then take over and allocate a new channel. It important that the system follows these changes at sufficient speed for the user to be unaware of it happening.

While the mobile is in use, adjacent base stations are checked to determine whether they will give a stronger signal. The moment this is so and, providing there is a free channel available, the instruction is relayed on the voice channel (not a control channel) to use the new one. This is all done in a fraction of a second.

All users should be aware that conversations made on analogue cellular networks are not secure. *Scanners* can tune in to the band of frequencies used for the service and rapidly check the spectrum pulling out the most powerful signals. Some people make a hobby out of this type of eavesdropping. Some may be mischief-makers – politicians and others in high office beware!

One of the disadvantages of owning a cellular phone is its desirability to the petty thief. The handheld variety is easily stolen and quickly disposed of in a pub. Unfortunately, people tend to leave them in full view on the car parcel shelf, shop counter or similar place. There has even been some incidence of phone snatching in the street while it is being used.

As soon as the theft is discovered, the sensible user will inform the service provider (see *consumer advice* later) and the phone will be disconnected from the network. However, there may be some delay and the owner may be responsible for the cost of all calls made until then.

HAD THEIR CHIPS

Because the phone is easily disconnected, it may be thought that it is hardly worth stealing for the sake of a few calls. Unfortunately, it is a relatively simple job to change an analogue phone's ESN (and hence its identity) by a process known as "re-chipping". This is possible because the identification number is carried on an i.c. which can be replaced to provide a new number. The phone can then be sold on and re-connected to the network.

One particularly sneaky activity brought about by re-chipping is the fraudulent use of a customer's line without actually stealing the handset. This is done by using a little detective work to find out the genuine ESN. Another phone is then "cloned" by re-chipping with the same number. Phantom calls then turn up on the legitimate account holder's bill.

The network operators are aware of this and the problem is much less prevalent than it used to be. Computer programs oversee the system. If a phone appears to be making calls in two places at once or being used in widely different places with only a few minutes between, there is clearly a cloning problem and an alert is signalled. Digital phones overcome the problem by having the ESN on a smartcard which is removed from the handset when it is not in use. More will be said about this presently.

DIGITAL COMMUNICATIONS

The foregoing has been concerned with *analogue* cellular networks. These are still the workhorse of mobile communications in the UK and are expected to remain so until at least 1996. However, digital services are catching on fast and are gradually displacing the analogue ones.

Even so, much of what has been said is true for the new digital systems. In fact, there is a great deal of digital technology used in the operation of an analogue network. At the moment, most customers are buying analogue phones and these are perfectly adequate for day-to-day business and social use within the UK. Such users can be assured that the service will be available for many years – at least until 2015.

The defunct Hutchison Telecom *Rabbit* was an early *digital* system. This allowed for outgoing calls within a radius of some 100 metres of a base station. A network of such base stations were set up at garages, underground stations, banks and similar key locations where the Rabbit logo is still to be seen. It seemed like a good idea at the time but without blanket coverage, and with only outgoing calls possible, there proved to be insufficient appeal.

Of the present digital services, there are two families of equipment – GSM (mentioned earlier) which operates on frequencies adjoining those used for the analogue networks and PCN (personal communications system) which operates on a higher frequency range, around 1800MHz. Digital systems provide better sound quality, but this is not in itself very important. Analogue sound quality is as good as it needs to be. GSM was intended to provide uniformity.

The analogue systems being used in various countries operate to different standards and this can be a problem. Travelling businessmen needed to hire handsets and be connected to each national network on passing from one country to another. GSM removes this need and provides a standardised service. With GSM, there can be one phone number and one bill wherever calls are made. It will only be necessary to have the correct service agreement between the participating national networks.

An advantage of a digital system is that encryption is simple and this can make the conversation totally secure. By using a *Subscriber Identity Module* (SIM) card, security is greatly improved. This card carries the ESN and other customer details. When the phone is used, the SIM is inserted and without this the phone is useless. By carrying the card on the person, theft of the phone is pointless.

By the end of 1993, all forms of cellular phones were available in GSM format – hand portables, car phones and transportables. GSM has a claimed UK coverage of 90 per cent. It will eventually span Europe and, ultimately, the whole world – at least, that is the dream. GSM followed the 1983 *Memorandum of Understanding* and is based on a European standard agreed between 22 operators in 19 countries.

The first GSM service in the UK was provided – albeit in a restricted service – by Vodafone in December 1991, with Mercury adding its own GSM offering *Eurodigital* in Autumn 1993. Cellnet's GSM came on stream in July 1994.

Other countries with GSM networks operating are Germany, Italy, Greece, Denmark, Sweden, Switzerland, Austria, Belgium and Norway. Luxembourg, France, Ireland, Portugal and Spain also became operational during 1994.

However, users report that many of these services are very fragmented. This is because, while analogue systems are well-established and have grown to provide excellent coverage, digital ones begin by covering major urban areas and follow with the less popular ones.

JUICY ORANGE

Personal Communication Networks came about from the Government's invitation in 1989 to apply for PCN operators' licences. PCN phones operate in conjunction with a SIM card which stores more personal information than with GSM – details of special services requested, etc.

PCN networks offer many optional services and potential customers will need to look carefully at those available to find the product which suits his or her needs best. They are far too numerous to be discussed in detail here.

Many of the services are free or provided at a reduced price compared with the analogue systems. Choosing a mix of such services can customise the phone to the individual's requirements. Unfortunately, detailed information about PCN services is changing so rapidly that several suppliers will probably need to be asked to be sure of obtaining correct and unbiased information.

The first PCN service to come on stream in the UK was Mercury *One-2-One* in Autumn 1993. With handsets manufactured by Siemens, Motorola and NEC the network originally extended to the boundaries of the M25 and was targeted at business users in London. Mercury is extending the service – the intention is to cover the South East and eventually become nationwide by the late 90s. One-2-One had approximately 100,000 subscribers in late 1993 and coverage is about 24 per cent of the UK population at the time of writing.

The Nokia Orange phone which works exclusively with the Orange service from Hutchison Telecom.

Recently, Hutchison Telecom (UK) – owned by Hong Kong based Hutchison Whampoa (65 per cent), British Aerospace (30 per cent) and Barclays (5 per cent) – have announced their *Orange* PCN network with phones manufactured by Nokia (*Orange Phone*) and Motorola (*MR1*) now available in High Street stores such as Dixons, Currys, Rumbelows and Hutchison outlets. Some readers may have been mystified by the rather cryptic *Orange* advertising in the media. At the time of writing, the network covers over 65 per cent of the UK population (about 35 million) and was expected to be ahead of its target of 70 per cent (40 million) by the end of 1994 and 90 per cent (50 million) by mid-1995. The Nokia *Orange Phone* offers a two-line service whereby the same phone can have two numbers and two separate accounts – perhaps to separate private and business use. *Orange* charging is made by the second rather than the minute or half-minute as is the tradition with the analogue networks.

PCN systems are already well advanced in the UK but less well so in other countries. For reasonable European coverage GSM is therefore the preferred choice. At the time of writing, PCN networks were also operating in Germany and Thailand. Italy and France are scheduled to follow in the near future.

THE CELLULAR ROAD

Britain is fortunate in having had a comprehensive fixed telephone network for many years. Mobile systems are therefore seen as complementing the existing one.

This is not the case in certain other countries. These still use antiquated analogue equipment (sometimes a hand-me-down from a country going digital) and there may be no service at all outside the main urban areas. For such places, the direct jump to cellular can improve the country's infrastructure and provide the main service at minimum cost.

CONSUMER ADVICE

The unparalleled growth in mobile communications has come about by making a desirable product affordable to the masses. Even so, the best piece of advice is to ask yourself – do you *really* need a mobile phone? Is it just to impress your friends? Is it wanted merely as a status symbol?

Women who regularly travel at night will certainly find peace of mind in owning one. If you do decide to buy a cellular phone, look around and compare true costs. Perhaps you can wait for another year or so to allow the digital networks to increase their coverage.

Remember, you are buying a complete package (connection to a particular system, cost of monthly line rental, tariff, etc.) – not simply the purchase of a piece of hardware. There may be incentives such as free connection, free off-peak calls for a certain period, cashback schemes, etc. and these will change from time to time.

For general social and business use within the UK, you are likely to be advised to use the established analogue system offered by Cellnet or Vodafone. Cellnet is the UK's largest analogue network operator with over 1000 cell sites and about 750,000 subscribers making three million calls each day. They also have exclusive coverage of the Isle of Man and Channel Islands which may be important to some users.

There may be local weak spots on one system or the other and advice should be taken on this point. However, intense competition has led to there being little to choose between the two operators.

There is a bewildering range of tariffs and the user will need to look carefully for the one which suits his or her needs best. Some offer a lower fixed monthly charge but a higher call charge (low user rate). Others offer a higher charge and a lower rate per call (business rate).

There will be variations in the cost of peak and off-peak calls. Certain services may be requested such as three-way conversations, a facility for recording incoming messages while the user's phone is switched off, etc. There may be other options such as call diversion and international facilities.

POWER INSURANCE

Hand portables often have various battery options which allow different periods of use before the need for recharging. For some users this may be an important consideration. A typical nickel-cadmium battery pack will provide between 10 and 22 hours of standby use. While actually talking, the time is greatly reduced – to about 60 and 120 minutes respectively.

Usually a larger capacity nickel cadmium pack is available and a nickel hydride option, if available, will extend the time still further. A fast mains or car cigar lighter charger can restore the battery in about 30 minutes. The standard "desktop" mains unit supplied with the phone may take around eight to 10 hours to charge the standard battery.

Remember to include insurance in your costs. That "£49" phone may be really worth £350. Profits will be made from the services you use and these will soon pay for the discounted hardware. However, the true price will have to be paid to replace the phone if it is lost or stolen. Your household insurance company may not be keen to include a mobile phone on your existing policy but it is worth asking.

It must be remembered that there is no local area service on the popular cellular systems. Calls to the BT or Mercury network are charged at the same rate regardless of distance and only depending on whether the time is peak or off-peak and the tariff selected. Thus, the full STD code must be entered each time even if the called party is just around the corner. Generally, calls are not charged for unless they are answered but, of course, "answering" includes any recorded message.

Users need to keep an eye on their itemised bills, however, since there have been reported errors. These are generally overseas calls made via old-technology fixed telephone exchanges at the distant end. These have been known to signal back a fee when the call was unsuccessful. Note that BT subscribers make calls to the mobile network at the "M" rate.

POWER TO THE PEOPLE

The dealer will use a *Licensed Service Provider* (or the shop may be a member of a chain owned by a service provider) who will access the network. The service provider will deal with all the day-to-day customer services such as billing and general enquiries. A contract will be signed to provide service for, say, one year at a certain monthly rate.

The Service Provider will enter the Mobile Number and ESN on to a terminal and data regarding any special services which the subscriber needs such as those mentioned previously. The information will be taken up by the network operator and programmed into the MTX. Note that not all special services are available on all tariffs. For example, international calls may be barred. With luck, the mobile will be on-air before leaving the shop.

Peoples Phone is one of the UK's most well-known independent service providers supplying 10 per cent of new cellular customers with their airtime. Peoples Phone have more than 110,000 customers and a total turnover in excess of 100 million. Over the last six months alone, they have spent more than £5M on improvements and new equipment. With 60 High Street retail outlets throughout the UK, Peoples Phone has the second largest nationwide chain after the BT shops.

CRYSTAL BALL

It is fanciful to imagine that every spot on earth could be covered by a cellular network. What about travellers in the remote desert, the arctic, the Australian bush or the middle of the ocean? A satellite service could be the answer. The proposed system (the *Iridium* project being developed by Motorola in Phoenix, Arizona) involves placing rings of satellites around earth.

