

**FREE**  
PICTUTORIAL  
SUPPLEMENT

**EVERYDAY**

MARCH 1998

**PRACTICAL**

# ELECTRONICS

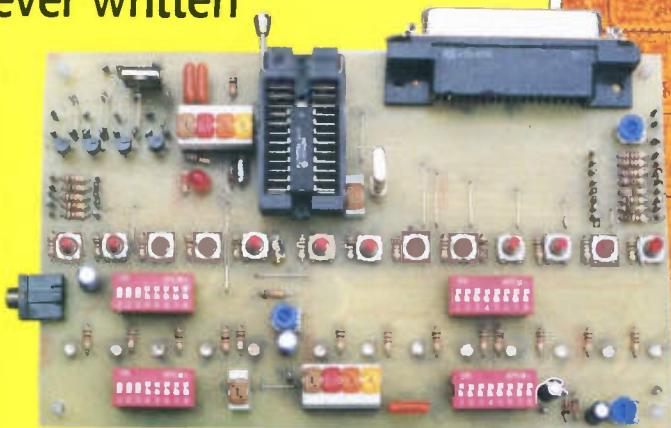
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## **FREE INSIDE** **EPE PIC** **TUTORIAL - Part 1**

**Special 16 Page Supplement**

The best introduction to  
using PIC Microcontrollers  
ever written



## **AUDIO SYSTEM** **REMOTE CONTROLLER**

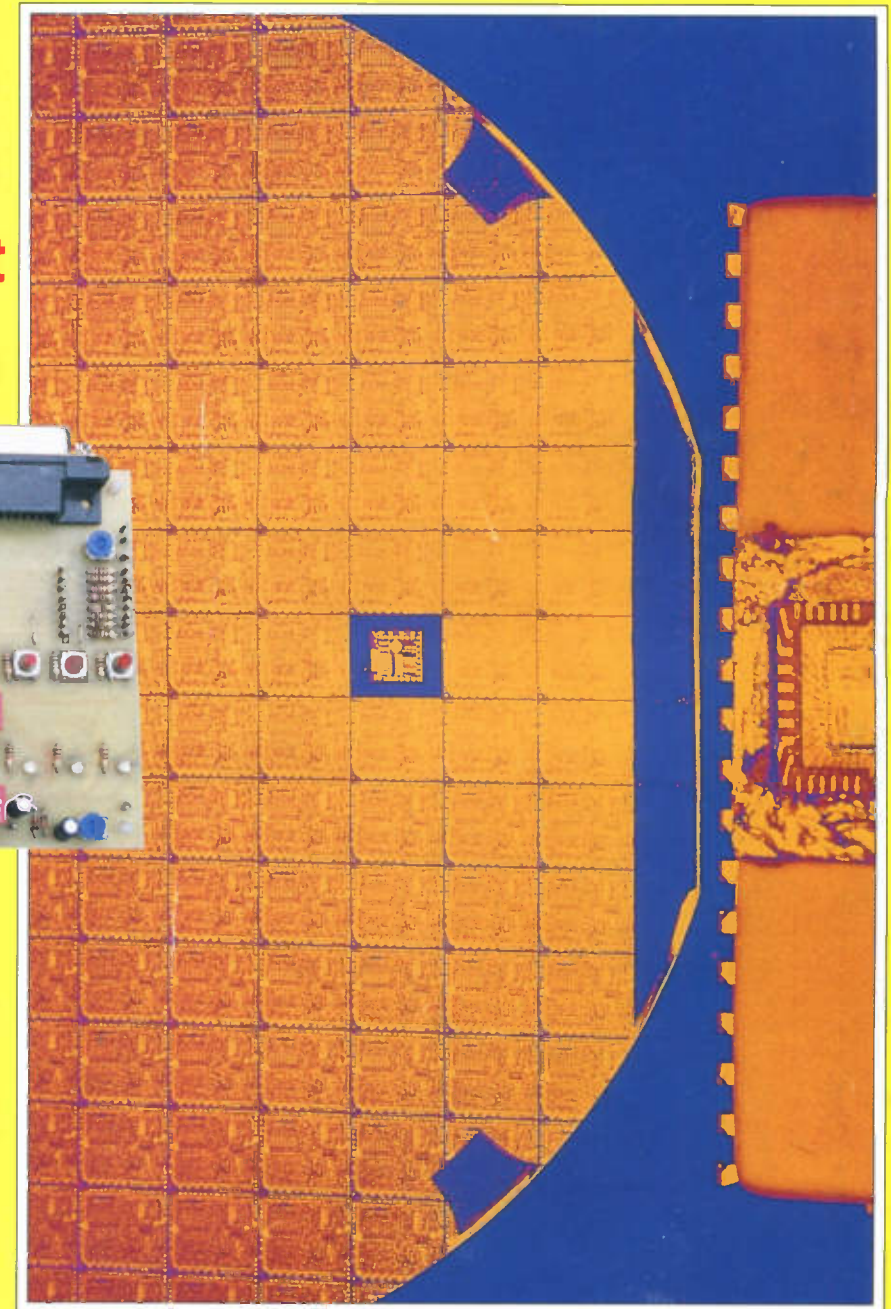
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Simple but effective  
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Detects static electricity,  
tracks interference  
and live wires, tests  
continuity, capacitors,  
diodes and batteries



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### PLANS

**PORTABLE X RAY MACHINE PLANS** Easy to construct plans on a simple and cheap way to build a home X-ray machine! Effective device, X-ray sealed assemblies, can be used for experimental purposes. Not a toy or for minors! £6/set. Ref F/XP1.

**TELEKINETIC ENHANCER PLANS** Mystify and amaze your friends by creating motion with no known apparent means or cause. Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect. Excellent for science projects, magic shows, party demonstrations or serious research & development of this strange and amazing psychic phenomenon. £4/set Ref F/TKE1.

**ELECTRONIC HYPNOSIS PLANS & DATA** This data shows several ways to put subjects under your control. Included is a full volume reference text and several construction plans that when assembled can produce highly effective stimuli. This material must be used cautiously. It is for use as entertainment at parties etc only, by those experienced in its use. £15/set. Ref F/EH2.

**GRAVITY GENERATOR PLANS** This unique plan demonstrates a simple electrical phenomena that produces an anti-gravity effect. You can actually build a small mock spaceship out of simple materials and without any visible means - cause it to levitate. £10/set Ref F/GRA1.

**WORLDS SMALLEST TESLA COIL/LIGHTENING DISPLAY GLOBE PLANS** Produces up to 750,000 volts of discharge, experiment with extraordinary HV effects, 'Plasma in a jar', St Elmo's fire, Corona, excellent science project or conversation piece. £5/set Ref F/BTC1/LG5.

**COPPER VAPOUR LASER PLANS** Produces 100mw of visible green light. High coherency and spectral quality similar to Argon laser but easier and less costly to build yet far more efficient. This particular design was developed at the Atomic Energy Commission of NEGEV in Israel. £10/set Ref F/CVL1.

**VOICE SCRAMBLER PLANS** Miniature solid state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit. Use on telephone to prevent third party listening and bugging. £6/set Ref F/V59.

**PULSED TV JOKER PLANS** Little hand held device utilises pulse techniques that will completely disrupt TV picture and sound works on FM too! DISCRETION ADVISED. £8/set Ref F/TJ5.

**BODYHEAT TELESCOPE PLANS** Highly directional long range device uses recent technology to detect the presence of living bodies, warm and hot spots, heat leaks etc. Intended for security, law enforcement, research and development, etc. Excellent security device or very interesting science project. £8/set Ref F/BHT1.

**BURNING, CUTTING CO2 LASER PLANS** Projects an invisible beam of heat capable of burning and melting materials over a considerable distance. This laser is one of the most efficient, converting 10% input power into useful output. Not only is this device a workhorse in welding, cutting and heat processing materials but it is also a likely candidate as an effective directed energy beam weapon against missiles, aircraft, ground-to-ground, etc. Particle beams may very well utilize a laser of this type to blast a channel in the atmosphere for a high energy stream of neutrons or other particles. The device is easily applicable to burning and etching wood, cutting, plastics, textiles etc. £12/set Ref F/LC7.

**DYNAMO FLASHLIGHT** Interesting concept, no batteries needed just squeeze the trigger for instant light apparently even works under water in an emergency although we haven't tried it yet! £6.99 ref SC152

**ULTRASONIC BLASTER PLANS** Laboratory source of sonic shock waves. Blow holes in metal, produce 'cold' steam, atomize liquids. Many cleaning uses for PC boards, jewelry, coins, small parts etc. £6/set Ref F/ULB1.

**ANTI DOG FORCE FIELD PLANS** Highly effective circuit produces time variable pulses of acoustical energy that dogs cannot tolerate. £6/set Ref F/DOG2.

**LASER BOUNCE LISTENER SYSTEM PLANS** Allows you to hear sounds from a premises without gaining access. £12/set Ref F/LLIST1.

**PHASOR BLAST WAVE PISTOL SERIES PLANS** Handheld, has large transducer and battery capacity with external controls. £6/set Ref F/PS4.

**INFINITY TRANSMITTER PLANS** Telephone line grabber/room monitor. The ultimate in home/office security and safety! simple to use! Call your home or office phone, push a secret tone on your telephone to access either: A) On premises sound and voices or B) Existing conversation with break-in capability for emergency messages. £7 Ref F/ELEGRAB.

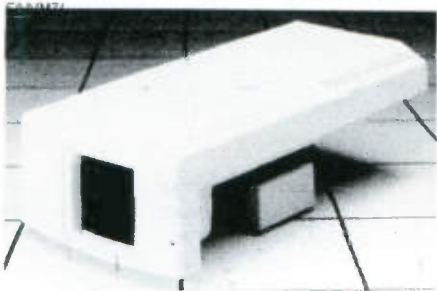
**BUG DETECTOR PLANS** Is that someone getting the goods on you? Easy to construct device locates any hidden source of radio energy! Sniffs out and finds bugs and other sources of bothersome interference. Detects low, high and UHF frequencies. £5/set Ref F/BD1.

**ELECTROMAGNETIC GUN PLANS** Projects a metal object a considerable distance - requires adult supervision £5 ref F/EML2.

**ELECTRIC MAN PLANS, SHOCK PEOPLE WITH THE TOUCH OF YOUR HAND!** £5/set Ref F/EMA1.

**PARABOLIC DISH MICROPHONE PLANS** Listen to distant sounds and voices, open windows, sound sources in 'hard to get' or hostile premises. Uses satellite technology to gather distant sounds and focus them to your ultra sensitive electronics. Plans also show an optional wireless link system. £8/set ref F/PM5.

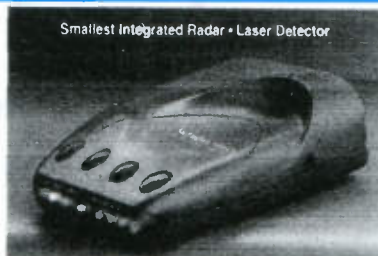
**2 FOR 1 MULTIFUNCTIONAL HIGH FREQUENCY AND HIGH DC VOLTAGE, SOLID STATE TESLA COIL AND VARIABLE 100,000 VDC OUTPUT GENERATOR PLANS** Operates on 9-12vdc, many possible experiments. £10 Ref F/2FOR1.



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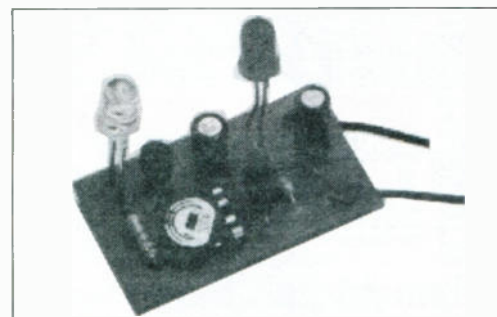
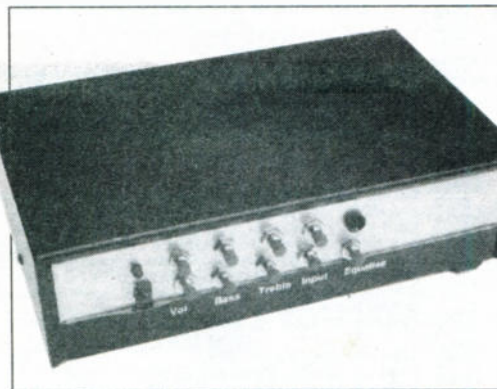
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Pack of 4 £10 ref DNIC2



### TZS4 INFRARED NIGHT SIGHT

One of our top most selling night sights is this Russian TZS4. This sight enable you to see in very low light levels, or with the aid of the built in infra red illuminator - in total darkness. In 1/4 moonlight you would spot a man at 150m, in total darkness at 75m. Magnification 2.3x, 240x66x190mm, 0.9kg, focusing range 1.5m-infinity, M42 camera mount included, runs on 2xAA batteries, 100mm focal length, 8 deg illuminator divergence, 50hrs continuous (no illuminator) 10hrs with carrying case and strap. TZS4 Nightsight £199 ref BAR61



## Projects and Circuits

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Don't be a dim-witted road menace – have a brilliant flash of inspiration and get lit-up on time!
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With this amazing electronic analogue of the Swiss Army Knife, let the Force reveal itself!
- INGENUITY UNLIMITED** hosted by Alan Winstanley **181**  
Fan Failure Monitor; Flame Effect; L.E.D.s as Photocells;  
DMM Temperature Probe; Current Monitor for Power Supplies
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Have you an opportunist burglar near you? Probably – and here's *your* opportunity to inexpensively deter his anti-social tendencies
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PCBs for *EPE* projects – some at "knockdown" prices! Plus *EPE* software

## FREE

- EPE PIC TUTORIAL SUPPLEMENT – 1** by John Becker **between pages 200 and 201**

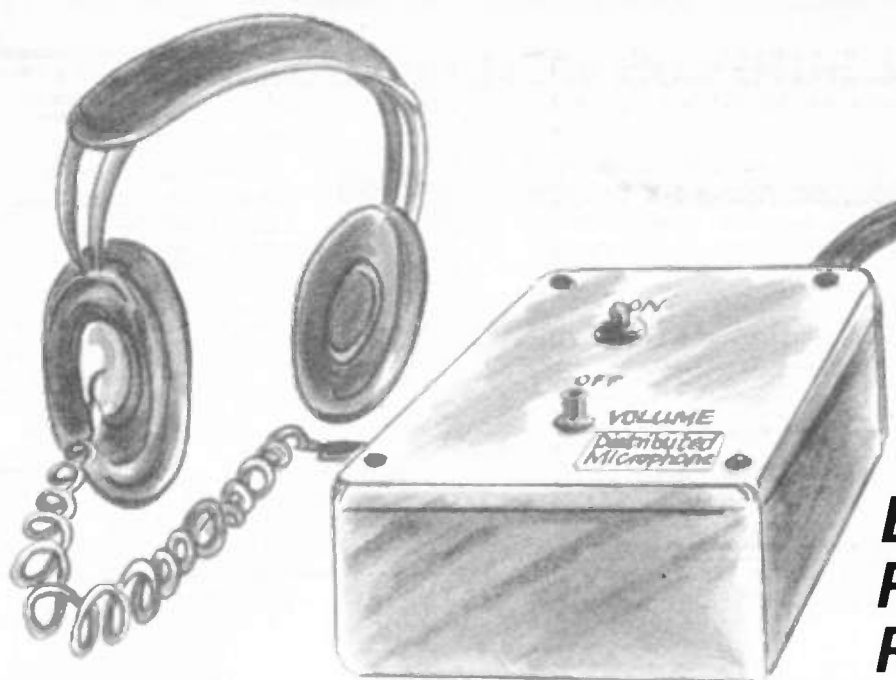
By popular demand – quite simply the easiest practical introduction to using PIC microcontrollers. This month: assembling the versatile Tutorial demonstration p.c.b. and your first steps in using it!

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Our April '98 issue will be published on Friday, 6 March 1998. See page 163 for details.





## **EXPERIMENTAL PIEZO-CABLE PROJECTS**

## **NEXT MONTH**

### **SINGLE OR DUAL-TRACKING P.S.U.**

This simple to build power supply unit will provide a single regulated output of 2 volts to 20 volts at 250mA, or it can be switched to provide a dual supply, suitable for most i.c. experimentation and testing, of 1 volt to 10 volts on either side of earth. This dual supply automatically tracks each side to the other, so that both positive and negative output rails keep in step.

### **PATENT YOUR INVENTION**

Most of us have had an idea for an invention at some time or another but, unlike the writer (whose words are automatically copyrighted), the would-be inventor must take steps to protect his idea with a patent. Each year around 20,000 patents are taken out by UK residents and of these around 4,000 are from individual inventors rather than businesses and universities. However, before you dash off to the Patent Office with a sheaf of diagrams, it might be wise to check if your idea is patentable at all and on the necessary steps and likely costs of the process. This article explains it all.

Certain types of thermoplastics exhibit piezoelectric properties and these materials can be formed into sheets, thin films or cables. In this article we take a look at piezoelectric cable and show how it can easily be used in a variety of applications by the hobbyist.

The article also provides full constructional details for two simple projects: A Distributed Microphone which uses the cable taped to a window pane, piano soundboard, etc., as a simple acoustic transducer, plus an amplifier and headphones. And a Vibration Alarm, where the cable can be clipped to a fence to detect intruders, or used for door or window security, vehicle detection, etc.

### **RC-METER**

A PIC controlled radio control meter for testing RC transmitters, receivers and servos.

The transmitter frequency, number of channels, frame time and individual channel pulse widths of up to eight channels can be displayed simply by holding the RC transmitter close to the unit. The RC-METER transmitter pulse detector system will only detect pulse data from radio control transmitters using 100 per cent amplitude modulation. However, the frequency readout will operate as long as at least 4ms of transmitted signal is detected, so it can still be used with the more modern FM transmitters.

By connecting a flying lead from one of the radio control receiver's channel outputs to the RC-METER connector, the meter can display the received pulse width and frame time. The meter can also produce a servo drive signal, mimicking the output of a receiver.

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**8 OHM PM SPEAKERS**, size 8" x 4", pack of 2. These may be slightly rusty and that is why they are so cheap, but are electrically OK, Order Ref: D102.  
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**13A SOCKET**, virtually unbreakable, ideal for trailing lead, Order Ref: D95.  
**PIEZO BUZZER** with electronic sounder circuit, 3V to 9V d.c. operated, Order Ref: D76.  
**DITTO** but without internal electronics, pack of 2, Order Ref: D75.  
**LUMINOUS ROCKER SWITCH**, approximately 30mm sq, pack of 2, Order Ref: D64.  
**ROTARY SWITCH**, 9-pole 6-way, small size and 1/4" spindle, pack of 2, Order Ref: D54.  
**FERRITE RODS**, 7" with coils for Long and Medium waves, pack of 2.  
**DITTO** but without the coils, pack of 3.  
**SLIDE SWITCHES, SPDT**, pack of 20, Order Ref: D50.  
**MAINS DP ROTARY SWITCH** with 1/4" control spindle, pack of 5, Order Ref: D49.  
**ELECTROLYTIC CAP, 800µF** at 6-4V, pack of 20, Order Ref: D48.  
**ELECTROLYTIC CAP, 1000 + 1000µF** 12V, pack of 10, Order Ref: D47.  
**MINI RELAY** with 5V coil, size only 26mm x 19mm x 11mm, has 2 sets changeover contacts, Order Ref: D42.  
**MAINS SUPPRESSOR CAPS, 0.1µF 250V a.c.**, pack of 10, Order Ref: 1050.  
**TELESCOPIC AERIAL**, chrome plated, extendable and folds over for improved FM reception, Order Ref: 1051.  
**MES LAMP HOLDERS**, slide onto 1/4" tag, pack of 10, Order Ref: 1054.  
**PAX TUBING**, 1/2" internal diameter, pack of 2, 12" lengths, Order Ref: 1056.  
**ULTRA THIN DRILLS**, 0.4mm, pack of 10, Order Ref: 1042.  
**20A TOGGLE SWITCHES**, centre off, part spring controlled, will stay on when pushed up but will spring back when pushed down, pack of 2, Order Ref: 1043.  
**HALL EFFECT DEVICES**, mounted on small heatsink, pack of 2, Order Ref: 1022.  
**12V POLARISED RELAY**, two changeover contacts, Order Ref: 1032.  
**PAXOLIN PANEL, 12" x 12"**, 1/16" thick, Order Ref: 1033.  
**MINI POTTED TRANSFORMER**, only 1.5VA 15V-0V-15V or 30V, Order Ref: 964.  
**ELECTROLYTIC CAP, 32µF** at 350V and 50µF section at 25V, in aluminium can for upright mounting, pack of 2, Order Ref: 995.  
**PRE-SET POTS**, 1 megohm, pack of 5, Order Ref: 998.  
**WHITE PROJECT BOX** with rocker switch in top left-hand side, size 78mm x 115mm x 35mm, unprinted, Order Ref: 1006.  
**6V SOLENOID**, good strong pull but quite small, pack of 2, Order Ref: 1012.  
**FIGURE-8 MAINS FLEX**, also makes good speaker lead, 15m, Order Ref: 1014.  
**HIGH CURRENT RELAY**, 24V a.c. or 12V d.c., 3 changeover contacts, Order Ref: 1016.  
**LOUDSPEAKER**, 8 ohm 5W, 3-7" round, Order Ref: 962.  
**NEON PILOT LIGHTS**, oblong for front panel mounting, with internal resistor for normal mains operation, pack of 4, Order Ref: 970.  
**3.5MM JACK PLUGS**, pack of 10, Order Ref: 975.  
**WANDER PLUGS**, pack of 10, Order Ref: 986.  
**PSU**, mains operated, two outputs, one 9.5V at 550mA and the other 15V at 150mA, Order Ref: 988.  
**ANOTHER PSU**, mains operated, output 15V a.c. at 320mA, Order Ref: 989.  
**PHOTOCELLS**, silicon chip type, pack of 4, Order Ref: 939.  
**LOUDSPEAKER**, 5" 4ohm 5W rating, Order Ref: 946.  
**230V ROD ELEMENTS**, 500W terminal ended, 10" long, pack of 2, Order Ref: 943.  
**LOUDSPEAKER**, 7" x 5", 4ohm 5W, Order Ref: 949.  
**LOUDSPEAKER**, 4" circular, 6ohm 3W, pack of 2, Order Ref: 951.  
**FERRITE POT CORES**, 30mm x 15mm x 25mm, matching pair, Order Ref: 901.  
**PAXOLIN PANEL**, 8 1/2 x 3 1/2 with electrolytics, 250µF and 100µF, Order Ref: 905.  
**CAR SOCKET PLUG** with PCB compartment, Order Ref: 917.  
**4-CORE FLEX** suitable for telephone extensions, 10m, Order Ref: 918.  
**VERO OFF-CUTS**, approximately 30 square inches of useful sizes, Order Ref: 927.  
**PROJECT CASE**, 95mm x 66mm x 23mm with removal lid held by four screws, pack of 2, Order Ref: 876.  
**SOLENOIDS**, 12V to 24V, will push or pull, pack of 2, Order Ref: 877.

**2M MAINS LEAD**, 3-core with instrument plug moulded on, Order Ref: 879.  
**TELESCOPIC AERIAL**, chrome plated, extendable, pack of 2, Order Ref: 884.  
**MICROPHONE**, dynamic with normal body for handholding, Order Ref: 885.  
**CROCODILE CLIPS**, superior quality flex, can be attached without soldering, 5 each red and black, Order Ref: 886.  
**BATTERY CONNECTOR** FOR PP3, superior quality, pack of 4, Order Ref: 887.  
**LIGHTWEIGHT STEREO HEADPHONES**, Order Ref: 898.  
**PRESETS**, 470 ohm and 220k, mounted on single panel, pack of 10, Order Ref: 849.  
**THERMOSTAT** for ovens with 1/4" spindle to take control knob, Order Ref: 857.

**12V-0V-12V 10W MAINS TRANSFORMER**, Order Ref: 811.  
**18V-0V-18V 10W MAINS TRANSFORMER**, Order Ref: 813.  
**AIR-SPACED TRIMMER CAPS**, 2pF to 20pF, pack of 2, Order Ref: 818.  
**AMPLIFIER**, 9V or 12V operated Mullard 1153, Order Ref: 823.  
**2 CIRCUIT MICROSWITCHES**, pack of 4, Order Ref: 825.  
**LARGE SIZE MICROSWITCHES**, (20mm x 6mm x 10mm), changeover contacts, pack of 2, Order Ref: 826.  
**MAINS VOLTAGE PUSH SWITCH** with white dolly, though panel mounting by hexagonal nut.  
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All with 220V/240V primary winding  
**0V-30V + 0V-30V** at 120VA would give you 30V at 4A or 60V at 2A, price £8, Order Ref: 8PG2.  
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**0V-35V + 0V-35V** at 150VA would give you 35V at 4A or 70V at 2A, price £8, Order Ref: 8PG9.  
**0V-35V + 0V-35V** at 220VA would give you 35V at 6 1/2A or 70V at 3 1/4A, price £9, Order Ref: 8PG4.  
**0V-110V + 0V-110V** at 220VA would give you 110V at 2A or 220V at 1A, price £10, Order Ref: 10PG5.  
**0V-45V + 0V-45V** at 500VA would give you 45V at 11A or 90V at 5 1/2A, price £20, Order Ref: 20PG7.  
**0V-110V + 0V-110V** at 500VA would give you 110V at 5A or 220V at nearly 3A, price £25, Order Ref: 25PG8.

## NORMAL MAINS TRANSFORMERS

**5V 45A**, £20, Order Ref: 20P16.  
**6V 1A**, 2 for £1, Order Ref: 9.  
**8V 1A**, £1, Order Ref: 212.  
**9V 1/2A**, 2 for £1, Order Ref: 266.  
**9V 1A**, £1, Order Ref: 236.  
**9V 3A**, £2, Order Ref: 2P408.  
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**12V 1 1/2A**, £1.50, Order Ref: 1.5P41.  
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**18V 1 1/2A**, £1, Order Ref: 491.  
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**24V 1A**, £2, Order Ref: 2P413.  
**24V 1 1/2A**, £2.50, Order Ref: 2.5P15.  
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**40V 2A**, £3, Order Ref: 3P107.  
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**675V 100mA**, £5, Order Ref: 5P166.  
**4kV 2mA**, £5, Order Ref: 5P139.  
**6V-0V-6V 5VA**, 2 for £1, Order Ref: 612.  
**6V-0V-6V 10VA**, £1, Order Ref: 281.  
**7.5V-0V-7.5V 8VA**, £1, Order Ref: D104.  
**7.5V-0V-7.5V 50VA**, £4, Order Ref: 4P98.  
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**12V-0V-12V 3VA**, £1, Order Ref: 636.  
**12V-0V-12V 6VA**, £1, Order Ref: 811.  
**12V-0V-12V 30VA**, £2.50, Order Ref: 2.5P15.  
**15V-0V-15V 1VA**, £1, Order Ref: 937.  
**15V-0V-15V 15VA**, £2, Order Ref: 2P68.  
**15V-0V-15V 25VA**, £2.50, Order Ref: 2.5P24.  
**18V-0V-18V 10VA**, £1, Order Ref: 813.  
**20V-0V-20V 10VA**, £1, Order Ref: 812.  
**20V-0V-20V 10VA**, £2, Order Ref: 2P85.  
**20V-0V-20V 20VA**, £2, Order Ref: 2P138.  
**20V-0V-20V 40VA**, £3, Order Ref: 3P205.  
**20V-0V-20V 80VA**, £4, Order Ref: 4P36.  
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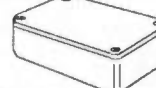
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VOL. 27 No. 3

MARCH '98

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## BIGGER THAN EVER

What you have in your hands is one of the biggest issues we have ever produced. Many months ago John Becker, our Technical Editor, suggested we publish a tutorial on PICs. Over the months this has taken shape from John's initial thoughts and investigations into what we believe is the best introduction to PIC microcontrollers ever written.

As it developed, the course gave us a problem - we wanted to publish the series fairly quickly, as many readers were clamouring for just this information, but we were already running *Teach-In '98* which takes up around eight pages of the magazine each month. Unless we threw out some regular features, or some projects, there just was not room for the PIC material. Furthermore, two tutorial type series running together for about six months would, no doubt, put off the readers who were not interested in either subject. Although we suspected the number of such readers would be very small, we had no wish to alienate them.

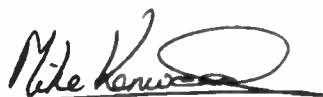
The obvious answer was to run John's *EPE PIC Tutorial* series as extra supplements, in that way we could retain the regular content of the magazine and add in the new series, hopefully keeping everyone happy. We have also decided not to let the *EPE PIC Tutorial* series spread over too many months - hence the increase of 16 pages for the FREE Special Supplement in this issue, and similar FREE supplements in the April and May issues.

## SENSITIVE

Moving away from microcontrollers, microprocessors and microcomputers and firmly back to the hobbyist who wants to experiment with simple circuits, next month we have a couple of very unusual "experimental" projects. They are both based around piezoelectric sensor cables which, frankly, I had not previously come across. These cables look just like ordinary screened leads but are made from PVDF (polyvinylidene fluoride) which is a piezoelectric material. This means that any movement, vibration, etc., experienced by the cable is turned into a small electrical signal which is easily sensed at the cable end.

Our two simple projects use this cable, one as a Distributed Microphone, which can use a window pane or part of a musical instrument, i.e. piano soundboard, with a short length of cable taped to it as a microphone. The other is a Vibration Sensing Alarm with many possible applications including: Fence Alarm, Door or Window Security, Pressure Pad Alarm, Parking Aid, etc.

I am sure you will find this article informative and the piezoelectric cable fascinating. No doubt many readers will come up with individual and unusual uses for the cable.



## AVAILABILITY

Copies of *EPE* are available on subscription anywhere in the world (see below), from all UK newsgagents (distributed by Seymour) and from the following UK electronic component retailers: Maplin - all stores throughout the UK (and in S. Africa); Greenweld Electronics; Cirkut Distribution; Omni Electronics. The magazine can also be

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

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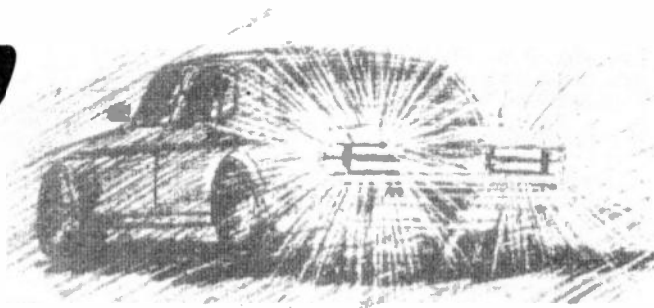
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## LIGHTING-UP REMINDER



**BART TREPAK**

*Don't be a hazard to other drivers, simply ensure your lights are on!*

**M**OST modern cars are now fitted with an alarm which sounds if the lights are left on when the ignition is switched off and the driver's door opened. This effectively eliminates the possibility of inadvertently leaving the lights on when leaving the car and returning to it to find that the battery has gone flat.

While the results of leaving lights on overnight can be embarrassing, especially when trying to start the car the next morning, they are not dangerous, unlike driving off in the evening and forgetting to switch the lights on in the first place. In major cities, where the street lighting is generally very good, it is quite easy to overlook the need to switch one's own lights on as the other traffic and pedestrians can be clearly seen.

Similarly, when undertaking a longer journey which begins when it is still daylight, dusk can also approach unnoticed, especially as one's eyes adapt to the diminishing light level. The driver is then subjected to flashing headlights of other motorists as they attempt to remind him of his omission, often initially unsuccessfully as the signals are either taken to apply to someone else, or dismissed as a mild form of road rage by another driver in a hurry.

### KEEN INTEREST

The police also tend to take an interest in cars which show no lights as they think, not unnaturally, that the driver is not familiar with his vehicle and therefore suspect that it might be stolen. The driver is then stopped while his identity and ownership of the car are checked, which would be applauded if the car were really stolen, but is unlikely to please the motorist who might be in a hurry to get to his destination.

Considering the simplicity of the circuit required, it seems strange that an alarm to remind the driver to switch on his lights when it is getting dark is not included on

all cars. Indeed, it would be quite a simple matter to arrange especially if this were fitted as a standard feature by the manufacturer. But this is perhaps the kind of technical wizardry reserved for the top of the range models where such extras can be sold for exorbitant prices to a technically naive motorist with deep pockets.

Be that as it may, it was decided to make such a device but to avoid interfering with the vehicle wiring (who wants to work in the cold with grease up to their elbows under the bonnet of a car when they can sit comfortably over a warm soldering iron?), the Lighting-Up Reminder was designed to be left on the dashboard and operate from its own 9V battery. Modifications are suggested, however, for connecting the unit to the vehicle battery and ignition, if preferred.

### CIRCUIT DESCRIPTION

The function which the circuit is required to perform could hardly be simpler and can be stated as follows: if the light level is *low*, switch the alarm *on* and if it is *high* switch the alarm *off*.

In practice, things are a little more complicated because the circuit cannot be fitted with an on/off switch to enable it to be switched off when the lights have been switched on, as it may then be left off, which would defeat its purpose! This means that the current consumption in both the standby and the alarm state must be very low if the battery is to last for a reasonable time.

This is, of course, not a problem if the circuit is intended to be connected to the vehicle battery as the circuit can then easily be switched on and off by means of the ignition switch, and also off once the alarm has been given, by the lights switch when the lights are switched on.

Examination of the circuit diagram in Fig.1 will reveal that a very small number of components are required for the

Lighting-Up Reminder. It is not often that such a simple circuit is published which performs not only one useful function but two – and not a microprocessor in sight!

The circuit is basically a complimentary astable multivibrator with feedback via capacitor C1 setting the rate of oscillation.

Phototransistor TR3 is used to turn the oscillation on and off. When the light level is low, the impedance of TR3 will be high, allowing the circuit to oscillate. When the light level is high, the base (b) of TR2 will be held below 0.6V so holding TR2 turned off, preventing oscillation from occurring.

Potentiometer VR1 can be used to adjust the sensitivity. In practise, though, the author found its use to be unnecessary.

Since there is no OFF switch, the alarm, once triggered, will be continuous until the ambient light level increases again. A buzzer or sounder would soon become annoying, to say the least, so a light emitting diode (l.e.d.) was chosen to perform the alarm function instead. This is quite visible in the fading light even when mounted on a box placed on the dashboard.

To save current, the circuit flashes the l.e.d. instead of providing a continuous display. This is not only more noticeable than a steady light but, by making the flashes short and infrequent, say once every five seconds or so, less distracting.

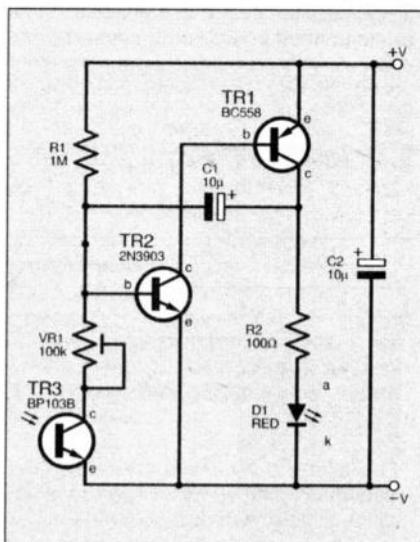


Fig.1. Complete circuit diagram for the basic Lighting-Up Reminder.

while the average current consumption is reduced to a very low level.

If wired separately from the ignition switch, the circuit can be in operation continuously even when the vehicle is left overnight. The l.e.d. then continues to flash during the hours of darkness and serve as a useful deterrent to potential thieves or joy riders, to whom a mysterious box on the dashboard emitting a flash of light every so often would signify an alarm of some sort, and therefore best left alone.

## CONSTRUCTION

The complete Lighting-Up Reminder circuit is built on a small printed circuit board (p.c.b.), for which the component layout and full size underside copper foil master are shown in Fig.2. This board is available from the *EPE PCB Service*, code 184.