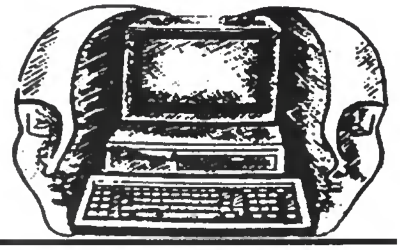
The signal from the phone would be passed to the nearest satellite and from there, it would hop from one to another until it lay above its destination. It would then pass to a ground station and be distributed via the national fixed or cellular network. Dual-use phones could switch automatically between cellular to satellite modes as required. Large sums of money have already been spent and pledged for development work.

Many of us now have several different telephone handsets. One is the familiar one for the fixed network. The second is a cordless telephone which is handy when gardening or working in the garage. This operates over a range of 100 metres or so from a base station situated in the house. There may also be a cellular handset in its various analogue and digital forms.

In the future, these may be integrated so that one handset provides all functions. It may also be that mobile costs fall in line with those on the fixed network with a single bill provided for all services.

Do you still want that mobile phone? □

INTERFACE



Robert Penfold

THE TWO previous *Interface* articles covered the use of a PC printer port as a general purpose digital input/output port. This month we progress to the use of the printer port as an 8-bit analogue input/output port.

As the printer port has eight output lines as standard, and can provide eight input lines with the addition of the circuit described in the February issue, it is possible to have both analogue-to-digital and digital-to-analogue converters working simultaneously on this port. Of course, many applications only require one or other of these converters, but where both are needed the printer port handles the task remarkably well.

Analogue Output

Digital to analogue conversion is a more simple prospect than a conversion in the opposite direction. Interfacing this type of converter to a computer is usually very straightforward as there is little or no "handshaking" to contend with.

In this case the printer port provides eight latching outputs, and no handshaking at all is required. The values for the converter are simply written to the data lines of the printer port at address &H278 (LPT2) or &H378 (LPT1), and the converter produces the appropriate output voltage.

The only point that has to be kept in mind is that the converter will take a short time to adjust to each new value. In most cases the adjustment time is quite short, and is typically only a microsecond or two. Of course, any amplifiers, filters, or other stages that process the output of the converter are likely to extend this "settling" time.

Where eight latching outputs are available the Ferranti ZN426E probably represents the simplest means of providing an analogue output. Fig. 1 shows the circuit diagram for a PC analogue output port based on this chip.

The full scale output voltage is equal to the reference voltage fed to pin 5. This terminal can be fed from an external reference voltage of up to 3V, but in most cases the built-in 2·55V reference is perfectly adequate. In fact, the built-in reference voltage generator is a high quality type that is not easily bettered. R1 is the discrete load resistor for the voltage source, and C1 is its decoupling capacitor.

Output Voltage

The output voltage from IC1 (in volts) is equal to the value written to the printer port multiplied by 0·01. For example, a value of 147 would provide an output potential of 1·47V (147 × 0·01 = 1·47).

In most practical applications this output voltage range will have to be modified using an amplifier or an attenuator. In virtually all cases it will be a small amount of amplification that is required. This is the purpose of IC2, which also provides output buffering.

The non-inverting mode amplifier IC2 can have its closed loop voltage gain varied from unity to about 11 times by means of preset VR2. Maximum voltage gain is obtained with VR2's wiper at the bottom end of the track. Theoretically, maximum output voltages of between 2·55V and 28V can be achieved.

However, the maximum output voltage of IC2 is about 2V less than its supply potential, or about 3V if it is powered from a 5V supply. Therefore, maximum output voltages of more than 3V require IC2 to be powered from a higher supply potential of up to about 30V. This means using a separate supply for IC2, since the converter circuit must be powered from a 5V supply.

Preset potentiometer VR1 is the offset null control for IC1. This is only really needed if IC2 is used with VR2 set towards maximum gain, and a high degree of precision is required. Otherwise, it can simply be omitted.

If preset VR1 is included, the best way to find the correct setting is to first write a low value to the port, and adjust VR1 for the correct output voltage. Then write a high value to the port and adjust VR2 for the appropriate output voltage. Repeat this process a few times until no further adjustment is needed.

If VR1 is omitted, write a value of 255 to the port and then adjust VR2 for the required maximum output voltage. Reasonable accuracy should then be obtained over the full range of output voltages. The current consumption of the analogue input circuit is about 8mA, incidentally.

Writing to the port is very easy, and using GW BASIC it is just a matter of writing the values to the appropriate address using the OUT command. For example, "OUT &H378,123" would write a value of 123 to a digital-to-analogue converter connected to printer port LPT1.

Analogue Input

The circuit diagram for the analogue-to-digital converter is shown in Fig. 2. This is based on the Ferranti ZN448E, or the virtually identical ZN447E and ZN449E. The only difference between these three devices is their guaranteed accuracy.

The ZN448E is the most widely available version, and its accuracy of 0·5 l.s.b. (least significant bit) is good enough for virtually all practical applications. The ZN447E has a higher accuracy figure of 0·25 l.s.b., but tends to be quite expensive and is over-specified for most purposes. Although the least accurate of the three, the budget ZN449E is adequate for many applications, and it is relatively cheap if you can locate a source of supply.

These chips are successive approximation converters having built-in clock oscillators. The only discrete component required for the clock oscillator is a timing capacitor (C2). The specified value sets the clock frequency at a little under the maximum usable clock frequency of 1MHz.

In practice these chips invariably seem to perform properly with the clock oscillator operating well in excess of 1MHz. However, since only nine clock cycles are needed in order to complete a conversion, some 100,000 conversions per second are possible with the clock frequency at about 0·9MHz. Few real-world applications require a sampling rate as high as this.

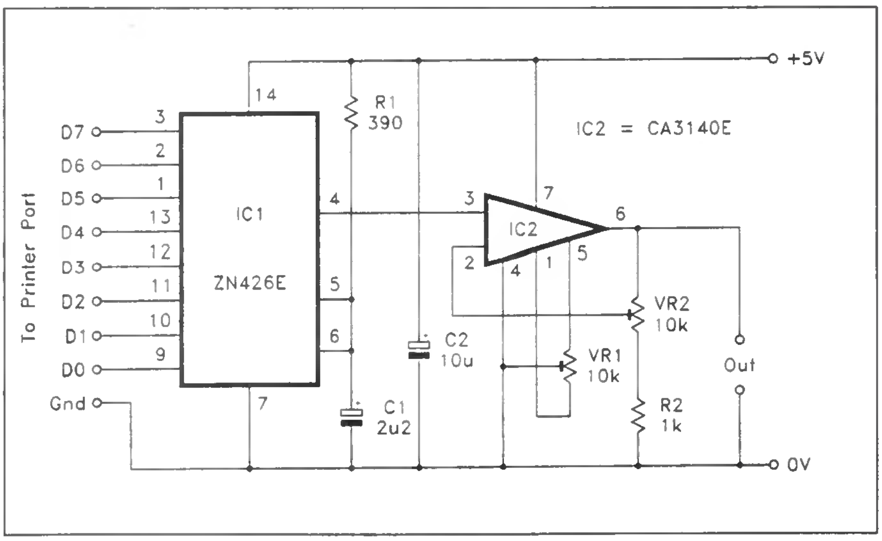


Fig. 1. The PC printer port D/A converter circuit diagram.

Voltage Generator

The full scale voltage is set by a reference potential, and like the ZN426E, the ZN448E has an integral 2·55V reference generator. This has R1 and C1 as its load resistor and decoupling capacitor. R2 is the "tail" resistor in the comparator stage at the input of the converter, and it must be driven from a negative supply rail.

If a suitable supply rail is not available it is possible to generate one using a couple of trigger/inverters in the circuit shown in Fig. 3. The PC input port (Fig. 2 *EPE* March 1995) uses one inverter from a 74LS14 package, and the negative supply generator can conveniently be based on two of the five unused sections of this device. Note that this circuit produces a negative output potential of just 3V, which requires the value of resistor R2 in the converter circuit to be reduced to a value of 47 kilohms.

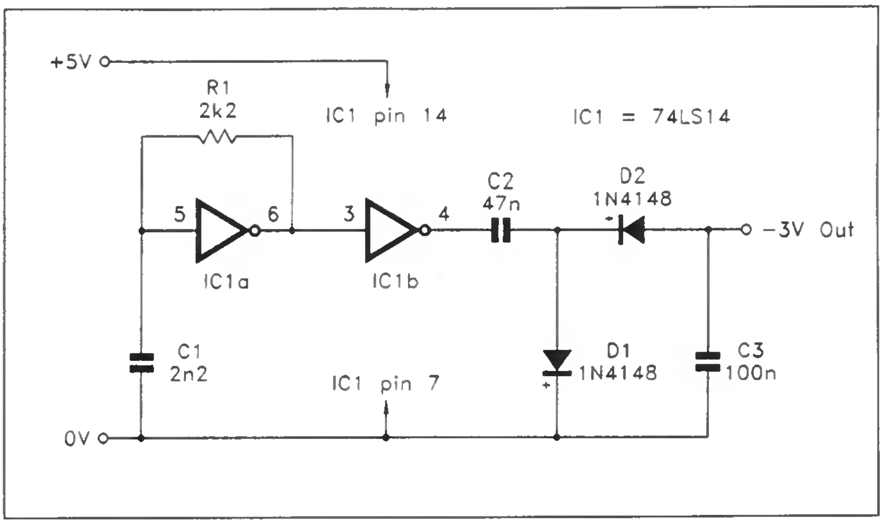


Fig. 3 The simple negative supply generator circuit diagram.

Input Voltage

An input voltage in the range 0V to 2·55V can be applied direct to the analogue input at pin 6 of IC1 (Fig. 2), but this is not the recommended way of doing things. There is a small input offset voltage that will slightly reduce accuracy at low input voltages unless it is trimmed out.

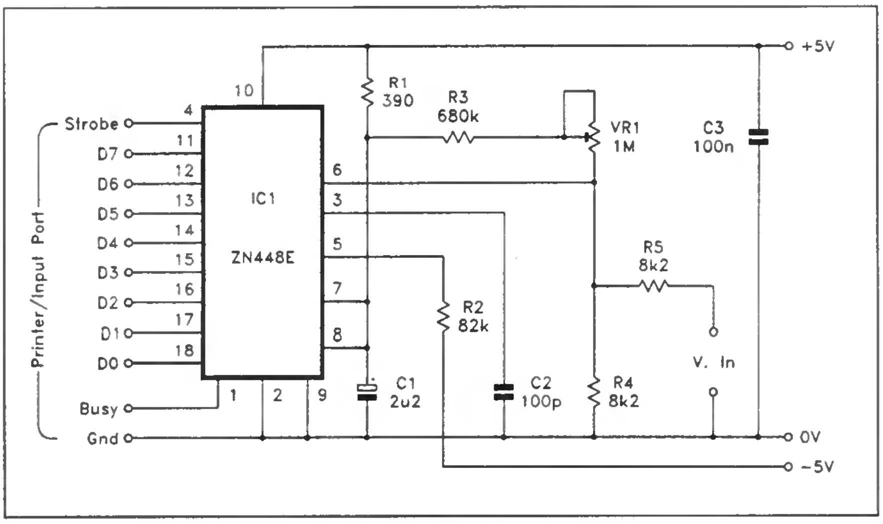


Fig. 2. Circuit diagram for the printer port A/D convertor.

This offset can be nulled by applying a minute positive bias to the input signal. This is achieved by applying the input voltage to IC1 via a potential divider, and then using a resistance from the output of the reference source to the input of IC1 to provide the offset bias.

In this case resistors R4 and R5 act as a potential divider which attenuates the input signal by 50 per cent. This gives a full scale value of 5·1V. Resistor R3 and preset VR1 provide the positive offset bias, and VR1 is adjusted for optimum accuracy at low input voltages.