None of the components are critical and assembly is quite straightforward. The phototransistor specified is housed in a clear l.e.d. type package as this makes it very easy to mount on a box by using a suitable l.e.d. clip. Note that the shorter lead on this component (adjacent to the flat portion of the rim) is the collector and the longer lead the emitter. There is no base connection.

It is a good idea to use a high intensity l.e.d. as this will attract attention more readily than a standard type.

The completed circuit may be tested before the phototransistor is fitted by connecting a 9V battery and checking that the l.e.d. flashes. Alternatively, the phototransistor may be fitted and shielded from ambient light, or the circuit taken into a dark room, where it should start oscillating.

Leaving potentiometer VR1 set to a mid-way position will probably be satisfactory in most situations.

Once the circuit is operating satisfactorily, it should be mounted in a small plastic box, large enough to take a 9V PP3 battery and the p.c.b. The completed unit can be placed on the car dashboard where it may be secured with a strip of double-sided adhesive tape if required.

Details of this are not given as this will depend on the particular box available and the personal preferences of the constructor. There are no heavy components on the printed circuit board and the whole circuit can easily be mounted in the box supported by the l.e.d. and phototransistor leads.

## CURRENT FACTORS

With a 9V supply, the l.e.d. only switches on for about 10ms about every five seconds with the components suggested. The average current drain is around 120 $\mu$ A when the light is flashing, falling to around 9 $\mu$ A when it is in stand-by mode. The l.e.d. current is about 60mA, but since it flows for a very short time, no damage occurs to the l.e.d. or transistor while providing a bright flash even at lower supply voltages.

Coupled to the fact that the circuit operates down to around 3V, it can be seen that a battery will last a long time. By increasing the value of the capacitor, the frequency of the flashes could be further reduced, decreasing the average current

drawn and further increasing the battery life.

Alternatively, the circuit may be powered from the 12V car battery via the cigar lighter socket. The circuit could also be "built into" the car and connected to the vehicle wiring, giving the possibility of switching the alarm off automatically once the warning had been heeded and the lights switched on.

This could be done by utilising the voltage that would now appear across the lights to switch on another npn transistor connected across the phototransistor which would disable the alarm, as shown in Fig.3.

## DASHED SIMPLE!

There is a better way, however, and one which can be used without modifying the circuit of Fig.1, or indeed making any connections to the vehicle wiring, except perhaps to the battery supply if this is felt desirable.

The light level at which the circuit will switch can be varied by adjusting potentiometer VR1 as this will depend to a large extent on the position of the phototransistor within the car. By mounting the unit under the dashboard, for example, where it will be somewhat darker, the circuit will begin to flash when the light level is higher than it would if the circuit were mounted directly behind the windscreen.

A good place would be just in front of the steering wheel where the speedometer and other instruments are located, although care should

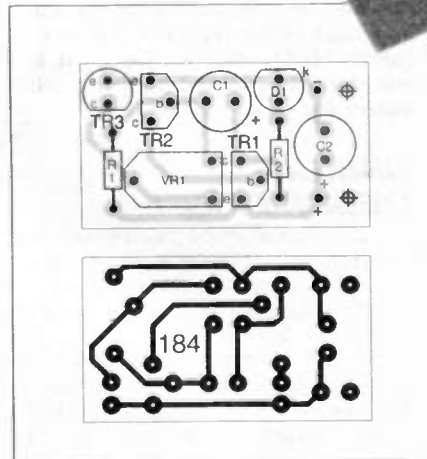
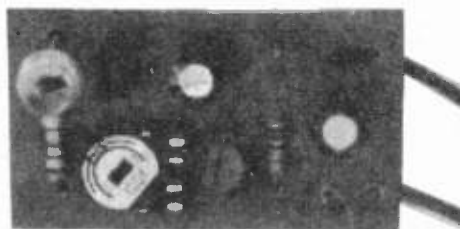


Fig.2. Printed circuit board component layout and full size copper foil master pattern.



Completed prototype printed circuit board.

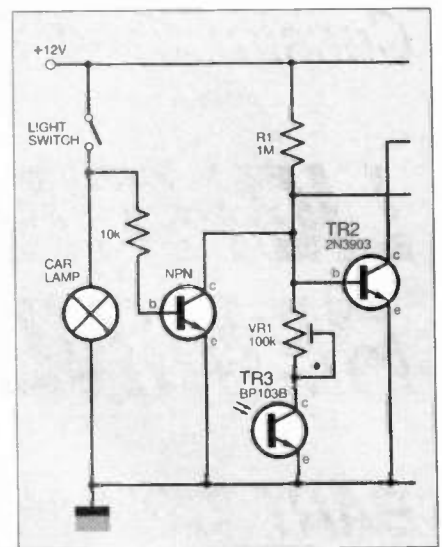


Fig.3. Disabling the circuit when lights are switched on.

## COMPONENTS

### Resistors

R1 1M  
R2 100 $\Omega$   
All 0.25W 5% carbon film.

See  
**SHOP**  
**TALK**  
Page

### Potentiometer

VR1 100k min. preset, horiz

### Capacitors

C1, C2 10 $\mu$  radial elect. 16V  
(2 off)

### Semiconductors

D1 5mm standard red l.e.d.  
TR1 BC558 npn transistor  
TR2 2N3903 npn transistor  
TR3 BP103B npn phototransistor

### Miscellaneous

B1 PP3 battery, with connector (see text)  
Printed circuit board, available from the *EPE PCB Service*, code 184; plastic box, size to choice; l.e.d. clip; connecting wire if transistor mounted off-board (see text); solder pins; solder, etc.

Approx Cost  
Guidance Only

**£12**  
excl. battery

be taken to ensure that the driver's view of these is not obstructed. Here, it would be sheltered from the direct glare of street lights and the phototransistor would also be illuminated by the instrument lights which come on as soon as the vehicle lights are switched on and would thus serve to switch the circuit off.

## BULB FAILURE WARNING

By mounting the phototransistor close to one of the vehicle lights being switched, the circuit would provide a third function as well. This is shown in Fig.4 and as well as acting as a lighting-up reminder and burglar deterrent, it would also perform another very useful service by providing a "lamp failure warning" when the car lights switch is turned on.

This is achieved because the l.e.d. would continue to flash if the relevant bulb did not turn on when the light switch was operated, instead of stopping, as would be the case if the phototransistor was illuminated by a "working" bulb.

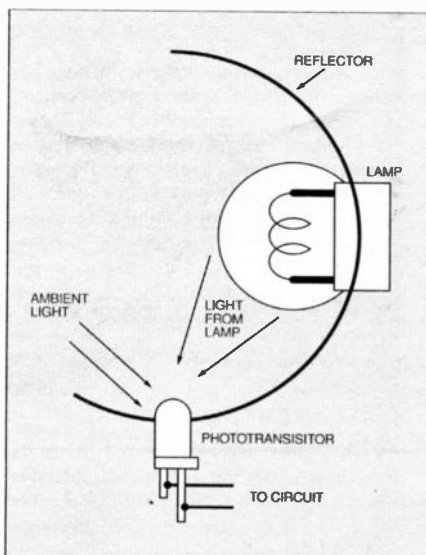
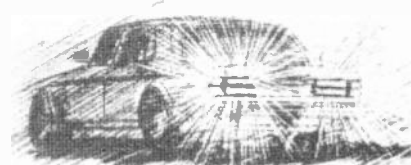


Fig.4. Mounting the sensor phototransistor in the car light reflector will give a "bulb failure" feature. You will need to build a complete unit for each lamp to be monitored.

To do this, the phototransistor would need to be mounted remote from the rest of the unit (which would be inside the car on the dashboard) and connected to it by means of a suitable length of twin cable.

Since the phototransistor may then be more exposed to the elements, depending on the position and the way it is mounted, care should be taken to ensure that water does not come into contact with any of the connections.

To monitor all the car's lights, it would probably be easier to build four Reminder circuits rather than trying to arrange for four phototransistors to control one flasher circuit. This would also give an indication as to which lamp had failed and, since the cost of the components is minimal, worth the extra effort. □



## SHOP TALK with David Barrington

### EPE PIC Tutorial (Supplement)

Most of the components needed for the *EPE PIC Tutorial* printed circuit board (p.c.b.) should be available from many of our component advertisers - study their adverts. The only criterion, apart from technical spec., is will they fit on the p.c.b.?

All switches for the prototype model are RS components and were purchased through **Electromail** (☎ 01536 204555), their retail outlet. Quote the following codes if ordering from them: the d.i.l. 4-pole changeover (S1-S4), code 337-554; the p.c.b. mounting push-to-make can be either 320-900 (cheaper) or 321-650 types; the d.i.l. 1-pole changeover, 336-674; for the 8-way d.i.l. slide switch quote code 103-0771.

We understand that **Magenta Electronics** (☎ 01283 565435) are putting together a kit of parts, excluding Zif socket and displays, for the sum of £27.95 (£42.95 built and tested), add £3 for p&p. The Zif socket and displays are being offered separately. Readers might also like to check out the **ESR Electronic Components Web site** at: <http://www.esr.co.uk>.

The printed circuit board for the *PIC Tutorial* is available from the **EPE PCB Service**, code 182 (see page 235). The software is also available from the Editorial Offices on a 3.5 inch PC-compatible disk, order as *PIC-Tutor*. There is a nominal charge of £2.75 each (UK) to cover admin costs, the actual software is free. For overseas readers, the charge is £3.35 surface mail and £4.35 airmail.

Alternatively, the *PIC Tutorial* software can be downloaded free from the **EPE Web site**:

<ftp://ftp.epemag.wimborne.co.uk/pub/PICS/PICtutor>.

### The Handy Thing

With surface mount components being so small, it should come as no surprise to readers that component suppliers only offer these for sale in packs of 10 plus. Even so, some of these are still reasonably priced.

For the potentiometer, a knob-pot has been specified for *The Handy Thing* as they are very compact, having the resistive element inside the knob itself. The one in the model is a 1W P16NP series linear cermet type and came from **Farnell** (☎ 0113 263 6311), code 350-655. At around £4, readers may opt to use a standard miniature pot instead, plus a separate knob.

The very fine Kynar wire (30 a.w.g.) is a silver coated "wirewrap" wire and was chosen for ease of soldering. It should be stocked by most good component suppliers.

If problems are experienced in finding the SOT23 surface mount transistor, the author obtained his from **Gothic Crellon** (☎ 0118 978 7848). The box came from **Maplin**, code FX73Q.

The small double-sided printed circuit board is obtainable from the **EPE PCB Service**, code 183.

### Lighting-Up Reminder

Although the components required for the *Lighting-Up Reminder* project are not critical, it was thought best to use a highly sensitive phototransistor and a high intensity light emitting diode (l.e.d.) in this very simple circuit.

The BP103B npn phototransistor was tracked down to **Maplin**, code CY87U. Other component suppliers will, no doubt, be able to offer a suitable alternative device.

The small printed circuit board is available from the **EPE PCB Service**, code 184. If you wish to monitor four sets of car lights you will need to obtain four p.c.b.s.

One final point, unless you are a wizard with car wiring, it is recommended you stick to the stand-alone version.

### Switch-Activated Burglar Alarm

Just a few general guidelines are needed concerning the supply of parts for the *Switch-Activated Burglar Alarm*.

The circuit should work with almost any 12V relay that has a coil resistance of about 300 ohms or more. However, if it is to fit on the circuit board the "high power" relay specified should be used. This is an ultra miniature, single-pole, changeover 10A mains relay stocked by **Maplin**, code YX97F.

If the unit is to be mounted where it can be easily spotted, you should use a key-operated switch for the "arm" switch S1. This should be generally available.

It is advisable to buy sensor switches that are specifically designed for use in burglar alarm systems rather than trying to improvise using general purpose components. Bear in mind that only the surface mounting switches and magnets are suitable for use with most plastic and metal windows and doors. You could try contacting **Bull Electrical**, **J&N Factors** and **Maplin**, who may be able to offer a variety of security switches (see their adverts for contact numbers).

### Audio System Remote Controller

Several of the parts called up for the *Audio System Remote Controller* will have to be ordered specially if they are to fit on the p.c.b.

Starting with the LMC1983 audio controller, this was purchased from **Maplin**, code GX48C. This was the only source we were able to find, and, at the time of writing, they informed us that they only had a few left. If any reader finds another source perhaps they can let us know.

Next the IS1U60 infra-red receiver. The only source appears to be **Electromail** (☎ 01536 204555), code 577-897. The 12V 280 ohm coil relay came from **Maplin**, code DC80B, and fits directly on the power supply p.c.b. The mains transformer (code YJ50E) and the insulated phone socket panel (code JK17T) also came from the latter company.

The two printed circuit boards are available from the **EPE PCB Service**, codes 185 (PSU) and 186 (Main Board). The software can be downloaded free from our Web site:

<ftp://ftp.epemag.wimborne.co.uk/pub/PICS/Remote>.

A ready-programmed PIC16C84 is available (mail order only) from **Mark Skeete** for the sum of £15. Payment should be made out to **Mr. M. Skeete** and sent to: **Mr. M. Skeete, 39 Sedgwick Road, Leyton, London, E10 6QP**.

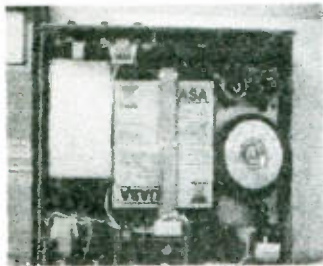
### PLEASE TAKE NOTE

#### PIC Noughts & Crosses Game (Sept '97)

Our PIC Disk-1 and web site have been updated to include the author's changes to the source code format for this software. The hex codes remain unchanged.

#### Surface Thermometer (Jan '98)

Page 70. Calibration should be undertaken with the Multimeter connected between IC2 pin 7 and IC2 pin 14 (not 0V).



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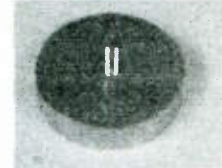
**BBC selector videocrypt 's'  
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Interesting new item in this week is this Selector. Originally made for the BBC to send encrypted video films to your VCR at night time. The project seems to have failed.

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These units are sold as strippers but we imagine you could use one to convert a monitor into a TV or maybe use the videocrypt side of things for something else. Supplied complete with manual and mains lead. Clearance price just £9.95 ref BBC1X.



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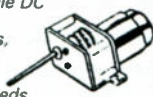
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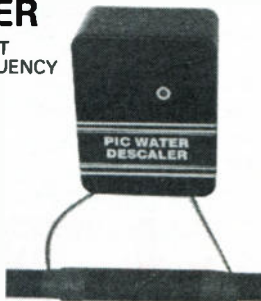
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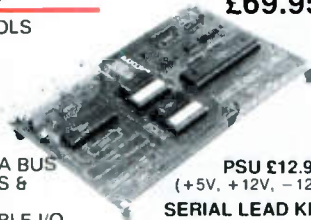
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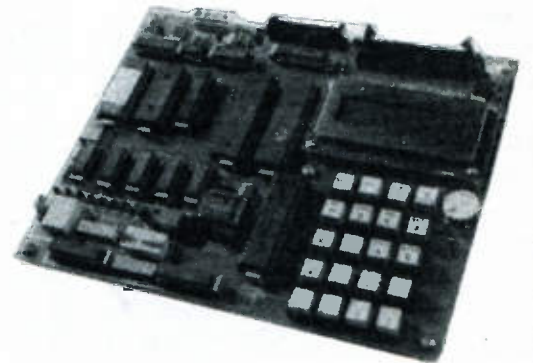
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# THE HANDY THING

**BILL MOONEY**

*This is an amazing Thingy - it does almost as much as the Swiss Army Knife, just by divining static electricity fields!*

**T**HIS project is an electronic analogue of the Swiss Army Knife. It probably can't be used for predicting earthquakes or eclipses, but it will do just about everything else.

It will detect static electricity, track interference and live wires, test continuity and assess very high resistances. The creative user will no doubt come up with several other useful functions.

## ORIGINS

A new version of the old mains tester appeared on the market recently, but instead of a small neon lamp, it contained a light emitting diode (l.e.d.) driven by an electronic circuit and powered by a couple of button cells.

It is a remarkable device, offering all the functions above in the form of a small terminal driver. As an electronics designer, the author was, of course, curious as to how it managed to do all this and set about designing a version for amateur construction.

One can't expect to engineer the screwdriver (!) but a project box would be acceptable if some extra features were added to compensate. Observing the behaviour of the device and a few back-of-the-envelope schematics soon lead to a plausible circuit which could perform in a similar way. The functional schematic is shown in Fig. 1.

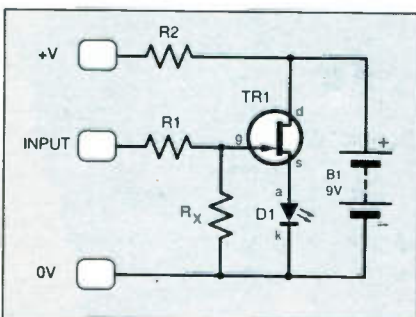
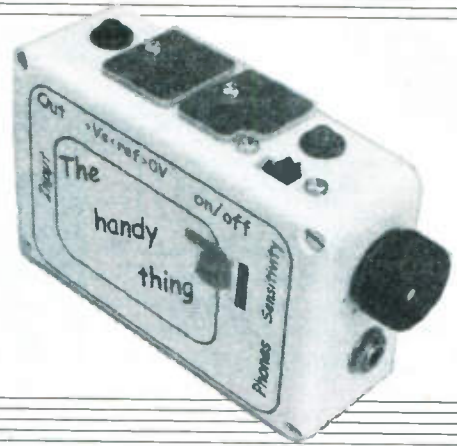


Fig. 1. Functional schematic circuit diagram of The Handy Thing.



increases, the gate becomes increasingly negative compared to the source and eventually reaches the pinch-off point of the f.e.t.

At this point, the current in the l.e.d. is still very low, its resistance high, and it is effectively off. A positive-going voltage on the gate causes the f.e.t. to turn on again, increasing the voltage on the l.e.d. to the point where its resistance decreases and it lights.

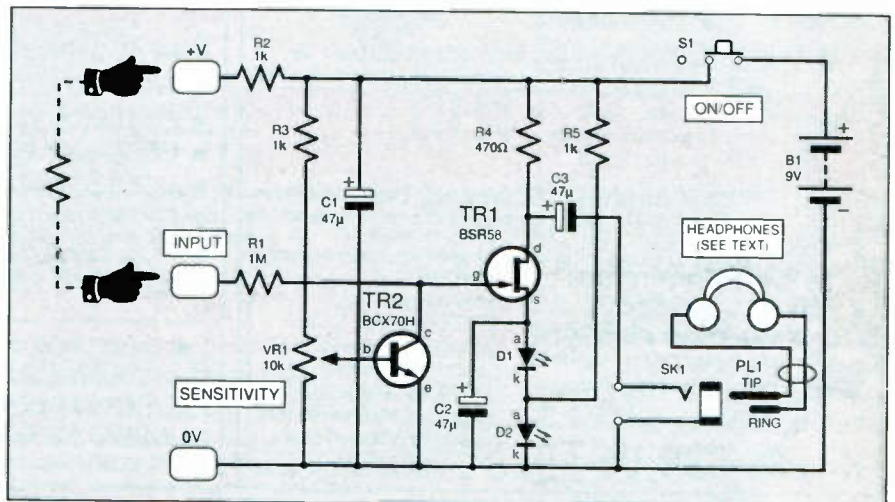


Fig. 2. Final circuit diagram for The Handy Thing.

It is called a *Handy Thing* not only because it is just that, but because the hands and body resistance of the operator play a vital role in its operation.

In standby mode, this circuit will draw negligible current, a fraction of a microamp. Also, like the commercial device, it has a very high input impedance. Placing the small input plate near a positive electric field results in an induced gate voltage, causing the field effect transistor (f.e.t.) TR1 to conduct and the output l.e.d. D1 to light.

Variations in input voltage produce corresponding changes in the brightness of the output l.e.d. The high input impedance means that practically no power is drawn from the charged body under test. Electric fields can therefore be readily detected, both static and alternating.

An elegant feature of this circuit is the dual function of the output l.e.d., which is in the source (s) path of the f.e.t. The complex resistive properties of this diode allows it to provide the gate bias for the circuit. The gate is held at 0V by resistor  $R_x$  so, as the voltage on the l.e.d.

Now we see the principle on which The Handy Thing works. For example, touching the positive (+V) plate at the same time as the input plate causes the voltage on the gate to rise, so lighting the l.e.d. - a test of continuity.

For best utility from the device, this functional circuit should be kept in mind. But a few refinements are necessary to make the unit more practical.

## WORKING CIRCUIT

To make a real working version of Fig. 1, the circuit must become a little less elegant. The first problem is the impractical value of the input resistor  $R_x$ . The highest value resistors which are readily available, 1MΩ (one megohm) or even 10MΩ are much too low if the very high input impedance of the f.e.t. is to be utilised.

Banks of 10MΩ resistors are practical up to 200MΩ or so but, ideally, we want something like 500MΩ or even 1000MΩ. An *npn* transistor, TR2, connected across the input as shown in Fig. 2, provides an ideal solution with the added advantage that the parameters can be varied widely.



When this transistor is off, i.e. no current flowing into the base (b), the collector (c) appears as an insulator with no connection between f.e.t. gate (g) and ground (0V).

Under these circumstances, a charge placed on the gate will remain there, holding the f.e.t. on (high positive charge), or off (high negative charge), or at some intermediate state.

This is of limited use and requires the gate to be discharged before each measurement. Potentiometer VR1 is a variable source of bias for transistor TR2 and at around 0.6V, the base begins to draw current, thus causing a minute current to flow in the collector circuit.

Transistor TR2 effectively becomes a very high value resistor from gate to 0V and it discharges the gate capacitance continuously. Potentiometer VR1 can easily be adjusted to give any required input impedance and discharge rate. The discharge rate is linear with time since the collector is a constant current source and this conveniently gives a clean end point.

A real resistor would produce a tailing effect which would be a little less effective. Although its action is a bit more complex, VR1 can be considered as a Sensitivity control adding valuable flexibility to the device. The most useful setting corresponds to a discharge time of about one second.

## BIAS POINT

The second difficulty concerns the f.e.t. bias point. Most l.e.d.s are well alight with a supply of 3V, the most common f.e.t. turn-on point. Since f.e.t.s with very low pinch-off are not so common, a better solution is to use two l.e.d.s in series, and this works nicely.

A circuit of this type would strictly not need an on/off switch but this device is likely to be on the shelf for long periods of time and even a small leakage will flatten the battery. It could also be inadvertently placed near a static source or a live mains field and draw considerable current.

Using an on/off switch (S1) and making one of the l.e.d.s a supply indicator gives it a useful function. The l.e.d. D2 in Fig.2 is supplied by a 1k $\Omega$  resistor, R5, and is permanently on when the supply is present.

The 3V on this l.e.d. is, therefore, added to the voltage on l.e.d. D1 to provide the gate bias. In standby mode with no input, the current through D1 is negligible. When an input is present, the currents combine in D2 which changes a little in brightness with increasing input, but this is of no consequence.

Other elements in the circuit are more straightforward. A drain load (resistor R4) for TR1 develops a low impedance audio signal which can be monitored via capacitor C3 using a pair of stereo headphones. These can be wired in series to give a load of 64 ohms.

Capacitor C2 partly decouples the l.e.d.s to a.c. signals, giving increased gain to mains 50Hz and noise. Resistor R1 protects the gate from damaging discharges; R2 protects the supply if plates +V and 0V are inadvertently contacted; R3 expands the useful range of the Sensitivity control VR1.

## CONSTRUCTION

The circuit is built on a double-sided printed circuit board (p.c.b.) using surface mount devices (SMDs). The second side the p.c.b. is simply unetched copper foil. Details of the component mounting side, together with full size master, are shown in Fig.3. It is available from the *EPE PCB Service*, code 183.

There is a temptation to go for a very small package when SMDs are involved. This could involve on-board l.e.d.s and possibly miniature solder-in lithium batteries. However, a more pedestrian approach is

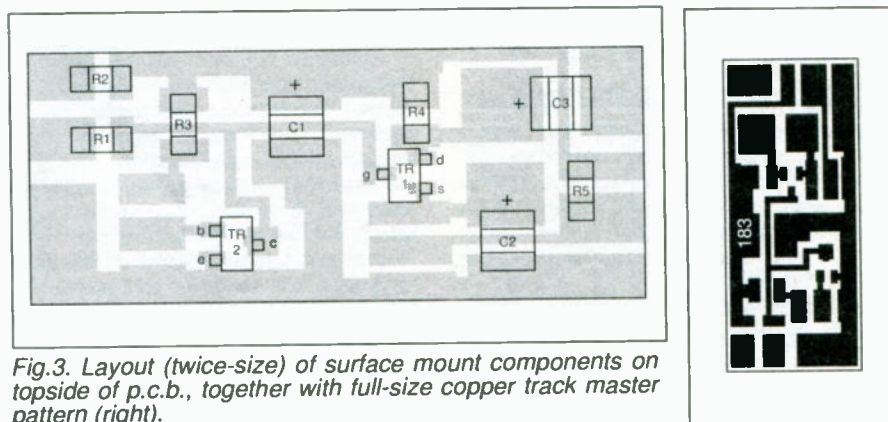


Fig.3. Layout (twice-size) of surface mount components on top side of p.c.b., together with full-size copper track master pattern (right).

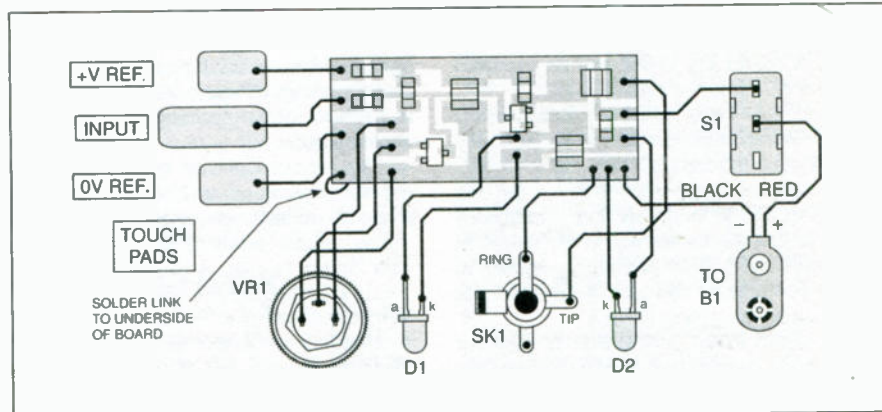


Fig.4. Interwiring between off-board components and p.c.b.

## COMPONENTS

### Resistor

R1 1M  
R2, R3, R5 1k (3 off)  
R4 470 $\Omega$   
All resistors SMD type 1206

See  
SHOP  
TALK  
Page

### Potentiometer

10k knob-pot (see text)

### Capacitors

C1 to C3 47 $\mu$  tant., SMD, 16V (3 off)

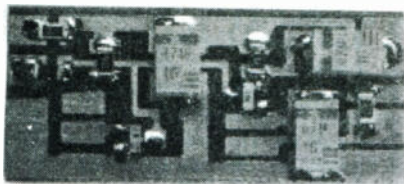
### Semiconductors

D1 red l.e.d., high brightness, 5mm dia.  
D2 yellow l.e.d., high brightness, 5mm dia.  
TR1 BSR58 j.f.e.t., SMD SOT23  
TR2 BCX70H npn transistor, SMD SOT23

### Miscellaneous

S1 min. s.p.s.t. slide switch  
SK1 3.5mm mono jack socket  
B1 PP3 9V battery  
Printed circuit board, double-sided, available from the *EPE PCB Service*, code 183; l.e.d. mounting clip, 5mm (2 off); plastic case, 75mm x 50mm x 25mm; Kynar connecting wire; M2 round head nuts and bolts; sensing pads (see text); rework flux; solder, etc.

Approx Cost  
Guidance Only **£17**  
excluding batt.



Surface mount components on completed circuit board.

described here for general construction, which is nonetheless still quite compact.

Before commencing component assembly, lightly spray the p.c.b. trackside with rework flux. This will provide a hard protective coating when dry and will help stop the SMDs from sliding about when soldering them.

It is good practice to solder the f.e.t. (TR1) in place last of all. The general method of adding SMDs (in a hobbyist situation) is to solder one end in place while holding the chip down with non-magnetic tweezers. To do this a small quantity of solder is carried on the iron bit to the joint (contrary to normal advice regarding soldering!).

Having anchored one end, the second can be soldered by the more effective technique of placing the solder on the pad at the same time as the iron. By this method more flux is present to protect and clean the copper pad and component contacts, resulting in a cleaner job. The first end can then be resoldered to make a better joint.

Silver loaded solder is available for surface mount work and has a slightly lower melting point. However, ordinary 60/40 alloy solder will work well for this type of non-critical work.

In this simple unit there are no tight spots, so the order of component addition is not important. Note the polarity of the tantalum capacitors, they are not reversible. The polarity of the l.e.d. is as indicated; as is that of the transistors, of course.

## CASING THE THING

The unit is conveniently built into a small plastic box measuring 75mm × 50mm × 25mm. The internal layout of the case and the interwiring are shown in Fig.4 and the photographs.

The case material is quite soft and one or two protrusions inside the case can be removed with a sharp modelling knife – to make the battery fit more snugly and to create a flat surface for one of the input sensing plate bolts.

Similarly, a small rectangle can be cut out for the on/off switch slider. All sensing plates and the on/off switch are held in place with 1.5mm × 6mm round head bolts. A solder tag inside the box is used for connection to the circuit board.

The “+V” and “0V” reference inputs can be made from double or single-sided copper-clad fibreglass, but the “input” plate must be single-sided to avoid the odd effects of charge build up. The dimensions of these electrodes are not very critical in this application and were largely chosen to fit the position on the unit. Suggested pad dimensions are given in Fig.5.

A 3.5mm mono jack socket is used for headphone connection. Ideally, the phones should be wired in series to a mono socket giving in-phase signals in each ear, but this means dedicating a pair of phones for this

purpose. Simply plugging in a pair of stereo phones to the mono socket gives one channel which is quite effective.

The other option is to use a stereo socket wired as mono and accept the out-of-phase nature of the signal. To do this, the two central conductors are connected as ground and signal, the screens being connected together and left floating.

For potentiometer VR1, a knob-pot is specified as they are very compact, having the resistive element inside the knob itself. A standard miniature potentiometer may be used instead, plus a separate knob.

It is advisable to mount all the hardware on the box and glue the populated p.c.b. in place before wiring up. Use the finest wire

size battery is recommended to give a reasonable service.

The current drive for l.e.d. D1 is largely determined by the value of resistor R4. Increasing its value would reduce the current drawn, but with a loss of brightness.

Assuming that the above test procedure works, the next action is to set the position of potentiometer VR1. To do this, cause l.e.d. D1 to turn on, as above, and then remove contact with the input plate so that the charge is retained.

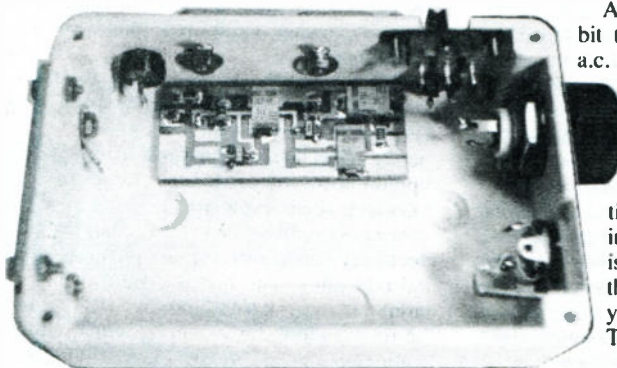
Now turn VR1 anticlockwise until the l.e.d. extinguishes. Repeat the operation, adjusting VR1 until it takes about a second or so to change from full brightness to fully extinguished.

All of these procedures can be a bit tricky if static fields or mains a.c. currents are nearby, but it becomes quite easy with practice. Shorter or longer time constants may be set in a similar manner.

The technique of operation varies according to the job in hand and some interpretation is often necessary. If you keep the functional diagram in mind you will gain most utility from The Handy Thing.

## CONTINUITY

Probably the most practical use for this device is for testing continuity. Examples of this



Positioning of components prior to interwiring. The p.c.b. could be held in place by self-adhesive double-sided pads or tape.

possible for hook-up. The author used Kynar wire-wrap wire because it is very fine at 30 a.w.g. and the silver plating ensures good soldering.

Some self-adhesive sponge tape under the battery will stop it from moving.

Finally, it is useful to label up the various functions. The least expensive approach is to simply design the label using a suitable computer program and print it out on paper. It is then glued in place and can be lacquered if required. A typical example of this flexible approach was used for the prototype as illustrated.

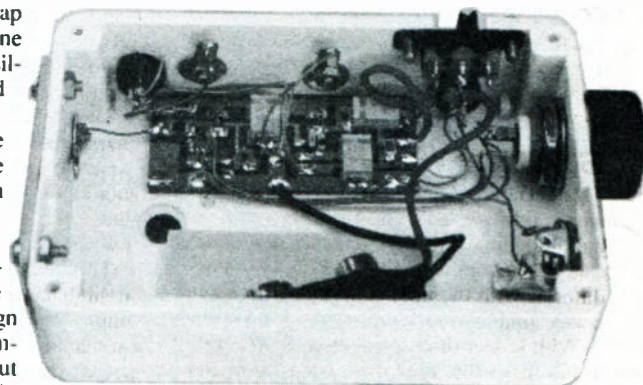
## SETTING UP

After a close visual inspection, the first job is to check the current drain as a general indication that all is well. With the output l.e.d. off, the standing current is about 7mA. This is all going into the on/off l.e.d., D2, and could be reduced even more by increasing the value of resistor R5, although with some loss of brightness and a less steady light output.

Turn the sensitivity control VR1 fully clockwise, i.e. to turn off transistor TR2. Next touch the input plate with left index finger whilst holding the right hand index finger on the +V plate. The output l.e.d., D1, should light to full brightness and remain on.

Continue to contact the input but transfer the right finger to the 0V plate and l.e.d. D1 should extinguish.

At full brightness the current drain is about 18mA and an alkaline PP3-



Completed interwiring to off-board components.

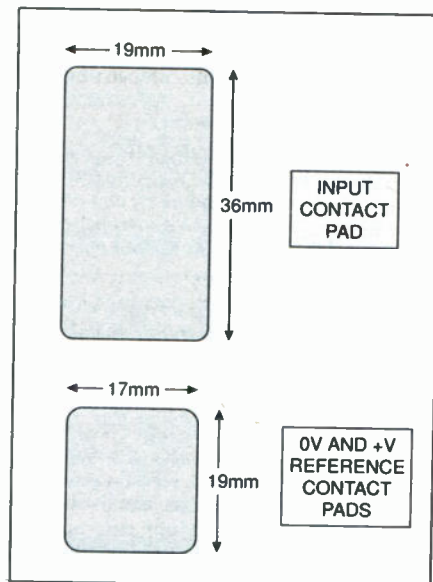


Fig.5. Suggested dimensions for the “p.c.b. touch pads”.

would be checking for blown fuses, open connections, blown bulbs and so on. For this function, the index finger of the right hand is contacted with the +V plate and the sensitivity control is set to the standard setting, of about one second time constant, as described above.

The fuse, or whatever, is held in the left hand, making electrical contact with one end. The free end is then placed in contact with the input plate. If the circuit is completed, a small current will flow into the gate resistor (R1) raising the voltage to approach +V and turning on TRI.

The l.e.d. D1 will light up in proportion to the conductivity, up to a point. Low value resistances, such as fuses, will result in the l.e.d. reaching full brightness. Be aware that blown items could still provide a high resistance path so that if there is any doubt, such as the l.e.d. not being fully on, the sensitivity control can be reduced to a shorter time constant.

Resistance assessment generally requires judicious use of the sensitivity control. Low value resistors up to 100kΩ or so can be distinguished with a very low time constant of about 0.1 seconds. Resistance in the 1MΩ to 10MΩ region require about 0.5 seconds.

Very high resistances greater than 100MΩ, found in static dissipative materials for example, require a time constant greater than one second, corresponding to maximum sensitivity. Under these circumstances, mains electrical fields and nearby static build-up can interfere with the test.

Diode operation can be checked easily using similar principles but reversing the connections to show unidirectional current flow.

## STATIC FIELDS

The Handy Thing will differentiate between positive and negative static charge build-up on insulating materials and indicate the voltage magnitudes. The start condition is with the time constant set to about one second.

With longer time constants you will need to discharge the input plate occasionally by momentarily touching it whilst maintaining contact with the 0V plate.

A useful experiment is to charge up a clean wine glass and a plastic container by giving their surfaces a couple of rubs with some clean cotton (not softened) or tissue paper.

Bring The Handy Thing input plate to within a few centimetres of the glass. Note that l.e.d. D1 lights up and remains on whilst approaching the charged surface, but extinguishes while moving back from the charged source.

Try this a few times. Even a short movement towards the glass lights the l.e.d. and similarly the smallest movement back extinguishes it. If it is held at a fixed position, the l.e.d. will extinguish in about a second.

In this experiment, you will have just determined a *positive* static charge on the glass, which is typical for this material.

Now repeat the experiment with the plastic container. The opposite response should now be found. Moving the input plate towards the charged surface will extinguish the l.e.d. and a slight movement away from the charge is required to light

Table 1. Main functions of The Handy Thing

FUNCTION	INPUT	+V	0V	SENSITIVITY	PHONES
Continuity Low Resistance <100k	Contact		—	Min ~ 0.1 sec.	—
Continuity Medium Resistance 1M ohm	Contact		—	Medium ~ 0.5 sec.	—
Continuity Very High Resistance >10M ohm	Contact		—	Max ~ 1 sec.	—
Damp Tracking	Wall contact		—	Variable	
Static Charge +Ve or -Ve	Proximity + ← — —	—		~ 1 sec.	
Interference	Proximity	—		1 sec. / variable	
Live Wire Tracing	Proximity ← - - - ->	—		1 sec. / variable	
Battery Check	Contact	—		Min ~ 0.1 sec.	—
Diode Check	Contact		—	Variable	—
Capacitor Check	Contact			Variable	—

the l.e.d. and detect its presence. This represents a *negative* static charge build-up, which is common on plastics.

These results are typical, but static electricity is a mysterious phenomenon and odd things can happen. Be especially careful if the relative humidity (RH%) in the room is low; for example, with central heating on and cold frosty weather outside.

Charge storage leads us to capacitor and battery operation. The Handy Thing will test to see if a capacitor is functioning. To do this test, connect the capacitor to the +V and 0V plates for a few moments to charge it up. Then connect the capacitor between 0V and the input such that the positive capacitor electrode contacts the input plate.

The l.e.d. should light, indicating that charge has been stored. Reversing the capacitor so that the input plate is negative should not light the l.e.d. Repeat this a few times just to be certain, particularly with low value capacitors; around 100pF.

This test gives an indication of leakage in high capacitance electrolytics, for example, by assessing how long they hold the charge. Larger capacitors can be connected using the body as a conductor, but devices in the picofarad range will have lower capacity than the body and should be connected directly to the plates.

For checking whether a battery is producing a terminal voltage, the 0V reference is contacted with a right finger, one battery terminal with a left finger and the second battery terminal contacts the input plate. Reversing the battery should light the output l.e.d. only when the +V contacts the input.

In most cases this go/no-go test will suffice, but some indication of the voltage is possible if the sensitivity control is calibrated. The prototype was marked at 1V and 30V by noting the setting where the l.e.d. switches on. This was for estimation of static field strength in volts per metre. It is left to you to develop this with your own Handy Thing.

## POWER CHECK

When tracking mains voltages with The Handy Thing, it detects the a.c. electrical field component on the line. It must be pointed out that this device is NOT designed for direct contact with live mains and there is no need to do so.

It is possible to get positive indications from the static charge on nearby objects, particularly in dry conditions. This difficulty can be overcome by reducing the sensitivity setting and by listening to the 50Hz signal with headphones.

Another useful indicator consists of waving The Handy Thing from side to side, sweeping rapidly over 20cm or so. If the signal is a.c. mains derived, the l.e.d. streak will be intermittent, whereas with static present the line is continuous.

In this way, live mains and interference sources from dimmer switches, for example, can be pinpointed. When tracing mains it is possible to get dips in the signal if the Live wire is eclipsed by the neutral and you should be aware of this.

Avoid going near exposed live conductors with the Handy Thing: if you get to this stage you should be using other techniques.

## WATER DIVINING

Finally, we come to water divining. An unexpected application of The Handy Thing is testing for dampness in walls. This involves the right index finger in contact with +V plate whilst pressing the input plate screw heads firmly against the wall. Conductivity through the damp wall injects current into the input.

The left hand can contact the wall, moving around to map out damp areas as indicated by increased brightness of the output l.e.d. This is certainly an area where you can develop techniques to match the prevailing conditions. One method which works well is as follows:

Contacting the +V plate, press the input onto the wall about one metre above floor level and adjust the sensitivity until the l.e.d. is just about extinguished. Move down the wall in increments, contacting it in 10cm steps, noting the brightness and backing off the sensitivity as required if the l.e.d. saturates.

This will map out damp patches quite well, but the technique is open to all sorts of errors, including mains electrical fields, static on the body, type of footwear, and so on.

Various functions of The Handy Thing are summarised in Table 1. Remember how the device is working and, like a divining rod, the results may need a little intuitive interpretation.

## RECORDING UNHAPPINESS

Barry Fox reiterates the music industry's unhappiness over recordable CDs.

**T**HIS YEAR looks all set to become a very unhappy one for the music industry. The product everyone has been waiting for, a recordable CD that works like magnetic tape but gives rapid access without the need to rewind, is finally reaching the shops. Technical bugs are being ironed out, prices are falling faster than expected and the computer industry has now broken down the artificial barriers built by the record companies to discourage home copying of CDs and vinyl LPs.

Philips makes at least half the recorders sold, under its own and other manufacturers' brand names, and estimates that a total of two million will have been sold in 1997 and five million will sell in 1998. Because recordable CD is not a new format which will eventually create a new market for prerecorded music, the music industry stands to gain nothing from its success.

The first CD-recorders cost £1000 and used only CD-R, write-once, blanks to record either computer data or music. Tracks and files can be deleted from a CD recording, by altering the disk's index of contents so that a player cannot read the deleted data. But the space is not recovered for re-use.

New erasable recorders, for use with PCs or a home hi-fi, cost between £300 and £500 and can use either write-once CD-R blanks or erasable CD-ReWritable disks. CD-RWs rely on phase change technology; a coating of rare earth material switches between amorphous and crystalline state when struck with a laser beam, and this slightly changes its reflectivity.

Until now, CD-RW recorders would only allow the disk to be re-used after bulk erasure of all the stored information. Philips' new models use the Universal Disk Format to arrange data on the disk. This allows random erasure of music and computer file recordings so that an erasable CD behaves like a very high capacity floppy disk.

### Keeping on Track

At the record industry's request, there are two types of recordable CD blank. They each have an embossed groove in the surface to guide the laser during recording, and the groove undulates slightly to provide timing information. Blanks intended for use with a hi-fi recorder to copy music undulate slightly differently from blanks for use with a PC to backup data from the hard disk. Write-once consumer audio blanks cost

around £5 and computer blanks around £1. The price is still reducing, to stimulate recorder sales and increase demand for RW disks. These cost up to £20 but prices will fall with mass production.

In many countries consumer blanks also carry a tax or levy intended to compensate the music industry for revenue losses due to home recording. Philips admits it is unsure how much tax is being levied, in which countries and where the collected monies are going. Disk maker Verbatim is unable to say what it collects on blanks, and for whom. Lists compiled by the record industry's world trade body the International Federation for the Phonographic Industry, show wide and continually changing national disparities, even inside the EC where there is free trade between countries with different levies.

Austrians, Belgians, Danes, Fins, French, Germans, Greeks, Italians and Spaniards all pay different amounts, which must be shared between literally scores of copyright bodies. In Ireland, like the UK and Luxembourg, there is not yet any legislation. Holland and Sweden started but scrapped levy schemes. Portugal and Japan plan to start charging.

Computer software company Adaptec has now undermined the whole concept of split pricing and consumer levies by releasing software called Easy-CD which lets a PC recorder make audio recordings on computer blanks. "Compile Greatest Hits" CDs, promises Adaptec.

### Pricing Secrecy

The record industry does surprisingly little to dissuade people from making home copies. Record buyers know that the price of CDs has risen, to around £15, while the cost of pressing a disk has fallen from £2 to 30p or less. So they feel little guilt. The British Phonographic Industry says it has not produced any information since 1990 because pricing policies vary so widely in the UK. The IFPI says it is asked "all the time" who pockets the difference between pressing costs and retail prices, but as an international body steers clear of local pricing issues. Polygram says it is now industry policy to keep costs secret, because each artist jealously negotiates their own confidential royalty deal.

Says Peter Scaping, Director of Research and Development and General

Manager of the BPI, which is the trade body representing the UK record companies: "It is inappropriate for the BPI to comment on commercial matters which are the responsibility of its individual members". And he would "be grateful if I would not press members of his staff on these points".

Unfortunately for the record industry, Recordable DVD, an erasable disk that holds at least four times as much music, movie or computer data as a recordable CD, is already on the way, and coming far sooner than expected. Toshiba has said it will launch DVD recorders before the end of this year, 1998, with the hardware built into PCs and the set-top boxes needed to receive digital TV.

### Multi-Gigabyte Disks

A pressed DVD Video disk or DVD-ROM, as already on sale, stores at least 4.7 gigabytes per side. The DVD Forum of ten companies agreed the standard for DVD-RAM, an erasable DVD that uses phase change technology, in July 1997. The storage capacity so far achievable is 2.6GB per side, but the target is 4.7GB to match a pressed disk.

Shortly before Christmas, Toshiba surprised the trade by promising to start selling 2.6GB DVD-RAM by mid-1998, set the standard for 4.7GB DVD-RAM at the same time and launch 4.7GB drives by early 1999. Hitachi and Panasonic are ready with RAM recorders, too.

The rush comes because Philips and Sony have developed their own erasable DVD format and won support from computer companies including Hewlett Packard, Yamaha, Mitsubishi/Verbatim and Ricoh. They call their format DVD-ReWriteable to tie up with the CD-RW recording system currently on sale. Prototype DVD-RW drives are due by Spring 1998. DVD-RW capacity is currently 3.0GB, with 4.7GB the target.

Early adopters should be wary. Both camps admit that few of the DVD Video players and DVD-ROM drives sold over the last year will be able to play disks recorded on any of the new DVD recorders. The lasers currently in use cannot read the phase change disks, which have lower reflectivity than ordinary pressed DVDs. Both camps also admit that there will be limited compatibility between first generation low capacity hardware and the 4.7GB full capacity systems sold later.

Continued on next page

# NEW FLOPPY FORMATS

Floppies of 100 megabytes and more are on the way – Barry Fox has tracked down some early details.

**T**HE floppy disk is dead, killed by multimedia bloat. Computer sound and picture files are now so large that today's floppies cannot hope to store them. Now there are two new floppy formats, with much greater storage capacity and backwards compatibility, so that new drives can also read and write to conventional floppies.

The 9cm (3.5 inch) magnetic floppy disk, developed by Sony more than ten years ago, spins at 300 r.p.m. while the heads step between tracks which are 0.2mm apart. These broad tolerances ensure that a disk recorded on one PC drive will play back on another, even if the heads are not identically aligned. Disks cost only pence. But the slow spin speed limits the rate at which data can be streamed to only around 100 kilobytes/second, and the wide tracks limit storage capacity to 1.44 megabytes. So floppies cannot store and deliver moving pictures and sound.

## Super Disk

Five years ago Sony proposed that its hifi Mini Disc could be used to store 200MB of data. But MD relies on expensive magneto-optical recording technology, and blanks cost around £5 each. Now Sony has developed a High-Capacity Floppy Disk, HiFD, which uses low cost magnetics but matches MD's 200MB capacity. Sony's traditional competitor, Panasonic, is backing a rival magnetic floppy, called Super Disk, which uses different technology and holds 120MB.

Super Disk stores data in tracks which are 0.01mm apart. A laser in the drive looks for a guide track which is pre-embossed on the blank disk, and uses it as a reference to steer the magnetic heads. The disk spins at 720 r.p.m. and streams data at 565 KB/second, which is fast enough for moving video. Imation (formerly 3M), will make Super Disks. So will Maxell and Mitsubishi. Compaq, NEC and Gateway will build Super Disk drives into PCs, along with Panasonic. The system is due for launch over the next few weeks.

Sony's HiFD shoots even higher, using even narrower tracks, just 9µm wide. The blank disk is pre-formatted, with a magnetic guide track permanently embedded in the surface. This steers the heads in the PC drive, so that they can always follow the data tracks accurately. The guide tracks remain after the data has been erased.

The HiFD disk spins at 3600 r.p.m. to stream data at up to 3.6MB a second, which can cope with high quality video. Sony will launch the system early next year. No price has been set but it will be pegged to compete with Super Disk.

Both systems will be sold with the promise that the new high capacity drives can also use conventional floppies. PC users who do not need compatibility have a wider choice of new storage technologies. Philips is now selling recordable CDs, which have a capacity of 650MB and play back like conventional CD-ROMs. Iomega will soon launch Clik, a 40MB magnetic hard disk the size of a large postage stamp that costs under \$10. The Clik disk slots into a drive that looks like a pocket dictation machine and connects to a portable PC. Or, says Iomega, a digital video camera can have a built-in Clik drive to record 40 snapshots on a removable disk.



## Ventura Hobby

FROM its inception in 1995, Ventura Hobby has set out to achieve one thing – sell the best tools money can buy at simply unbeatable prices! Ask them today and they'll tell you that's exactly what they are doing.

One name in particular stands out at Ventura Hobby – Dremel. Featuring in recent TV commercials and many large retailers, Dremel is firmly established as a brand leader in precision power tools. Indeed their products have been likened to the versatility of the Swiss Army knife!

With rapidly growing sales, Ventura Hobby is one of the UK's largest independent Dremel dealers, stocking the full range of tools and accessories, including the now-famous *Multi*. With a new promotion offering a £10 voucher towards future purchases of Dremel products, Ventura expect a very busy season!

Ventura will ship any order over £10 free of charge and will be pleased to send you a Dremel brochure and price list, also free of charge.

For further information, contact Ventura Hobby, Dept EPE., 134 Crosslet Vale, London SE10 8DL. Tel: 0181 694 9913. Fax: 0181 691 4399.

## Webbed Kit-up Source

ESR Components tell us that they have established a website facility that is intended to help you obtain components for EPE projects. On their site you can now find component lists for our recent projects. They show all components and accessories available, including items sourced specifically for these projects. Prices for each item are shown, together with ESR's order code.

They have, they say, done their best to match all items to those specified in the EPE article. They do not, however, supply the ready-made p.c.b.s or pre-programmed microcontrollers and eproms.

The beauty of ESR's facility is that you can order the components direct from the company via the Web. And while you're on the web, you can also order the p.c.b.s direct from us. This is the way things are going folks!

The website address for ESR's kitting facility is:

<http://www.users.zetnet.co.uk/esr/epe.html>.

For other information, contact ESR Electronic Components, Dept EPE, Station Road, Cullercoats, Tyne & Wear NE30 4PQ. Tel: 0191 2514363. Fax: 0191 2522296.

E-mail: [sales@esr.co.uk](mailto:sales@esr.co.uk).

Web: <http://www.esr.co.uk>.

Continued from previous page

The RAM standard requires the use of a protective cartridge or caddy, to stop people touching the disk. The only concession is that if the disk is single-sided, it may be broken out of the caddy and used as a bare disk in a tray drive. But after breakout the disk becomes read-only.

RW disks can be used in a caddy, but it is not a requirement. This follows from the different way in which the two types of disk, RAM and RW, store data.

## Pre-Embossed

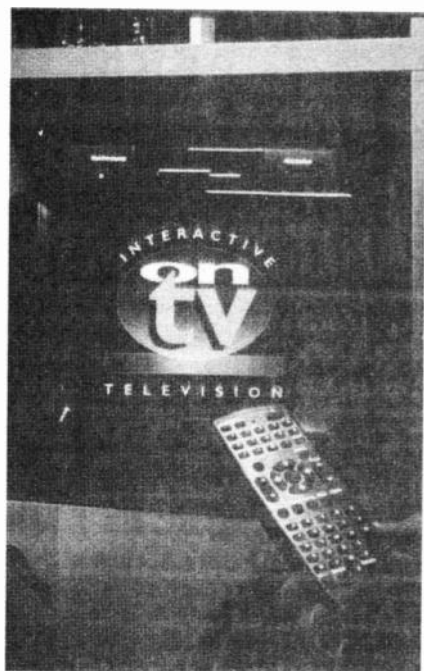
Both DVD-RAM and DVD-RW blank disks are pre-embossed with a groove which guides the laser during recording. The RAM disk records user data both in the groove and on the land areas to either side, so the laser must continually

switch focus between high land and low groove. The RW disk records data only in the groove, so it must be packed more tightly.

The RAM disk is also pre-embossed with bursts of digital code which the recorder and player use as headers to label the user's data. The RW recorder records the headers at the same time as the user's data.

DVD-RAM disks spin at constant linear velocity, like a CD-ROM; DVD-RW disks spin at constant angular velocity, like a computer hard disk.

Philips says the CAV system speeds data searching, and the other differences between RW and RAM make it easier to build recorders and players which play all kinds of CD and DVD disk, with or without caddies. Toshiba says it can do the same with RAM technology, and caddies are needed to protect all types of recordable DVD against fingermarks.



## Net Access Eased

**P**OWERNET International, a leading independent communications company, is taking a bite at the computer industry's dominance of access to the Internet. It is launching a TV set-top box which is intended to slash the cost of getting connected to the Net, as well as simplifying access to it.

Schools and colleges are expected to benefit from this easing of the process and cost of getting connected to the World Wide Web.

The company, which is part of Freecall Ltd., the UK's largest independent provider of free-to-call telephone numbers, has launched OnTV which does away with the requirement for a computer in order to get on-line with the Net.

This hi-tech unit, costing just £299.99, when connected to a phone line and a normal TV set can deliver the Internet straight into the home, classroom or office. All that is required to surf the Net is a special remote control which comes included with the OnTV Net Station package. OnTV also offers wordprocessing and E-mail.

All the user has to do is plug the unit into the TV aerial socket as well as a normal telephone socket, follow the on-screen instructions and the smartcard provided gives a unique access password to get connected.

To obtain details of your nearest OnTV stockist, phone 0500 831831.

For other information, contact Powernet International, Dept EPE, Bracken House, Charles Street, Manchester M1 7BD. Freecall: 0500 011 501. Freefax: 0500 011 502.

E-mail: support@powernet-int.co.uk.  
Web: <http://www.powernet-int.co.uk>.

# Outlawing Paper Satellites

Barry Fox

**T**HE International Telecommunication Union has outlawed "paper satellites". This clears the way for Astra to start launching digital satellites into the new orbital slot at 28 degrees East, early this year from Baikonur in Kazakhstan.

Rival satellite operator Eutelsat has been claiming prior rights to the same slot, while failing to use it. The ITU's World Radiocommunications Conference has decided that anyone applying to the ITU for a slot must now show "administrative due diligence". They must name the company which is making the satellite, prove they have booked a rocket to launch it and identify the launch site. If this does not stop people "hoarding" slots, the ITU will start charging an annual registration fee.

## Merlin's Matchbox Magic

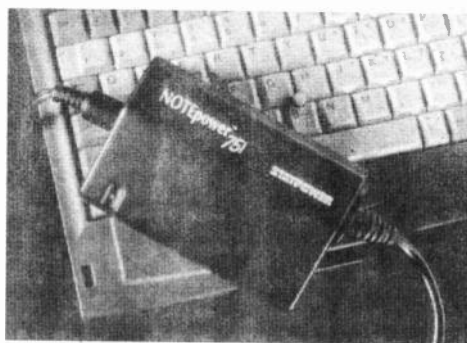
MERLIN Equipment's new NOTEpower 75i inverter allows you to run and recharge notebook computers, camcorders, mobile phones and video games in your car. By simply and silently converting the car's 12V battery power to 230V a.c., the unit allows you to run your equipment all day without the need to buy spare battery packs.

NOTEpower 75i is matchbox-sized and simply plugs into the car's cigar lighter socket. Output is then available from the standard socket on the side of the unit.

Merlin say that the unit has a wide range of other useful applications as well, naming tape recorders, bubblejet printers and power tools. (Merlin also do other inverters too.)

Reassuringly, it incorporates an alarm which will warn if the car's battery is getting low, at which point it turns the inverter off to allow restarting of the car!

For more information contact Merlin Equipment, Dept EPE, Unit 1, Hithercroft Court, Lupton Road, Wallingford, Oxon OX10 9BT. Tel: 01491 824333. Fax: 01491 824466.



## EOCS INVITES YOU

DON BRAY, Hon. Sec. of the Electronic Organ Constructors Society has sent us details of the provisional dates for EOCS meetings for 1998. The branches stated are London, South Essex, North West and South Coast.

In his covering note, Don says that any *EPE* reader is welcome to attend if they give him a call first. He will be even more pleased if you decide to join this well established and well-worthwhile society.

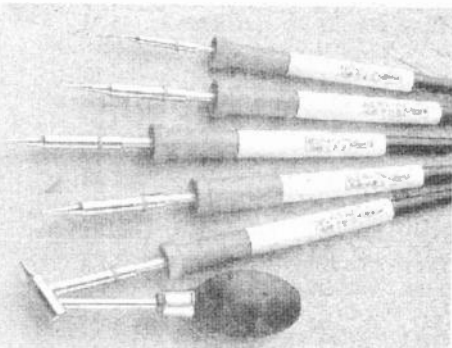
For more information, contact Don Bray, EOCS, 34 Etherton Way, Seaford, Sussex BN25 3QB. Tel: 01323 894909. Fax: 01323 492234.

## NEW PENCIL IRONS, OLÉ

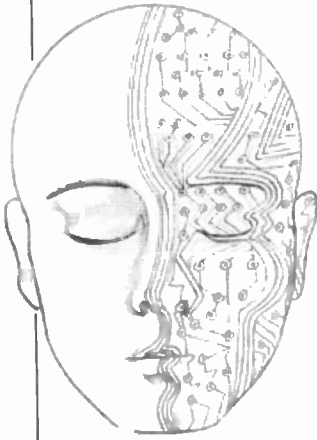
ESR have added a new comprehensive range of soldering irons from the Spanish manufacturer JBC Soldering Solutions. The range includes standard pencil irons from 11W to 32W, 60W instant heat irons, 135W gas irons, and temperature controlled irons and soldering stations.

JBC have been manufacturing soldering irons since 1929 and have only recently brought this reliable and professional range to the UK. Although the full range, including surface mount and desolder stations, is aimed at the electronic manufacturing industry, these high quality products are equally suitable for education or hobby use. They are very competitively priced.

Full details of the range are available from ESR Electronic Components, Dept EPE, Station Road, Cullercoats, Tyne & Wear NE30 4PQ. Tel: 0191 2514363. Fax: 0191 2522296. E-mail: sales@esr.co.uk. Web: <http://www.esr.co.uk>.

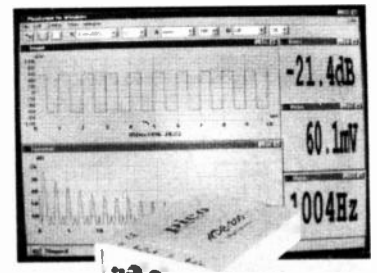


# INGENUITY UNLIMITED



Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas *must be the reader's own work* and **not have been submitted for publication elsewhere**. The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**

Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. They could earn you some real cash and a prize!



## WIN A PICO PC BASED OSCILLOSCOPE

- 50MSPS Dual Channel Storage Oscilloscope
- 25MHz Spectrum Analyser
- Multimeter
- Frequency Meter
- Signal Generator

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours.

Every six months, Pico Technology will be awarding an ADC200-50 digital storage oscilloscope for the best IU submission. In addition, two single channel ADC-40s will be presented to the runners up.

## Fan Failure Monitor – A Whirly Warning System

**T**HE CIRCUIT of Fig. 1 may be suitable for most d.c. brushless fans. Its output is CMOS logic level compatible and is high either when the fan is not turning or is disconnected, and low when the fan is running. The circuit could form the input of an alarm or monitoring system where failure of a cooling fan, for example, could have serious consequences.

The circuit relies on the current fluctuations associated with the turning of the blades. Under quiescent conditions, TR1 is biased into saturation, needing a  $V_{be}$  reduction of 100mV to bring it to a point where TR2 can turn on. When the fan is running normally, TR1 base is biased towards 0V, turning it off and permitting TR2 to conduct. The collector of TR2 therefore drops to near 0V to indicate that the fan is operating. Capacitor C2 ensures that a continuous logic low is seen when the fan is running.

Should the fan circuit become open, TR1 is then biased on, switching out TR2, the collector of which goes high, and generating a logic high output. The circuit has been tested on a 12V 0.15A fan.

*Gerard La Rooy,  
Christchurch,  
New Zealand*

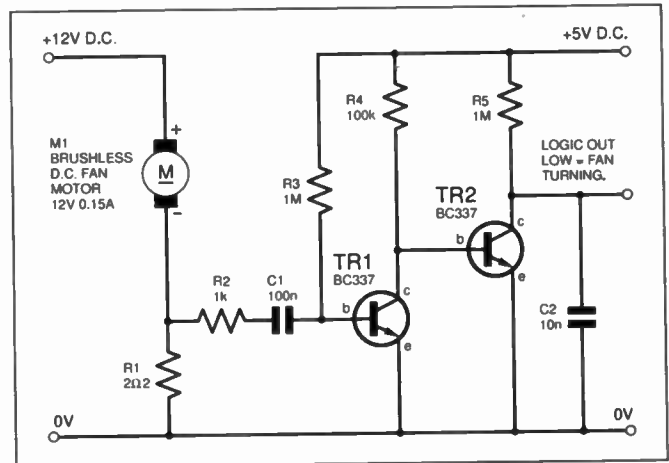


Fig.1. Circuit diagram for the d.c. brushless motor failure alarm.

## Flame Effect – for Model Makers

**T**HE CIRCUIT of Fig. 2 is capable of driving a single l.e.d. to replicate the flickering effect of a fire or flame. It can be used to illuminate a trackside bonfire for a model railway, or to add interest to a decorative candle display for example.

The circuit consists of IC1, a 555 running in its astable mode, the output from which is used to clock a 4017 decade counter. The first four counter outputs are connected to resistors of differing values which lead to the anode of D1. This has the effect of keeping the l.e.d. continuously illuminated but with a constantly changing intensity.

Resistors R3 to R6 could be anything up to about 2kΩ, and R1, R2 and C1 were selected for best effect. A yellow l.e.d. is more realistic for candle flame effects, whereas an amber colour is better if a bonfire effect is required. High-intensity and large 10mm l.e.d.s could be useful for experimenting with.

*Ian Hill,  
Plymouth,  
Devon.*

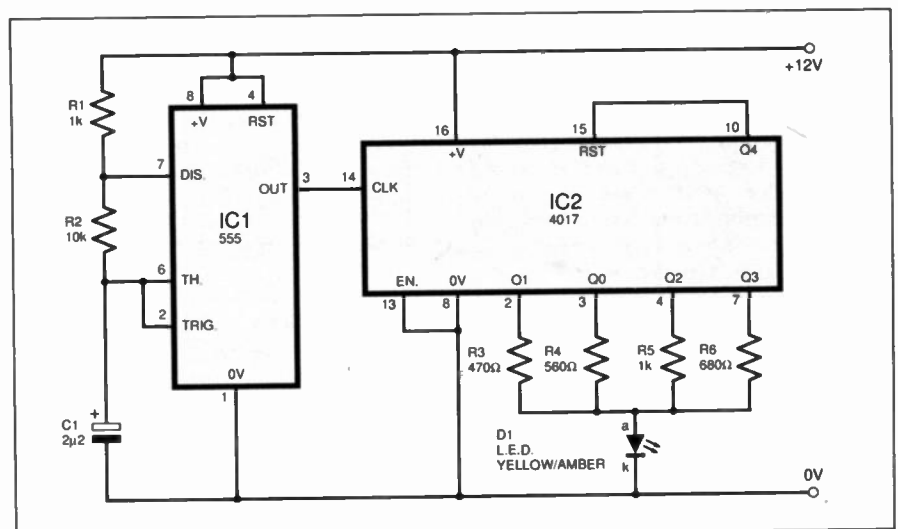


Fig.2. Circuit diagram for the Flame Effect.

## L.E.D.s as Photocells -

LIGHT emitting diodes can be used as photocells which, in some instances, will avoid the need to purchase more expensive photo-transistors. The current available is too low to provide any useful power ( $1\mu\text{A}$ ) but the voltage available under a low load (e.g. connected to a digital voltmeter) can be as high as 1.2V in direct sunlight. The voltage is proportional to the log of the light intensity.

As a demonstration, the circuit of Fig. 3 utilised a high-intensity green l.e.d. as a photocell, and formed a sensor which allowed a flashing halogen lamp to operate in darkness only. The external flasher circuit was enabled by a "high" at TR1 collector. Any general purpose *npn* small signal transistor would be adequate.

Gerard La Rooy,  
Christchurch, New Zealand.

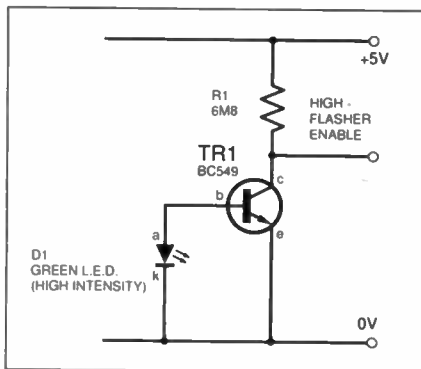


Fig.3. L.E.D. used as a photocell to provide a light dependent logic signal.

## DMM Temperature Probe -

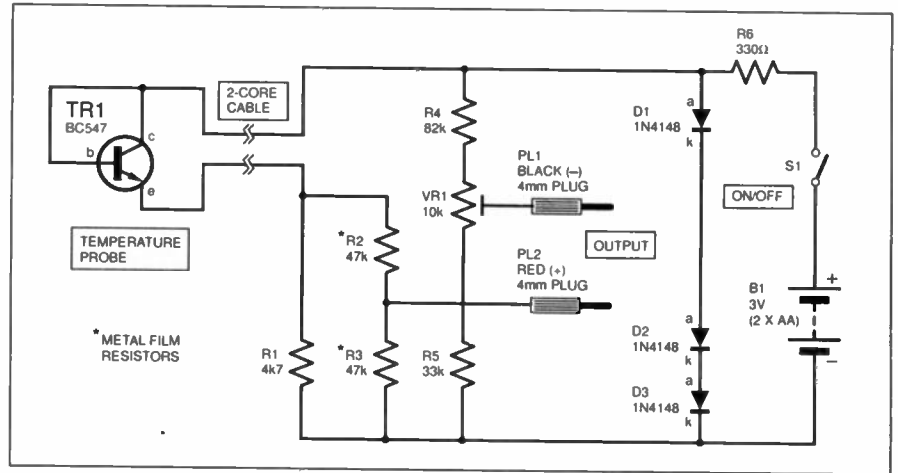


Fig.4. Temperature Probe for Digital Multimeters.

THE CIRCUIT depicted in Fig. 4 takes advantage of the fact that the voltage across a transistor varies by about 2mV for every  $1^\circ\text{C}$  of temperature change, to produce a cheap and simple add-on module for an ordinary digital multimeter (DMM).

Resistor R1 limits the amount of emitter current flowing through transistor TR1 whilst a potential divider consisting of R2 and R3 halves the transistor's rate of temperature change, to a convenient  $1\text{mV}/^\circ\text{C}$ . These two resistors should preferably be low noise metal film types. The voltage present at PL2, the red output plug, is biased upwards by approximately 0.6V when the probe is at  $0^\circ\text{C}$ , so the voltage at the black output plug PL1 is also biased up by 0.6V using R4, VR1 and R5.

This is done so that  $0^\circ\text{C}$  at the probe reads as 0mV on the multimeter display.

The supply voltage to the circuit is derived from two "AA" cells, regulated to approximately 2V by the three diodes D1 to D3 and resistor R6, so that the circuit does not need to be constantly re-calibrated when the battery gradually discharges. The probe should work over a range of at least  $-20^\circ\text{C}$  to  $+100^\circ\text{C}$ , but the probe should be completely waterproofed to avoid spurious readings, e.g. by embedding it in a test tube or similar. VR1 should be adjusted so that the meter display reads zero when the probe is immersed in icy water, or it can be calibrated against another thermometer.

David Watson,  
Barnsley, South Yorkshire.

## Current Monitor for Power Supplies - Non-invasive Treatment

MY BENCH p.s.u. is made from a transformer rescued from an old cine projector, and can deliver a hefty 10 amps at 15V. It has several outputs - a.c., d.c., regulated, unregulated, fixed and variable! My difficulty was to monitor the total current drawn from the combination of outputs.

My solution is shown in Fig. 5. This uses a 20mm ferrite toroid (L1), wound with 25 turns of 0.2mm insulated wire. One of the transformer outputs (before the power supply's

rectifier) simply passes through the centre of the toroid en route to the output terminals of the power supply. The current induced in the toroid is buffered by IC1a, then rectified by D1 and smoothed by C1.

IC1b is simply a comparator, the level of which is set by VR1. IC2a is an inverting amplifier which toggles the colour of the bi-colour l.e.d. D2. This l.e.d. acts as a "power on" indicator when green, and turns red to indicate an over-current condition.

alerting the user to reduce the load. The only setting up required is to load the circuit under test and, with the aid of an ammeter, adjust VR1 until the l.e.d. changes colour. Being "non-invasive", the circuit can be used to monitor any a.c. overload situation, including mains supplies.

Matthew Waite,  
Beeston,  
Leeds.

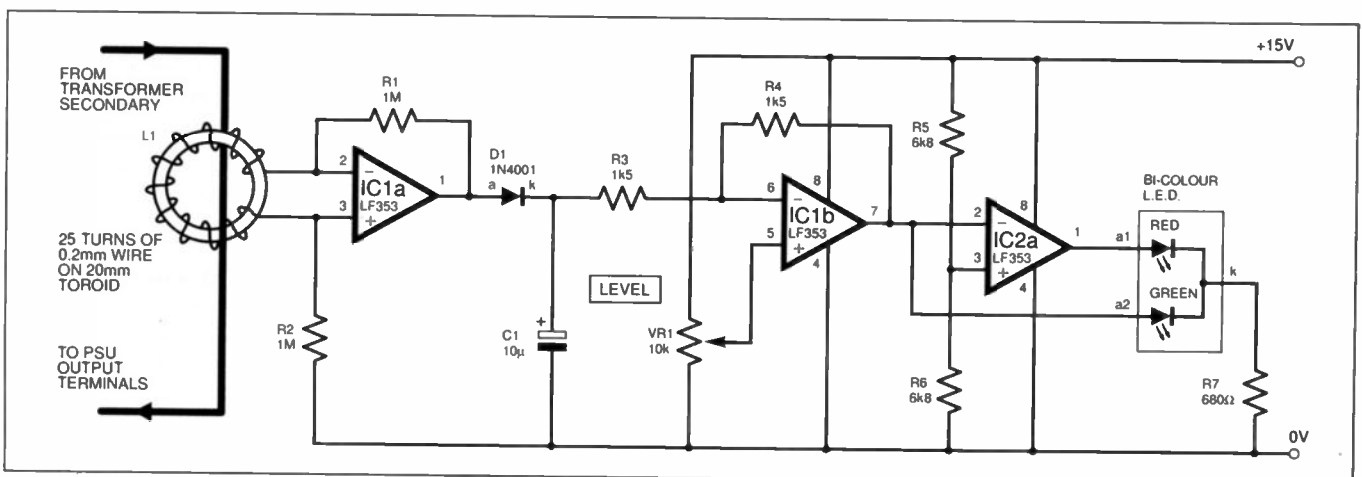


Fig.5. Circuit diagram for an a.c. overload current monitor.