Obviously other full scale voltages can be obtained by using suitable values for R4 and R5, but the parallel resistance of these two resistors must be about 4 kilohm or it may not be possible to obtain a suitable offset voltage using VR1. In many practical applications R4 or R5 will have to be a preset resistor so that the full scale input voltage can be trimmed to precisely the required figure.

The ZN448E has tristate outputs, but this facility is not required here. Pin 2 is connected to the 0V rail so that the data outputs of IC1 are permanently enabled. These lines feed into the eight input lines of the add-on circuit featured in the February 1995 *Interface* article.

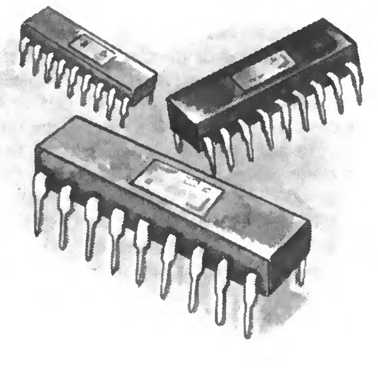
In order to start a conversion it is necessary to pulse pin 4 of IC1 low. The conversion starts when this terminal returns to the high state. The printer port's "strobe" line is the obvious choice to drive the "start conversion" input.

Pin 1 of IC4 goes high when the conversion has been completed, and this line can be monitored using the printer port's "busy" input. A software loop is then used to provide a hold-off until the conversion has been completed.

As the length of time taken for each conversion is constant at about 10 microseconds, it is possible to simply use a timing loop to prevent the port from being read prematurely. This is my preferred approach, as it leaves the "busy" handshake line free for other purposes. Of course, with a relatively slow language such as an interpreted BASIC there is no need to worry about a hold-off. Each conversion will be completed long before the program moves on to the routine that reads the port.

The following GW BASIC routine will read the analogue input port and write the returned value on the screen. It is basically just the same routine that is used to read the 8-bit input port, but line 5 has been added to provide a start conversion pulse on the "strobe" line. Bear in mind that the "strobe" line is inverted, so a value of 1 (not 0) is needed to set it low.

```
5 OUT &H37A,1
10 OUT &H37A,0
20 X = INP(&H379) AND 120
30 X = X/8
40 OUT &H37A,4
50 Y = INP(&H379) AND 120
60 Y = Y * 2
70 Z = X + Y
80 PRINT Z
```

THE NAME OF THE GAME COUNTERSPIN

ROY BEBBINGTON PART 2

THE Name of the Game is a series of electronics projects based on party games or TV quiz games. Featuring something old, something new, there are electronic versions of popular, well-established TV games such as *Countdown* and *Catchword* with alphanumeric displays, new games employing electronic word-making, and games of skill.

Accessories, used in various games, such as an interval timer, an electronic dice, a precedence switch, a heads/tails unit, are the subjects of later constructional articles.

COUNTERSPIN is an electronic selector for the numbers game of the popular TV quiz *Countdown*. In addition, it can be used for other games that need random number selection, or as a 0-999 counter. It features decade counters driving up to three 7-segment l.e.d. displays. By switch selection the displays are capable of randomly displaying:

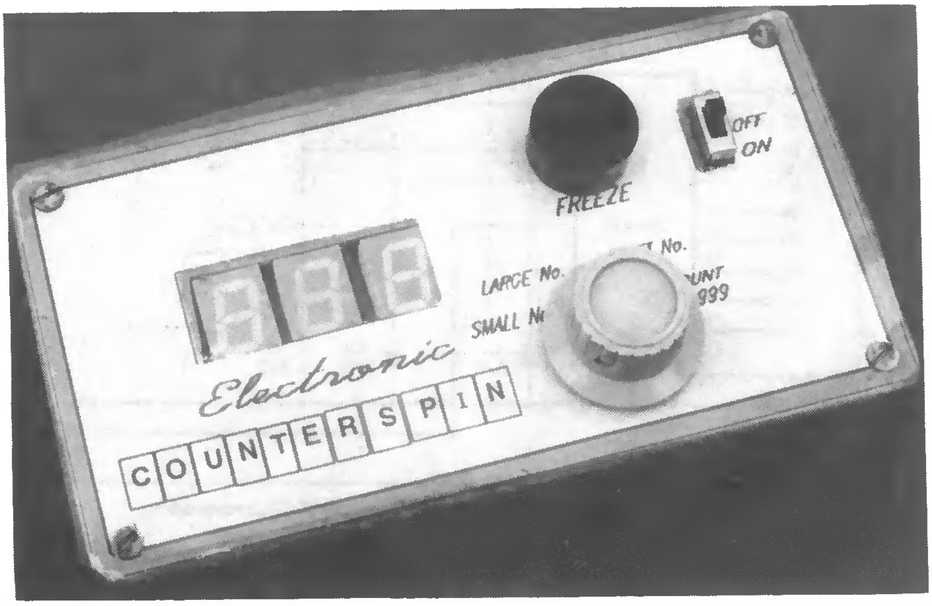
- small number up to nine
- selection of four large numbers (25, 50, 75, 100)
- target number up to 999
- count number from 0 to 999 for timing purposes.

COUNTDOWN PRINCIPLE

In the TV game of *Countdown*, apart from the target number, all the numbers are selected by cards. However, *Counterspin*, as presented here, selects all numbers automatically using electronic counters. For those unfamiliar with the TV game, here are the general rules:

A contestant generally has a random selection of one large number (25, 50, 75, or 100) and five small numbers (one to nine). A target number is then selected by a counter. Any or all of the selected large and small numbers can then be added, subtracted, multiplied or divided in an attempt to obtain the target number, or as close to it as possible.

Contestants write down the large and small numbers as they appear, and then make their calculation. After a given time limit (say 30 seconds) a quizmaster ascertains whether they have achieved the target number, and the contestant with the nearest result shows how it was obtained. Scoring could be five points on target, reducing by the difference number for the player nearest to the target, e.g. four away from the target number could earn the winner one point.



FRONT PANEL DISPLAY

The front panel, as shown in the photograph, houses the three 7-segment l.e.d. displays (X1, X2, X3 in Fig. 1), which serve as dual-purpose indicators for the two decade counters. The rotary *Select* switch, (S1), performs various functions. It *selects* the four number modes (Small, Large, Target and Count), and also switches the display constantly on in the *Count* position.

The right-hand on/off switch (S3) controls the +9V battery supply. In the *on* position the supply is connected to the clock generator and, depending on the position of the *Select* switch (S1), either the large number counter or the random number counter is also powered. To conserve battery power, although the clock pulses are activating the counters, the displays are inhibited (except in the count position) until a number is selected by the *Freeze* pushbutton switch (S2).

MODE SELECT

Switch S1 provides four switchable modes, as follows:

Small Number (S): counter IC5 in operation giving numbers between zero and nine when switch S2 is pressed. A zero can be ignored and another selection made if agreed.

Large Number (L): counter IC2 in operation giving numbers 25, 50, 75 or 100 when switch S2 is pressed.

Target Number (T): counters IC3 to IC5 in operation giving numbers from zero to 999 when switch S2 is pressed.

Count 0-999 (C): counters IC3 to IC5 in operation and a count number of up to 999 is displayed. The count can be started at zero by switching S3 off and then on again, and it can be stopped momentarily by pressing the *Freeze* pushbutton switch S2. When S2 is released, the count will continue from where it was interrupted, unless reset by the on/off switch.

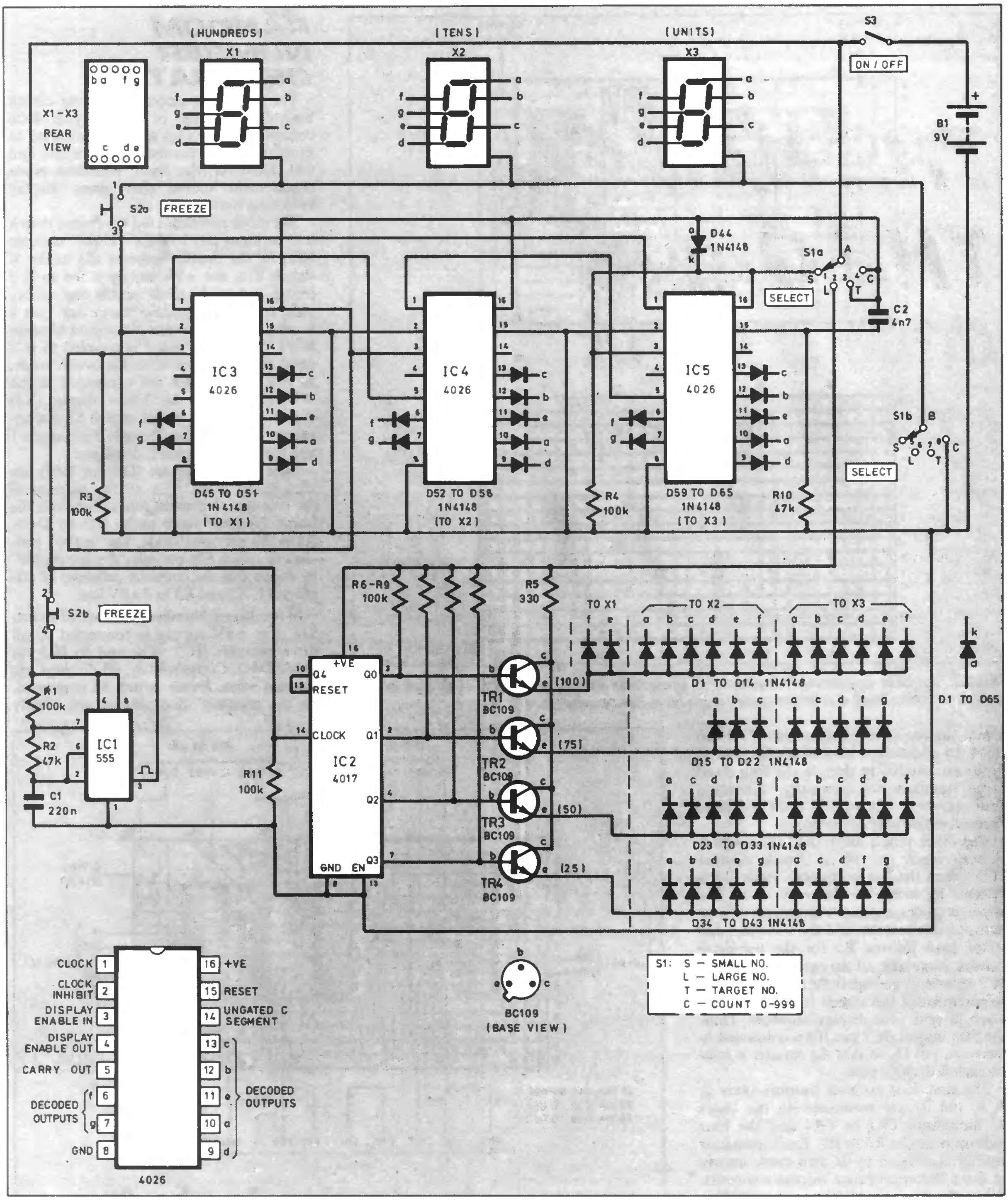


Fig. 1. Circuit diagram for the Counterspin games unit.

COUNTERSPIN CIRCUIT

The circuit diagram for the *Counterspin* unit is shown in Fig.1. Basically, it consists of three stages, namely, a clock generator (IC1) using a 555 timer to supply timing pulses for two counter arrays: a type 4017 counter (IC2) for the four large numbers, and three 4026 type counter-decoders (IC3 to IC5) for the small numbers, the target number and the zero to 999 count facility.