# READOUT

**John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!**

## Win a Peak DTA30 Transistor Analyser

The DTA30 will test and identify the type (*npn/pnp*) and the leads of any bipolar transistor connected to it.

Every month Peak Electronic Design Ltd will be giving a DTA30 to the author of the best *Readout* letter published.



### ZN416 RADIO CHIP

Dear EPE,

I notice in the Jan '98 issue that you have included a design using the ZN416 radio chip (*Simple MW Radio*). This chip was manufactured by Ferranti, who were then acquired by GEC-Plessey. The latter have reorganised, sold off manufacturing rights for various designs (such as voltage references – taken over by Zetex) and ceased production of many other "old-technology" devices.

The ZN416 is, unfortunately, one of those no longer manufactured and has been obsolete since mid '96. Maplin (at the time of writing) have some stock left, but once gone this cannot be replaced. This situation is likely to be the same with other suppliers.

Many semiconductor devices that were the main-stay of electronics during the '70s and '80s are now being replaced by new technology – the chances of contributors including obsolete devices in their designs are now higher than ever. It would be prudent for contributors to check

component availability, before including it in a design for publication, with suppliers. Many manufacturers provide information on their websites about the status of their products.

**Robert Ball,  
Maplin Electronics PLC.  
Maplin Technical helpline:  
01702 556001.**

*We always vet projects for component availability prior to acceptance for publication. Occasionally, though, a product can become obsolete after acceptance, in which case we check that at least one supplier still has the device available in reasonable quantity. This was the case with the ZN416E for the Simple MW Radio.*

### PIC NOUGHTS OPTION

Dear EPE,

Recently I received an E-mail from an EPE reader who was encountering errors when using MPASM V1.4 to assemble the software for my *PIC Noughts and Crosses* game (Sep '97).

I used MPASM V1.0.05 which has minor differences that V1.4 does not recognise. The main reason for the problem was the name given to the Option Register at address 0x81. The name "option" is reserved in V1.4 since it is an instruction for the PIC16C5x devices. The name in my source code has therefore been changed from "option" to "optreg". This name was defined in the PIC16C84.H file and used in the GAME1.ASM file.

Also the label "End\_Of\_Code" at the end of the GAME1.ASM file has now been deleted as MPASM V1.4 rejected this as an illegal label. The label was needed many years ago for earlier versions of the assembler but doesn't seem to be required now – funny how things change.

**Paul Hackett, via the Net**

*Paul's amended files were put onto our PIC-Disk on 18 December 1997, our Website was updated a few days later.*

*The "option" problem may also raise its head for people who want to translate TASM files to MPASM format. Many TASM-written programs use OPTION as an equated label. For my in-preparation PIC-Toolkit project which, among many other things, translates from TASM to MPASM (V1.4), OPTION is converted to OPSHUN!*

## ★ LETTER OF THE MONTH ★

### DISCO LIGHTS AND SAFETY

Dear EPE,

Terry de Vaux-Balbirnie's *Disco Lights Flasher* of Dec '97 looks a very good one and I'm sure that it will appeal to many people, so well done EPE!

I would like, though, to mention a couple of points relating to the safety of mains/battery equipment. They are not criticisms, but are based on my experience gained working within industry, acquiring knowledge about minimising safety risks in the manufacturing of mains powered items.

Some form of electrical safety warning should be given on the unit itself, such as a ready-made label (available from RS/Electromail), advising people to "disconnect the mains supply before removing the cover". I know this sounds obvious, but so many people will forget when they find the batteries exhausted in the middle of an event, especially knowing that the mains is opto-isolated within the unit. Changing the batteries having forgotten to unplug from the mains could result in a rather nasty shock!

The photographs of the finished unit show some of the mains interconnection wiring cable tied between the mains cable at each outlet. A few more ties could be added to restrict the movement of any cables in the event of them breaking loose

from their connections, something that can happen to disco equipment through vibration during travel etc.

In Fig.4, the fuseholder's live out, common neutral and earth wires can be tied at each socket so as to include the individual live socket wire into the bundle. The live in and out of the fuseholder can also be tied together close to the contacts. Finally, a cable tie can be fitted to each group of three wires going to the p.c.b. mains connections (TB1 and TB2).

Obviously, in industry, far more work would be required to meet marketing safety requirements. For home-made products, the above notes are just a guide to improving the minimum safety levels.

Keep up the good work. I am particularly keen on the projects using PICs. I have built my own version of the 16C84 programmer, based on your *Simple PIC Programmer* (Feb '96), and am keen to experiment!

**Bill Ellingford,  
(reader of PE and EPE for many years!), via the Net**

*We are very much aware of the needs to ensure that safety is stressed to our readers and are always grateful for other people's observations on this matter. Thanks for all the other useful comments in your two E-mails.*

### MORE SAFETY

Dear EPE,

Whilst looking through EPE back issues for inspiration, I couldn't help but notice the number of times that "Scotch Locks" were recommended for connecting into existing wires on cars. This may be considered better than twisting and taping, but only just.

Unfortunately, I have seen them used on main ignition cables, which has virtually cut them in half. As we all know, this reduces their current carrying capabilities, so heat is produced in excess, increasing the risk of fire. Could an alternative method (twisting and soldering, perhaps) be recommended?

As yet, I haven't heard of any fatal injuries, but the more they are used, it's only a matter of time. As an EPE reader and motor trade worker I am very concerned about this. I may be able to bring cars back to life, but people I can't.

Thanks for making electronics interesting and fun to be involved with.

**Dave Clarke, via the Net**

*Thanks Dave, useful comments. Scotch Locks have their uses and benefits, otherwise they would not be sold, but obviously caution and common sense should be exercised when using them, as with any current carrying connector. What techniques do other readers use for connecting car electrics?*

## AN "L" OF A PROBLEM!

Dear EPE,

I would love to construct the *EPE Virtual Scope* (Jan/Feb '98). To this end I sent off for the software to check out on my computer as recommended in the article. My computer is an NEC Powermate SX/16i AT clone, 80386SX processor, no co-processor, MS-DOS 6.22 (Rev.A).

On receiving the software, I attempted to follow your instructions. The first problem came with the instruction "From DOS, copy the software into your QBasic directory". I do not have a QBasic directory, only a file called QBasic in the DOS directory. I therefore made a directory named QBasic and copied your files into it.

The next problem came when trying to follow the instruction "Now load QBasic with the command: qbasic/l". The computer came back with "Bad command or file name". I then resorted to loading QBasic with the command: "qbasic/l". This resulted in a list of the "/(switch)" commands available, but which did not include the "/l" switch. Now matter how I try, I cannot get QBasic to load with "qb/l".

Trying to run VSCOPE.BAS when QBasic has been loaded just using the command "qbasic", the program stops with the message "File not found" with the command "getmousecode" highlighted, indicating the file name held in file\$ could not be found.

I then loaded the MOUSE01.BAS program into QBasic and ran it. This ran successfully, the pointer moving and the pixel position counts updating properly.

I do not understand your reference to changing .BAT files, the only one I've got is AUTOEXEC.BAT.

Although you say in the article that you cannot help on specific machine problems, perhaps you can throw some light on my problems as other readers may be having similar trouble.

**R. Bradley,  
Scarborough, N. Yorks**

*I believe I can! First, on the "/l" switch problem, I now find that it is not necessary to use "/l" when running the VScope through QBasic. It seems that only QuickBASIC needs the "/l" command. This switch tells QuickBASIC that it is to also load a library sub-program that allows machine code to be run in parallel with the BASIC commands.*

*It appears that QBasic already has this sub-program within its command structure. I am used to using QuickBASIC rather than QBasic, and prefer it for a variety of reasons but they are both held in the same directory named QBASIC. As it happens, when I use the "qbl" command, my set-up automatically assumes that I am wanting to use QuickBASIC rather than QBasic and responds accordingly. If I just type "QBasic", then QBasic itself is loaded. If, though (as prompted by your comments), I type "QBasic/l" then I too get the same screen display of switches available as you described in another part of your letter - I was unaware of this probability.*

*Conclusion 1: if you are using QBasic do not use the "/l" command. If you are using QuickBASIC, you MUST use "qbl" as stated.*

*Conclusion 2: In making your directory having the name QBASIC, you should not only have copied in our files, but also the actual QBasic program from DOS. As things stand with you at present, running QBasic from DOS, the VSCOPE.BAS program looks for its machine code files (getmousecode sub-routine) in the same directory as it itself is held. Since our files are in your directory QBASIC and not DOS, VScope is not able to find them.*

*You have already found that MOUSE01.BAS runs OK and I assume that this is because you put this test program into DOS, along with the VSCOPEMS.COM machine code.*

*This is one solution to you running the main VScope program: put it and all its files into DOS.*

*Another solution is (as above) put all our files into your new QBASIC directory, including a copy of QBasic.*

*A third solution is to keep all your VScope files in one directory (say one named SCOPE perhaps). Then run QBasic from DOS, but with the VSCOPE.BAS program's calls to the .COM machine code files (named near the head of the program) amended to include the new directory path, as follows (for SCOPE as the directory):*

```
file$ = "C:\SCOPE\SCOPEMS.COM"  
file2$ = "C:\SCOPE\SCOPEMG.COM"
```

*You would then similarly amend the file call in MOUSE01.BAS.*

*(It is recommended that you get rid of the directory you created with the name QBASIC, unless you actually want to put QBasic in it.)*

*The .BAT files you query are files (Batch files) frequently written by programmers to route program-launching from one directory to another (amongst other things).*

*For example, if I am in my directory named PIC and I want to use QuickBASIC (held in directory QBASIC), calling it with the "qbl" command, and then return to the PIC directory once finished with QuickBASIC, I use a file named QB.BAT that is held in the PIC directory. This file contains the following commands:*

```
cd\qbasic  
qb/l  
cd\pic
```

*It was written when in DOS EDIT and saved in the PIC directory as QB.BAT.*

*Each time I type "qb" when in the PIC directory, the computer searches for the file QB.BAT, opens it and takes each statement within it as a command.*

*The first command is "cd\qbasic", i.e. change directory to that named QBASIC, which it does.*

*The second is "qbl". It issues this command which is recognised by QuickBASIC as meaning: load QuickBASIC and its machine code accessing library sub-program (ll). This action occurs and I am now in QuickBASIC and can do what ever I want to do from within it.*

*When I finally tell QuickBASIC that I want to exit from it (ALT, F, X), the .BAT again takes over at the exit and performs the next command, "cd\pic", meaning change to the directory named PIC. I am now back in PIC, as wanted.*

## MS-TAKEN IDENTITY

Dear EPE,

I'm an occasional user of your *Direct Book Service*. Although I sign myself as "Ms" the order usually arrives here addressed to "Mr". I recently received yet another miss-titled package. Come on EPE, this is the late '90s! It isn't only men who are interested in electronics!

**Ms M. Saunders  
Manningham, Bradford**

*Far be it for me to comment on the inner workings of DBS, so I shan't!*

*What I would question, though, is why in these late '90s we need to use any sort of "honorific" when addressing mail? Whilst it may have been appropriate to the outlooks of the Victorian era, are we not now more liberated?*

*Basically, most people's names are unique at a given address. The use of an honorific such as Mr, Mrs, Miss, Ms, Master or Esq seems utterly irrelevant unless it helps to clarify for which person the mail is intended. Even then, the use of the person's first name (I won't say Christian name in this multi-religious age) would clarify the matter, and be more sociable. What does the recipient's gender or marital status matter to the postman?*

*Editorially, we make no discrimination - all readers are welcome irrespective of attributes! However, we do know that many women are interested in electronics, although not in such quantity as men. Over the years we have published a number of projects written by women. My sub-editor on PE was a woman - Helen Armstrong, who now edits a competitive journal!*

*I also know that the Open University has at least one lady electronics tutor - I watched her series on late night OU a couple of years ago. We are also aware of recent reports that girls are better school achievers than boys!*

*Ladies, if you want to make your presence in electronics better known, write to us!*

## VSCOPE CLOCKING

Dear EPE,

I have noticed in the VScope program that if the scope is not tracing/ displaying a waveform, the real-time clock in the top left-hand side of the screen stops displaying the correct time. If the scope is set to continue tracing/displaying a waveform the clock corrects itself, bringing up the current time.

This is only a minor bug, but any bugs are to be reported.

**Gareth Wilkins, via the Net**

*It's not a bug - it's the way I wrote it! All the clock access (DATE\$, TIME\$) was intended for was to give a unique identity to scope data files output to disk. It was only an after-thought to also put the data onto the screen for the sake of screen dumps to a printer.*

*There is no easy way, however, of keeping the clock updated while in the machine code routines and data is being input from the interface circuit or output to the printer. One would need to access system interrupts from within the machine code to achieve this.*

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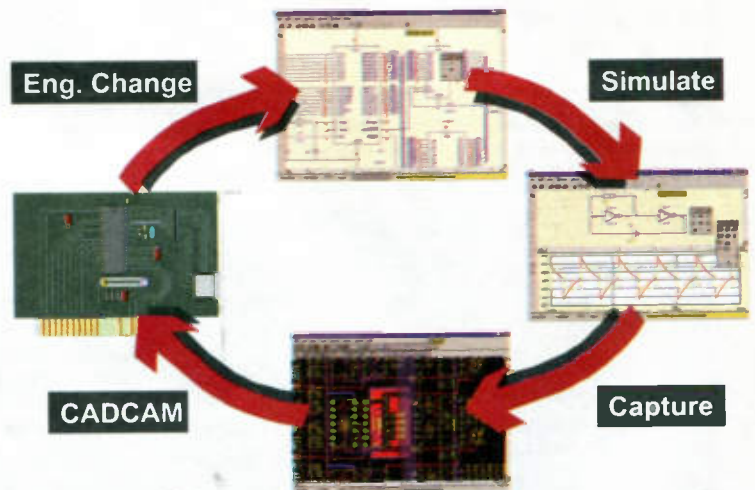
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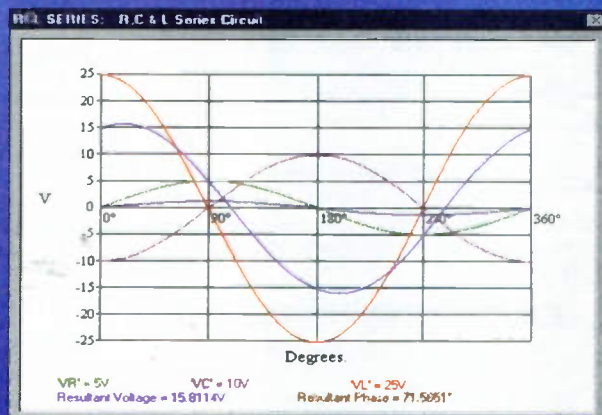
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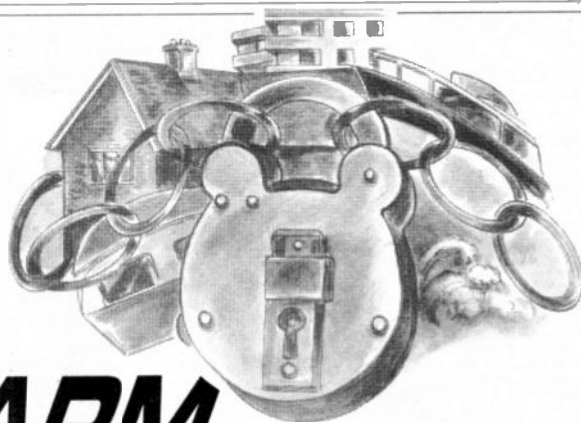
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# **SWITCH- ACTIVATED BURGLAR ALARM**



**ROBERT PENFOLD**

*Don't become a statistic!  
Beat the burglar with this  
low-cost, adaptable design.*

**I**N THE not too distant past any form of burglar alarm project was very much in the "minority interest" category. These days things are very different, and probably due to a combination of increasing crime rates and greater affluence, burglar alarm projects now rank amongst the most popular of all.

Although there are now some very high-tech alarms available, for most purposes something more basic is perfectly adequate. The burglar alarm project featured here is very simple indeed, and it relies on simple sensor switches to detect intruders.

Nevertheless, it can provide very effective protection for a house or flat, and it can also be used with sophisticated sensors if preferred. The unit is powered from a 12V battery, but its negligible standby current consumption means that each set of batteries will have virtually their "shelf" life.

## **EXIT/ENTRY TIME**

There is a slight problem with any burglar alarm system, and this is simply that there must be some reliable means for the user to exit and enter the premises without activating the alarm. The modern trend is to have some form of remote control device which enables the user to switch the alarm on and off from outside the protected premises. The alarm described here uses the simple alternative of built-in timers, see Fig.1, which enable users to exit the premises before the alarm becomes active, and prevent the alarm from sounding as soon as it is activated.

The second, entry delay gives the users time to enter the premises and switch off the alarm before it activates the bell or siren. Although more simple than a remote control system, this method probably offers greater security, and does not require the users to carry a remote control transmitter around with them.

## **SENSORS**

There are various types of sensor switch for use with burglar alarms, and the most simple of these is the microswitch. This is basically just an ordinary mechanical switch mechanism, but instead of having a lever, pushbutton, etc., it is designed for automatic control. In a burglar alarm context this means that it is operated by opening a door or window.

Reed switches are a more popular alternative to microswitches. This type of switch closes when a magnet is positioned nearby, and opens again when the magnet is removed.

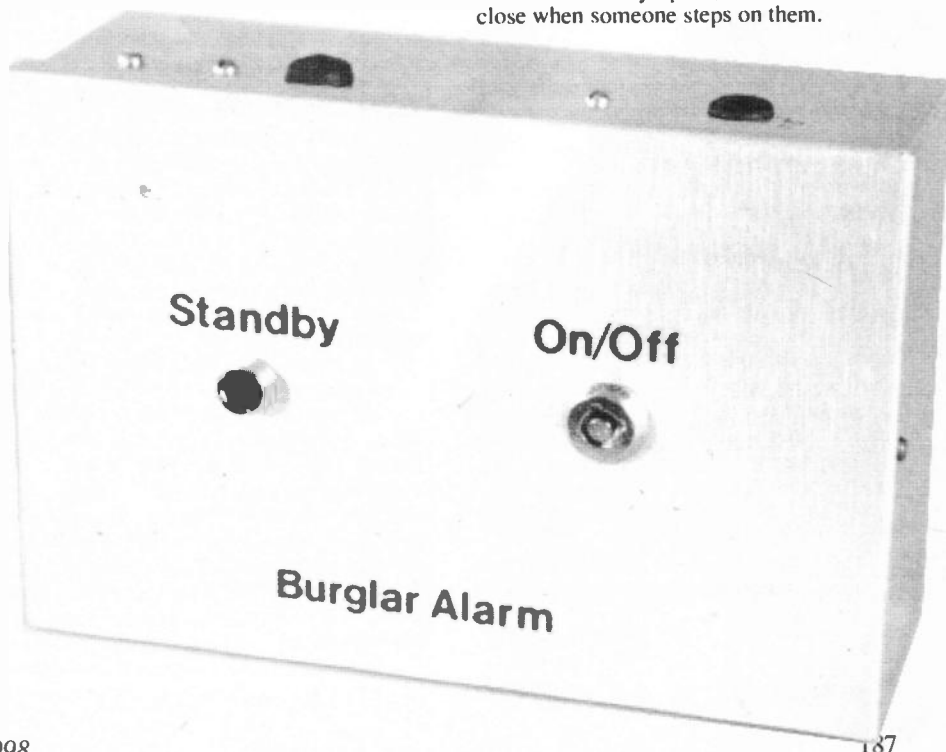
When used with a burglar alarm, the reed switch itself is normally mounted on a

door or window frame, and the magnet is fitted in a suitable position on the door or window. Therefore, under standby conditions the switch is closed, but when the door or window is opened the switch contacts also open. For obvious reasons, this type of sensor is called a "normally closed" switch.

Microswitches are vulnerable to dirt and dust "gumming up the works", but the sealed nature of reed switches gives them total immunity to this problem. Also, in practice it is generally much easier to install reed switches than the micro variety. There are now plenty of reed switches and magnets available that are specifically designed for use in burglar alarm systems.

## **ON THE MAT**

In addition to door and window sensors many alarm systems have additional protection provided by switch-mats. These mats are normally open (n.o.) switches that close when someone steps on them.



In normal use they are positioned under rugs or carpets and positioned at strategic points. For example, a switch-mat can be positioned just inside a door or in front of a safe or cupboard where valuables are stored.

It is possible to use a more sophisticated sensor such as an infra-red or ultrasonic type with a simple switch activated alarm, provided the sensor controls a relay. The contacts of the relay are simply wired to the inputs of the alarm circuit along with the sensor switches.

## SYSTEM OPERATION

The block diagram for the Switch-Activated Burglar Alarm is shown in Fig.1 and helps to explain the basic way in which this alarm functions. In Fig.1 there are three normally open and three normally closed switches, but the unit will operate with any number of either type. The normally open switches are wired in parallel, and the normally closed types are connected in series.

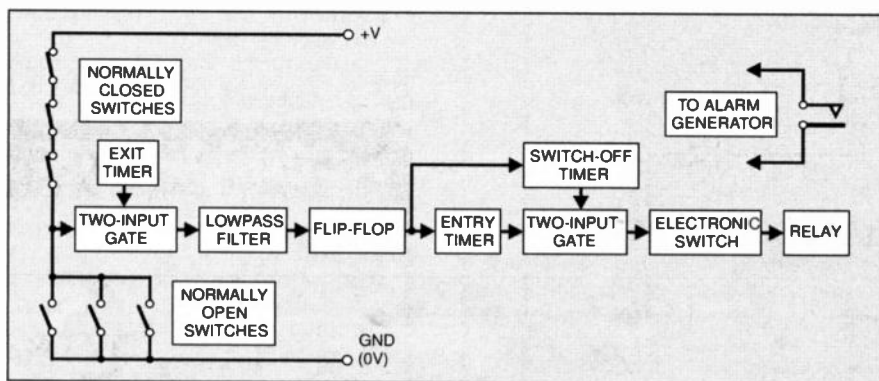


Fig.1. Block schematic diagram for the Switch-Activated Burglar Alarm. The system will operate with any number of sensor switches.

Under standby conditions the normally closed switches take the input of the alarm circuit high, but if one of these switches opens, the input goes low and the alarm is activated. The normally open switches have no effect on the circuit under standby conditions, but closing one of these switches again results in the input of the alarm being taken low, and the circuit being activated.

The switch arrangement shown in Fig.1 is a slightly simplified version of the "real thing", and in the actual circuit there are resistors to limit the current flow through the switches and to ensure that the input is taken low if one of the normally closed switches is activated.

## TIME DELAY

As pointed out previously, it is necessary to have a "delayed period" at switch-on to give the user time to leave the premises. A simple 2-input gate circuit is used at the input of the alarm, with one input fed from the switches and the other driven from a simple timer circuit. This ensures that the output of the gate is held low regardless of the states of the input switches, until the output pulse from the Exit timer has finished.

The output from the gate is fed to a lowpass filter that removes any brief output pulses. These do not occur during normal operation, but can be caused by lighting or noise spikes in mains wiring. Without this filtering it is likely that

frequent false alarms would occur, because the input wiring acts as a very effective aerial that will pick up any electrical noise in its vicinity.

## SOUND-OFF

Once activated, the alarm must continue to sound even if the door or window is closed again. The filtered signal is therefore used to drive a simple bistable "flip/flop" circuit.

This is a sort of basic memory circuit, and once its output is set to the "high state" it will remain in that state until the flip/flop is reset. In this case the only way of resetting the bistable is by switching off the unit, waiting a few seconds, and then switching on again.

The output of the flip/flop drives two timer circuits, and one of these provides the entry delay. This provides a hold-off of about 30 seconds. The second delay circuit provides an automatic switch-off that silences the audio alarm generator after about six minutes of operation.

already explained, it is possible to use any number of sensor switches.

Resistor R4 limits the current flow to a safe level when one of the normally open switches closes. Without this resistor the sensor switches would place a direct short-circuit across the supply lines. Resistor R5 ensures that the input of the alarm is pulled low when one of the normally closed switches is activated (opened).

The input gate is IC2b, and being a 2-input NOR type its output goes "low" if input 1 or input 2, or both are taken high. Under standby conditions the input at pin 1 is taken high by the normally closed switches (S2, S3) and the other input is controlled by the output of IC1a.

This gate has its two inputs connected together so that it functions as a simple inverter. Its input is fed from a simple C-R timing network comprised of resistor R1 and capacitor C1, and these provide the Exit delay.

Initially, C1 will have no charge and the input of IC1a will be low, resulting in its output going high. This provides an initial hold-off since with one input of IC1b high, its output must be low regardless of the input level from the sensor switches.

After about 30 seconds the charge voltage on C1 reaches a high enough level to send the output of IC1a low, and the output state of IC1b will then be the opposite of the input level from the sensor switches. Light emitting diode D1 is switched on during the exit delay period provided by IC1a, but it switches off at the end of the delay period when the output of IC1a goes low. The users must therefore exit the premises before D1 switches off.

Under standby conditions the output of IC1b will be low, but when the alarm is activated it will go high. Resistor R6 and capacitor C2 provide the lowpass filtering which removes any spurious pulses on the output of IC1b. The filtered signal is sent through the remaining two gates of IC1 which are connected in series so that they provide a simple non-inverting buffer action.

## SET/RESET

The first two gates in IC2 are connected to form a conventional set/reset flip/flop, and at switch-on this circuit is provided with a positive reset pulse by capacitor C3 and resistor R8. This places the output of the flip/flop at IC2b low, but the output will go to the high state and remain there if the alarm is activated and a high input level is received from IC2b.

The Entry delay is provided by another C-R timing network, this time in the form of resistor R10 and capacitor C4. IC2b acts as an inverting buffer at the output of this timing circuit.

Under standby conditions there is no charge on C4, the input of IC2c is low, and the output of IC2c is high. The output of IC2d must therefore be low, common emitter switching transistor TR1 is turned off, and the relay RLA is not activated.

About 30 seconds after the alarm has been triggered, the charge voltage on C4 is high enough to send the output of IC2c low, and the output state of IC2d then depends on the input signal to its other

This automatic switch-off is now a standard feature of burglar alarms and it is actually now a legal requirement. It prevents the alarm from sounding for long periods and causing unnecessary annoyance to those living nearby.

Another 2-input gate combines the outputs of the timers and drives a simple electronic switch. The electronic switch controls a relay, and the relay contacts in turn control the alarm generator.

## CIRCUIT OPERATION

The full circuit diagram of the Switch-Activated Burglar Alarm is shown in Fig.2. This circuit is based on two CMOS logic devices, and these are both 4001BE quad 2-input NOR gates. CMOS logic devices have the advantages of cheapness and an extremely low current consumption when operating under static conditions.

This means that the circuit will consume a few milliamps when first switched on, and a somewhat higher current of about 40 milliamps when it is activated, but for the rest of the time it will consume a minute current that will not significantly drain the battery. Even if the unit is left running for several hours a day the battery drain will be insignificant.

Designations S2 and S3 are the normally closed switches, while S4 and S5 are the normally open sensor switches. For the sake of clarity only two switches of each type are shown in Fig.2, but as

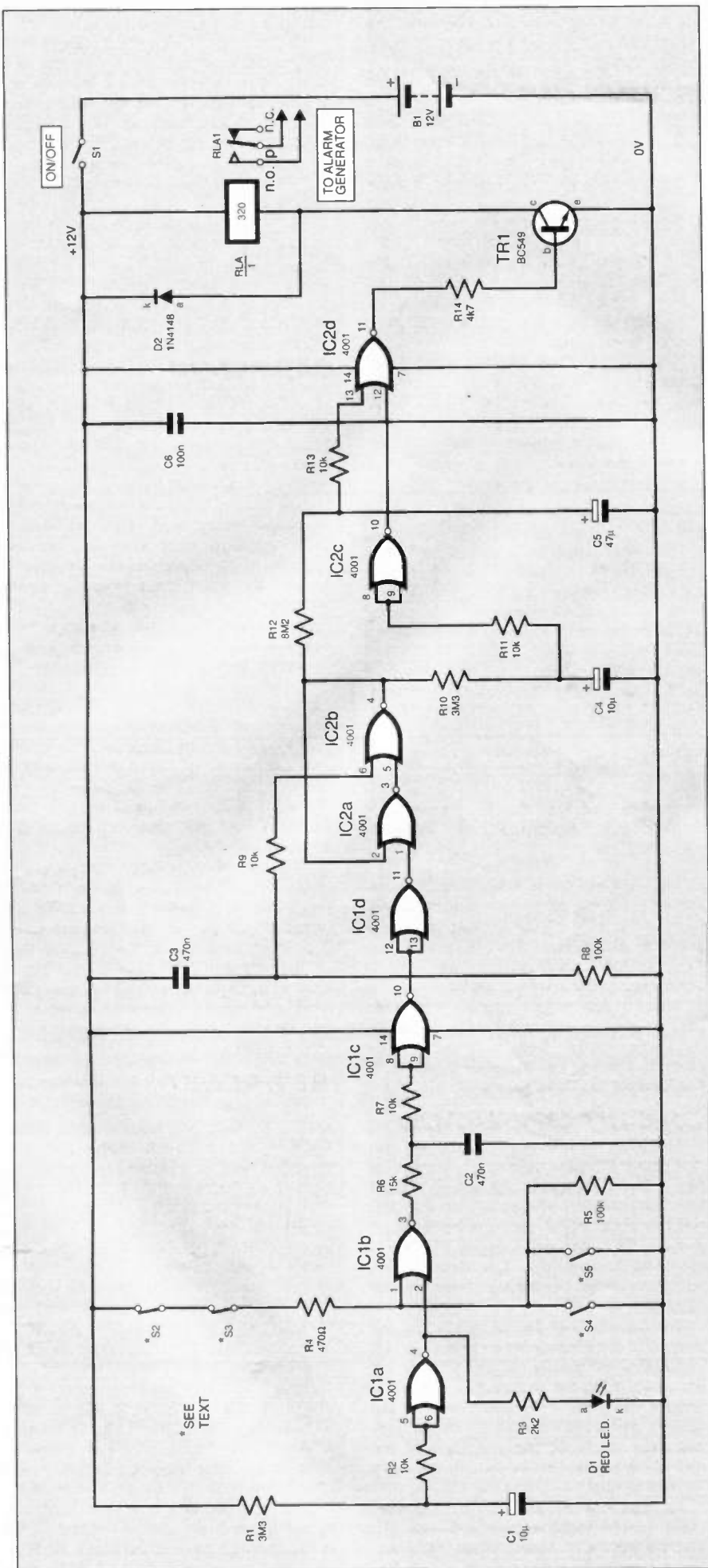


Fig.2. Full circuit diagram for the Switch-Activated Burglar Alarm.

input (pin 13). This input is fed from the output of the flip/flop via yet another C-R timing circuit, this time using resistor R12 and capacitor C5. The high values of these components produce a very slow charge rate, and the input level to IC2d will be low for about 6.5 minutes after the alarm has been triggered and the output of the flip/flop has gone high.

With both inputs of IC2d low its output goes high, switching on transistor TR1, the relay, and the alarm generator. The input level to pin 13 of IC2d reaches a valid high logic level about six minutes after the alarm generator was activated, and the output of IC2d then goes low again. This provides the automatic switch-off for the alarm generator.

## BATTERY POWER

The alarm circuit is powered from a 12V supply, and this is the potential needed to guarantee reliable operation of the relay. A real-world 12V relay, however, is virtually certain to work properly using a 9V supply, even when the battery voltage has fallen somewhat due to ageing.

It is, therefore, worthwhile trying the unit on a 9V supply, because the running costs

## COMPONENTS

### Resistors

- R1, R10 3M3 (2 off)
  - R2, R7, R9, R11, R13 10k (5 off)
  - R3 2k2
  - R4 470Ω
  - R5, R8 100k (2 off)
  - R6 15k
  - R12 8M2
  - R14 4k7
- All 0.25W 5% carbon film

See  
SHOP  
TALK  
Page

### Capacitors

- C1, C4 10μ tantalum bead, 25V
- C2, C3 470n polyester, 7.5mm lead spacing (2 off)
- C5 47μ tantalum bead, 16V
- C6 100n ceramic

### Semiconductors

- D1 5mm panel mounting light emitting diode, red
- D2 1N4148 silicon signal diode
- TR1 BC549 npn transistor
- IC1, IC2 4001BE CMOS quad 2-input NOR gate (2 off)

### Miscellaneous

- S1 s.p.s.t. key-operated switch
- S2, S3 sensor switches, normally closed - n.c. (see text)
- S4, S5 sensor switches, normally open - n.o. (see text)
- B1 12V battery pack (8 x HP7 size cells in holder) (see text)
- RLA 12V 320 ohm coil, single changeover contact relay (see text)

Aluminium box, approx. size 155mm x 105mm x 52mm approx.; 0.1 inch matrix stripboard, size 42 holes x 29 copper strips; 14-pin d.i.l. holder (2 off); battery connector (PP3 type); screw-terminal connector block; multistrand connecting wire, solder, etc.

Approx Cost  
Guidance Only

**£15**

excl. sensor switches & batts.

will be significantly reduced if the unit will run from six rather than eight batteries.

## CONSTRUCTION

The stripboard component layout, together with the small amount of hard wiring, and underside copper track details are shown in Fig.3. Start construction by trimming the board to the required size of 42 holes by 29 strips using a hacksaw.

Next, drill the two 3.3mm diameter mounting holes, and make the breaks in the copper strips using either the special tool or a hand held twist drill bit of about 5mm diameter. Construction of the board follows along the normal lines and is largely straightforward, but there are one or two points that require some amplification.

The integrated circuits are CMOS devices and therefore require the normal anti-static handling precautions. They must

be mounted in holders and not soldered directly to the circuit board.

Do not fit them into their holders until the circuit board and all the wiring has been completed. Try to touch the pins of the integrated circuits as little as possible when fitting them into their holders.

The circuit will work with any 12V relay that has a coil resistance of about 300 ohms or more. However, the component layout shown in Fig.3 is only suitable for the specified relay, and using an alternative will require either the board layout to be redesigned slightly or the relay to be mounted separately in the case and hard wired to the circuit board. Unless there is a very good reason to use an alternative it is definitely advisable to use the specified component. This relay has contact ratings of 10A at up to 30V d.c. or 240V a.c. (3A with inductive loads), which is sufficient to

control any normal audio alarm generator.

Tantalum capacitors (also known as tantalum "beads" due to their bead-like appearance) are specified for C1, C4, and C5. It is essential for these three capacitors to have very low leakage currents, because the accuracy of the Exit, Entry, and automatic Switch-Off timers will otherwise be reduced. The times will either be greatly extended, or in an extreme case they will last indefinitely.

Tantalum capacitors should give good performance, as should the various "superior" grade electrolytic capacitors. Ordinary "bog-standard" electrolytic capacitors are unlikely to give usable results.

## CASING-UP

If the finished unit is going to be mounted out in the open on a wall where

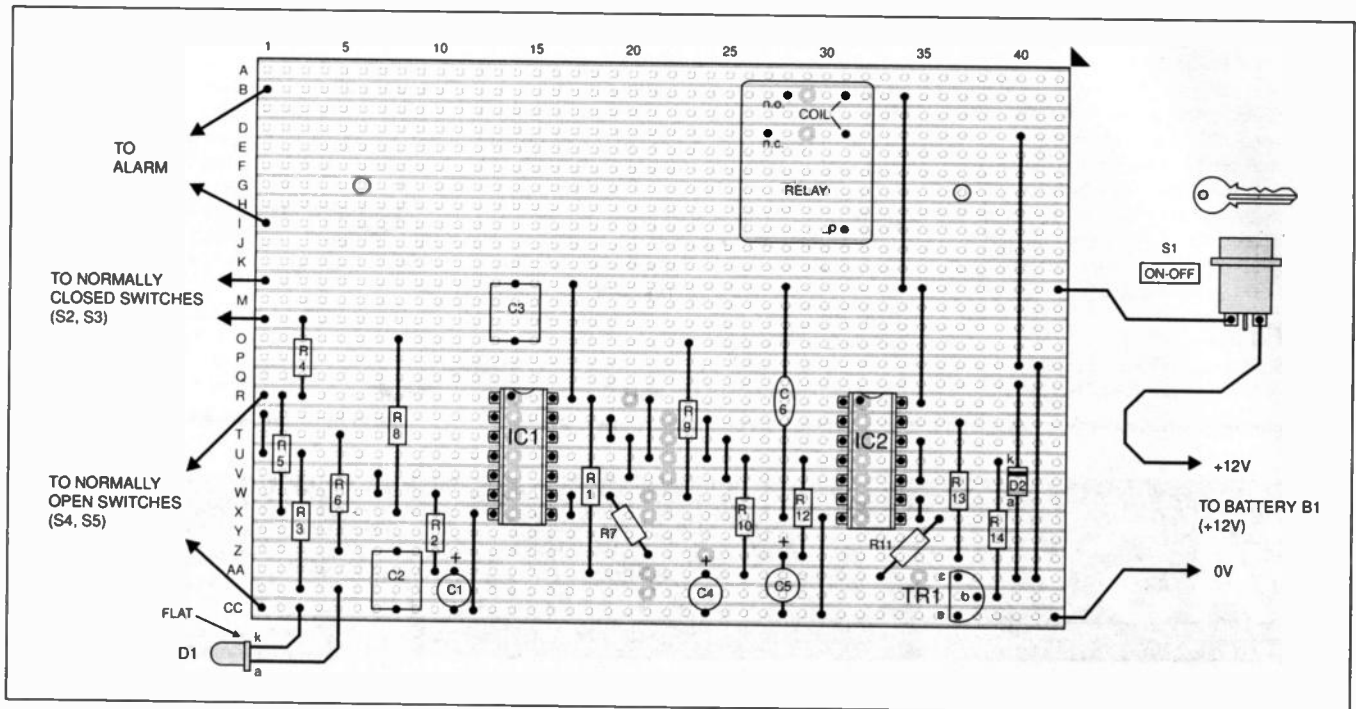
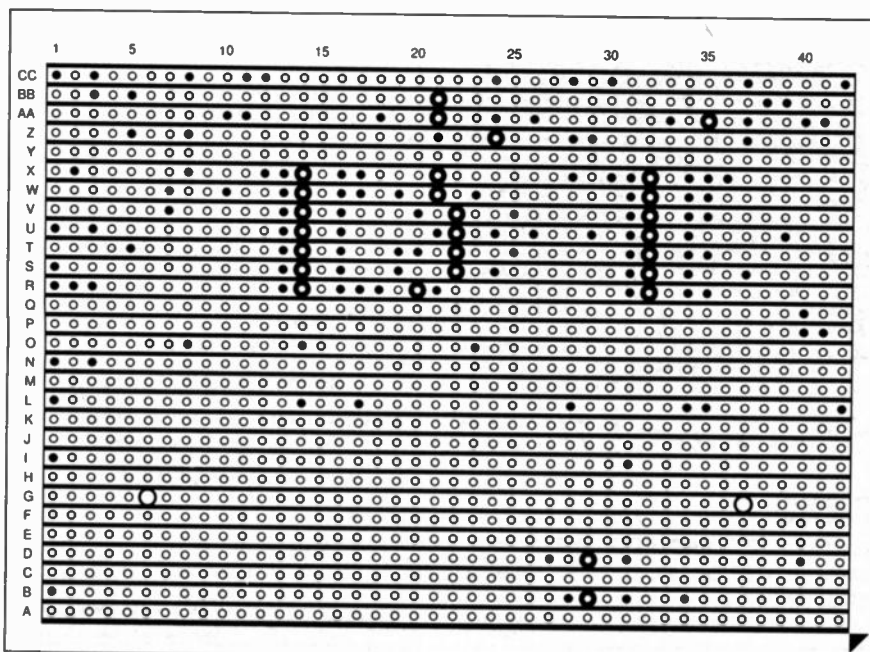


Fig.3. Stripboard component layout, wiring details and (below) underside copper tracks showing breaks required in strips.



it will be clearly visible it is essential to fit it in a tough and waterproof case. Metal wall mounting cases specifically designed for security installations are available, and diecast aluminium boxes are also well suited to this application.

If the unit is mounted where it can easily be spotted it is essential to use a key-operated switch for S1. It is also necessary to have the cables which connect the unit to the alarm generator and the sensor switches buried in the wall or protected by a tough conduit so that they cannot be cut easily. The requirements are less stringent if the alarm is to be concealed in a cupboard, although it would probably still be a good idea to use a key-switch for S1.

The exact layout of the unit inside the case is not critical, but make sure that you arrange things so that there is enough space for the sizeable battery pack. The component board is mounted on the rear panel of the case using 6BA or metric M2.5 bolts, together with spacers about 6mm long to hold the connections on the underside of the board well clear of the metal case. It is advisable to connect the board to the sensor switches and alarm



generator by way of a screw-terminal connector block rather than simply wiring them direct to the board.

**Beginners should only use the unit with a battery powered alarm generator and should not use the relay to control the mains supply. If an experienced constructor uses the alarm to control a mains powered load the unit must conform to the standard safety regulations.**

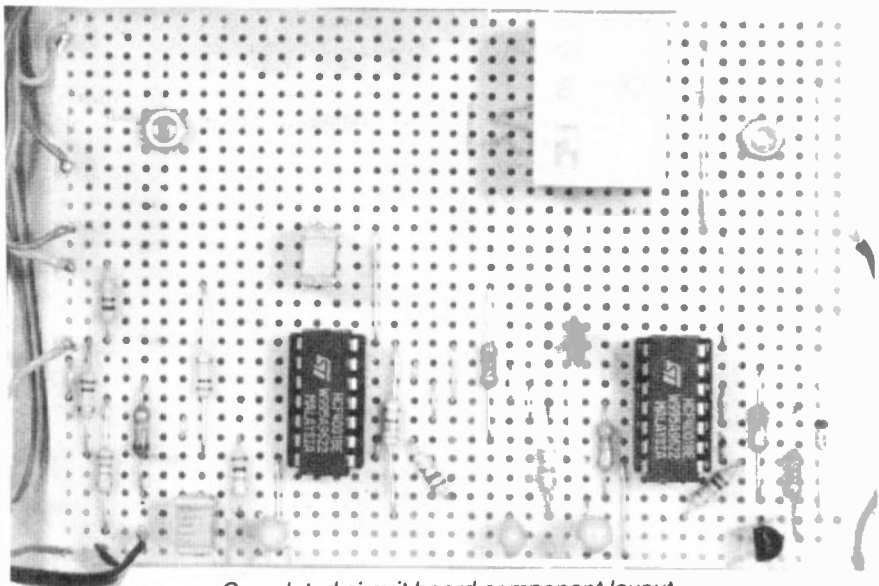
**The mains supply is potentially lethal and only those who genuinely know what they are doing should build and install equipment which connects to the mains supply.**

It is advisable to buy sensor switches that are specifically designed for use in burglar alarm systems rather than trying to improvise using general purpose components. The switches are usually supplied with leaflets giving detailed installation instructions. Bear in mind that only the surface mounting switches and magnets are suitable for use with most plastic and metal windows and doors.

If the system is augmented by a sophisticated sensor such as an infra-red type, this will probably have changeover relay contacts that enable it to be used as an n.c. sensor or an n.o. type. It is best to opt for n.c. operation as this gives better security. Cutting a wire to an n.o. sensor disables it, whereas cutting a wire in the n.c. loop results in the alarm being activated.

### TESTING

The Switch-Activated Burglar Alarm should be given some basic testing before



Completed circuit board component layout.

it is connected to the alarm generator. As an initial check, ensure that l.e.d. indicator D1 lights up when the unit is switched on, and that it switches off about 30 seconds later. The Exit Delay circuit is functioning properly if D1 operates correctly.

Note that the actual delay times of all three timers might differ significantly from the specified delay periods. With simple C-R timer circuits it is not possible to achieve a high degree of accuracy.

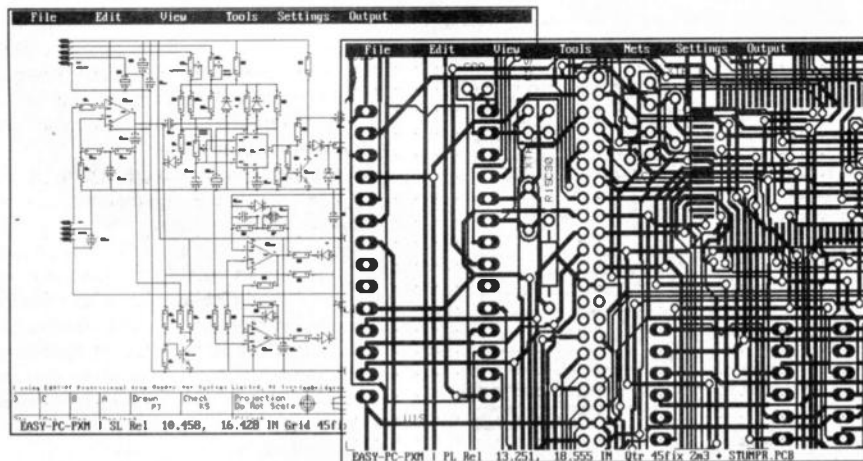
If the l.e.d. D1 functions correctly, trigger the alarm while D1 is switched on, but

return all the switches to their standby states before it switches off. If all is well the relay will not switch on about 30 seconds after D1 switches off, and the entry delay has finished.

If the alarm is then triggered again, this should result in the relay switching on after a delay of about 30 seconds. Finally, the relay should cut out again about six minutes or so later. Capacitor C5 is probably of inadequate quality if the relay fails to cut out, or takes much longer than six minutes. □

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# INTERFACE

Robert Penfold



## SIMPLE TRANSISTOR CHECKER

**T**HIS series of *Interface* articles is primarily aimed at those who have a good general knowledge of electronics, computers, and programming. However, it might be as well to devote the occasional article to the basics of computer interfacing as the techniques involved are not the sort of thing that you learn from normal sources on electronics and programming.

In fact, modern computer languages do their best to hide the hardware from the programmer, and most Windows based programming languages do not have any built in means of directly accessing the hardware.

This is one of the reasons that the software provided in this series is usually in the form of a program for GW-BASIC or QBasic. The latter is supplied with the MS-DOS and Windows 95 operating systems. I think I am right in saying that GW-BASIC is not provided with any current operating systems, but it was certainly provided with MS-DOS for many years, and is in the hands of many PC users.

### Basic for Windows

We are occasionally asked by Windows 95 users if we can supply any details of how to obtain either GW-BASIC or QBasic. QBasic is actually supplied on the Windows 95 CD-ROM, but it is not installed if you opt for the "typical" installation. It can be found on the CD-ROM in the Others/Oldmsdos subdirectory.

This is a DOS program, and it therefore has to be run by first restarting the computer in MS-DOS mode, or by operating the Start button and then selecting Programs and the MS-DOS prompt. There is a compiled version of QBasic called QuickBASIC, but it could be difficult to obtain these days.

Being a compiled language it produces stand-alone .EXE files that run much faster than equivalents run under an interpreted BASIC such as GW or QBasic. Note that this increased speed causes problems with many programs written for QBasic, and that delays may have to be added at strategic points in order to get QBasic software to run properly as compiled QuickBASIC programs.

### INPs and OUTs

Some microprocessors have the input and output circuits in the memory map, but the 8086 series of processors used in PCs have separate memory and input/output maps. There are different instructions for accessing the two maps, and the BASIC instructions used to read from and write to hardware addresses are INP and OUT.

These instructions are also available in MS-DOS versions of the C and C++

programming languages incidentally. As far as I can gather, they are not available in VisualBASIC or 32-bit versions of Windows C++ languages.

They are sometimes to be found in 16-bit Windows C++ languages, and Borland's C++ version 4.5 can actually take source code written for a DOS version of C and turn it into a program that will run in its own window under Windows 3.X or 95. In general though, directly accessing the hardware using modern programming languages is a difficult affair, and initially it is best to settle for an "olde worlde" language such as QBasic.

### Fundamentals

When using high level languages you can to a large extent forget that the computer is operating on data in the form of binary numbers. When directly accessing the hardware it is usually essential to have a fundamental understanding of the binary numbering system, but an advanced knowledge of the subject is not needed.

In an ordinary decimal number the digits represent the number of units, tens, hundreds, thousands, etc. In a binary number there are only 1s and 0s, and the digits represent the number of units, twos, fours, eights, sixteens, and so on. (See last month's *Teach-In '98* tutorial.) This is convenient in that the hardware can represent the 1s and 0s by two voltage levels (around 3V to 5V for a 1, and 0V to 2V for a 0).

Computers generally work on the basis of a eight bits at a time (bytes), or multiples of eight bits. Computer ports are normally byte-sized, and therefore have eight input or eight output lines. These data lines are usually designated D0 to D7, or possibly something like PA0 to PA7 (port A line 0 to port A line 7). Line 0 is the least significant bit, or the one which handles the units in other words.

### Family Values

When writing data to an output port it would often be useful to have individual control over the output lines. Unfortunately, most microprocessors and computer languages do not give this sort of control, and you have to write a value to the port that will set to all eight lines simultaneously. Some computer languages have the option of using binary values, but in most cases the value is written to the port in the form of an ordinary decimal number from 0 to 255, or in hexadecimal form.

Determining the correct decimal number for a given set of output states requires some simple addition. The values needed to set each output line high are shown as follows:

Line	D7	D6	D5	D4	D3	D2	D1	D0
Value	128	64	32	16	8	4	2	1

As a simple example, to set lines D0, D1, and D6 high (logic 1) and the other lines low (logic 0) a value of 67 would be written to the port ( $1 + 2 + 64 = 67$ ).

In many applications it is unnecessary to think in terms of the actual binary patterns written to the output port. For instance, when driving a digital-to-analogue converter a value of a 0 sets the minimum output potential, working through to a value of 255 which sets the maximum output voltage. You can operate in terms of decimal values producing appropriate output voltages, and the binary codes in between are of no practical consequence.

### Listing 1: Transistor Checker Program

```
10 REM SIMPLE TRANSISTOR
CHECKER PROG
20 CLS
30 OUT &H378,1
40 A = INP(&H379) AND 16
50 IF A = 0 THEN B = 1
60 OUT &H378,2
70 A = INP(&H379) AND 16
80 IF A = 0 THEN B = 2
90 OUT &H378,4
100 A = INP(&H379) AND 16
110 IF A = 0 THEN B = 3
120 LOCATE 10,10
130 GOSUB 300
140 B = 0
150 OUT &H378,223
160 A = INP(&H379) AND 32
170 IF A = 32 THEN B = 1
180 OUT &H378,191
190 A = INP(&H379) AND 32
200 IF A = 32 THEN B = 2
210 OUT &H378,127
220 A = INP(&H379) AND 32
230 IF A = 32 THEN B = 3
240 LOCATE 12,10
250 GOSUB 300
260 FOR D = 1 TO 10000
270 NEXT D
280 B = 0
290 GOTO 30
300 IF B = 0 THEN PRINT " "
310 IF B = 1 THEN PRINT "Low Gain
Device"
320 IF B = 2 THEN PRINT "Medium
Gain Device"
330 IF B = 3 THEN PRINT "High
Gain Device"
340 RETURN
```

## Being Individual

The situation is different when the output lines are controlling individual items of hardware, or they have separate functions.

Suppose that the output port is controlling eight relays, and that setting a line high turns on the relay that it controls. For a given set of ons and offs you have to add up the values for the lines you wish to set high, and then output that value to the port. Some computer peripherals have control registers that govern the way in which the hardware functions.

Many of the circuits featured in this series utilize the bi-directional properties of a modern PC printer port. In other words, the port can be set to operate as an 8-bit input or output type.

For printer port 1 (LPT1) data is written to and read from hexadecimal address 378, and the data direction is controlled by bit 5 at hexadecimal address 37A. Setting this bit high sets the port to operate as an input, and setting it low gives normal output operation.

These two lines of GW or QBasic would therefore set the printer port to operate as an input type, read the port, and print the returned value on the screen:

```
10 OUT &H37A,32
20 X = INP(&H378)
30 PRINT X
```

There is a slight complication in that the four least significant bits at address &H37A are also used as handshake outputs. The value written to address &H37A would therefore have to take into account the output states required on any of the handshake lines that were actually in use.

## Transistor Checker

The Simple Transistor Checker circuit of Fig.1 and the accompanying GW/QBasic software, Listing 1, demonstrates some simple interfacing principles. The hardware connects to printer port 1, and Fig.2 provides connection details for the 25-way male D-type connector.

As there is separate hardware and largely separate software for testing *npn* and *pnp* devices, both types can be tested simultaneously. Essentially the same method is used to test both types, so we will only consider *npn* testing here.

The basic action of the system is to first set D0 high and then check to see if the collector of the test device has gone low. Resistor R4 acts as the collector load resistor for the test component. A large base current is supplied via resistor R1, and only a low current gain is required in order to take the collector terminal low.

The collector of the test component is monitored via a handshake input of the printer port which is at bit 4 of address &H379. Variable "B" starts with a value of 0, but it is changed to 1 if the collector is taken low.

Next a smaller base current is fed to the "test" transistor by taking D0 low again and setting D1 high. Again a check is made to see if the collector has been taken low, and the value assigned to "B" is changed to 2 if it has. Since a lower base current is used, the test transistor must have a higher current gain in order for its collector to go low.

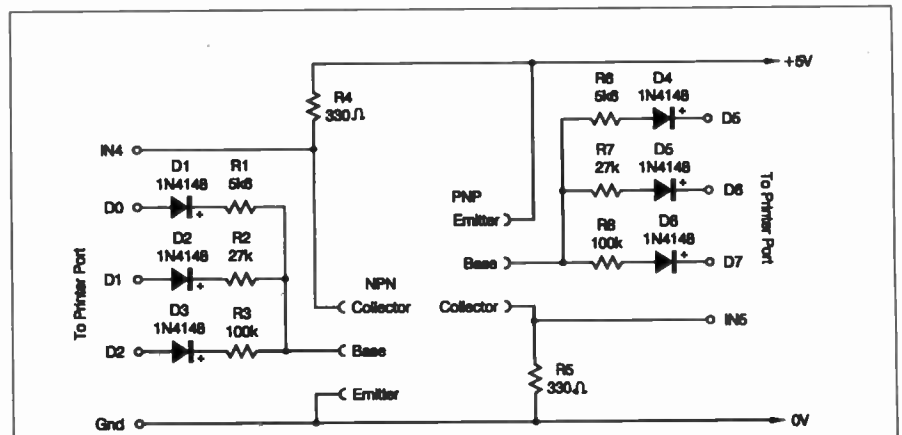


Fig.1. Circuit diagram for the Simple Transistor Checker.

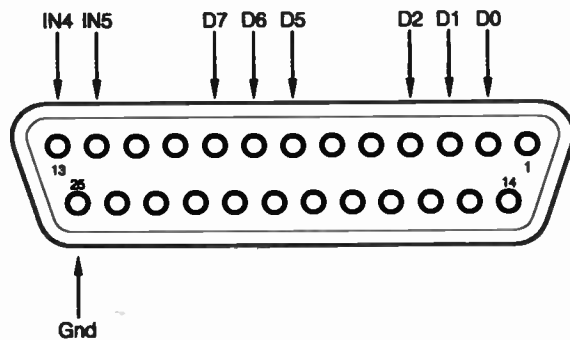


Fig.2. Details of the connections to the printer port.

Finally, D1 is set low and D2 is set high in order to provide a much lower base current via resistor R3. The logic level at the collector is then checked again, and the value assigned to "B" is changed to 3 if it is low.

With the very low base current supplied via R3, the collector will only go low if the test device has quite a high current gain. A subroutine is then called, and this prints a message on the screen that is appropriate to the value stored in "B" (e.g. "Medium Gain Device" if "B" has a value of 2).

## Software

The output lines of the printer port are at address &H378, and bits 0, 1, and 2 are set high using values of 1, 2, and 4 respectively. Checking the state of the handshake input represents a slight problem as we only need to know the state of bit 4, but the INP function reads all eight bits.

The standard solution to the problem is

to use bitwise ANDing. The AND function checks two numbers on a bit-by-bit basis, and only places a 1 in the answer if that bit is at 1 in both of the numbers. This enables unwanted bits to be masked off.

In this example we only need to know the state of bit 4, which contributes 16 to the value read from address &H379 when it is high. The value read from this port is therefore ANDed with a masking number of 16.

In the masking number bit 4 is set at 1 and all the other bits are set at 0. Because the other bits are at 0 in the masking number, they must be at 0 in the answer. On the other hand, bit 4 is at 1 in the masking number, and will also be at 1 in the answer if this bit is at 1 in the value read from the handshake port (or 0 if it is not). We therefore end up with an answer of 16 if IN4 is high, or zero if low.

The bitwise AND function is used a great deal when writing software for computer add-ons.

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# New Technology Update

*The potentially hazardous ceramic beryllium oxide is being replaced by the safer aluminium nitride in power semiconductor manufacturing – Ian Poole reports.*

THE dissipation of heat from semiconductor devices has always been a problem. In the early days of integrated circuits it seemed that there would be a relatively small limit the number of devices which could be placed onto a single chip. However, the introduction of MOS circuitry enabled very much higher levels of integration to be achieved.

Nowadays, by a combination of improved circuit design to reduce power consumption, reduced voltage rails, and improved package design to remove heat more effectively, very high levels of integration are possible.

In the field of radio frequency design, though, the problem is slightly more difficult to overcome. Transmitter driver and output amplifiers dissipate relatively high powers, and the very application means that large amounts of heat have to be dissipated. This means that the devices in these circuits must be capable of handling relatively high power levels. Accordingly, a major part of the design of any power device is involved with the package and ensuring that the heat can be removed effectively.

## Beryllium Oxide

For more than 40 years the ceramic beryllium oxide has been used. It combines the features which are required for use in these applications. Not only does it have a very high thermal conductivity, but it is also an insulator. It is ideal for use within semiconductor manufacturing techniques, because metallised pads can be placed down upon it. Its major disadvantage is that it is a potential health hazard.

Some years ago beryllium oxide heat-sink pads could be obtained on their own. Now this is banned. However, beryllium oxide can still be used inside high power semiconductors. This creates the problem that when boards using these semiconductors are scrapped, special procedures have to be used. Also, if the devices are removed from boards they then have to be treated very carefully to ensure that they are not ruptured.

All of this places considerable inconvenience on the user, especially as many countries have very stringent restrictions on the use and disposal of beryllium oxide. As a result, pressure has been mounting for device manufacturers to seek a solution.

## Safer Alternative

Now a new alternative is beginning to appear on the market. Aluminium nitride (AlN) is rapidly being adopted by many manufacturers for their high power r.f. devices. Much of the current success has

resulted from the solution of a number of technical issues which had been outstanding for some time. Now it can be manufactured in high volumes with consistent properties. It is also possible to put down areas of metallisation allowing it to be used in virtually all applications.

Aluminium nitride is a non-hazardous ceramic material which offers very similar properties to that of beryllium oxide. Now a variety of brazed AlN r.f. packages are being mass produced, including the flanged bolt down types of large r.f. power devices, as well as new flangeless surface mount variants.

## Developments

A number of developments have enabled the new material to be introduced. One of the earliest problems was in producing the powder required as part of the production process. It was found that the properties varied from one batch to the next and this resulted in an inconsistent final product. There was found to be a particular problem with the thermal conductivity which was most important. This was solved by improving the carbothermal reduction process to give the very high levels of purity which were required.

Once this was achieved the methods developed in the laboratory for small quantities had to be translated so that they could be used for full production. To achieve this, a family of binders and plasticisers was developed which enabled the material to be formed either by extrusion or pressing.

Firing methods also required attention. Methods were developed which enabled the process to be completed without contamination of the material from carbon or oxygen which caused a significant reduction in the thermal conductivity. All of this resulted in a material which consisted of 97 per cent AlN, and about 3 per cent of other materials required to enable the material to be in the right form.

## Post Processing

A number of processes can be carried out on the material to enable it to be used in a more versatile manner. Via holes (holes through the material) are often required to enable connections to be routed through the material. This can be achieved in two main ways:

Holes can be punched through the material prior to firing when it is soft. The metallisation for the connection can either be added later, or the holes can be filled with metal and the ceramic with the metal can be fired to give the through connection.

Alternatively, the holes can be cut into the fired ceramic. This is performed by a standard CO<sub>2</sub> or Nd:YAG laser. However, the cutting conditions must be carefully controlled so that damage to the surrounding ceramic is minimized. It is also necessary to suppress the creation of any aluminium metal which in turn can be converted into aluminium oxide (Al<sub>2</sub>O<sub>3</sub>). This seriously degrades the metal adhesion which is required if the holes are to be metallised to provide a through connection, which is normally the case.

## Applications

R.F. amplifiers are of great importance these days. Power amplifiers for use in cellular telephone base stations are in great demand. With networks covering an ever increasing proportion of the globe, and with new technologies like CDMA starting to be introduced there is an enormous requirement for new base stations.

This demand has added fuel to the requirement for r.f. power amplifiers. Although it is possible to build these amplifiers from discrete components, there is a growing trend to use thick or thin film amplifier blocks. Again these require efficient heatsinking and AlN is ideal for this application.

However, the ceramic has to be capable of undergoing the processes. The main one is the metallisation. Not only do via holes have to be created, but also surface metallisation has to be laid down. For thick film circuits, a metal paste is laid down in the required pattern. This can also be used to fill any via holes to give through connectivity. In the firing process this is converted into permanent areas of metallisation for connections.

For thin films a different process is preferred. Typically, vapour deposition techniques similar to those used for integrated circuits are used after the ceramic has been fired. As with any thin film metallisation process, very careful cleaning is required to ensure the metallisation is free of pinholes, pits and impurities.

## Results

The results from tests performed on the material have been very encouraging. Not only does it appear to perform well for discrete devices, but it has been shown that thick and thin film devices which use aluminium nitride as the base material have good reliability figures. This is good news for the electronics industry because not only does it appear to overcome the safety problems which were encountered when using beryllium oxide, but it gives a good final product which can be used in a variety of applications.



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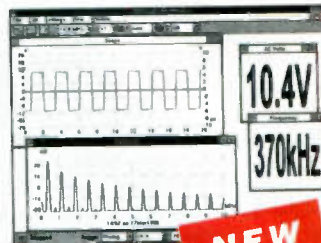
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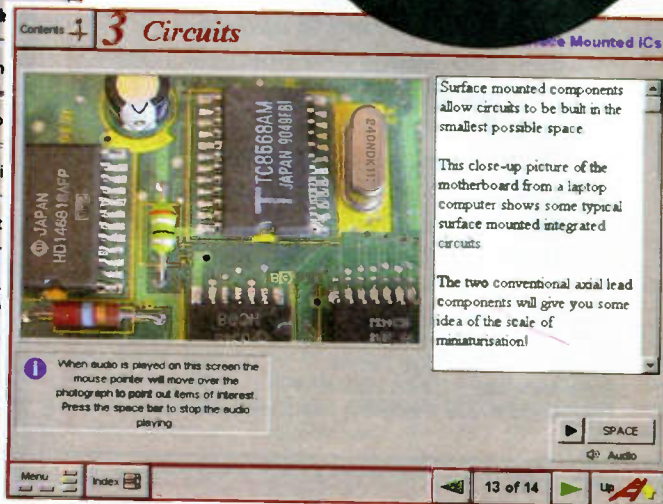
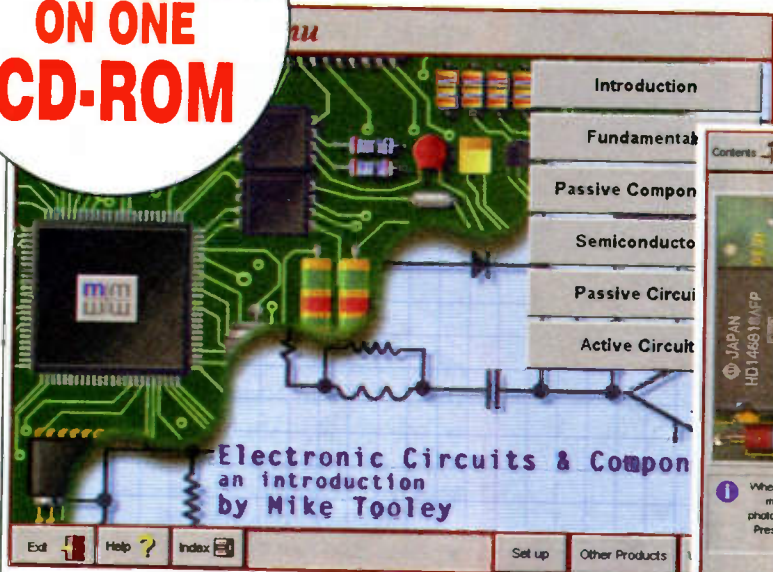
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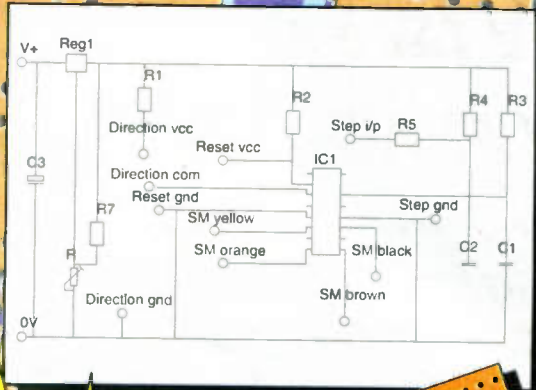
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# STRIPBOARDMAGIC

## REVIEW

ANDY FLIND

*Reviewing a program that will make laying out and constructing projects on stripboard much easier.*

**A**LTHOUGH a printed circuit board provides a neat and robust finished project there are still many good reasons for occasionally building circuits on stripboard. A ready-made p.c.b. might not be available, and even where the facilities exist the constructor may not wish to bother with the time-consuming and messy process of making one. The circuit could be a "one-off", where appearance is unimportant so long as it works reliably.

The most common use of stripboard is probably for making prototypes for circuit testing, however, as it lends itself well to rapid modifications. Large circuits in particular can be built in sections to be linked up for testing, with the part currently under development occupying a breadboard which would probably be incapable of holding the entire project.

### IT'S MAGIC

Stripboard design brings its own problems, however. Many designers dislike the process of laying out projects on it, and with so many unused holes it is far too easy to accidentally insert a component in the wrong position. Missed track "breaks" frequently cause problems and

when this happens it can be very difficult to locate the cause of the resulting circuit failure. Ambyr's new computer program "StripboardMagic" goes a long way towards overcoming these difficulties, and should prove to be very useful to anyone using stripboard for whatever reason.

"StripboardMagic" is supplied on a CD-ROM and comes with little documentation apart from licence and registration details and a welcoming leaflet with some encouraging pictures. Documentation isn't really needed however, as once loaded a series of quick and simple "help" tutorials will have the new user up and running within a couple of hours.

Installation is very easy as in most cases all that is necessary is to insert the CD in the drive and the process initialises automatically, prompting for destination directories etc. in the usual manner. By default it creates and installs into an "Ambyr" directory in the "C" drive and an uninstaller is provided in case later deletion is required.

There are two main working screens in the program, selectable simply by clicking on two "tabs". Each has two main windows. The first screen is for schematic circuit layout, with a library of

components on the left and a drawing area to the right. A library of over seven hundred components is supplied, but sensible naming and organisation allows the user to find required parts easily. These are brought into the drawing area by the "drag-and-drop" method, and connected by clicking sequentially on each pair of connection points. With practice a neat diagram can be produced, but if the user simply wants a physical layout it's faster to just bang it together and ignore the appearance as the layout process works just as well!

D.I.L. packages are handled particularly well by this part of the program as they are represented simply as boxes with the appropriate number of connection points in the same positions as the physical component. This allows them to be used quickly and easily in designs having specialised i.c.s. Connections can be specified as "off-board" for items like batteries or variable resistors, and external connection points can be set for random placement or positioning to the right-hand or left-hand ends of the board.

### LAYOUT

Once the schematic has been prepared the fun begins. Clicking on the "Physical" tab switches the program to the layout screen. The left-hand column now contains the list of components used in the schematic drawing and on the right-hand side there is an attractive picture of a piece of stripboard, in an appropriate light brown colour, just like the real thing.

The number of holes can easily be altered by adjustment of "rows" and

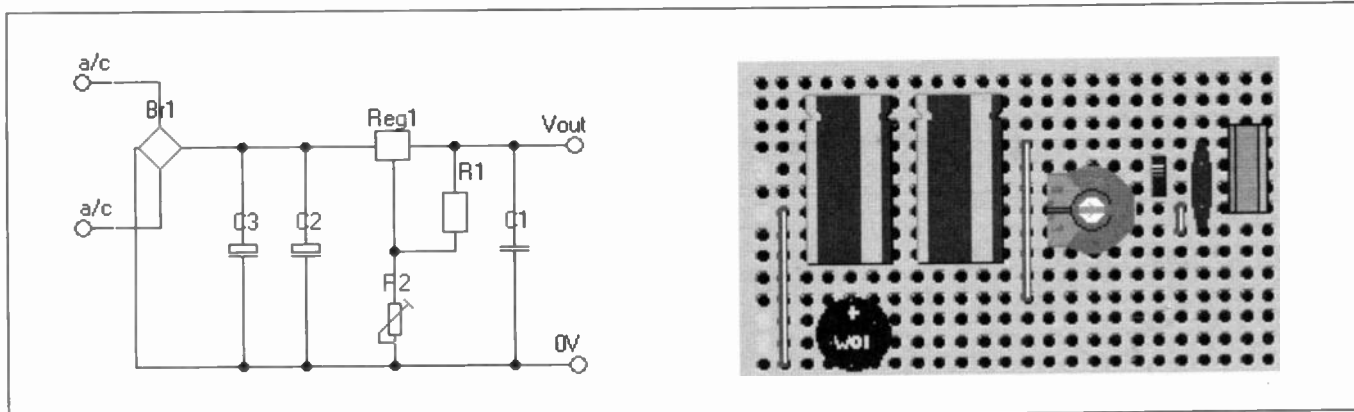
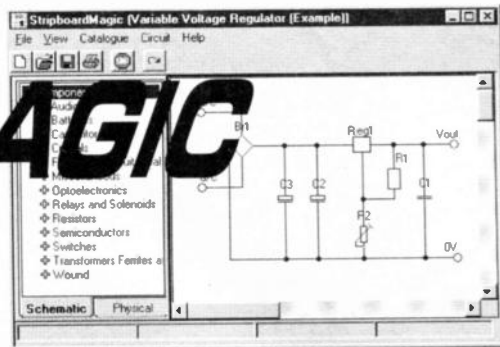


Fig. 1. Circuit diagram and the equivalent stripboard layout generated by StripboardMagic.

"columns" in a pull-down menu. Components can be selected from the list and inserted in any order, by drag-and-drop or with an auto-insertion "toolbar" button. When critical components have been placed, another button activates automatic insertion of the remaining components and any links required. However, the real power of this software is the ability to produce a complete layout from scratch, a procedure started by a single click on a toolbar button.

Surprisingly complex circuits can be laid out in a minute or two, and watching the process is sheer delight for anyone who has spent hours producing layouts the hard way with a pencil and paper. Usually the program will generate a layout with surprisingly few links though obviously this will depend upon the circuit presented to it.

## COMPRESSION

Following component placement the layout can be "compressed", again with a simple click on a button and finally one of the menus offers the option of cropping unused board. This usually results in a very neat and compact board.

this stage, where each solder joint and break can be ticked off to ensure that none are missed.

Finally, for designers with the patience to enter the necessary information, the software can even produce a component list complete with order codes of a favourite supplier ready for posting or faxing! All these items can be printed, individually or together by any Windows printer, with the physical layout in full colour where the printer supports it. The author tested this on an ageing Hewlett Packard HP500C colour inkjet and obtained excellent results.