The clock pulses are supplied by the 555 timer, IC1, which is connected as an astable multivibrator. When the supply is switched on by S3, pulses are present on IC1 output pin 3 at a frequency dependent on the values of resistors R1, R2 and capacitor C2.

For the values shown, the rate is about thirty pulses per second (30Hz), but this can be varied, if necessary, to suit individual requirements. For instance, for the count zero to 999 facility, resistor R1 could be replaced by a 500 kilohm panel mounting potentiometer, and capacitor C1 increased in value to about 2µ. The clock rate potentiometer could then be calibrated to give ten counts per second. The counter would then represent a total count-time of $999 \times 0{\cdot}1 = 99$ seconds.

The output pulses available from IC1 pin 3 are fed to the break contacts of the *Freeze* push-button switch S2b, the output side of which is connected to the clock inputs of counters IC2 and IC5.

LARGE NUMBER COUNTER

Unlike the outputs of the 4026 counter-decoder chips, the outputs of the 4017 counter chip used to select one of the four large numbers must not sink or source a current exceeding 10mA and so cannot directly drive the 7-segment l.e.d. displays;

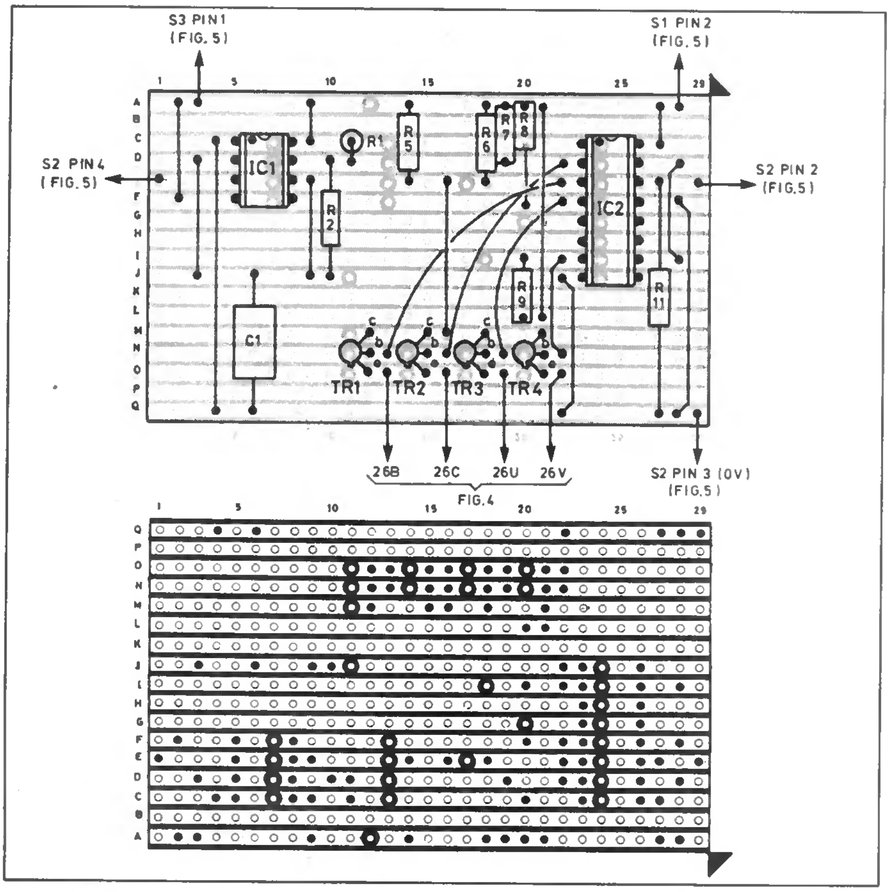


Fig. 2. Topside component layout and underside stripboard track cuts and solder joints for the Clock Generator and Large Number counter board.

RANDOM NUMBER GENERATOR

The random number generating circuit basically consists of three type 4026 counter-decoder i.c.s serially connected to generate display numbers between zero and 999. However, the Small Numbers mode requirement means that some display switching is necessary.

The clock pulses are fed via *Freeze* switch S2b to input pin 1 of the "Units" counter IC5. In the Small Numbers (S) mode of switch S1a, the +9V supply is fed to IC5 pins 3 and 16, its clock enable and supply pins, respectively. IC5's "carry out" pin 5 is coupled to IC4 input pin 1 (and likewise IC4's "carry out" pin 5 is coupled to IC3 input pin 1). However, in this switch mode, as IC3 and IC4 are not connected to the +9V supply, only the "Units" display (X3) is active. Pressing *Freeze* switch S2 disconnects the clock pulses from IC3 input pin 1 and the active number is displayed.

Note that the diodes (D45 to D65) are required in series with all the outputs of the counters to prevent interaction with the Large Number diode paths (D1 to D43). As in the previous mode, the "make" contacts of switch S2a provide "display enable" by connecting the common cathodes of displays X1, X2 and X3 to the 0V line.

In the Target Number (T) mode of switch S1a, the +9V supply is connected to all three counters (IC3, IC4, and to IC5 via diode D44). Consequently, all displays are enabled when *Freeze* switch S2 is pressed. As the counters' clock inputs are serially

hence the use of driver transistors TR1 to TR4. In addition, a host of diodes (D1 to D43) are needed to decode the four fixed large numbers so, ironically, providing four numbers out of the 1000 available forms a major part of the circuit.

The clock pulses are routed from switch S2b to input pin 14 of decade counter IC2. When the Large Number mode (L) is selected by switch S1 the +9V on its S1a wiper provides a positive supply to IC2 to activate this counter and the common collector load resistor R5 for the transistor drivers. Normally, all ten outputs of counter IC2 repeatedly go high in turn. However, the requirement in this circuit is for the generation of only four display numbers. Thus, the fifth output (IC2 pin 10) is connected to the reset, pin 15, so that the counter is reset on each fifth clock pulse.

The first four counter outputs (pins 2, 3, 4 and 7) are connected to the bases of transistors TR1 to TR4 and the four pull-up resistors R6 to R9. Each transistor emitter is coupled to its own diode matrix to drive the appropriate display segments. When the *Freeze* push-button switch S2 is operated, its S2b contacts open and pulses are disconnected from the input to counter IC2. Consequently, the particular IC2 output activated at that moment remains high.

Simultaneously, the "make" contacts of switch S2a close and the common cathodes of the displays are now connected to the 0V line. The relevant transistor is switched on by the counter's active output and current is supplied via the diodes in its emitter circuit to illuminate the designated segments of the displays. For example, if IC2 output pin 2 (designated "75") is frozen, TR2 is turned on and current flows through diodes D15 to D17 causing display X2 to show "7", and through diodes D18 to D22 causing display X3 to show "5".

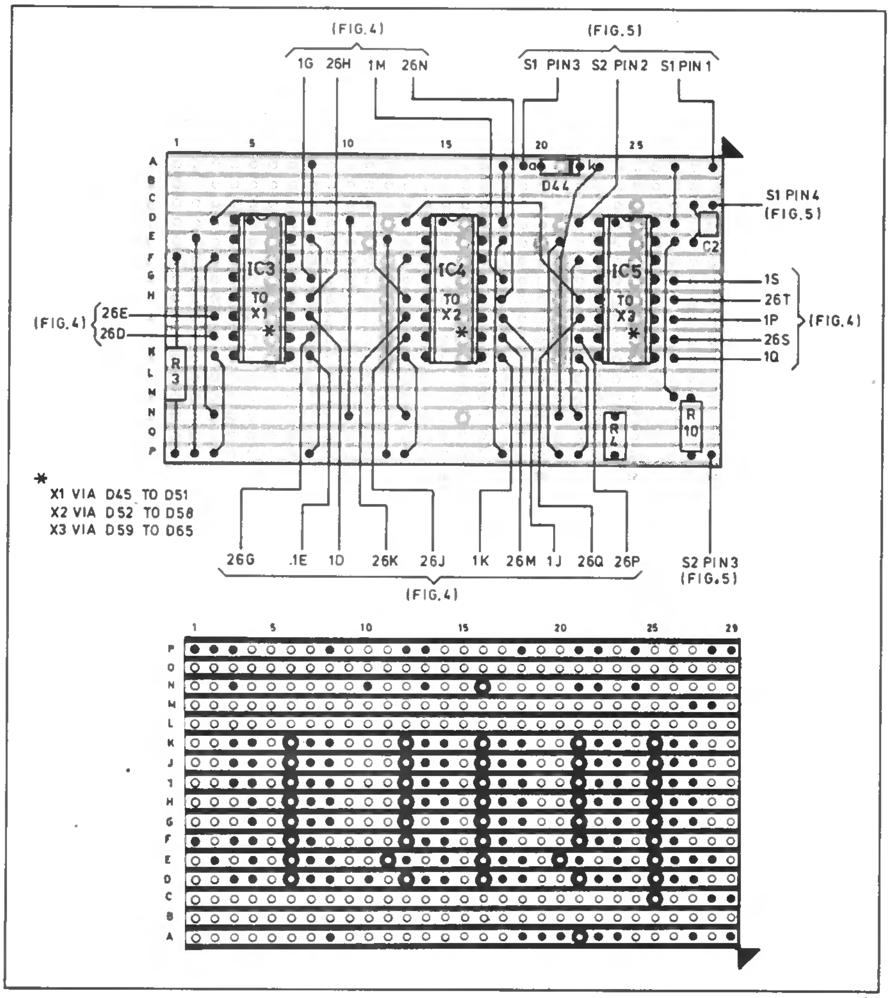


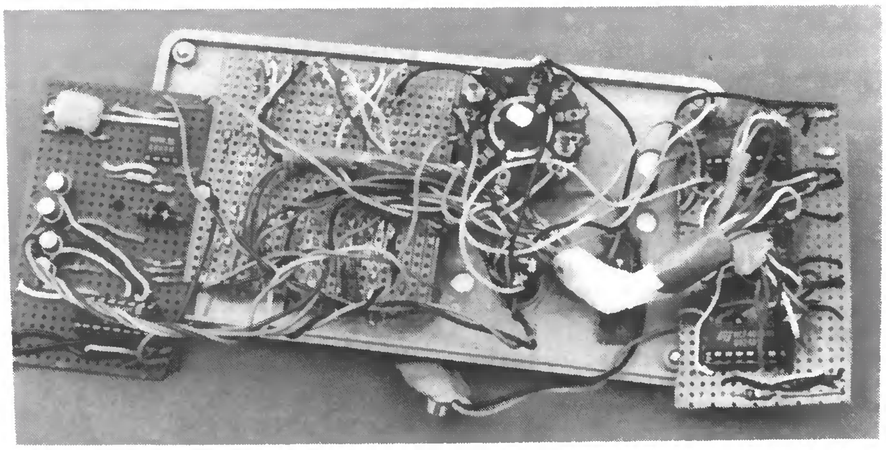
Fig. 3. Topside component layout and underside stripboard track cuts and solder joints for the Random Number Generator board.

connected, the count runs from zero to 999.

Strictly speaking, target numbers in the TV game *Countdown* are three figure numbers, but there seems no reason why numbers below 100 cannot be accepted. If a number is too low to make a reasonable calculation then the *Freeze* switch S2 button can be pressed again.

The count 0-999 (C) mode of switch S1 is similar to that of the Target mode in that all three counters (IC3 to IC5) are operative. This mode is not part of the TV *Countdown* game, but since the count to 999 facility is available, it can be used as a timing facility.

In the Count mode (C), switch S1b connects the common cathodes of displays X1, X2 and X3 to the 0V line, overriding the action of switch S2a. In this way, the time interval can be displayed and monitored. This facility is useful for checking the elapsed time and also allowing the count to be frozen from time to time; e.g. for "stopping the clock" when questions are being asked.