Additionally the circuit diagram and layout may be exported as "bitmaps" for use by other programs. The illustrations in this article were produced by importing them into Corel software for cropping and size adjustment as required.

Library components may be altered or deleted and new items can be added. The process is naturally a little complicated as the physical component must correspond with its schematic partner and both must be linked to the library which offers them in the schematic layout part of the program. It's not nearly as difficult as the

screen mode instead of the recommended "16-bit" mode. Once this was corrected the whole program appeared to run more smoothly and the problems ceased. Ambyr are aware of this difficulty with 256-colour mode and are currently trying to rectify it, so anyone without 16-bit mode but considering purchasing this program would be well advised to check the situation with them first.

## MANUAL TWEAKS

From the users' point of view the old pencil-and-paper method still gives more complete control of layout than the software and it is usually possible to compress a layout further, but generally such ultimate precision and compression is not necessary. Even where it is, a lot of time and effort can be saved by having the software provide a layout as the starting point!

No allowances are made for such factors as the capacitance between stripboard tracks or the need to keep high-impedance sections short and close together, so circuits requiring attention to this sort of layout detail will need a greater degree of manual work and potential users should be aware of this.

0	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1																								
2																								
3																								
4					C3(+)				C2(+)		jmp1(a)												Reg1(in)	
5	Vout																	R1(1)		C1(1)			Reg1(out)	
6													R2(a)					R1(2)					Reg1(adj)	
7	0V	jmp 2(a)			C3(-)				C2(-)								R2(w)		jmp3(a)	C1(2)				
8													R2(b)						jmp3(b)					
9																								
10																								
11					Br1(+)							jmp 1(b)												
12	a/c					Br1(ac2)																		
13	a/c			Br1(ac1)																				
14		jmp 2(b)			Br1(-)																			

Fig.2. "Spreadsheet" details of track breaks and connections for the layout shown in Fig.1.

It's possible to have a lot of fun simply watching this program at work. If the layout generated is not to the designer's taste simply placing a few components before starting the automatic routine will often produce something entirely different, and the speed of the process makes it possible to try several different versions before selecting one as a "final" version for construction.

The program may also be instructed to produce a layout for "plug-in" breadboard instead of stripboard. This results in lots of wire jumpers which are shown in colour to make their routing easier to follow. Readers following the *Teach-In '98* series may well appreciate this feature.

## "SPREADSHEET"

In addition to the circuit diagram and layout, the program generates a "spreadsheet" giving details of all track breaks and component and link connection positions on the board, intended for use during construction. This should minimise the number of errors introduced at

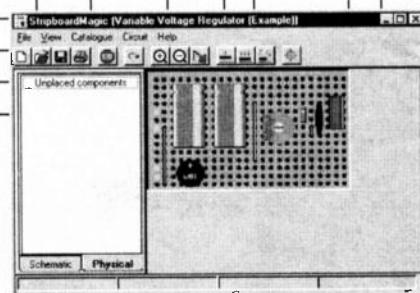
process encountered by the author in an expensive PCB layout package however.

A pixel-editing program is required for creating or altering the graphics for a component. Corel Photopaint was tried successfully but Windows "Paint", supplied as part of Windows 95, will do just as well and Ambyr say that, in fact, many of the symbols supplied were created using just this.

## REQUIRE POWER

On the downside, a reasonable amount of computing power is necessary to run this package. Windows 95 or Windows NT is currently essential and the minimum hardware configuration is a 486 DX4, but a Pentium of some description is probably preferable. This review was carried out using a P150 with 32Mb of RAM.

Initial attempts to use the program generated frequent "out of memory" failures but a call to Ambyr brought immediate assistance, and it was discovered that the problem was caused by the computer being set to "256-colour"



On the whole though, this is a software package that is easy, intuitive and a pleasure to use. At the current asking price it represents very good value for money and should prove extremely useful to anyone using, or thinking about using, stripboard.

The author wishes to thank Ambyr Limited for provision of the review copy of "StripboardMagic".

StripboardMagic is available from Ambyr Ltd., 84 to 86 Park Lane, Thatcham, Berkshire, RG18 3PG. Tel/Fax 01635 521285.

E-mail [info@ambyr.com](mailto:info@ambyr.com). Web site <http://www.ambyr.com>.

The software costs £39.95 inclusive. It is also available from Maplin - order code NN97F.

# EPE PIC TUTORIAL

JOHN BECKER

PART ONE

## WHAT IT'S ALL ABOUT

**S**INCE Derren Crome's *Simple PIC16C84 Programmer* was published in *EPE* February '96, reader interest in PIC microcontrollers has been intense. In response to that interest, we have published a variety of projects using PIC devices, ranging from the sophisticated *PIC-A-Tuner* (May '97) to the simplicity of the *PIC Digital/Analogue Tachometer* (Dec '96).

However, whilst the published designs have satisfied the call for projects that require few components yet have sophisticated capabilities, they have also prompted many readers to asked for more information on how to use PIC microcontrollers in designs of their own invention.

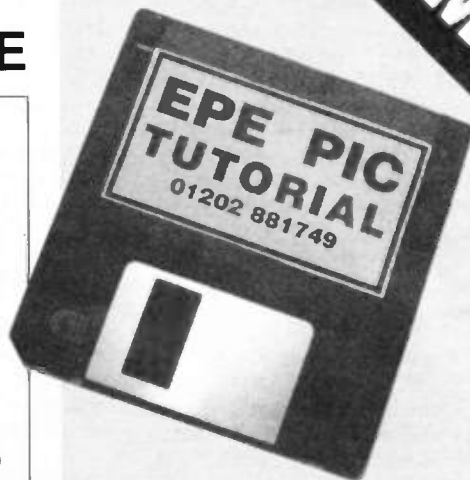
The requests have, until now, been met with a sympathetic ear and a reference to the *PIC16/17 Microcontroller Data Book* and the *Microchip Embedded Control Handbook*, both of which are readily available from Microchip, the manufacturers of the PICs (more details later) and from various component distributors and retailers. The former book gives technical information on the PIC programming commands, whilst the second gives detailed listings of extensive programming examples.

For many readers, though, the first book does not go into enough detail about how the codes are actually used and how they can be arranged in meaningful sequences to perform specific tasks. The second goes into too much detail for simple programming information to be readily located.

In the words of one interested party, "I find the *PIC Data Book* too skimming on everyday detail, and the published software too complex. Please show me how to get to grips with the *essence* of PICs. Tell me, step by step, how to get started with writing *simple* programs, how to just turn on a single I.e.d., for example. Then take me forward from there."

That, then, is the objective of this series of articles, to get you started with PICs.

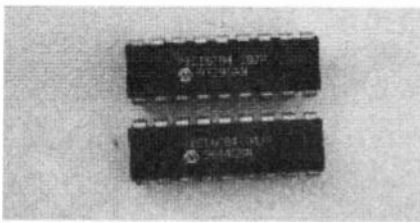
FREE SUPPLEMENT



Quite simply the easiest way to learn about using **PIC** Microcontrollers!



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## WHAT'S A PIC?

A PIC chip, in this context, is a microcontroller integrated circuit manufactured by Arizona Microchip. A microcontroller is similar to a microprocessor but it additionally contains its own program command code memory, data storage memory, bidirectional (input/output) ports and a clock oscillator. Many microprocessors require the use of additional chips to provide these requirements; microcontrollers are totally self-contained.

The great advantage of microcontrollers is that they can be programmed to perform many functions for which many other chips would normally be required. This not only makes for simplicity in electronic designs, but also allows some functions to be performed which could not be done using normal digital logic chips – i.e. circuits for which, previously, a microprocessor would have been required.

There are many families of PIC microcontroller available, ranging from those which can only be programmed once, to those that can be repeatedly reprogrammed. There are two basic families of the latter: those that require an ultra-violet light unit to erase their previous data before being reprogrammed, and one device family which is electrically erasable.

In the latter PIC microcontroller family is the PIC16C84, which is the device which we shall use throughout this series of articles. It has been chosen because of its ease of reprogramming. It is an Eeprom (electrically erasable programmable read only memory) device. This means that it can be rapidly reprogrammed as often as you wish, without the need for ultra-violet erasing.

Also, just introduced to the market is the PIC16F84, which Microchip describe as their "flash" equivalent to the PIC16C84. As far as these tutorials are concerned, the two devices can be regarded as being interchangeable. You may use the 'F84 in place of the 'C84 if you wish.

Much of the information about the commands which we present here is, in most instances, applicable to other members of the PIC family. Once you understand a PIC16C84 you should have no difficulty applying your knowledge to other PICs.

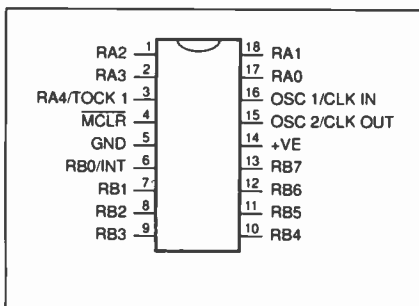


Fig.1. Pinouts for the PIC16C84 and PIC16F84.

## BASIC PIC16C84 SPECIFICATIONS

35 single-word commands (see Table 1)  
 1k × 14-bit EEPROM program memory  
 36 × 8-bit general purpose SRAM registers  
 16 special function hardware registers (see Table 2)  
 64 × 8-bit EEPROM data memory  
 1,000,000 data memory erase/write cycles (typical)  
 Data retention >40 years  
 5 data input/output pins, Port A  
 8 data input/output pins, Port B  
 25mA current sink max. per pin  
 20mA current source per pin  
 8-bit timer/counter with 8-bit prescaler  
 Power-on reset (POR)  
 Power-up timer (PWRT)  
 Oscillator start-up timer (OST)  
 Watchdog timer (WDT) with own on-chip RC oscillator

Power saving Sleep function  
 Serial in-system programming  
 Selectable oscillator options:  
 RC: low cost RC oscillator  
 XT: standard crystal resonator (100kHz to 4MHz)  
 HS: high-speed crystal/resonator (4MHz to 10MHz – PIC16C84-10 only)  
 LP: power-saving low frequency crystal (32kHz to 200kHz)  
 Interrupts:  
 External, RB0/INT pin  
 TMRO timer overflow  
 Port B RB4 to RB7 interrupt on change  
 Data EEPROM write complete  
 Operating voltage range: 2.0V to 6.0V  
 Power consumption:  
 <2mA @ 5V, 4MHz  
 60µA typical @ 2V, 32kHz  
 26µA typical standby @ 2V

Note, though, that the demo board used in this series can only be used to program the PIC16C84 and PIC16F84.

There are two versions of these chips, having the suffix -04 and -10 respectively. The suffix indicates the maximum clock rate at which the chip can be used: -04 means 4MHz, -10 means 10MHz. You may use either speed rating for this series of articles, although the -04 is likely to be stocked by more suppliers.

## WHAT YOU NEED

There are really only five things that you need in order to program a PIC, a PC-compatible computer, a standard (Centronics) parallel printer port connecting lead, a power supply capable of delivering between 12V and 14V d.c., a word-processing program, and a PIC assembly and send program.

It seems likely that any PC-compatible computer can be used. The author has programmed PICs using several different machines, from a 10-year old Amstrad 1640 having an 8086 processor, to a modern Pentium-driven Dell. Neither speed nor memory capacity are important in this application. The software provided and the files you generate by modifying it (as you are encouraged to do) will probably require about 500 kilobytes (0.5Mega).

Data is output from the computer to the PIC via the normal LPT1 parallel printer port (address &H378). It is output serially, data on port line D0, and a clock signal on line D1. The use of a standard parallel printer connector/lead is preferable, but not essential. An alternative (low-cost) interconnection method is described.

You must be sufficiently familiar with your computer to know how to operate it from the MS-DOS environment, i.e. to come out of the Windows environment (if you have it) and back into MS-DOS from where the software which assembles and sends the program code data to the PIC can be run.

You must also be able to use a word-processing program. This must be capable of producing a text file that is totally without formatting and printer commands. That is, it must be able to generate a pure ASCII text file (and to input one).

If your machine has the MS-DOS EDIT program on it, and all recent machines should have, this can be used as your text writing software. It automatically generates a pure ASCII text file.

The power supply can, if you wish, be taken from the computer. Both 12V and 5V are available on the expansion ports which are accessible from within the computer. More details will be given during the construction section.

Other power supply sources may be used instead. Basically only about 20 milliamps are required. However, a minimum availability of around 200mA would be preferable to adequately power the demo board we shall be using throughout this series.

If really pressed for a power source, a 12V car battery could be used. The demo board includes a regulator i.e. to split the supply down to the secondary level of 5V.

## ASSEMBLY SOFTWARE

The PIC assembly and send software is available free from our editorial office (details are shown in the Resources panel). This software is known as TASM (which simply stands for Table Assembly) and originates from the Public Domain Shareware Library. It is not to be confused with other software which includes the word TASM in its description or title.

It should be noted that, whilst the PIC Tutorial software on the disk is free, there is a nominal registration fee to be paid to the copyright owners (in USA) if you intend to use TASM beyond a *reasonable* trial period. The current registration fee is US \$50. Details of how to pay the fee are included on the disk. (We would regard using TASM throughout this tutorial series as being "reasonable" without the need for registration.)

Also supplied as part of TASM is an enormous text file telling you all about it. It is capable of doing far more things than just assemble PIC programs.

Another program is supplied with our TASM disk – the Send program, written for EPE by Derren Crome – which sends the TASM-assembled code to the PIC as a serial stream of binary data.

# TUTORIAL CONCEPTS EXAMINED

## TUTORIAL 1:

Minimum commands needed  
Port default values  
Instruction .ORG  
Instruction .END  
Instruction .AVSYM

## TUTORIAL 2:

File registers  
Bits  
Bytes  
Set  
Clear  
Command CLR  
Command CLRWF  
Command BSF  
Command BCF  
Ports and Port directions  
Register STATUS  
STATUS register bit 5  
Pages 0 and 1

## TUTORIAL 3:

Names in place of numbers  
Case sensitivity  
Labels  
Repetitive loop  
Command GOTO  
Instruction .EQU

## TUTORIAL 4:

Command MOVLW  
Command MOVWF  
Command RLF  
Command RRF  
Command BTFSS  
Command BTFSC  
Instruction #DEFINE  
Instruction PAGE0  
Instruction PAGE1  
Register PORTA  
Register TRISA  
Register PORTB  
Register TRISB  
Register PCL  
Double-naming numbers  
Bit naming  
Program counter  
STATUS register bit 0  
Carry flag  
Bit codes C, F, W  
Bit testing  
Conditional loop

## TUTORIAL 5:

STATUS bit 2  
Zero flag  
Bit code Z  
Command MOVF

## TUTORIAL 6:

Command INCF  
Command DECF  
Command INCFSZ  
Command DECFSZ  
Counting upwards (incrementing)  
Counting downwards (decrementing)  
Use of a file as a counter

## TUTORIAL 7:

Switch monitoring  
Command ANDLW  
Command ANDWF

Command ADDWF  
Command ADDLW  
Nibbles  
STATUS bit 1  
Digit Carry flag  
Bit code DC

## TUTORIAL 8:

Increasing speed of TUT7  
Bit testing for switch status

## TUTORIAL 9:

Responding to a switch press only at the moment of pressing

## TUTORIAL 10:

Performing functions dependent upon which switch is pressed  
Use of a common routine serving two functions

## TUTORIAL 11:

Reflecting PORTA's switches on PORTB's l.e.d.s  
Command COMF  
Command SWAPF  
Inverting a byte's bit logic  
Swapping a byte's nibbles

## TUTORIAL 12:

Generating an output frequency in response to a switch press  
The use of two port bits set to different input/output modes  
Command NOP

## TUTORIAL 13:

Command CALL  
Command RETURN  
Command RETLW

## TUTORIAL 14:

Tables  
Register PCL (again)  
Register PCLATH

## TUTORIAL 15:

Using four switches to create four different notes  
Use of a table to selectively route program flow

## TUTORIAL 16:

Indirect addressing  
Using unnamed file locations  
Port B internal "light-pullups"  
Register FSR  
Register INDF  
Register OPTION

## TUTORIAL 17:

Tone modulation  
Command XORLW  
Command XORWF  
Command IORLW  
Command IORWF

## TUTORIAL 18:

Register INTCON  
Command OPTION  
Register TMR0  
Use of internal timer

## TUTORIAL 19:

BCD (Binary Coded Decimal) counting

## TUTORIAL 20:

Precision timing at 1/25th second  
Counting seconds 0 to 60

## TUTORIAL 21:

Using 7-segment l.e.d. displays  
Showing hours, minutes and seconds  
Command IORLW (usage)

## TUTORIAL 22:

Using intelligent l.c.d.s  
Setting l.c.d. contrast  
Initialising the l.c.d.  
Sending a message to the l.c.d.

## TUTORIAL 23:

Coding hours, minutes and seconds for an l.c.d.  
Shortened clock monitoring code  
Command SUBLW  
Command SUBWF

## TUTORIAL 24:

Adding time-setting switches

## TUTORIAL 25:

Dual use of port pins for input and output  
Configuring program for alarm system monitoring

## TUTORIAL 26:

Writing and reading EEPROM file data  
Register EECON1  
Register EECON2  
Register EEDATA  
Register EEADR

## TUTORIAL 27:

Integrating EEPROM data read/write into alarm system

## TUTORIAL 28:

Interrupts  
Command RETFIE

## TUTORIAL 29:

Command SLEEP

## TUTORIAL 30:

Watchdog timer  
Command CLRWDT

## TUTORIAL 31:

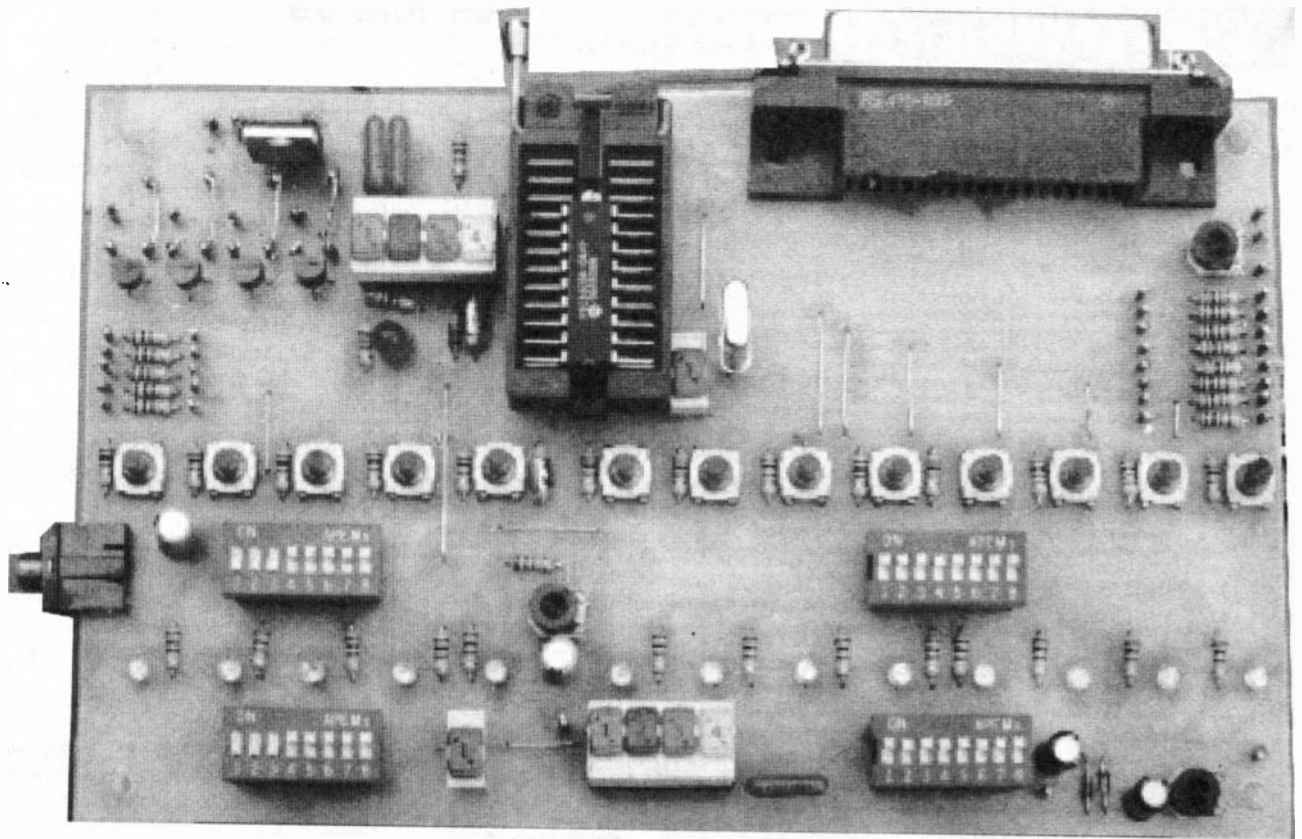
Misc Special Register bits

## TUTORIAL 32:

Programming  
PICs vs. hardware  
Summing-up

**FREE  
SOFTWARE  
ON DISK  
OR VIA  
OUR  
WEBSITE!**





You may well have heard of other PIC assembly programs, such as MPASM, for example. Whilst MPASM is generally regarded as being the industry-standard PIC assembly program, we have chosen to use TASM instead for three reasons.

TASM is the assembly program supplied to us with Derren Crome's PIC programmer at a time before we at *EPE* were familiar with using PICs. Consequently, it has become the program that the author has "grown-up" with and now knows pretty intimately. Secondly, many readers have acquired TASM through us as shareware software.

Thirdly, because TASM can be used free for a reasonable length of time, readers who do not yet know if they will take to PIC programming can try it and see how they get on. If, ultimately, they find they don't take to it, they are not required to pay the TASM registration fee.

There is, in fact, very little difference in the way that programs are written for TASM and MPASM. The PIC command codes used are identical. It is simply a matter of there being very slight grammatical differences in the way that each program line is written in the text editor. Anyone familiar with TASM will readily be able to convert their thinking to MPASM, and vice versa.

Note, though, that software written for TASM cannot be loaded into a PIC through MPASM, and vice-versa. The program text lines must conform to the grammar of the assembling program.

In a future issue we shall present a program written in Basic which makes the majority of the required to convert from one assembler to the other.

A bit more information about MPASM will be given at the end of the Tutorial series.

## A FIFTH NEED

Throughout this series of articles, we shall examine in a fair amount of detail the commands which it is expected you will find most useful. It is hoped that it will give you all the necessary information which will enable you to conceive a design in which you can use the PIC16C84 to control whatever situation you wish, and to write the code that will let it do so.

There is, though, much more to writing programs than you may at this moment fully appreciate. Knowledge about individual commands and the way in which they can be used is not enough in itself. Programming is a way of looking at the world in ways that other people may not recognise. You must have the mental ability to see each programming situation as a step-by-step function, analysing in your mind exactly how it is that you need to specify the complete program flow.

You have to write the sequence of events with the correct grammar, with the correct spelling and in the correct order. Undoubtedly you will make mistakes while you are writing the code, failing to see the correct sequence of events and using incorrect command structures.

You require the ability to analyse what you have done wrong and to correct it. You are likely to be confronted with an overall task that may, on occasion, take you into several days or even weeks of dedicated concentration.

Programming, to those who have the ability to see things "as they are" and not "how they seem to be", can become extremely addictive. You could find yourself compelled to get back to the keyboard and PIC programmer at any conceivable hour. You had better have an understanding family!

## FIRST THINGS FIRST

To get you started programming PICs, we shall first ask you to assemble a printed circuit board which will be used to illustrate the program examples that we shall discuss. The board comprises a single PIC16C84 microcontroller, 14 light emitting diodes (l.e.d.s) and several banks of switches. In Tutorial 21 you will be asked to also connect the p.c.b. to a 4 × 7-segment l.e.d. display and, in Section 22, to a 2-line 16-character "intelligent" liquid crystal display (l.c.d.).

Using the switches and the example simple programs, you will be encouraged to build up your experience of how the PIC16C84 can be made to respond to different practical situations.

Having told you, in as few words as are really necessary, about the p.c.b. and its circuit, we shall start at the very beginning of programming. The first lesson will be about the very minimum of information that needs to be written into a program listing before the PIC can do anything else.

We shall then, "step by step", take a specific very simple task, such as turning on an l.e.d., and describe in detail each of the commands that are required to do the task.

Having described one task, we then take that idea a stage further, adding a few more commands that will enhance the capabilities of the program. Each of these commands will similarly be discussed in detail. Thus we shall progress, taking simple ideas, and illustrating how they can be achieved and then enhanced.

We feel that this approach is far more useful than describing each and every one of the commands in turn before we ever get to use them. Most people learn by doing, reading about things in short

# COMPONENTS

## Resistors

R1	2k2
R2 to R4,	
R6 to R18,	
R32 to	
R36	1k (21 off)
R5	10k
R19 to R31,	
R37 to	
R44	100Ω (21 off)
All 0.25W 5% carbon film.	

## Capacitors

C1, C2	10p polystyrene (2 off)
C3	1μ radial elect. 16V
(see text)	
C4, C5, C8	100n polyester (3 off)
C6, C7	22μ radial elect. 16V (2 off)

## Potentiometers

VR1, VR3	100k min. horiz. preset, round (2 off)
VR2	5k min. horiz. preset, round

## Semiconductors

D1, LA0 to	
LA4, LB0	
to LB7	red l.e.d. (14 off)
D2 to D4	1N4148 signal diode
(3 off)	
TR1 to TR4	BC337 npn transistor
(4 off)	
IC1	PIC16C84 microcontroller
(see text)	

## Miscellaneous

S1 to S4,	
SA20, SA21,	
SA20,	
SB21	4 × d.p.c.o. slide switch, p.c.b. mounting (2 off)
S5, S6	d.i.l. 1-pole changeover (2 off)
SA0 to SA4,	
SB0 to	
SB7	min. s.p. push-to-make switch, p.c.b. mounting (13 off)
SA10 to	
SA14,	
SA30 to	
SA34,	
SB10 to	
SB17,	
SA30 to	
SA37	8-way d.i.l. slide switch (4 off)
SK1	36-way Centronics socket (see text) p.c.b. mounting
SK2	jack socket, 3.5mm stereo, p.c.b. mounting
X1	3.2768MHz crystal
X2	4-way multiplexed 7-segment display, common anode (optional - see text)
X3	2-line 16-character intelligent l.c.d. (optional - see text)

Printed circuit board, available from the *EPE PCB Service*, code 182; 8-way d.i.l. socket (6 off); d.i.l. socket for IC1 (see text); 1mm double-sided terminal pins; 10-way ribbon cable (25cm approx.); personal headphones, see text; flat-based p.c.b. supports (4 off); solder, etc.

Approx Cost  
Guidance Only

**£35**

sections and applying the knowledge in practical bite-sized chunks. A complete chapter on all the commands in sequence would be too much to remember and understand in one go.

The complete list of commands for the PIC16C84 is shown later in Table 1 (page 12). All except two of them will be

# RESOURCES

The printed circuit board for the PIC Tutorial is available from the *EPE PCB Service*, code 182.

The other components are obtainable from many retail suppliers, including some advertisers in *EPE* - study the adverts. The author's components were all purchased from RS Components (trade only), tel: 01536 201201. The retail outlet for RS is Electromail, tel: 01536 204555.

Software for the PIC Tutorial is available from the *EPE* editorial office on a 3.5 inch disk, order as *PIC-Tutor Disk*. There is a nominal charge of £2.75 (UK)

to cover our admin costs, the software itself is free. For overseas readers, the charge is £3.35 surface mail, £4.35 airmail. Alternatively, the software can be downloaded free from our Web site: <ftp://ftp.epemag.wimborne.co.uk/pub/PICS/PICtutor>.

You may order our other PIC software disk at the same time (order as *PIC-Disk 1*). The same nominal charges apply. This disk holds the majority of the PIC software we have published over the last two years. It too is on our Web site - examine the Web site menu for more details.

discussed and demonstrated. The reason for omitting the two (OPTION and TRIS) is that Microchip recommend that they are not used in order to maintain upward compatibility with later series of PICs; the PIC17xx series has dropped them.

As we shall see, there are a lot of "bit-orientated" sub-commands available as well as the main commands. Some of these are similar in operation and close examination will be given only to the principle ones - once you understand these, use of the similar bit-setting commands available will become obvious from reading the *PIC Data Book*.

## TUTORIAL SECTIONS

Following this introduction, the Tutorials themselves are split into 32 sections. Each Tutorial deals with specific coding topics but, in most cases, is a direct follow-on from the previous Tutorial, and is nearly always visually illustrated by the displays on the p.c.b. The exception to the latter is when sound is used as the output medium, when a pair of personal stereo headphones is needed.

At the end of most Tutorials there are a few simple exercises which allow you

to experiment with the simple program presented in that section. You will only be expected to use the commands that have already been introduced to you.

None of them should tax your brain too much, but they will, hopefully, encourage you to think of alternative ways in which the same basic task can be tackled, or to consider other tasks that can be achieved using similar techniques.

By the end of the series, you will know how to get the PIC16C84 to respond to switches and other external signal sources, send data to various types of display, to create sound, to be the heart of a 24-hour clock, to store data in its non-volatile Eeprom memory, and to monitor an intruder alarm system.

Readers who have had experience of programming in Basic, or with other types of microprocessor, will find that once a few commands have had their functions explained, using them will rapidly become instinctive. The author, having many years of such practice, effectively learned about PICs and how to use them over a single weekend following the reading of Derren Crome's article and doing a bit of experimenting.

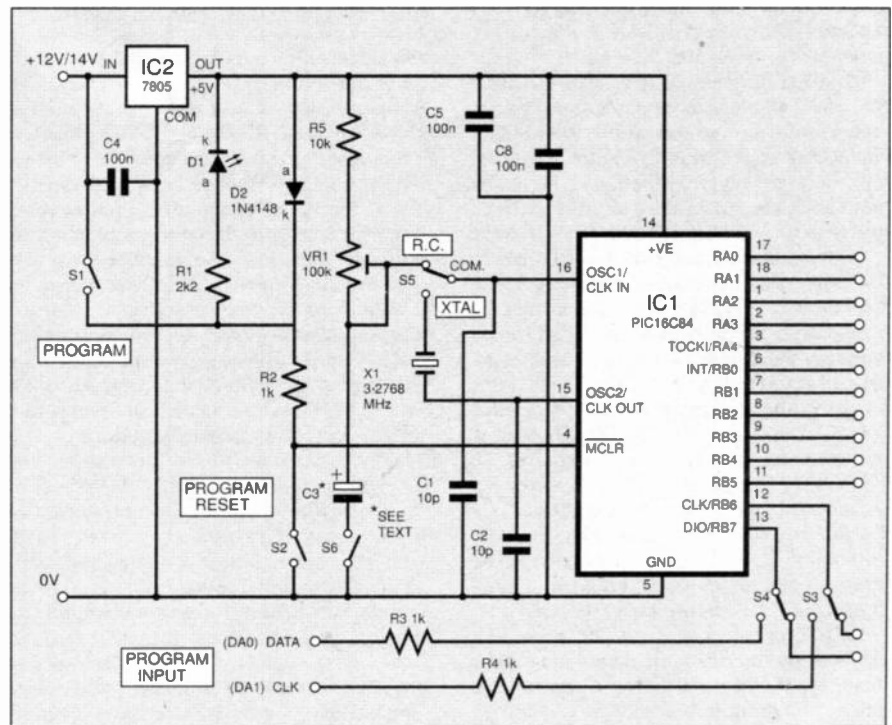
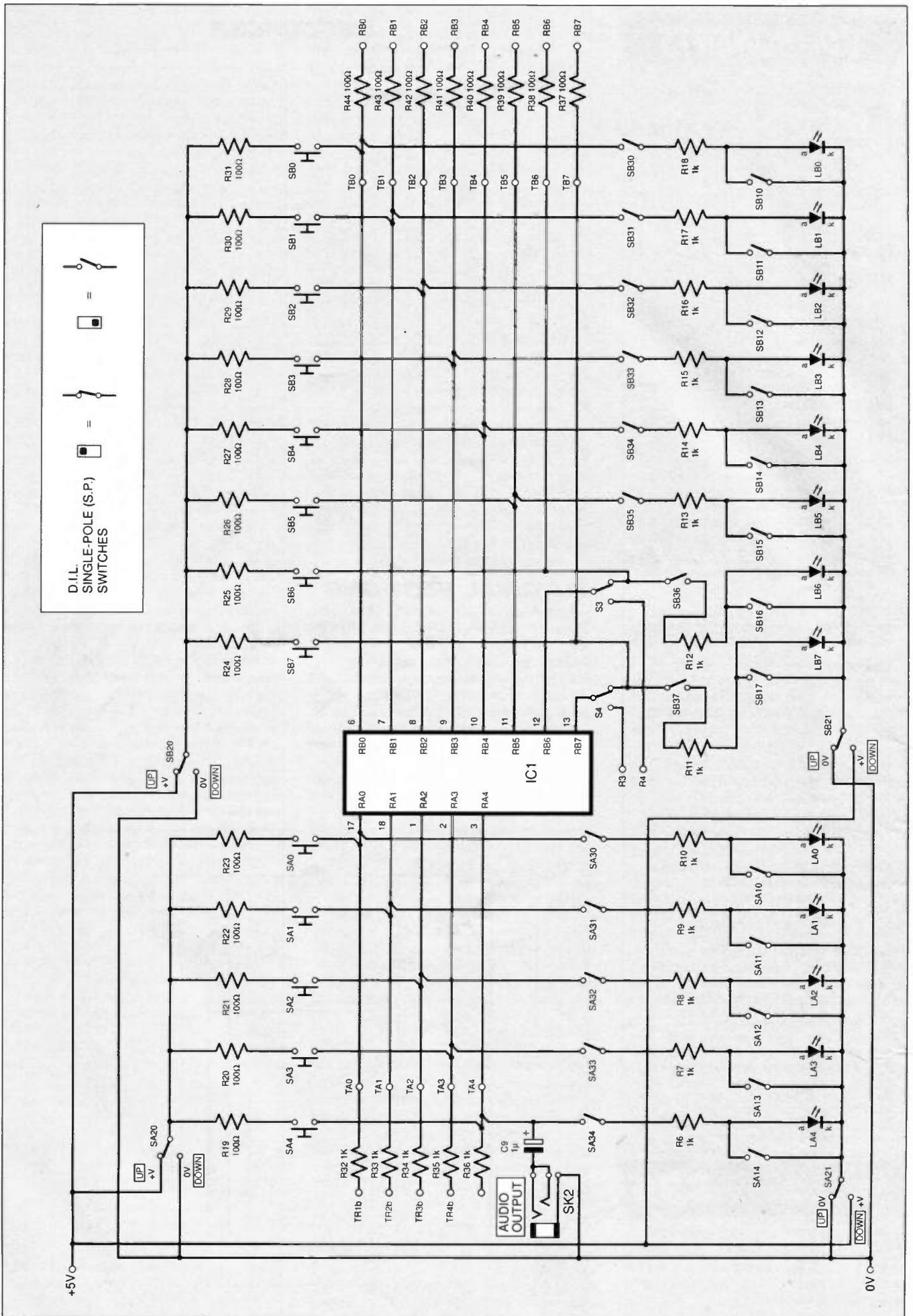


Fig.2. The programming heart of the PIC16C84 Tutorial circuit. It can be used as a stand-alone programmer.





Other readers without such experience will, it has to be said, have to become accustomed to understanding programming itself as a step by step process. An analytical mind is required and there is no easy way in which programming can be taught to those who lack this capability.

## DEMO CIRCUIT

Now let's move formalities out of the way as quickly as we can, getting the demonstration circuit and p.c.b. described and assembled. Then we can enjoy the fun part, playing with programs and flashing lights!

Although the circuits and printed circuit board have been designed specifically for this Tutorial series, the whole set-up will be of enormous value when prototyping your own PIC designs in the future. The various built-in switching and output options available, whilst not catering to every eventuality, will save a great deal of bird's nesting and improvised component connections.