Photograph showing the interconnecting cabling between the three stripboard assemblies and the switches.

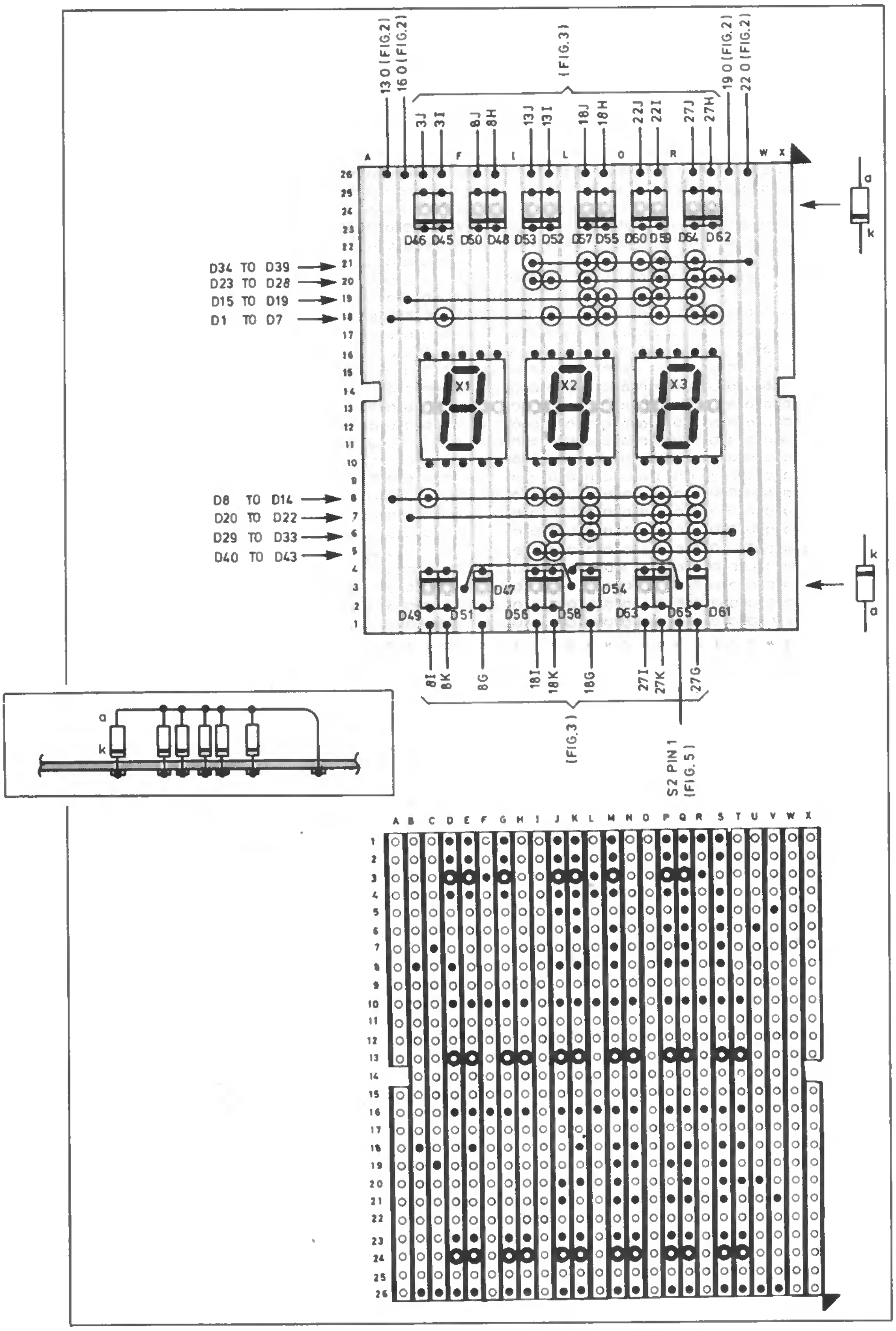


Fig. 4. Topside component layout and underside stripboard track cuts and solder joints for the Display/Matrix board. The insert shows an example of how the vertically mounted diodes should be connected.

At switch-on, a small value capacitor, C2, connected to the +9V rail, provides a brief positive pulse to IC5's reset pin 15, to reset the count to zero. If necessary, *Freeze* switch S2 can be pushed in at switch-on by S3 to hold the zero ("000") until players are ready to start the count.

COMPONENTS

Resistors — See SHOP TALK Page

R1, R3, R4 R6 to R9, R11	100k (8 off)
R2, R10	47k (2 off)
R5	330

All 0·25W 5% carbon film

Capacitors

C1	220n polyester (see text)
C2	4n7 ceramic

Semiconductors

D1 to D65	1N4148 signal diode (65 off)
TR1 to TR4	BC109 *npn* transistor (4 off)
IC1	555 timer
IC2	4017 decade counter
IC3 to IC5	4026 counter-decoder (3 off)
X1 to X3	0·56in 7-segment l.e.d. display, common cathode (3 off)

Miscellaneous

S1	3-pole 4-way rotary switch
S2	2-pole make and break pushbutton switch
S3	single-pole on/off slider switch

Case, ABS plastic size 146mm x 76mm x 46 mm (internal measurements); stripboard 0.1in matrix, size 17 strips x 29 holes (Fig.2); stripboard 0.1in matrix, size 16 strips x 29 holes (Fig.3); stripboard 0.1in matrix, size 24 strips x 26 holes (Fig.4); 8-pin d.i.l. socket, 16-pin d.i.l. socket (4 off); knob; AA-type cell (6 off) and holder with clip; 8BA nuts, bolts and washers (2 off); stranded connecting wire; solder, etc.

Approx cost guidance only **£19** *excl. batteries*

CONSTRUCTION

Component assembly of *Counterspin* is made on three small pieces of stripboard. All components are mounted on these except for the three front panel switches S1, S2 and S3.

Stripboard assembly details for the Clock Generator and Large Number counter board are shown in Fig.2. The stripboard has a 0.1 inch matrix of 17 strips x 29 holes and the length is cut to slot into the grooves in the walls of the suggested plastic ABS box.

The stripboard copper underside layout shows all the solder points and the cuts to be made in the strips. Look out for any whiskers of copper that may be short-circuiting adjacent strips following track cutting. It is advisable to check for this with an ohmmeter or continuity tester at various stages during construction.

Sockets are recommended for all the i.c.s. Static charges can ruin CMOS chips, so it is a good policy to keep them in their original packing until ready for use, and fit them last.

Assembly details for the Random Number Generator board are shown in Fig.3. Again, the stripboard length is cut to slot into the grooves of the box and has a matrix of 16 strips x 29 holes. All components and fixed links are shown and the underside drawing indicates the soldered connections and cuts in the copper strips.

Assembly details for the Display/Matrix board are shown in Fig.4. The stripboard size is 24 strips by 26 holes. The most compact layout for the "large number" diodes (D1 to D43) is to mount them vertically as shown in the inset figure example. If the leads are kept short, the diodes sit comfortably below the level of the displays and the front panel.

The Display/Matrix board is secured behind the front panel by two 8BA nuts, bolts and washers. Suitable viewing cut-outs are, of course, needed in the front panel. Holes also need to be drilled in the front panel to mount the three switches, S1 to S3.

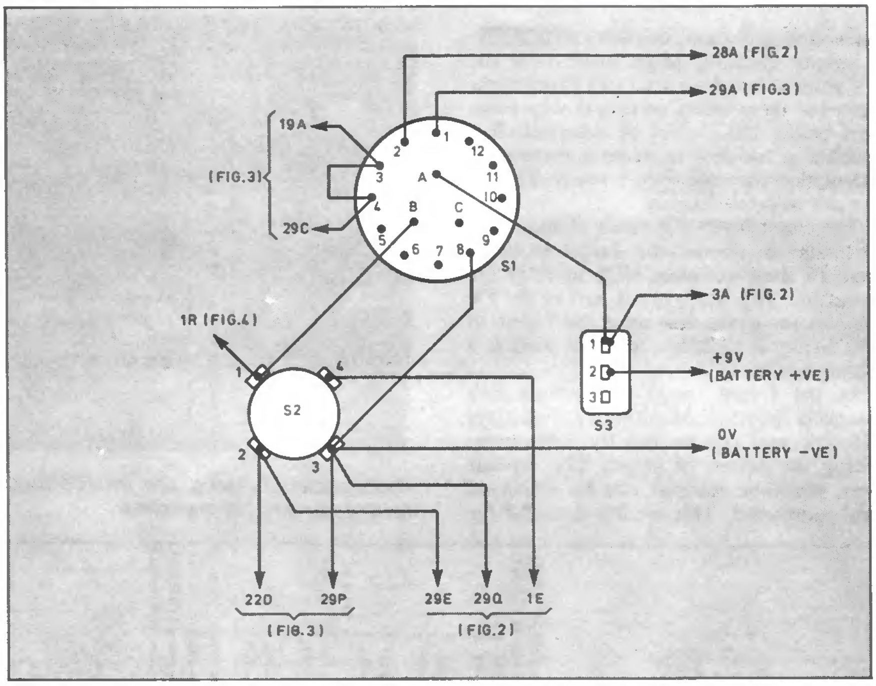
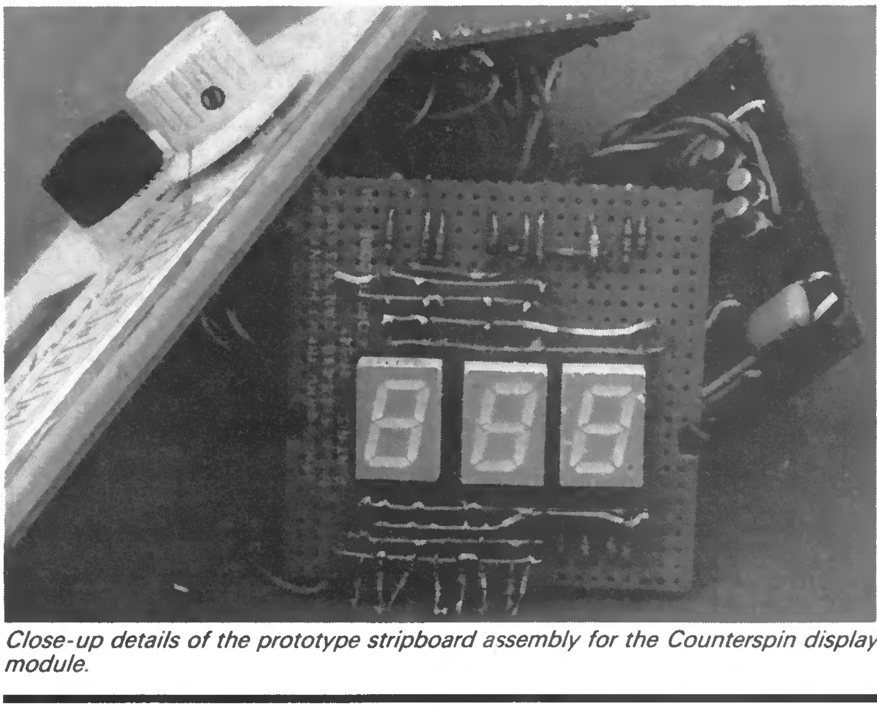


Fig. 5. Wiring details for the switches, showing stripboard destinations by figure number and matrix numbers.

Details of the connections between the switches and the stripboard assemblies are shown in Fig.5. The destinations of wires going to the stripboards are quoted as numeric-alpha codes indicating the matrix hole address. Multi-stranded insulated wire is recommended for all interconnections between the three stripboard assemblies and the switches.

The unit is powered at 9V by six type AA cells connected in series. Although the quiescent current is only about 5mA, the current consumption can vary between 60mA to over 100mA when the *Freeze* switch (S2) is pressed (about 10mA per display segment).