The pinout diagram for the PIC16C84 is shown in Fig.1 (see page 2). The device is shown in the circuit diagram of Fig.2 (page 5), designated IC1, and the components which allow it to be programmed from a PC-compatible computer, using the previously-mentioned TASM software.

To program IC1, a 12V to 14V supply is switched by S1 to its control pin 4. The l.e.d. D1 indicates when S1 is switched on. In non-programming mode, pin 4 is held at about 4.4V via diode D2.

Switch S2 is the Reset control, switching it on takes IC1 pin 4 to 0V, holding the chip reset. Resistor R2 protects the power lines at this time.

Switches S3 and S4 connect the computer's printer port (LPT1) data lines D0 and D1 to IC1 pins 12 and 13. Line D0 carries the data, D1 carries the clock signal. These switches prevent interaction between the PIC and the PC when the PIC is actually running a program.

How to load a program into the PIC will be discussed after the p.c.b. assembly has been described.

There is a choice of clock oscillator techniques offered, either RC (resistor-capacitor) or crystal controlled. The frequency generated using the former is variable by preset potentiometer VR1 across a range determined by the value of capacitors C1 and C3. Different frequency settings will be used at various stages throughout these tutorials.

## SWITCHING OPTIONS

The crystal oscillator will only be used towards the end of the series when an accurate clock frequency is required. In other prototyping applications, crystals having different frequencies may be used in place of the 3.2768MHz device shown.

The switching options and demo l.e.d.s are illustrated in Fig.3. The PIC16C84 has two input/output ports, Port A and Port B. Each pin of each port has its own l.e.d. and set of switches. The somewhat unusual numbering of these items is because of the way in which the port pins are numbered.

Numbering the l.e.d.s. and switches similarly helps to clarify which components are referred in this text. Resistors are numbered conventionally since they are not actively discussed.

Switches SA0 to SA4 and SB0 to SB7 are push-to-make switches for Port A and Port B respectively. Resistors R19 to R31 protect the ports from excess current flow if the switches are pressed when the ports are configured as outputs.

Switches SA10 to SA14 and SB10 to SB17 allow the l.e.d.s to be bypassed when the push-switches are required for use.

Switches SA20, SA21, SB20 and SB21 reverse the polarity of the bias voltage received by the port pins when they are in input mode and use of the push-switches is required.

Switches SA30 to SA34 and SB30 to SB37 connect the ports to the networks of l.e.d.s and associated switches. Resistors R6 to R18 are ballast resistors for the l.e.d.s and also protect the ports from excess current flow if switches SA10 to SA14 and SB10 to SB17 are switched on when the ports are configured as outputs.

Resistors R32 to R44 protect the ports from excess current flow when they are in output mode and external circuits are connected to the ports via these resistors. Direct connection to all port pins can be made without the intervening resistors.

Note that the resistor values have been selected to provide the best circuit protection that is compatible with letting all aspects of the demo board function satisfactorily. The values are not necessarily those which would be best suited to a stand-alone design for other applications. Provision has been made on the p.c.b. for most resistors to be readily changed for other values.

## RESIST IT!

On the subject of resistors, there is an occasional misconception that the PIC can drive l.e.d.s without the use of ballast resistors. This seems to have come about because the *PIC Data Book* states that the PIC16C84 has a "high current sink/source for direct l.e.d. drive".

Indeed, it has this attribute, but this should not be taken so literally. There is a maximum voltage that can be applied across an l.e.d., typically 2V. Unless the PIC is being powered at or below the same voltage as is safe for the l.e.d., a ballast resistor *should always be used* in series with a PIC pin and an l.e.d.

You may "get away" with driving an l.e.d. from a PIC being powered at 5V and not using a resistor. No doubt you will have seen circuits where resistor-free l.e.d.s are being PIC-driven (even in *EPE*), but it is not a "good practice" technique.

Such circuits probably work for one of three reasons: the PIC is overload protected for short periods of time, with its output voltage becoming lower than normal maximum (current source) or higher than normal minimum (current sink); the l.e.d. has a better ability to withstand over-voltage than its data sheet would imply; the "on" period of the l.e.d. is too short for damage to occur.

Whatever the reason, though, the PIC and the l.e.d. are still being worked beyond their normal specifications and damage could result.

However, note that there are some types of l.e.d. available that already have a ballast resistor built in - an additional resistor is not required with these types, provided

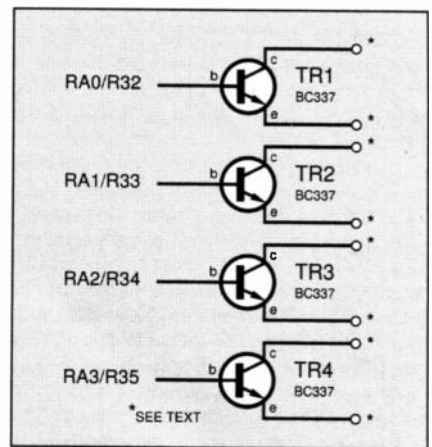


Fig.4. Port A's buffer transistors.

that the internal resistor is suited to the voltage to be applied across the l.e.d.

## CURRENT AMPLIFIERS

In Fig.4 are shown four transistors, TR1 to TR4. These are connected to the first four pins of Port A and are useful for controlling other components or circuits which require a higher current than the PIC can supply.

They have open collectors and emitters which may, therefore, be connected as desired. Use of the transistors will be seen when we examine 7-segment display control.

## PRINTED CIRCUIT BOARD

Details of the printed circuit board component layout and master full size track pattern are shown in Fig.5 and Fig.6. This board is available from the *EPE PCB Service*, code 182.

The p.c.b. will eventually be connected to two types of display, multiplexed 7-segment l.e.d.s and intelligent l.c.d.s, which will be discussed in Tutorials 21 and 22.

Looking at the trackside of the p.c.b., note that some resistor positions have circular pads around their holes, as opposed to oblong ones. All these holes should be drilled out to 1.0mm diameter to allow terminal pins to be inserted. (In manufacture, all holes are drilled to a standard 0.8mm diameter.)

The terminal pins allow resistors to be soldered across them above the board, enabling different values of resistor to be readily used for other future applications.

You do not *have* to mount the resistors this way and you may, if preferred, insert them into the p.c.b. in the normal way. Whichever method you choose, at present only those resistor values shown should be used.

All other circular pad holes should be drilled out wherever 1.00mm terminal pins are used for external wiring connections. You may require larger holes for jack socket SK2.

It is suggested that the dual-in-line switches should be mounted in i.c. sockets, allowing their easy removal should you ever wish to. The likely life is around 20,000 operations for the d.p.c.o. switches, and 2000 operations for the s.p.s.t. types.

It is essential that a socket is used for

the PIC16C84. You have a choice of type, however. The suggested type is a zero insertion force (ZIF) socket, which allows easy insertion and removal of the PIC.

At the time of designing the p.c.b., the author was unable to obtain an 18-pin ZIF, and had to use a 24-pin "universal" type, ignoring the unused pin receptacles. Universal ZIF sockets accept chips of different pin widths, from 0.6 inches to 0.3 inches (PIC16C84 width). However, it is known that 18-pin 0.3-inch ZIF sockets are currently available from some suppliers.

Alternatively (and more cheaply), a standard 18-pin socket may be used. The board allows either type to be mounted.

You could also use an ordinary 24-pin socket soldered into the board, and then push in a universal ZIF when needed, allowing it to be used in other applications. This technique would also allow a single-in-line 9-pin socket to be inserted into the board as well, catering for direct insertion of a PIC should the ZIF not be to hand. This was the author's technique, as seen in the photograph.

### P.C.B. ASSEMBLY

Assemble the p.c.b. in any order you wish. It is suggested, though, you do it in order of wire links, i.e. sockets, "inserted" resistors, diodes, transistors, l.e.d.s, capacitors, presets, and IC2, treating each group separately.

Connect capacitor C3 across the terminal pins allowed for it, ensuring its correct polarity. This capacitor is required until we reach program TUT11 (Tutorial 12), from then on it will be switched out of circuit. The switch setting diagrams show whether or not C3 is required.

The push-switches are probably best soldered into the board, rather than using sockets for them (their pins might not fit into all types of d.i.l. socket).

Now solder 1.0mm terminal pins into all the remaining holes, including those for the crystal. Do not solder in the crystal, but solder it across the pins, allowing different crystals to be used in the future.

There is a choice regarding how the board is to be coupled to the computer. As shown, a Centronics connector is used (SK1), allowing a standard printer cable to be plugged in. This is by far the easiest method of interchanging computer connections between this p.c.b. and a printer, saving fiddling around at the back of the computer each time you want to change over.

The other method is to use a 3-way cable soldered to the p.c.b. at the designated points, terminating it at the other end with a 25-way D-type connector (male), which is plugged into the computer in place of the printer cable. The connections are shown in Fig.7. Note that the standard printer cable has different connectors at each end.

For those who wish to use the PC's expansion socket as the source of power, the connector's slot designations are also shown in Fig.7. Single-sided 0.1 inch pitch stripboard (Veroboard) can be cut to size and used as the connector plug. Check the PC's manual for the correct orientation of the socket and the plug. **Ensure that the stripboard tracks do not short between the connector's terminals.**

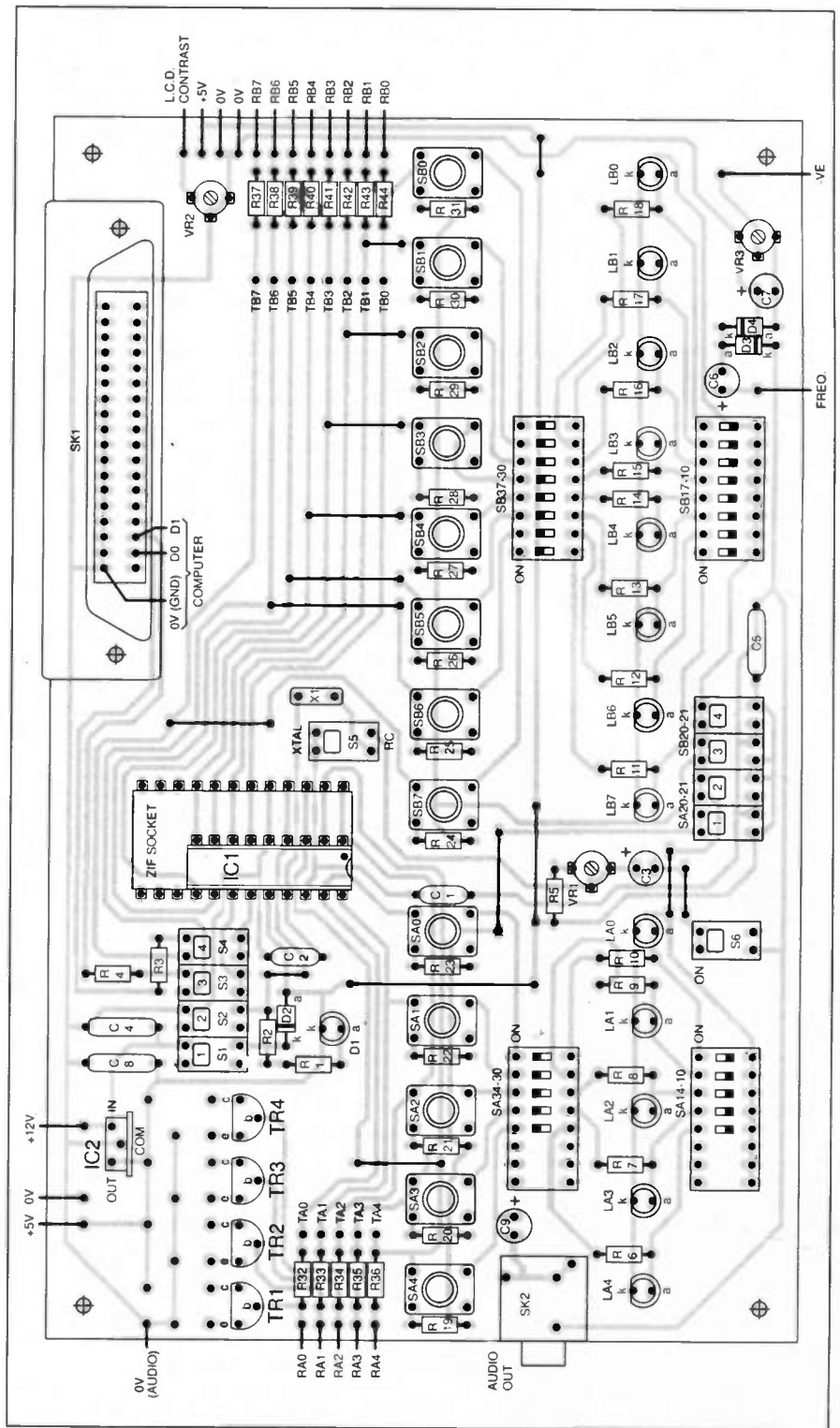


Fig.5. Component layout on the PIC16C84 Tutorial p.c.b.

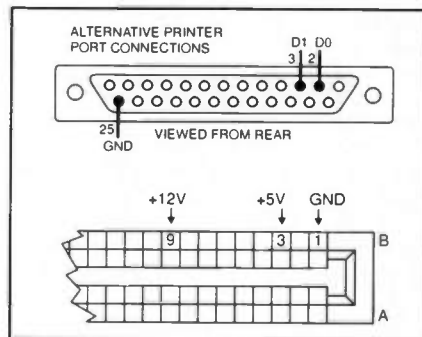


Fig.7. Relevant printer port (top) and expansion port (bottom) connection details (see text).

### FIRST CHECKS

Before inserting the PIC, couple the board to a 12V to 14V d.c. power supply (preferably stabilised). If you have to use a 15V supply, use it in series with two 1N4001 diodes (in the positive line) to drop the voltage down below 14V.

Now, and throughout the Tutorials, you will be asked to set various switches according to simple schematic diagrams. The logic of the switching is shown in Fig.8.

Set all slide switches as shown in Fig.9. You will probably find that a small screwdriver is best for changing the settings, the switch toggles being so small.

Turn on the power and check that the input voltage is within the 12V to 14V

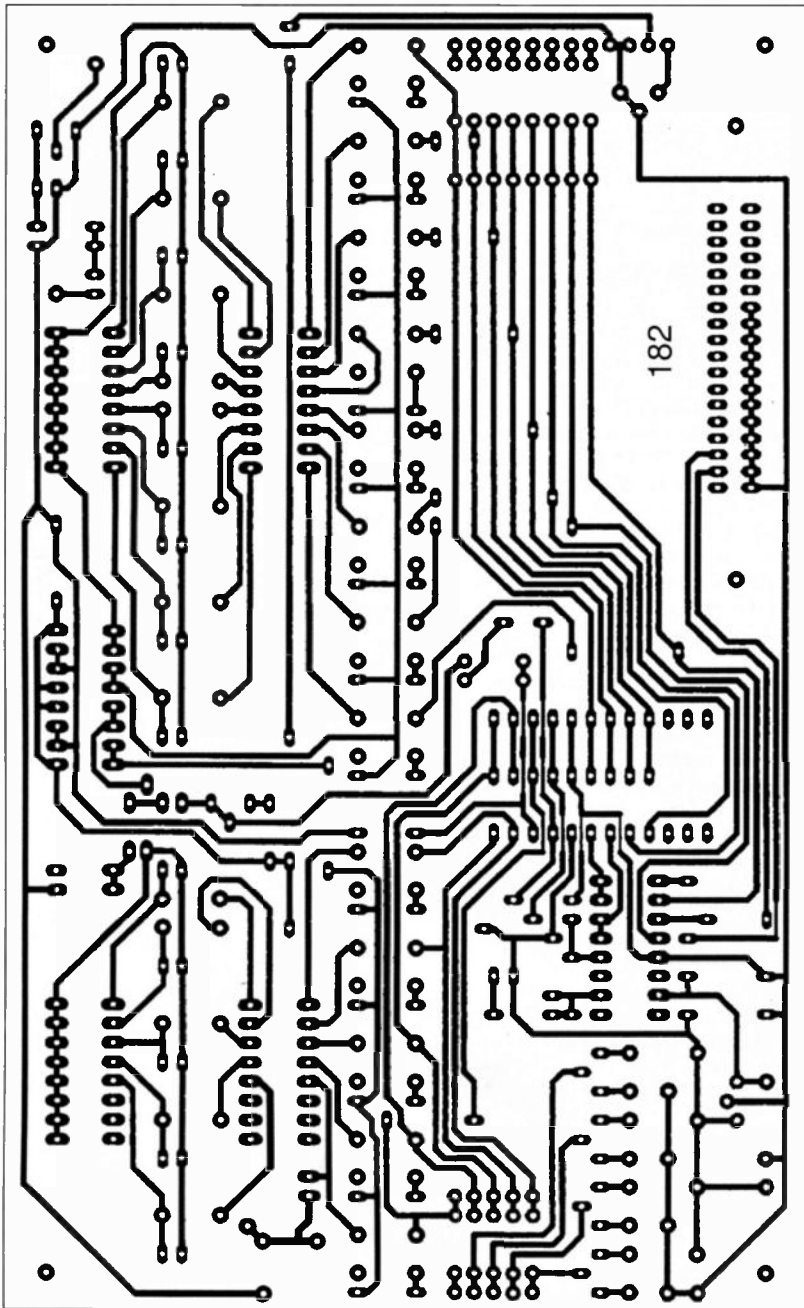


Fig.6. Full size track master foil layout.

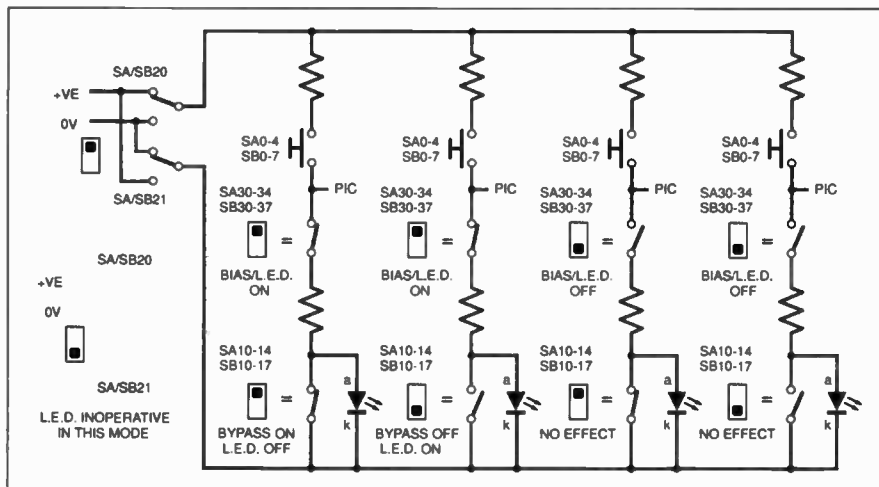


Fig.8. Logic of the switching and l.e.d. configurations shown in Fig.3.

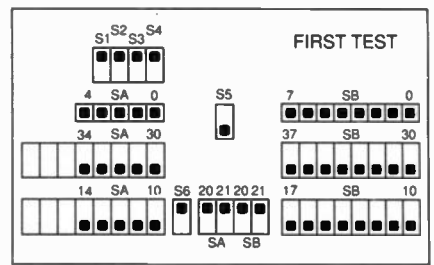


Fig.9. Initial switch settings.

range, and that 5V is present at the output of IC2. No l.e.d.s should be on. Check that about 4-4V is present at IC1 pin 4 (it may be a bit higher - 4.7V on the prototype - but not significantly lower).

If you experience problems at any stage of checking, they should be rectified before moving between each checking stage. Poor soldering is the most likely cause.

Switch down S1 (Program on) and check that l.e.d. D1 comes on and that 12V to 14V is present on IC1 pin 4. Switch down S2 (Reset on) and check that pin 4 is now at 0V. Switch off (up) S1 and S2.

Switch up SA30 to SA34 and SB30 to SB37 (bias/l.e.d. path on). Pressing each of the push-switches in turn should cause its corresponding l.e.d. to come on. Switch down SA20, SA21, SB20 and SB21 to reverse the voltage polarity across the push-switches. Press the latter again - the l.e.d.s should not come on.

Switch up SA20, SA21, SB20 and SB21. Switch up SA10 to SA14 and SB10 to SB17 (l.e.d.s off, bypass on). Again press the push-switches; the l.e.d.s should still stay off.

Switch down SA10 to SA14 and SB10 to SB17 (l.e.d.s on/bypass off). That completes the initial checking.

### DEMO PREPARATION

The demonstration disk contains the PIC programming software and TASM documentation, plus all the demo files used in these Tutorials. They must be copied onto your hard disk (usually drive C), after which the demo disk should be put away in a safe place, just in case you need it again.

To copy the software onto the hard disk, return to the MS-DOS mode, from which you should see the following on your screen:

```
C:\ >
```

If not, type:

```
c:
cd\
```

Put your demo disk in whichever drive takes a 3.5 inch disk. Now type the following commands. (All commands are followed by pressing <enter>):

```
md pictutor
cd\pictutor
copy a:*.*
```

The first command creates a directory called PICTUTOR. The second opens up that directory. The third command then copies everything from the demo disk into the PICTUTOR directory.

If your 3.5 inch drive is not drive A (as in the above), substitute the relevant letter instead of the a, e.g.:

```
copy b:*.*
```

Having copied the disk onto the hard drive, make another 3-5 inch copy of the hard disk PICTUTOR directory. Replace the original disk in drive A with a formatted blank disk and type:

```
a:
copy c:\pictutor\*.*
```

Put this disk safely away.

All the demo program files are written as ASCII text files (with a .ASM ending – pronounced “dot A.S.M.”) and need to be assembled as object code files (with a .OBJ ending) suitable for downloading to the PIC. They cannot be sent to the PIC as they stand.

To assemble a .ASM file, you must first be in the PICTUTOR directory. If you are not already in it, type:

```
c:
cd\pictutor
```

Taking file TUTTEST.ASM as an example, assemble it using this command:

```
tasm -1684 -b tuttest.asm
```

Note that there are three single spaces as follows:

```
tasm(space)-1684(space)-b(space)tuttest.
asm
```

This command line tells TASM to use the 1684 table (PIC16C84) to assemble a binary file (-b) from file TUTTEST.ASM. Your typed commands may be in capital letters if you wish.

The following messages will now appear, with a brief interval between them:

```
ASSEMBLER FOR PIC16C84 Version
3.0, October, 1993.
```

```
Copyright (C) 1985-1993 by Speech
Technology Incorporated
```

```
tasm: pass 1 complete.
```

```
tasm: pass 2 complete.
```

```
tasm: Number of errors = 0
```

```
C:\PICTUTOR>
```

The last message (C:\PICTUTOR) may vary depending on the version of MS-DOS you are using (it may just be C:\).

If you make any error in your typed command line and enter a file name which does not exist (e.g. TUYTEST.ASM), the following message will appear after the copyright statement:

```
tasm: source file open error on
TUYTEST.ASM
```

Other messages can also appear, depending on the nature of the error. For example you might type the wrong TASM table number (it has several tables for other processors, -1684 indicates the table for the PIC16C84):

```
tasm -1648 -b tuttest.asm
```

This would generate the message:

```
tasm: table file open on tasm1648.tab
```

Note that at various points in the text, we ask you to “load and run” program files. The meaning is that you should first assemble the .ASM file, and then send the resulting .OBJ file to the PIC.

You may find it preferable to do all the pre-assembly of our .ASM files before progressing through the Tutorials. There is a shorthand way of avoiding typing the full command line each time. First assemble

(for example) file TUT1.ASM using the following line:

```
tasm -1684 -b tut1.asm
```

When the assembly is complete, press the F3 key. This will cause the above line to reappear. Press the backspace key to remove the 1.asm. Now type 2.asm and press <enter> to assemble TUT2.ASM. Repeat this for all the Tutorial programs.

When asked to load and run, all you do now is use the Send routine (shortly to be discussed) with the named file.

## PIC CONFIGURATION

Having assembled a .ASM file, you can then download its .OBJ file to the PIC. Before we do it, though, run through the following procedures without the demo p.c.b. connected to the computer’s printer port, and without a PIC in the socket, just to get a feel for what you have to do. Switch on power to the p.c.b. and then type:

send

The following menu (call it Menu 1) will appear:

```
PIC16C84 Programmer by Derren
Crome
```

```
1..... PIC16C84 configuration set-up
```

```
2..... Load object code and send to PIC
```

```
3..... Quit program
```

```
enter option 1, 2 or 3
```

As the PIC needs to be configured to suit the programs which are to be used with it in this series, select Option 1, whereupon the following messages and menu (call it Menu 2) will replace the previous ones:

```
Program to set configuration fuses
```

```
WARNING: Any program presently in
the PIC16C84 will be erased
```

```
Please enter which type of oscillator you
wish the PIC16C84 to use:
```

```
1... LP low power crystal oscillator
(32KHz – 200KHz)
```

```
2... XT crystal oscillator (100KHz –
4MHz)
```

```
3... HS high speed crystal oscillator
(4MHz to 10MHz)
```

```
4... RC Resistor capacitor oscillator
```

```
Enter selection 1 to 4
```

For the first stages of the Tutorials we want to use the RC oscillator mode, so choose Option 4. Now three other options will appear in turn. Answer each as shown here (you only need to enter the initial letter of Yes or No, the software completes the word for you – you do not need to press <enter>):

```
enable watchdog timer ?
```

```
enter Y or N No
```

```
Enable power-up timer ?
```

```
enter Y or N No
```

```
Send configuration data to PIC16C84 ?
(Y/N)
```

Answer Y to the last question, which causes this next statement to appear:

```
Make sure PIC16C84 is in program
mode (12V-14V on pin 4)
then press a key to begin transfer
```

To put the PIC into program mode, set switches S1 to S4 in the following order:

S2 down (reset on), S1 down (12V on), S3 and S4 down (connections to computer printer port on), S2 up (reset off). Switching up S2 when S1 is on applies 12V to pin 4. When switch S1 is down, the l.e.d. (D1) near to it lights up.

Now press any key, after which this message will appear after a brief delay while the data is sent to the PIC:

**Configuration data sent**

**Now reset the PIC16C84 (pin 4 low briefly), press a key**

In response to this instruction, switch S2 down (Reset on) and leave it down (ignore the “briefly” statement). Then press any key. The screen will again show the three-option menu (Menu 1).

You will normally not need to use the configuration program again unless you wish to change the configuration.

Note, though, that occasionally (and for a variety of reasons) the configuration in the PIC can become corrupted. If you find that a program which you believe should run does not, run the configuration program to ensure that the PIC is correctly configured, and then re-send the program.

Sometimes corrupted configuration can prevent another program from replacing an existing one, the latter continuing to run even though the new one has been sent.

Three reasons for needing to reconfigure are worth mentioning. If you inadvertently change the settings of switches S1 to S4 while sending a program, the PIC may wrongly interpret the data being sent and change its configuration. Noise on the computer’s D0 or D1 lines could cause a similar effect. This is less likely if a proper printer cable is used.

Thirdly, a spike on the mains power line to the computer or power supply could corrupt the data, or the PIC’s response to it, during sending.

## SENDING PROGRAM

To send the .OBJ program to the PIC, we use Option 2 from Menu 1. Select Option 2 and the following two messages appear:

```
Program to load and transfer object
code to the PIC16C84
```

```
Enter name of object file:
```

At this last prompt, enter the name of the file you want to send, in this case we wish to send TUTTEST.OBJ, but we do not need to enter the .OBJ ending, we just type: \

```
tuttest
```

and press <enter>. (It does not matter if you do enter the .OBJ ending, the program will ignore it.) The screen then shows:

```
Enter name of object file: tuttest.obj
```

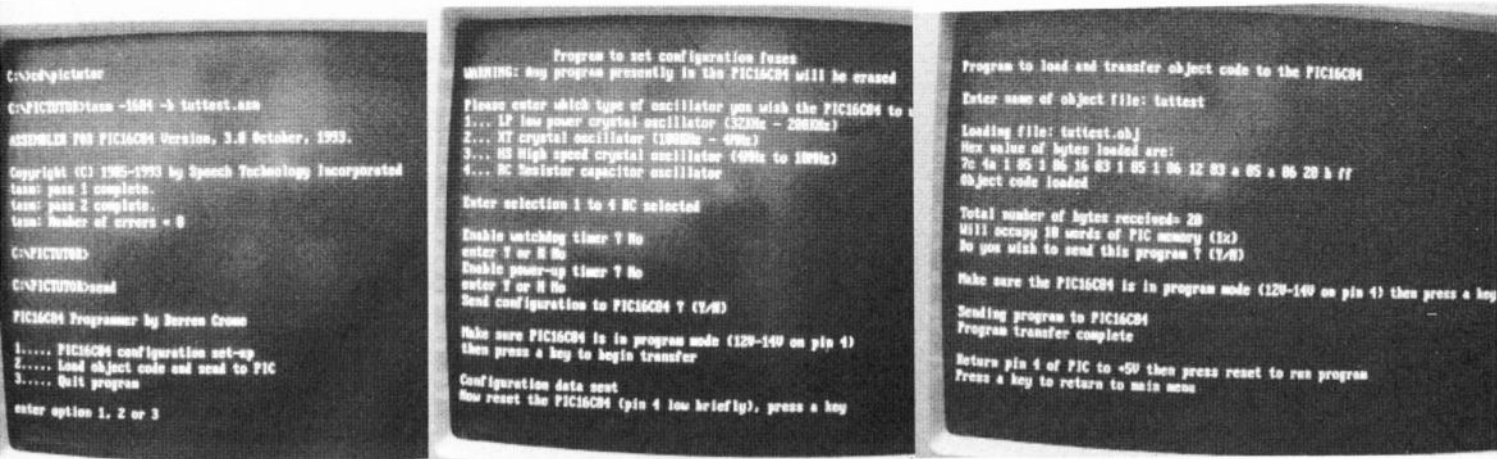
```
Loading file: tuttest.obj
```

```
Hex value of bytes loaded are:
```

(now the hexadecimal values of the bytes loaded are displayed, followed by:)

```
Object code loaded
```

```
Total number of bytes received = 20
Will occupy 10 bytes of PIC memory
(1%)
```



Textual prompts as seen on the computer screen for (left) TASM compilation plus Send menu (middle) PIC Initialisation and (right) Program Sending. The displays are shown compressed here for photographic reasons.

Do you wish to send this program ? (Y/N)

Now press Y, to bring up this message:

Make sure the PIC16C84 is in program mode (12V-14V on pin 4) then press a key

Switches S1 to S4 at this moment are still on (down) from the configuration setup procedure, so just switch up S2 (Reset off) and press any key. If you had not just been in configuration mode, but were downloading in the normal way, you would set the switches in the following order (the same as with configuration):

S2 down (Reset on), S1 down (12V on), S3 and S4 down (connections to computer printer port on), S2 up (Reset off).

Pressing any key will produce these messages, spaced by a short delay:

**Sending program to PIC16C84  
Program transfer complete**

**Return pin 4 of PIC to +5V then press reset to run program  
Press a key to return to main menu**

Now set the switches in the following order:

S2 down (Reset on), S1 up (12V off), S3 and S4 up (connections to computer printer port off), S2 up (Reset off). Ignore the statement to "press" reset. The act of switching up S2 (Reset off) sets +5V (actually about 4.4V, as mentioned earlier) onto pin 4 of the PIC.

That completes the downloading (sending) procedure and the program would now be running if it had been loaded for real. We will look at it in a moment.

Press any key to return to the main menu (Menu 1). Selecting Option 3 returns you to the MS-DOS prompt.

If you make a mistake when entering the file name, error messages will appear, such as:

**ERROR: cannot open file, press a key**

The latter indicates that a file name that does not exist has been entered.

If you make the mistake of selecting an option you don't want, you can usually abort from the Send program by simultaneously pressing the CTRL and BREAK keys on the keyboard, returning you to MS-DOS.

Be aware that the time taken to send a .OBJ file to the PIC depends on its length.

A full 1024 command file can take around 80 seconds. The delay exists because the PIC requires a minimum amount of time to store each command when received. The speed of operation has nothing to do with the speed of your computer.

In fact, the program has been over-generous on this and in theory it is possible to program the full PIC in about 12 seconds. However, the Send program is not suitable for modification unless you know C++.

### OPERATIONAL CHECK

Now you are ready to actually load a program, just to check out the system.

Preset potentiometer VR1 (program clock rate control) should be set fully clockwise for this test. It sets the program flow rate to its fastest (as allowed by the presence or absence of capacitor C3).

At other times we will leave it to your discretion to set VR1 to whatever position you feel best shows things happening at a readily viewable rate (occasionally, we may give you guidance on this point).

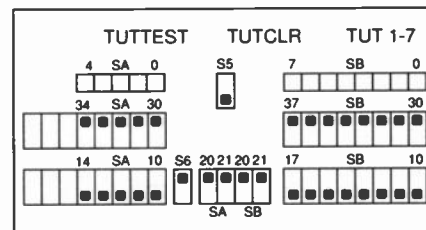


Fig.10. Switch settings for programs TUTTEST, TUTCLR and TUT1 to TUT7.

Plug the PIC16C84 into its socket, connect the demo p.c.b. to the computer's printer port and switch on power to the p.c.b. Set the switches on the p.c.b. according to Fig.10. We shall be observing the I.e.d.s on Port A (LA4 to LA0) and Port B (LB7 to LB0) – see Fig.5.

Run through the entire PIC initialisation and sending of TUTTEST.OBJ to the PIC as discussed above. Having loaded TUTTEST into the PIC, check that all Port A and Port B I.e.d.s come on in a repeating pattern. However, Port A I.e.d. LA4 will not come on unless switch SA4 is also pressed, since RA4 is "open collector".

The significance of an open collector here is that pin RA4 can never go high when in output mode unless it is biased to the positive line by a resistor. The resistor value will, in practice, need to be

chosen to suit the conditions being met, but typically might be between 1kΩ and 100kΩ. On the demo board, it can be 100Ω or 1kΩ, depending on the switch settings.

We suggest you examine TUTTEST.ASM after reading Tutorial 6, discovering and understanding how it works.

### GOT A PROBLEM?

There are two main reasons why you may not get a response from the I.e.d.s. You may have made an error while assembling the board. Check all component positions and orientations, thoroughly check your soldered joints and for solder shorts between tracks. Use a high-power magnifying glass for the latter.

The other reason is that your computer may have had its system configuration for the printer port changed from that normally used. The Send program needs to output its data through the parallel printer port via register &H378. There is no alternative to this.

Referring to your computer manual, establish what configuration has been given to the printer port and change it to the "normal" &H378 register. We cannot advise on how you can do this; if necessary ask your computer supplier.

However, if you have GWBasic or QBasic, the following routine will help you to check that data from the printer port is actually reaching the PIC:

```
10 DELAY = 10000
20 A = (A + 1) AND 255
30 OUT &H378,A
40 FOR B = 1 TO DELAY: NEXT B
50 GOTO 20
```

Running this routine, use an oscilloscope or voltmeter to check that the logic levels are changing on the PIC's pins 12 and 13 when switches S3 and S4 are switched down (on). The value of DELAY may be changed to speed up or slow down the rate of data change. The output rate on port pin D1 will be half that on pin D0 (PIC pins 12 and 13 respectively).

### TUTORIAL EXERCISES

Throughout these Tutorials we present various programming exercises at which to try your hand. In most cases, you are requested to modify an existing tutorial program. This requires it to be saved.

assembled and sent to the PIC.

It is important that when you make these changes, you do not save the variant under the same name as the original. It must have a different name. If you do save under the same name, the original file will be replaced by the new one.

You can save each program variant by any name of your choosing, but use the same .ASM extension as our examples use. You might consider using TRY1.ASM, TRY2.ASM, etc.

It is recommended that you save the original file under the new name before you make any changes, to avoid curse-worthy errors!

However, should you make the mistake of saving an altered file with the same name as the original, the latter file can be copied back onto the hard disk from your 3.5 inch disk.

If, for example, you wish to recopy TUT4.ASM back onto the hard disk, type the following:

```
c:
cd \pictutor
copy a:tut4.asm
```

Some versions of MS-DOS will ask you confirm that you wish to over-write the file of this name that is already on drive C; others will not, doing so anyway.