Close-up details of the prototype stripboard assembly for the Counterspin display module.

FURTHER ENLIGHTENMENT

Variations in the relative brilliances of the displays for different numbers may be noticed. This may compensated for by inserting additional resistors, of about 330 ohms, between the diode matrix outputs and the inputs to the display segments, as described for *Counterspell*. In this case, resistor R5 should be replaced by a wire link. As with *Counterspell*, this technique is likely to result in increased current consumption.

Next Month: We introduce "On Your Marks buttons" to show Quizmaster who answered first.

Techniques

ACTUALLY DOING IT!

by Robert Penfold

Over the years I must have received a few thousand readers' letters, and I cannot help noticing a steady trend. The general complexity of electronic projects has certainly increased over the years, and what is now an average sort of project would have been considered a fairly major undertaking twenty or thirty years ago.

You would have expected that the percentage of readers' letters asking for help with non-working projects to have increased, as it seems reasonable to assume that the greater complexity of modern projects gives more opportunity for something to go wrong. Surprisingly, the percentage of letters requesting help with non-working projects has, in fact, steadily reduced over the years. Letters of this type once accounted for the vast majority of the letters I received, but they are now a fairly small minority.

Possibly the general competence of electronics hobbyists has increased over the years, but I think it is more likely that improvements in methods of construction have reduced the chances of making mistakes. In particular, the vast majority of modern projects are based on a custom printed circuit board (p.c.b.). Using this method of construction it is comparatively easy to get everything right, and if a careless error should be made it will usually be spotted quite quickly.

Right Connections

This is not to say that building modern electronic projects is completely foolproof. Although there has been a trend towards having everything on the circuit board (including controls, sockets, etc.), most projects have at least a small amount of hard wiring, point-to-point wiring, or whatever other term you prefer. It is when completing this wiring that you find real opportunities to make mistakes.

Usually you will be working from a wiring diagram that provides good pictorial representations of the actual controls, sockets, transformers, or whatever, and the hard wiring should not, therefore, live up to its name. In practice it seems to be much easier to make the odd mistake when dealing with this wiring than when fitting the components to the printed circuit board.

One possible reason for this is that a printed circuit board normally has one hole per leadout wire, but it is quite normal for some of the tags on controls and switches to be left unused. For example, if a 5-way 1-pole switch is required, there is a slight problem as switches having this contact arrangement are not readily available.

The most practical choice is a 6-way 2-pole rotary type having its adjustable end-stop set for 5-way operation, and one pole ignored. Six tags of the switch would then be used, and the other eight would be left unconnected.

Some constructors seem to get worried if any components in a project have tags or pins that are left unconnected. This is not usually indicative of anything missing from a circuit diagram or wiring diagram. It occurs simply because many controls, sockets, etc. have "extras" that are not needed in a particular design, so they are left connected to "thin air".

It is perhaps worth pointing out that many integrated circuits (i.c.s) also have pins that are not connected internally, or which are not normally utilized (pins 1, 5, and 8 of most operational amplifiers for example).

When wiring up a project that has a number of unused tags you need to take extra care. Be especially careful if there are components which have no connections to a large proportion of the tags.

Jack sockets seem to be one of the main causes of confusion, as many of these are fitted with switch contacts that are little used in modern designs. Fig. 1 provides connection details for normal 3·5mm and 6·35mm (0·25 inch) *switched* jack sockets when the switch contact or contacts are not utilized.

Twinning

There is an increasing problem with components that do not conform to the traditional shapes and sizes. If a components list calls for (say) a 10k log potentiometer, in one of the larger components catalogues you may well be able to find a choice of half a dozen components that fit this general description (standard, miniature, small slider, large slider, etc.). Many switches and sockets are now also available in a variety of styles.

We would strongly advise beginners to look carefully at any photographs of the prototype unit, and then search some component catalogues for components that physically match up with the components used in the prototype. This should save you the trouble of having to work out the correlation between the tags on the component you have obtained and the one illustrated in the article. I have pointed out many times that a selection of component catalogues is an essential part of the hobby, and this remains as true as it ever was.

From time to time you will inevitably end up with a component that is correct in every detail, but which is physically quite different to the one illustrated in the wiring diagram. In this situation a test meter, even a very basic one, is more than a little useful.

With the meter set to a resistance range (or the continuity tester setting) you can use it to check such things as which tags of a switch are interconnected at each setting, and which tag of a socket connects through to a given tag on the plug. Such is the diversity of modern sockets, switches, etc., I tend to routinely check practically all switches and sockets to make sure I have not jumped to any wrong conclusions.

Wires

Unless large currents are involved, a fairly thin type of multi-strand connecting wire is the best choice. I normally use 7/0·2 p.v.c. insulated connecting

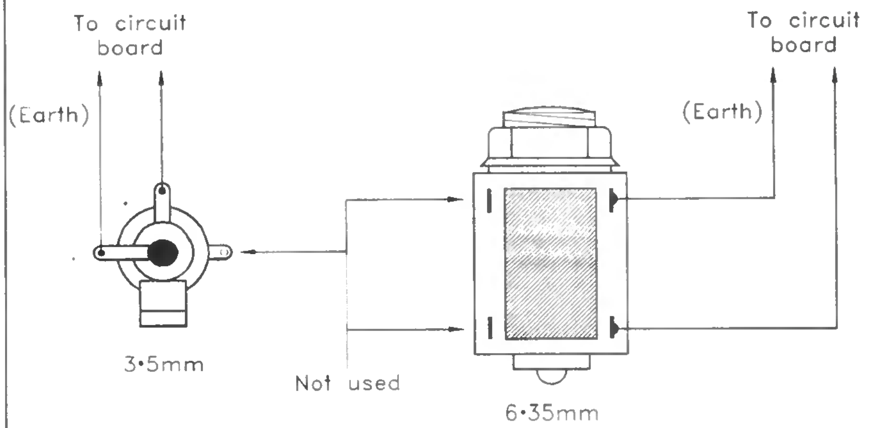


Fig. 1. The connections to switched jack sockets when the switch contacts are not used.

wire (i.e. it has seven strands of 0·2mm dia. wire).

It is probably best to avoid very thin grades such as 7/0·1 connecting wire as these tend to be a bit difficult to deal with. In fact some wire strippers are virtually useless with wire as thin as this. Always use proper wire strippers as knives or scissors would almost certainly damage the wires, which would severely weaken them.

One or two thicker gauges of connecting wire are listed in most component catalogues, but these are only needed for wiring that will carry high currents. If some form of heavy gauge connecting wire is needed the article concerned should make this clear, and suggest a suitable type of wire.

Do not try to use any form of single-strand wire or non-insulated wire for general project wiring. Non-insulated wires are almost certain to cause a few short circuits.

The stiffness of single-strand wire can make it a bit awkward to use, and even the slightest nick when stripping off the insulation will very seriously weaken it. If one or two wires in a multi-strand cable should be nicked slightly during the stripping process the cable will certainly be weakened, but probably not enough to cause it to fail.

Keep It Neat

A lot of hard wiring consists of groups of wires, such as three wires running from an area of the circuit board to the tags of a potentiometer. You can use individual wires, but I find that ribbon cable provides an easy means of obtaining neat results. This is a multi-way cable that has the wires side-by-side, giving it a flat, ribbon-like appearance. For project wiring it is probably best to use one of the thicker grades of ribbon cable.

The obvious choice is a 7/0·2 ribbon cable, and this is specifically designed as a general purpose multi-way connecting cable. The finer grades are intended for use with IDC connectors. They are usable for project wiring, but are relatively difficult to use.

Ribbon cable is available with a grey p.v.c. insulation, or with each wire in a different coloured sleeving. For project wiring it is recommended that multi-coloured "rainbow" type, even if this costs a little extra, be used. Having each wire a different colour makes it easy to identify each one, and greatly reduces the risk of any crossed-over connections.

Ten-way cable is sufficient for project wiring. If you should occasionally need to have more than ten wires running from the board to a large switch, it is easier to use (say) two eight-way cables rather than one 16-way type.

It is easy to peel off a cable having the required number of wires. It is equally easy to separate the wires at each end of a cable so that they can be stripped and connected to the tags. This cable is designed to pull apart with only a moderate amount of force.

Making Connections

Connecting wires to tags and pins is slightly more difficult than soldering components onto a circuit board, but it is still reasonably straightforward. Once a few millimetres of insulation has been stripped from a connecting wire it should be "tinned" with solder at both ends.

In other words, apply the hot bit of the soldering iron to one end of the wire and then feed in a small amount of solder. Then repeat this procedure with the other end of the wire. This makes the wire easier to deal with by bonding together the individual wires, and it also makes it much easier to produce reliable soldered joints.

The tags and pins of the controls, sockets, etc. should also be "tinned" with solder. In most cases there will be no difficulty in getting a nice coating of solder to flow onto the tags and pins.

Occasionally there may be problems due to a small amount of dirt or corrosion. The offending tags or pins must then be scraped with the small blade of a penknife or a small file to remove the contamination.

There should then be no difficulty in getting the solder to flow properly onto the cleaned surfaces. There is little chance of producing strong soldered joints on tags or pins that cannot be "tinned" properly.

Conversely, if the wire and the tag are properly "tinned" with solder, it is very difficult to produce a bad joint. If the component has genuine tags (complete with a hole) the end of the wire should be bent into a "U" shape and hooked through the hole in the tag.

Many potentiometers, switches, etc. now have pins rather than tags, so that they can be mounted on a printed circuit board. Components of this type are perfectly usable in a hard wired project, and it is just a matter of taking the end of the lead through one or two turns around the pin – (see Fig. 2).

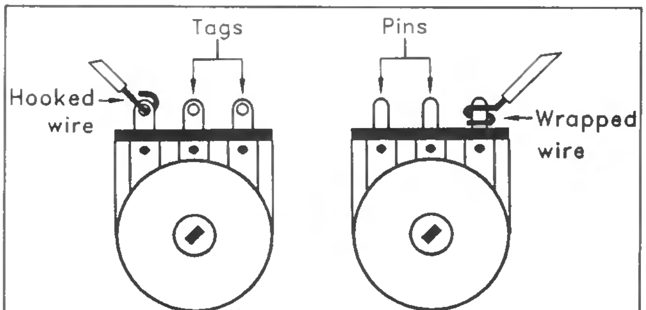


Fig. 2. No elaborate knots are needed prior to soldering wires in place.

Either way, with the bit of the iron applied to the joint and a small amount of solder fed in, a strong connection should be made. Provided the "tinning" has been done properly, simply putting some solder onto the bit, and then briefly applying it to the joint will produce a good joint.

Do *not* try this latter method when fitting components onto a circuit board. It more or less guarantees a fair percentage of "dry" joints and a project that will not work.

SHOP TALK
with David Barrington

National Lottery Predictor

Apart from the ready-programmed PIC microcontroller, almost all the other components required to build the *National Lottery Predictor* could be classed as standard items. However, the dual 7-segment display and the pushbutton switch will have to be selected carefully if they are to fit on the small printed circuit board.

The pre-programmed PIC16C54RC/P microcontroller chip is available from the author, price £7. He also has a consignment of dual displays and pushbutton switches. These are being offered as a pack, one each of display and switch, for the sum of £4. A floppy disk containing the complete Source Code together with other related files is also available for just £1.

All orders (*Strictly Mail Order Only*) should be sent to: **Mr. J. Ilett, 99 Telford Way, Yeading, Hayes, Middlesex, UB4 9TH**. All monies should be made payable to *J. Ilett*. All prices *include* postage and packing. Overseas customers add £2 to order.

The specified case used in the prototype model was purchased from **Maplin** and is their type 3415 box, code FK74R. The red display filter material also came from the same supplier, code FR34M.

Most of our component advertisers carry various versions of 7-segment displays and no doubt many will work in this circuit but check they have an identical pinout arrangement first, to make sure they will fit on the small p.c.b. The printed circuit board is available from the *EPE PCB Service*, code 935.

Auto Battery Charger

To date, we have only come across two stockists listing the ICL8069 1·2V voltage reference called for in the *Auto Battery Charger*. These are: **Maplin**, code YH39N and **Electromail**, code 428-969.

The ICL7611 micropower op.amp, chosen specially for its exceptionally low current requirement, should be available from most component suppliers. However, in case of difficulty it is listed by **Electromail** (☎ ***0536 204555***) and **Cricklewood** (☎ ***081 452 0161***).

The specified relay used in the prototype model has contacts rated 5A at 240V a.c. and comes from the 5A/10A miniature range sold by Maplin. The one suggested is the 12V version, coded JM18U 12V/5A Min. Relay. Other relays can, of course, be used but make sure that the contacts are adequately rated.

As the mains "live" connection is made *directly* to the relay contacts these pins MUST be covered with plastic insulation sleeving for added safety. It is also very important, for personal safety, that a well "Earthed" aluminium or metal case is used.

A further important point to note is that if resistor R6 is needed to complete the setting up, it *must* have a power rating of **3W minimum**. The Charger printed circuit board is available from the *EPE PCB Service*, code 934.

Light Activated Switch

Most of our component advertisers should carry the ORP12 light dependent resistor or its equivalent called for in the *Light Activated Switch*.

The circuit should work properly using almost any relay having a 12V coil with a resistance of about 300 ohms or more, but make sure you select one which has contacts rated for your intended application. The relay used in the prototype is the Maplin "10A Mains" type, code YX97F.

Switch On/Off Timer

Once again, the only item likely to cause concern for builders of the *Switch On/Off Timer* is the relay. This can be almost any 12V coil type with a resistance of 300 ohms or more, plus of course suitably rated contacts. Both the **Maplin** "10A Mains Relay" and the **Electrovalue** "Min. S.P.D.T. 3A" type worked successfully.

Continuity Tester

The CA3130E op.amp i.c. used in the *Continuity Tester* should not be replaced with a substitute op.amp. This i.c. operates well from a 6V supply, is capable of single supply operation and has good freedom from "latch-up." Most other op.amps do not match this specification and may not perform very well in this circuit.

The 6V buzzer used in this circuit was purchased from Maplin, code FL39N.

PLEASE TAKE NOTE

Moving Display Metronome *Jan. '95*

At the time of "going to press" we were unable to pass on a source of supply for the VN0610L f.e.t. specified for TR1 and TR2. We have since heard that Farnell (☎ ***0532 636311***) carry stocks of this *n*-channel device.

As this is an enhancement mode MOSFET device, it is suggested that a BS170 (available from Electrovalue – ☎ ***0784 442253***) would make a good substitute. The 2N5459 will not function in this circuit.

Alternatively, a reader has informed us that the circuit functions correctly with a ZTX300 *npn* transistor, with a 220 kilohm resistor in its base connection, replacing the specified device. (i.e. base to gate, collector to drain and emitter to source). It has also been suggested (but not tried) that almost any *npn* small signal transistor with an h_{fe} of around 300 (BC549C etc) would be OK, with a 10 kilohms resistor feeding the base, since the CMOS i.c.s are capable of sourcing the small amount of current required.

Our thanks to Mr. R. K. Stephenson and Mr. B. J. Taylor.

DIRECT BOOK SERVICE

The books listed have been selected by *Everyday with Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page. For another selection of books see next month's issue.

ELECTRONIC PROJECTS – BOOK 1
Published by *Everyday Electronics* in association with Magenta Electronics.
Contains twenty of the best projects from previous issues of EE each backed with a kit of components. The projects are: Seashell Sea Synthesiser, EE Treasure Hunter, Mini Strobe, Digital Capacitance Meter, Three Channel Sound to Light, BBC 16K Sideways Ram, Simple Short Wave Radio, Insulation Tester, Stepper Motor interface, Eprom Eraser, 200MHz Digital Frequency Meter, Infra Red Alarm, EE Equaliser Ioniser, Bat Detector, Acoustic Probe, Mains Tester and Fuse Finder, Light Rider – (Lapel Badge, Disco Lights, Chaser Light), Musical Doorbell, Function Generator, Tilt Alarm, 10W Audio Amplifier, EE Buccaneer Induction Balance Metal Detector, BBC Midi Interface, Variable Bench Power Supply, Pet Scarer, Audio Signal Generator.
128 pages (A4 size) **Order code EP1** **£2.45**

ELECTRONICS TEACH-IN 88/89 – INTRODUCING MICROPROCESSORS
Mike Tooley BA (published by *Everyday Electronics*)
A complete course that can lead successful readers to the award of a City and Guilds Certificate in Introductory Microprocessors (726/303). The book contains everything you need to know including full details on registering for assessment, etc. Starting with basic terminology, integrated circuits, logic families and numbering systems the text builds in stages, with revision and assessments built in, up to programming, languages, flow charts, etc. The course is ideal for the newcomer to the subject.
80 pages (A4 size) **Order code TI-88/89** **£2.45**

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ELECTRONICS TEACH-IN No.5 GUIDE TO BUILDING ELECTRONIC PROJECTS
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Due to the demand from students, teachers ... obbyists we have put together a range of articles fr... ues of *Everyday Electronics* that will assist t... ed with the construction of electronic project...
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SORRY SOLD OUT

88 pages (A4 size) **Order code TI5** **£2.95**

ELECTRONICS TEACH-IN No. 6 DESIGN YOUR OWN CIRCUITS
(Published by *Everyday with Practical Electronics*)
Mike Tooley B.A.
This book is designed for the beginner and experienced reader alike, and aims to dispell some of the mystique associated with the design of electronic circuits. It shows how even the relative newcomer to electronics can, with the right approach, design and realise quite complex circuits.
Fourteen individual p.c.b. modules are described which, with various detailed modifications, should allow anyone to design and construct a very wide range of different projects. Nine "hands-on" complete DIY projects have also been included so readers can follow the thinking behind design, assembly, construction, testing and evaluation, together with suggested "mods" to meet individual needs. The practical projects have each been designed to stand on their own as complete items of equipment. P.C.B.s for all the modules and projects are available by mail order.
The subjects covered in each chapter of the book are: Introduction and Power Supplies; Small Signal Amplifiers; Power Amplifiers; Oscillators; Logic Circuits; Timers; Radio; Power Control; Optoelectronics.
The nine complete constructional projects are: Versatile Bench Power Supply; Simple Intercom; Bench Amplifier/Signal Tracer; Waveform Generator; Electronic Die; Pulse Generator; Radio Receiver; Disco Lights Controller; Optical Communications Link.
136 pages **Order code TI6** **£3.45**

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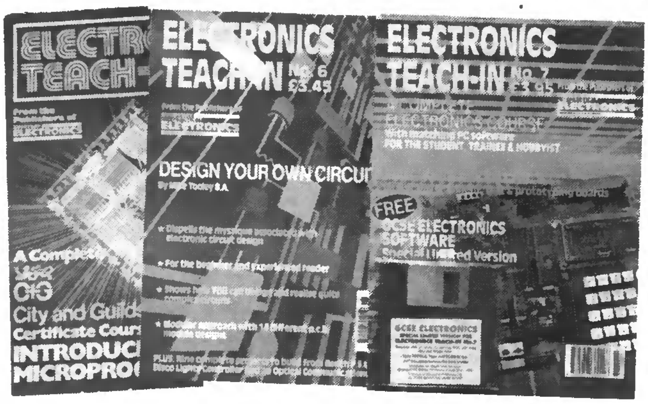
The highly acclaimed *Teach-In '92* series, which included the construction and use of the *Mini Lab* and *Micro Lab* test and development units, has been put together in book form. Additionally EPT Educational Software have developed a GCSE Electronics software program to compliment the course and a FREE DISC covering the first two parts of the course is included with the book.
An interesting and thorough tutorial series aimed specifically at the novice or complete beginner in electronics. The series is designed to support those undertaking either GCSE Electronics or GCE Advanced Levels, and starts with fundamental principles.
If you are taking electronics or technology at school or college, this book is for you. If you just want to learn the basics of electronics then this book is for you. If you are teaching electronics or technology you must make sure you see it. *Teach-In No. 7* will be invaluable if you are considering a career in electronics or even if you are already training in one. The Mini Lab and software enable the construction and testing of both demonstration and development circuits. These learning aids bring electronics to life in an enjoyable and interesting way: you will both see and hear the electron in action! The Micro Lab microprocessor add-on system will appeal to higher level students and those developing microprocessor projects.



Computers and Computing

HOW TO CHOOSE A SMALL BUSINESS COMPUTER SYSTEM
D. Weale
This book is for anyone intending to buy an IBM compatible computer system, whether it is their first system or a replacement. There are sections on hardware, application and systems programs and how to actually make your choice as well as sections on the law, ergonomics and a glossary of common terms.
The text contains many useful tips and some warnings (which could save much effort and expense).
114 pages **Order code BP323** **£4.95**

UNDERSTANDING PC SPECIFICATIONS
R. A. Penfold
If you require a microcomputer for business applications, or a high quality home computer, an IBM PC or compatible is often the obvious choice. They are competitively priced, and are backed up by an enormous range of applications programs, hardware add-ons, etc. The main difficulty for the uninitiated is deciding on the specification that will best suit his or her needs. PCs range from simple systems of limited capabilities up to complex systems that can happily run applications that would have been considered beyond the abilities of a microcomputer not so long ago. It would be very easy to choose a PC system that is inadequate to run your applications efficiently, or one which goes beyond your needs and consequently represents poor value for money.
This book explains PC specifications in detail, and the subjects covered include the following: Differences between types of PC (XT, AT, 80386, etc); Maths co-processors; Input devices (keyboards, mice, and digitisers); Memory, including both expanded (EMS) and extended RAM: RAM disks and disk caches; Floppy disk drive formats and compatibility; Hard disk drives (including interleave factors and access times); Display adaptors, including all standard PC types (CGA, Hercules, Super VGA, etc); Contains everything you need to know if you can't tell your EMS from your EGA!
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Ian R. Sinclair
In this book, you'll find out what a CD ROM is, how it works, and why it is such a perfect add-on for a PC, allowing you to buy programmes, text, graphics and sound on a CD. It also describes the installation of a CD ROM drive and a sound card, pointing out the common problems that arise, and then shows how to use them to create a complete multimedia presentation that contains text, photos, a soundtrack with your own voice recorded as a commentary, even animation and edited video footage.
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A CONCISE INTRODUCTION TO MS-DOS
N. Kantaris
This guide is written with the non-expert, busy person in mind and, as such, it has an underlying structure based on "what you need to know first, appears first". Nonetheless, the guide is also designed to be circular, which means that you don't have to start at the beginning and go to the end. The more experienced user can start from any section.
The guide covers versions 3.0, 3.1 and 3.2 of both PC-DOS and MS-DOS as implemented by IBM and other manufacturers of "compatible" microcomputers.
64 pages **Order code BP232** **£2.95**

MAKING MS-DOS WORK FOR YOU (covers version 6.2)
N. Kantaris & P. R. M. Oliver
This book was written with the busy person in mind and, as such, it has an underlying structure based on "what you need to know first, appears first". Nonetheless, the book has also been designed to be circular, which means that you don't have to start at the beginning and go to the end.
The book explains: How to write customised batch files which allow you to display what you want on your screen, and in the form and order you want it, instead of being forced to use the DOS prompt on a blank screen. How to design and set up a fast interactive and professional looking menu system, so that you or anyone else can run utility applications or commercial software packages easily. How the ANSI.SYS display and keyboard commands can be used to position the cursor on any part of the screen, change the intensity of the displayed characters or change their colour. How the Edit screen editor or the Edlin line editor can be used to enter ESCape (ANSI.SYS) commands into simple ASCII files to allow control of both your screen display and your printer. How to control the operation of the two main types of printers in use today, Epson compatible dot matrix and HP compatible laser printers. How to use several useful routines, such as moving and finding files, protecting files from accidental erasure, a simplified backup process, a screen saver, and a disc cataloguing system.
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In order to run and use programs operating under CP/M it is not essential to have an understanding of the system, but a reasonable knowledge of the subject can certainly be of immense help when minor problems occur, and also in fully exploiting the possible potential of the system. This book tells the story!
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Audio and Music

ACOUSTIC FEEDBACK – HOW TO AVOID IT

Feedback is the bane of all public address systems. While feedback cannot be completely eliminated, many things can be done to reduce it to a level at which it is no longer a problem.

Much of the trouble is often the hall itself, not the equipment, but there is a simple and practical way of greatly improving acoustics. Some microphones are prone to feedback while others are not. Certain loudspeaker systems are much better than others, and the way the units are positioned can produce or reduce feedback. All these matters are fully explored as well as electronic aids such as equalizers, frequency-shifters and notch filters.

The special requirements of live group concerts are considered, and also the related problem of instability that is sometimes encountered with large set-ups. We even take a look at some unsuccessful attempts to cure feedback so as to save readers wasted time and effort duplicating them.

Also included is the circuit and layout of an inexpensive but highly successful twin-notch filter, and how to operate it.

92 pages Order code BP310 **£3.95**

PRACTICAL MIDI HANDBOOK
R. A. Penfold

The Musical Instrument Digital Interface (MIDI) is surrounded by a great deal of misunderstanding, and many of the user manuals that accompany MIDI equipment are quite incomprehensible to the reader.

The Practical MIDI Handbook is aimed primarily at musicians, enthusiasts and technicians who want to exploit the vast capabilities of MIDI, but who have no previous knowledge of electronics or computing. The majority of the book is devoted to an explanation of what MIDI can do and how to exploit it to the full, with practical advice on connecting up a MIDI system and getting it to work, as well as deciphering the technical information in those manuals.

128 pages Order code PC101 **£6.95**

PREAMPLIFIER AND FILTER CIRCUITS
R. A. Penfold

This book provides circuits and background information for a range of preamplifiers, plus tone controls, filters, mixers, etc. The use of modern low noise operational amplifiers and a specialist high performance audio preamplifier i.c. results in circuits that have excellent performance, but which are still quite simple. All the circuits featured can be built at quite low cost (just a few pounds in most cases).

The preamplifier circuits featured include:– Microphone preamplifiers (low impendance, high impedance, and crystal). Magnetic cartridge pick-up preamplifiers with R.I.A.A equalisation. Crystal/ceramic pick-up preamplifier. Guitar pick-up preamplifier. Tape head preamplifier (for use with compact cassette systems).

Other circuits include:– Audio limiter to prevent overloading of power amplifiers. Passive tone controls. Active tone controls. PA filters (highpass and lowpass). Scratch and rumble filters. Loudness filter. Audio mixers. Volume and balance controls

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V. Capel

This book explores the various features, good points and snags of speaker designs. It examines the whys and wherefores so that the reader can understand the principles involved and so make an informed choice of design, or even design loudspeaker enclosures for him or herself. Crossover units are also explained, the various types, how they work, the distortions they produce and how to avoid them. Finally there is a step-by-step description of the construction of the *Kapellmeister* loudspeaker enclosure.

148 pages Order code BP256 **£2.95**

COMPUTERS AND MUSIC – AN INTRODUCTION
R. A. Penfold

Computers are playing an increasingly important part in the world of music, and the days when computerised music was strictly for the fanatical few are long gone.

If you are more used to the black and white keys of a synth keyboard than the QWERTY keyboard of a computer, you may be understandably confused by the jargon and terminology bandied about by computer buffs. But fear not, setting up and using a computer-based music making system is not as difficult as you might think.

This book will help you learn the basics of computing, running applications programs, wiring up a MIDI system and using the system to good effect, in fact just about everything you need to know about hardware and the programs, with no previous knowledge of computing needed or assumed. This book will help you to choose the right components for a system to suit your personal needs, and equip you to exploit that system fully.

174 pages Order code PC107 **£8.95**

ELECTRONIC PROJECTS FOR GUITAR
R. A. Penfold

This book contains a collection of guitar effects and some general purpose effects units, many of which are suitable for beginners to project building. An introductory chapter gives guidance on construction.

Each project has an introduction, an explanation of how it works, a circuit diagram, complete instructions on stripboard layout and assembly, as well as notes on setting up and using the units. Contents include: Guitar tuner; Guitar preamplifier; Guitar headphone amplifier; Soft distortion unit; Compressor; Envelope waa waa; Phaser; Dual tracking effects unit; Noise gate/expander; Treble booster; Dynamic treble booster; Envelope modifier; Tremelo unit; DI box.

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HIGH POWER AUDIO AMPLIFIER CONSTRUCTION
R. A. Penfold

Practical constructional details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. Includes MOSFET and bipolar transistor designs.

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Theory and Reference

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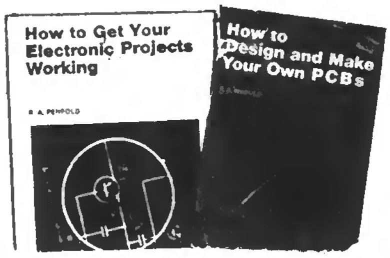

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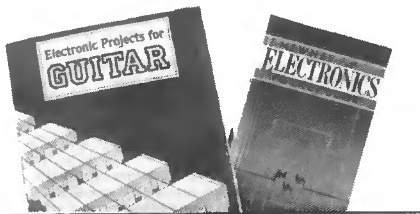

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A. Pickford
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REPORTING AMATEUR RADIO

Tony Smith G4FAI

MORSE TEST DISCUSSIONS

In the February issue it was briefly reported that the International Amateur Radio Union's Administrative Council (AC) had decided to "neither propose nor support a change . . . at this time" in the current ITU Radio Regulations that require a Morse test for operation in the amateur frequencies below 30MHz.

The IARU has now issued a a 26-page document which explains the background to this decision, and contains the report of the "CW Ad Hoc Committee", set up to make recommendations on this controversial issue.

The report begins with the definition of the Amateur Service as given by the International Telecommunication Union (ITU) in Article 1 of the International Radio Regulations:

"53. Amateur Service: A radiocommunication service for the purpose of self-training, *intercommunication* and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest."

The word *intercommunication* in this definition (italics added) is given a special significance in the Committee's report, and it considers RR 2735 (in Article 32 of the Radio Regulations) specifically in terms of this definition:

"2735. Any person seeking a licence to operate the apparatus of an amateur station shall prove that he is able to send correctly by hand and to receive correctly by ear texts in Morse code signals. The administrations concerned may, however, waive this requirement in the case of stations making exclusive use of frequencies above 30 MHz."

FUTURE CHANGE NOT RULED OUT

In essence, the Committee came to the conclusion that the Morse code, with its use of Q-code and unique abbreviations – understood by operators in every country, irrespective of the spoken languages used, provides an effective common language for radio amateurs, and that at the present time this is the only practical way that intercommunication, as defined in RR53, can be practised by the Amateur Service.

It recommended, therefore that no change be made in the present regulations. However, it did not rule out the possibility that future technical developments may provide "an alternative means for ensuring that amateur stations can intercommunicate, and that these new means could become sufficiently universal to obviate the present requirement."

IARU POLICY

At its meeting in Singapore on 10 to 12 September 1994, the IARU Administrative Council received the report of the CW Ad Hoc Committee and the following Resolution was adopted:

"Noting that the Morse code provides a means of intercommunication between peoples without regard to language barriers.

"Recognizing that the international radio regulations require that ability in the use of Morse code must be demonstrated before an operator's license for the use of amateur frequencies below 30MHz can be issued . . .

"Recognizing that support of this requirement has been affirmed at the most recent conference of each of the three IARU regional organizations . . .

"Further recognizing that future advances in communications technology may influence perceptions of the relevance of this requirement . . .

"Considering the report of the IARU CW Ad Hoc Committee, submitted to the Administrative Council in timely response to the Administrative Council's instruction at its Brussels meeting, September 1993 . . .

"Decides to neither propose nor support any change to the international radio regulations pertaining to Morse code . . .

"Invites member-societies to consider the matter at future regional conferences and through this medium to communicate their views to the Administrative Council."

UNDERSTANDING NEEDED

Putting the question of licensing requirements aside, the Committee suggests that a wider understanding of the position of Morse code in amateur radio is needed in training courses for all grades of the amateur radio licence.

This includes an appreciation of the purpose of the Morse code and its place in amateur radio as a background during study for the "codeless" licences for operation above 30MHz. This, it says, may ensure that future discussion about the role of Morse code in amateur radio will be conducted on a factual rather than an emotional level.

The Committee concludes that competency in Morse code is essential real world preparation for operating on the world-wide HF amateur bands. That it is also a mandatory regulatory requirement necessary to sustain the control and the special characteristics of the Amateur Service in international working.

It also says, "Every entrant to Amateur Radio should have an understanding of these matters and an appreciation of the thrills and satisfaction that competency in the Morse code can bring."

ESTABLISHED MORSE POLICIES

The Committee reviewed recent decisions or developments in the IARU Regions and in some member-countries. In 1993, IARU Region 1 decided to maintain its present position regarding the need for a Morse test. Region 2, at its conference in 1992, saw no need for any change to RR 2735, and Region 3, in 1994, unanimously supported the continuation of the Morse test as required by the ITU Radio Regulations.

The New Zealand Association of Radio Transmitters (NZART) after conducting a survey of its membership, developed a policy in 1994 supporting the continuation of the test under present circumstances. The Radio Society of Great Britain, in 1993, also conducted a survey in which support was two to one in favour of retention of the current Morse requirement.

The American Radio Relay League (ARRL), in January 1993, declared its support for the test, and instructed its representatives to insist before all national and international bodies that there be no modification to the present proficiency requirement.

OTHER BODIES

A seminar on Amateur Radio Communications, organised by the Asia-Pacific Telecommunity (APT), held in Tokyo in June 1994, agreed that the international Morse code should remain a basic requirement for amateur radio below 30MHz.

Finally, the Committee notes that within the ITU itself, the "Voluntary Group of Experts to study Allocation and Improved use of the Radio-frequency Spectrum and Simplification of the Radio Regulations", in its "Final Report to the Council and Administrations", proposes no change to the text content of Article 32 of the current Radio Regulations, indicating that no change is proposed to Regulation 2735 by the Group.

CELEBRATORY SATELLITE

On December 26, Russia launched its *RS15* amateur satellite to commemorate the 100th anniversary of the discovery of radio by Aleksandr Stepanovich Popov in 1895. Popov's work is the basis for the controversial Russian belief that he, and not Marconi, was the inventor of wireless communication.

The western world, of course, generally accepts that Marconi made his first transmissions in the same year, and is celebrating the centenary of that event also.

The basic details of the Russian satellite are: Uplink, 145·858MHz to 145·898MHz; Downlink, 29·354MHz to 29·394MHz; CW Beacon 1, 29·3525MHz; CW Beacon 2, 29·3987MHz.

Its weight is 70 kg; and it is orbiting the earth every 127.45 minutes. It is commanded by the RS3A control station at Moscow, headed by Leonid Maksakov, RA3AT. Comments and reception reports are requested, and should be sent to the RS3A Control Station, PO Box 59, Moscow 105122, Russia. *(W5YI Report).*

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