Having saved your changed file, you now assemble and send it to the PIC as we demonstrated earlier.

It is stressed again that the .ASM files MUST be in pure ASCII text formats without printer or display format commands embedded in them. If TASM receives an "impure" file, there is the danger that it could erase the .ASM file being assembled (as the author knows from experience)!

The author avoids this potential problem by writing in the full word-processing format (complete with non-ASCII commands) saving it as a .PIC file, then saving again as a pure ASCII file with the .ASM ending.

We shall not be giving possible solutions (of which there could be several) to any of the exercise questions. It is expected that you will persevere until you find a workable solution. Only in this way will you get into the habit of being presented with a computing problem, which you have to solve on your own, and then solving it.

However, if you do have any queries or comments about matters arising from this series of Tutorials, you are welcome to contact us by E-mail or post (or phone for really simple queries - ask for John).

## PIC CLEARANCE

Having established that program TUT-TEST is correctly controlling the I.e.d.s, you must now load TUTCLR.OBJ into the PIC. Assemble it as a .OBJ file, and then send it (as for TUTTEST.OBJ).

This program simply clears the first hundred or so program bytes of the PIC, setting them to zero (NOP), allowing the next program to run as though the PIC were "empty". No I.e.d.s should come on if you run it.

(Re-running the configuration program - Menu 1, Option 1 - would also achieve the same result since it automatically clears any previous program data.)

We are now in a position to start telling you about writing programs for a

### TABLE 1. PIC COMMAND CODES

COMMAND	OPERATION	SYNTAX	STATUS AFFECTED	TUTORIAL DISCUSSED
ADDLW	ADD Literal to W	ADDLW k	C, DC, Z	7
ADDWF	ADD W to f	ADDWF f,d	C, DC, Z	7
ANDLW	AND Literal and W	ANDLW k	Z	7
ANDWF	AND W with f	ANDWF f,d	Z	7
BCF	Bit Clear f	BCF f,b	None	2
BSF	Bit Set f	BSF f,b	None	2
BTFSC	Bit Test, Skip if Clear	BTFSC f,b	None	4
BTFSS	Bit Test, Skip if Set	BTFSS f,b	None	4
CALL	Subroutine Call	CALL k	None	13
CLRF	Clear f	CLRF f	Z	2
CLRWF	Clear W register	CLRWF	Z	2
CLRWDTC	Clear Watchdog Timer	CLRWDTC	TO, PD	30
COMF	Complement f	COMF f,d	Z	11
DECWF	Decrement f	DECWF f,d	Z	6
DECFSZ	Decrement f, Skip if 0	DECFSZ f,d	None	6
GOTO	Unconditional branch	GOTO k	None	3
INCF	Increment f	INCF f,d	Z	6
INCFSZ	Increment f, Skip if 0	INCFSZ f,d	None	6
IORLW	Inclusive OR Literal with W	IORLW k	Z	17
IORWF	Inclusive OR W with f	IORWF f,d	Z	17
MOVF	Move f	MOVF f,d	Z	5
MOVLW	Move Literal to W	MOVLW k	None	4
MOVWF	Move W to f	MOVWF f	None	4
NOP	No Operation	NOP	None	12
OPTION #	Load Option Register	OPTION	None	18
RETFIE	Return from Interrupt	RETFIE	None	28
RETLW	Return with Literal in W	RETLW k	None	13
RETURN	Return from Subroutine	RETURN	None	13
RLF	Rotate Left through Carry	RLF f,d	C	4
RRF	Rotate Right through Carry	RRF f,d	C	4
SLEEP	Power-down	SLEEP	TO, PD	29
SUBLW	Subtract W from Literal	SUBLW k	C, DC, Z	23
SUBWF	Subtract W from f	SUBWF f,d	C, DC, Z	23
SWAPF	Swap f	SWAPF f,d	None	11
TRIS #	Load TRIS Register	TRIS f	None	4
XORLW	Exclusive OR Literal with W	XORLW k	Z	17
XORWF	Exclusive OR W with f	XORWF f,d	Z	17

#### Legends:

b	Bit address	k	Literal or label
C	Carry	PD	Power-down
d	Destination	TO	Time-out
DC	Digit carry	W	Working register
f	Register file address	Z	Zero
		#	Use not recommended

PIC16C84. The command codes we shall discuss are shown in Table 1.

## TUTORIAL 1 CONCEPTS EXAMINED

Minimum software requirement

Port default values

Instruction .ORG

Instruction .END

Instruction .AVSYM

### PROGRAM - TUT1 SWITCH SETTINGS - as in Fig.10

The absolute bare minimum requirements for any PIC16C84 program which is to be compiled under TASM are shown in Listing 1.

In fact, none of the statements in this listing have anything directly to do with a functioning software program. Three are aimed directly at the TASM assembler; the others are comments to the programmer, or other reader.

#### LISTING 1 - PROGRAM TUT1

```
; TUT1.ASM - 28JUL97
; minimum requirement
.ORG $0004 ; Interrupt vector address
.ORG $0005 ; Start of program memory
(your program goes in here)
.END ; final statement
```

Such comments include program title and function, and notes about what particular program instructions within the list are intended to perform. Comments must always be preceded by a colon (;) so that TASM does not try to treat them as program commands.

Comments may appear anywhere within the program, and in any position where they do not interfere with a program command. It is convenient, though, to place them tabulated a short distance beyond the end of program command lines.

To take Listing 1 in detail, you will see that it starts with two comments, identifying the listing and its function:

```
; TUT1.ASM - 28JUL97
; minimum requirement
```

Next come two commands which are aimed at the TASM assembler and need not normally concern you - repeating them parrot-fashion in any software you write will normally suffice unless interrupts are involved:

```
.ORG $0004 ; Interrupt vector address
.ORG $0005 ; Start of program memory
```

These commands give the memory address (position) within the PIC at which a particular set of subsequent commands is to be placed. Such commands consist of the .ORG (origin) statement followed by a number, which may be expressed in hexadecimal (as shown here - preceded by

a \$ sign), or in decimal (4 and 5 in this case), or in binary (indicated by a % symbol prefix, e.g. %00000100 and %00000101).

With some assemblers, the numbers can point to any memory address, but TASM and its Send program require the use of addresses \$0004 and \$0005.

Derren Crome's explanation of his Send program in this respect is as follows:

*When the PIC is put into programming mode, it sets its internal counter to 0000, which is the reset vector address. It was decided to have the Send program to set this always to \$0005, which is the beginning of the program memory address space.*

*Addresses \$0001 to \$0003 are not of use to the user. Address \$0004 is the interrupt vector which is set by the first line in the assembly code. The user program starts at \$0005. The .ORG must be there so that the memory references generated by the assembler correspond with the actual locations of the instructions within the PIC.*

*The .ORG cannot be used elsewhere in the program since the pure binary object file generated by the assembler contains no address information. The Send program simply takes these bytes and transmits them to the PIC in sequential order.*

The Interrupt vector address at \$0004, and the subject of interrupts in general, will be dealt with in Tutorial 28. Ignore the concept for the moment.

The fifth statement in the listing is aimed at you, the reader: it tells you where your program is to be written. This will become evident as we progress through the example listings.

The final statement (.END) is another which is only required by the TASM assembler. It MUST always be placed at the very end of any listing which is to be passed through TASM. If you forget to include it, TASM will point out your error via the screen!

So, of the six lines in Listing 1, the only three statements actually needed are the two .ORGs and .END. Everything else is up to you.

## SYMBOLS AND LISTS

There is another instruction which you may see used at the beginning of some program listings - .AVSYM. This tells TASM that while it is assembling the code, it should also generate another disk file which shows the "aliases" names used and the values they represent (see Tutorial 3 on page 15).

This disk file has a .SYM extension (Symbol). Thus, when assembling TUT4.ASM (which includes the instruction simply for example), the file TUT4.SYM is generated as well as the normal TUT4.OBJ hex code file, plus the TUT4.LST file.

Except for TUT4.ASM, none of the text files associated with these Tutorials include .AVSYM in the initialisation headings. It may be inserted in the heading (as in TUT4.ASM) if you need the symbol file, but the author has never found a use for it - it just generates a lot of additional disk-consuming files.

The .LST files will be illustrated presently; they are always generated and are a useful source for error messages!

## INCAPABLE?

You might think that when TUT1.ASM is compiled by TASM and loaded into the PIC as TUT1.OBJ, that the PIC will be incapable of doing anything - it hasn't been told of anything to do. Almost true, but not quite!

The PIC16C84s have been told in manufacture to adopt certain "default" conditions when first switched on (these will be shown in Part 3). One of these conditions is that Port A and Port B are configured (set) to act as inputs.

What is not configured at this time is the binary value which is available to be output via those pins when they are first set as outputs from within the program.

At switch-on, any number could be set randomly within the PIC's memory, of between 0 and 255 (%00000000 to %11111111) for Port B, and 0 to 31 (%00000 to %11111) for Port A. It is often preferable, therefore, to set port output values to a known number, usually zero, as part of the opening program statements. This, too will become apparent as we progress.

## EXERCISE 1

1.1. Load TUT1.OBJ into your PIC, using the method described earlier, and run it. Note that pushing the push-switches will have an effect on the l.e.d.s, but not because the PIC is causing a response, rather because current direct from the power rails is able to pass through each l.e.d., its associated resistors and switches.

## TUTORIAL 2 CONCEPTS EXAMINED

File registers  
Bits  
Bytes  
Set  
Clear  
Command CLRf  
Command CLRW  
Command BSF  
Command BCF  
Ports and Port directions  
STATUS register bit 5  
Pages 0 and 1

PROGRAM - TUT2  
SWITCH SETTINGS - as in Fig.10.  
Preset VR1 fully anticlockwise (minimum rate)

At this point in time, a PIC without program commands is of no benefit to us! We shall now create a simple program which just turns on the series of eight l.e.d.s connected to Port B. Look at Listing 2.

As discussed, you will see comments at the start of the listing and within it, all preceded by a colon. You will also see the .ORG and .END statements. Sandwiched between them are several lines of code. Ignoring the numbers following the codes, there are only three different codes in use here: CLRf, BSF and BCF. They simply stand for CLear File, Bit Set File and Bit Clear File. An allied command to CLRf is CLRW (CLear Working register).

Load program TUT2.OBJ into the PIC16C84. Having loaded it, once Reset switch S2 is turned off (up), the program starts running. There will be a few seconds wait before you see anything happening.

At present, the oscillator which controls the PIC is only running at a very slow speed, about 1Hz or so (depending on the tolerance of the C3 and VR1 values). The internal workings of the PIC16C84 automatically divide any clock frequency by four, taking four counts to process a single command. During each of the four intervening pulses, different aspects of the command are processed. To all intents and purposes, each command takes four clock pulses.

The results of the first four commands will not produce any visible result. After a few seconds, though, each l.e.d. of Port B will come on in turn, in order of LB0 to LB7, with a pause between each change.

When the final l.e.d. (LB7) has come on, there are no more instructions to perform, so nothing more happens (in fact, the PIC is actually working its way through each of the null commands which were programmed in from the PICCLR program, but you won't see any result from these commands).

To see the sequence again, slide Reset switch S2 on and off (down and up), whereupon the program will restart from the beginning. The rate at which it occurs can be changed by adjusting preset VR1.

But, how does the program do what you see it has done? First, let's find out what File registers are and what commands CLRf, BSF and BCF do.

### LISTING 2 - PROGRAM TUT2

```
; TUT2.ASM
; setting Port B to output mode and turn on each l.e.d.
.ORG $0004 ; Interrupt vector address
.ORG $0005 ; Start of program memory

CLRF 6      ; set all Port B pins to logic 0
BSF 3,5     ; instruct program that a Page 1 command comes next
CLRF 6      ; set all Port B pins as outputs
BCF 3,5     ; instruct program that a Page 0 command comes next
BSF 6,0     ; set Port B pin 0 to logic 1
BSF 6,1     ; set Port B pin 1 to logic 1
BSF 6,2     ; set Port B pin 2 to logic 1
BSF 6,3     ; set Port B pin 3 to logic 1
BSF 6,4     ; set Port B pin 4 to logic 1
BSF 6,5     ; set Port B pin 5 to logic 1
BSF 6,6     ; set Port B pin 6 to logic 1
BSF 6,7     ; set Port B pin 7 to logic 1

.END        ; final statement
```





those which control Port B. In terms of writing to or reading from Port A and Port B, the two ports are treated as any other file destination.

However, Port A and Port B are different to other files in that they are for communication with the outside world. There are, in fact, two file registers associated with each port that are accessible to the programmer. One is used to set the direction in which the bits are to act, i.e. as inputs or outputs (it is also known as the Data Direction Register – DDR), and the other deals with the data written to (for output to the world) or read from (input from the world).

Each bit of the port direction registers can be individually set or cleared so that the same port may be used simultaneously for data input and output via different bits.

The file which controls the direction in which Port B pins respond is named in the PIC16C84 data sheet/book as TRISB. It is one of the named "special function files" (see Table 3) and is contained in memory byte address \$86 (we won't translate hexadecimal numbers into decimal since the latter are irrelevant in the context of file addresses).

The file which holds Port B's data, whether as input or output, is at memory byte address \$06 and, helpfully, is known in the PIC book as PORTB.

A minor inconvenience exists in the PIC16C84 in that addresses \$80 to \$8B can only be accessed by changing the value in another file, the STATUS file.

This file is held jointly at byte addresses \$03 and \$83. A single bit within STATUS is used to direct the program to numbers either below \$80 (known as Bank 0 or Page 0 addresses) or above \$7F (known as Bank 1 or Page 1 addresses); this bit is number 5.

When STATUS bit 5 is set (logic 1), it effectively adds \$80 to the memory byte address being accessed. When the bit is clear (logic 0), addresses below \$80 are accessed.

Thus, if you instruct that file 6 is to be accessed when STATUS bit 5 is low, the file *actually* at address 6 will be accessed. Conversely, if you instruct that file 6 is the subject when STATUS bit 5 is high, the file at address \$86 will be accessed.

Only files numbered \$00 to \$2F and \$80 to \$8B are available for use by the programmer. Also note that files \$07 and \$87 have no function.

## LISTING 2 COMMANDS

We can now examine each command of Listing 2 in turn and describe its purpose.

When the PIC16C84 is first switched on, the STATUS file is set to a default value with its bit 5 low. All file addresses are thus treated as being below \$80. (A table of all default values is given in Part 3.)

We have established that address 6 is that which holds the data for Port B. The first command, CLR F 6, thus clears the data which is held in Port B as a value available to be output, i.e. Port B is instructed to hold a value of zero.

The purpose of the program in Listing 2 is to output data to the eight i.e.d.s on Port B, and it has already been said that the default value of Port B's direction register (at \$86) is for all bits to be set for input (all bits are high – 11111111). Consequently we

## LISTING 3 - PROGRAM TUT3

```
; TUT3.ASM
; using names to ease writing of TUT2.ASM

STATUS:      .EQU 3      ; name program location 3 as STATUS
PORTB:       .EQU 6      ; name program location 6 as PORTB

              .ORG 4      ; Interrupt vector address
              .ORG 5      ; Start of program memory

              CLR F PORTB ; clear Port B data pins
              BSF STATUS,5 ; Page 1
              CLR F PORTB ; set all Port B as output
              BCF STATUS,5 ; Page 0

LOOPIT:      BSF PORTB,0 ; set Port B pin 0
              BSF PORTB,1 ; set Port B pin 1
              BSF PORTB,2 ; set Port B pin 2
              BSF PORTB,3 ; set Port B pin 3
              BSF PORTB,4 ; set Port B pin 4
              BSF PORTB,5 ; set Port B pin 5
              BSF PORTB,6 ; set Port B pin 6
              BSF PORTB,7 ; set Port B pin 7
              CLR F PORTB ; clear all PORTB pins
              GOTO LOOPIT ; go to address LOOPIT

              .END        ; final statement
```

## LISTING 3A (TUT3.LST)

```
0006 0000 STATUS:.EQU 3
0007 0000 PORTB: .EQU 6
0008 0000
0009 0004 .ORG 4
0010 0005 .ORG 5
0011 0005
0012 0005 01 86 CLR F PORTB
0013 0006 16 83 BSF STATUS,5
0014 0007 01 86 CLR F PORTB
0015 0008 12 83 BCF STATUS,5
0016 0009
0017 0009 14 06 LOOPIT: BSF PORTB,0
```

must now set them all as outputs, i.e. each to logic 0.

To do this, first the STATUS register at address 3 must have its bit 5 set high to point to addresses of \$80 and above; hence the command BSF 3,5.

Now we configure all of Port B for output mode with the command CLR F 6. Yes, it's the same command as cleared Port B's data, but because STATUS bit 5 is high, the value of 6 (\$06) has \$80 added to it, so the address actually accessed is that at \$86.

The commands which output data to the i.e.d.s are all concerned with Port B's data file at "real" address 6, so the addition of \$80 is no longer needed. The next command, BCF 3,5, thus clears bit 5 of the STATUS register at address 3.

All remaining commands in Listing 2 can now, in turn, set high each data bit of Port B at address 6: BSF 6,0, BSF 6,1, etc., so turning on the i.e.d.s in sequence from LB0 to LB7. Simple!

## EXERCISE 2

2.1. Using your text editor and TASM software, experiment with the eight commands relating to file 6, using different values (between 0 and 7) for the number following the comma. Do not change the number before the comma. Also experiment with changing BSF to BCF. Save under any name of your choosing.

2.2. Rewrite the program in Listing 2 so that it performs its actions on Port A instead of Port B. The equivalent data and direction addresses for Port A are 5 (\$05) and \$85, respectively.

Note that Port A only has five pins, not eight. What difference, if any, does this

make to the program? (Ignore the technicality that on the demo p.c.b., i.e.d. LA4 will only come on if switch SA4 is also pressed.)

## TUTORIAL 3 CONCEPTS EXAMINED

Names in place of numbers  
Labels  
Case sensitivity  
A repetitive loop  
Command GOTO  
Instruction .EQU

## PROGRAM – TUT3 SWITCH SETTINGS – as in Fig.10

In the previous section dealing with Listing 2, we were using numbers to indicate which file was being referred to. That's fine if there are only a few files whose address numbers can be easily remembered. As we progress with examining the PIC16C84 commands and example listings, we shall be using more and more files. If we continue to refer to them numerically, we're going to get lost! (What's file \$0C for? Is the data supposed to go to file \$1C or file \$1E?)

Human memories with numbers are notoriously bad! But we are (usually) much better with names. This fact was long ago recognised by program writers and many types of software now allow the use of names in place of numbers. TASM is no exception.

Let's examine how names can be applied to the numbered files in Listing 2. Have a look at Listing 3.

Any number written into a listing can be

represented by a name. It can be any name you like as long as you think you'll know in time to come what is meant by that name (n.b. TASM imposes a limit of 32 characters on name lengths).

There are also some names which it is better to allocate according to their function, especially those functions that already have names provided in the PIC data books, such names as STATUS and PORTB, for example.

The names are "case-sensitive". In other words, once you have equated a name with a number, further use of the name must be in exactly the same style as the original with regard to the use of upper and lower case letters. For example, PORTB and portb cannot be used interchangeably. You can, though, equate different styles of the same word to different purposes. The following would be legitimate (but not very helpful!):

```
FILE1:      .EQU 20
file1:     .EQU 30
```

However, the commands themselves may be in upper or lower case without causing problems.

In Listing 3, three names have appeared: the aforementioned STATUS and PORTB, plus LOOPIT. We'll keep LOOPIT a mystery for the moment (though we're sure you know what it's for).

With TASM, all name allocations must appear at the head of the program listing, in the initialisation block. Then the format for allocating a name to a number is to state the name at the left of a program line and immediately follow it with a colon (:). Now, with or without a space, the statement .EQU is made, followed by the number you wish to name.

In the case of the first line, STATUS is the name to be given to the numeral 3 (which, you will remember, is the file address number for the STATUS register). Hence, the statement:

```
STATUS:    .EQU 3
```

This simply tells TASM when it assembles the listing into code, that each time it comes across the name STATUS, it is to replace it in the code by the value of decimal 3.

The second line similarly allocates the name PORTB to file address 6:

```
PORTB:    .EQU 6
```

Compare Listing 2 and Listing 3 side by side: you will see how the program has been rewritten using the names in place of file numbers.

## ABOUT .LST FILES

Having assembled TUT2.ASM and TUT3.ASM through TASM, examine both the .LST disk files it generates during assembly. You will see from the coding that the substitution of numbers in place of the names has occurred, and that the two .LST files are identical, except for the last two (new) commands of TUT3.

Part of the TUT3.LST file is repeated here, in Listing 3A. Note that the full .LST files will also include the programmer's notes at the right. They have been omitted here to conserve space.

In Listing 3A, the lefthand column holds the line numbers as encountered from the text file listing (.ASM); these serve no pro-

gramming purpose and are simply there for TASM's benefit. They are in decimal.

The second column of four digits is the actual byte location number within the PIC at which the command will be placed. Note that it starts at 0000, which is repeated here three times simply because there is text on the rest of the line which is not a program command.

Note that the address number then jumps straight to 0004, the address to which the .ORG 4 statement refers. Code .ORG 5 states that the program itself is to start at location 5, which it does (0005) but columns three and four, which hold the 2-byte code, are not used until a command is encountered. In this case, command CLRF PORTB generates the code 01 86.

Although it is not evident in Listing 3A, the numbers in columns 2 to 4 are in hexadecimal. Also, note that the two bytes of columns 3 and 4 will ultimately be combined into one 14-bit byte when the code is loaded into the PIC16C84 by the SEND software. This operation was discussed in Derren Crome's article and will not be repeated here.

## TUT3 FOREVER!

Now load the code for TUT3.OBJ into your PIC and run it. It will be seen to start off in the same way as TUT2. Now, though, when it gets to the end of the code, the i.e.d.s will all go out and the sequence will repeat, indefinitely!

You will find that a fully-clockwise setting of VR1 is preferable, to increase the display rate.

The program difference now is that there are two extra commands and when command BSF PORTB,7 has been performed, Port B is cleared and the program follows the command GOTO LOOPIT.

LOOPIT is the name given to the address at which the command BSF PORTB,0 has been placed. During assembly by TASM, that address number has been noted and each time the assembler encounters a command reference to the address named LOOPIT, it substitutes the number for that address.

Names, when given to program listing addresses, as with LOOPIT here, are commonly known as "labels". Labels must always be followed by a colon (:).

Referring back to Listing 3A, the last line reads:

```
0017 0009 14 06 LOOPIT: BSF PORTB,0
```

Note the 0009 in column 2. In the rest of TUT3.LST that is not shown here, there is another statement:

```
0026 0012 28 09 GOTO LOOPIT
```

Now note the 09 in column 4. The two values are identical and intentional. The address for which LOOPIT is the reference name is at location 0009; the code 28 09 contains the instruction to GOTO (jump to), plus the address number to which it is to jump.

In other instances, the addresses may be much greater than the one illustrated here, and the two values will differ accordingly, but the point is that the name LOOPIT is replaced by an address value during assembly and as such is treated by TASM in the same way as were STATUS and PORTB.

This fact has another important

significance: when a number has a name allocated to it, each time TASM encounters that name it substitutes the appropriate number.

Consequently, the same name could, if you wished, be used for different purposes in the same program. It could be used as an address, or it could even be used as a bit number.

It would be legitimate, for example, to replace the command BSF PORTB,3 by the statement BSF PORTB,STATUS, because STATUS is the name allocated to be used as a substitute for numeral 3.

This particular example might never have relevance in practice, and could be misleading to anyone reading the program, but a similar situation might be beneficially used in other programs.

We shall see other examples of names being used as pointers to addresses when the address required may depend on a particular value established as a result of calculation, i.e. in the case of Indirect Addressing, which will be examined in Tutorial 16.

## EXERCISE 3

3.1. Do the same sort of program modifications that you did with Exercise 2, examining the results achieved. Also try changing the position of the LOOPIT address in the lefthand column, putting it alongside BSF PORTB,2 for example.

3.2. The command GOTO LOOPIT can also be put elsewhere; try putting it between BSF PORTB,4 and BSF PORTB,5 and see what the result is.

There is an easy way of moving it in this instance without actually doing so: put a semicolon (;) in front of the three lines following BSF PORTB,4. TASM will then treat these lines as comments and ignore them. The use of a semicolon is a handy way to temporarily omit commands when debugging programs.

3.3. What happens if a semicolon is put in front of any of the three CLRF PORTB commands?

3.4. What happens if the GOTO LOOPIT command occurs before the LOOPIT address?

You may sometimes need to use the Reset switch (S2) on the p.c.b.! (No damage can occur if the program "crashes".)

## PART TWO

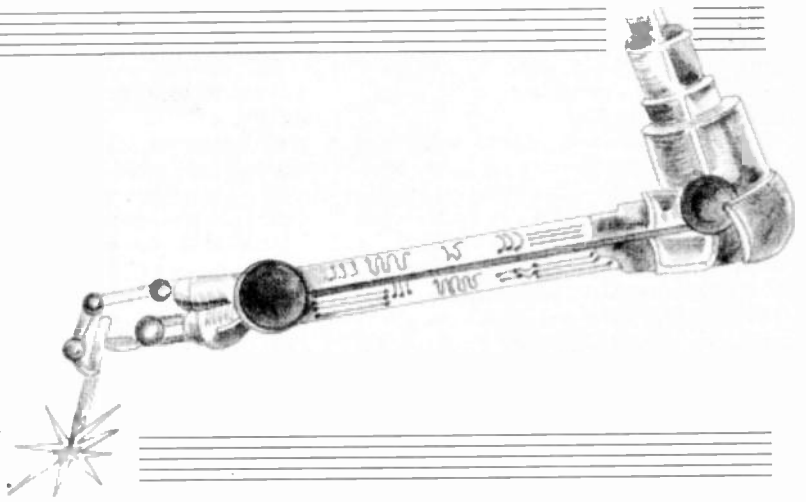
In Part Two we show how to use switches, generate sound, perform timing, and have more fun with our command performance!

TABLE 3. SPECIAL FUNCTION REGISTERS

REGISTER	ADDRESS	BANK	TUTORIAL
EEADR	09	0	26
EECON1	08	1	26
EECON2	09	1	26
EEDATA	08	0	26
FSR	04	0.1	16
INDF	00	0.1	16
INTCON	0B	0.1	18
OPTION	01	1	16
PCL	02	0.1	4
PCLATH	0A	0.1	14
PORTA	05	0	4
PORTB	06	0	4
STATUS	03	0.1	2
TMR0	01	0	18
TRISA	05	1	4
TRISB	06	1	4

# CIRCUIT SURGERY

ALAN WINSTANLEY



*We get to grips with voltage measurements, find out how to achieve negative voltages, explain what ground means and investigate transformer windings.*

## Teach-In '98 – Back to Basics

Most old-hands in electronics take lots of things for granted, and they often forget just how difficult it can be for newcomers entering this, the world's fastest-moving technology. This month's *Circuit Surgery* deals with a lengthy question from a reader following our *Teach-In '98* series. Jose Antonio of Spain sent by E-mail a few fundamental queries on the text so far. Jose asks:

*In Part 2 (December '97), you said: "For a silicon-based semiconductor diode to conduct, the anode must be 0.6V more positive than the cathode". In Parts 1 and 2 we have studied how to measure the voltage ACROSS the bulbs, ACROSS the resistors, and, in Part Two, ACROSS the rectifier diode. How do you measure the voltage at a point, like the anode?*

*In Part 3 (January '98), you said: "Each of these transistor types is available in two basic forms: n and p versions which operate with opposite (NEGATIVE AND POSITIVE) voltages applied. How can we apply a NEGATIVE VOLTAGE? As you said in Part 2, if I take a 9V alkaline battery and measure its output voltage under load, it goes from 9V to 0V (it goes flat). It does not go to -3V, -5V, -9V! On the other hand, in Lab Work in Part 3, you describe how to build a 5V Add-on Regulator that can give +5V and +12V. How can we apply a negative voltage? Is there a kind of battery that can give a negative voltage?*

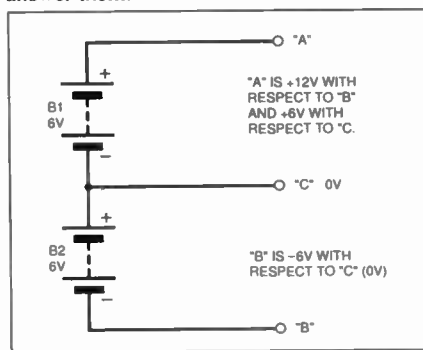
*In your diagrams of a transformer in Part 2, we can see two terminals in the input part (primary winding) and two terminals in the output part (secondary winding) and in the middle the steel laminations. I have seen a small transformer inside an adaptor and it has three terminals in the input part and three terminals in the output part. Could you tell me what is this third terminal and why you do not draw it in the diagram?*

*Also in Part 3, there is a new word "GROUND". Does it mean that you take a wire and connect it with this circuit and with the ground in a similar way that happens in the buildings with the electricity?*

*Finally, in Part 3, why don't you put the*

*battery and the arrow of the flow of current in this circuit like you did in the circuits diagrams in Part 1 and 2? I think it should be more easy to understand. Thanks for your help!*

Most of your queries relate to positive and negative voltages, and it is perfectly reasonable to ask, how can you have a negative voltage? Negative with respect to what? Or positive with respect to where? How can you have a potential which is less than zero volts? Why is the diode's anode 0.6V more positive? Such queries puzzle many newcomers. Let's take time out to answer them.



*Fig.1. All voltages are relative and are usually measured with respect to a 0V rail.*

The solution is that every voltage in a circuit is relative to a point somewhere in that circuit. Usually, all voltages are measured with respect to zero volts – the 0V supply rail. So you would hook the negative probe of your voltmeter to the 0V rail, and use the positive probe to measure any voltages, anywhere you like in the circuit. It is then normal just to read out any test measurements as voltages – so a point somewhere in the circuit could be said to be "+5V", somewhere else could be "-7.25V" or whatever.

Unless you are told otherwise, it is completely safe to assume that all of these readings are taken with respect to the 0V rail.

## Positively Negative

If you ask an auto-electrician to tell you about a car battery, they may say that the

terminals of a battery are at "+12V" and "-12V". *Teach-In* students will know that this means the voltage across the battery is actually 24 volts, which is obviously wrong! What the electrician should say is that the terminals are "+12V" and "0V". Even when small batteries are clearly labelled "+ +" and "- -", this is technically wrong, though the ordinary consumer won't know (or care). *Teach-In* students know better!

It is possible to produce negative voltages, simply by moving the reference point! It's all relative and is really quite easy. In Fig. 1, two 6V batteries have been drawn, connected in series. The voltage across them is therefore 12V in total: point "A" would be +12V and "B" would be 0V.

By taking a connection from the joint where both batteries are connected (point "C"), we can manipulate the reference level like this: imagine that you decide to call this new joint 0V, and we'll make this the new reference. If you had a digital multimeter, you could safely place your voltmeter negative probe (or should I say, 0V probe!) on "C" and measure +6V at point "A" with the other probe. So far so good.

If you then place the positive probe at point "B", your meter will now read -6V. It is displaying a negative voltage! This is because we have of course reversed the voltage input to the meter. A moving coil (analogue) meter could be damaged by this, but a digital multimeter will take it in its stride and show a negative voltage and minus sign on its display. In fact we haven't created a negative voltage at all, we have simply moved the reference point.

It would therefore be valid to label A, C and B as +6V, 0V and -6V respectively, because these voltages are all relative to each other, and everything is then relative to the 0V centre rail. Some circuits including some op.amp circuits do use a "split supply" which requires a centre 0V rail. They then have dual rails, such as ±15V.

## Mega Volts

It is also possible to have exceptionally high "negative" voltages generated in even the most modest of circuits. In

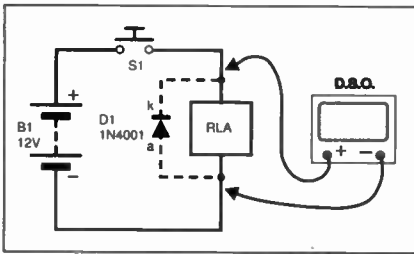
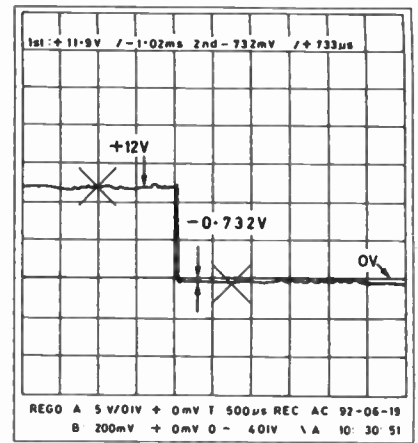
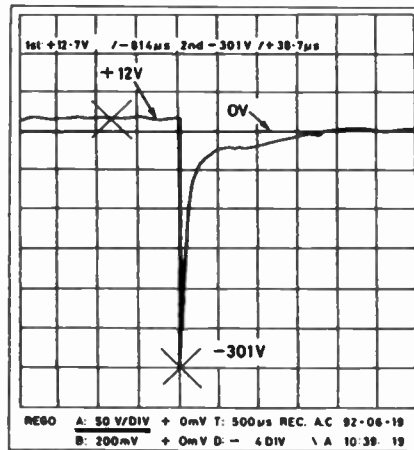


Fig.2a (above). A digital storage oscilloscope placed across a relay coil to measure back e.m.f.

Fig.2b (right). Negative voltages generated by the relay.

Fig.2c (far right). Negative voltage now suppressed by D1.



one experiment we managed to capture the reverse-voltage (back-e.m.f.) generated by a relay coil which had been powered from a 12V supply, see Fig. 2a. It is necessary to use a reverse-biased diode across a relay coil in order to snub out the huge reverse spike which is generated by a relay coil, when its surrounding magnetic field implodes back into the coil, generating a large voltage. Otherwise there is a serious risk of damaging any semiconductors on the same circuit.

The trace shown in Fig. 2b was captured on a digital storage oscilloscope and shows a negative voltage of an amazing -301 volts, generated by a 12V relay coil when the power was removed! Just for interest, Fig. 2c shows the result after a rectifier was added. Now the reverse voltage was only -0.732V measured, which is the voltage "across" the conducting rectifier when it shorts out that huge pulse. This brings me to another of your queries related to the voltage measurement "at" the anode of a diode.

This is one of those examples where we are not measuring a voltage with respect to the 0V rail. We've actually taken the voltmeter probes and placed them across the diode. So what you will measure is the diode's forward voltage when it is conducting. You could say that the anode is 0.6V more positive than the cathode, or the cathode is 0.6V more negative than the anode: it's the same thing.

## Tapped Transformer

Turning to your transformer query, what you have probably seen is a "tapped" winding, where a connection is made somewhere on the coil and taken to the outside world. On the secondary, it is probably a "centre-tapped" transformer with a 0V centre tap. This is used for rectification as shown in Fig. 3 which uses two rectifiers (compare this with the circuit shown in *Teach-In '98 Part 2*). It is not the best utilisation of a transformer but is seen in cheap undemanding power supplies.

It is still absolutely critical that the rectifiers and smoothing capacitor are connected the right way round. Failure to do so will lead to damage or even injury. Electrolytic capacitors must always be correctly polarised.

If there is an extra wire on the primary winding of the transformer, this is probably to allow it to be used on several mains voltages, such as 120V or 230V. The primary might be "hard wired" (permanently wired) for a particular country,

or there may be a selector switch on the product. Some transformers have dual primary windings which can be used in series or parallel at the relevant voltages.

## Ground Down

Your final query relates to the use of the word "ground". Good question! We're guilty of slipping in the word "ground" and taking its universal usage for granted. (I can also sympathise, because when a teenager I was brought up on American electronics books and I genuinely puzzled why a battery-operated project should be connected to "ground". Dad stopped me from hooking it to a radiator pipe.)

In most circuit diagrams, it is safe to say that there will be a 0V rail running throughout the circuit and returning to the battery or power supply. We draw this in full in our project drawings, but it is very common to see a "ground" symbol used in more complex circuits and data

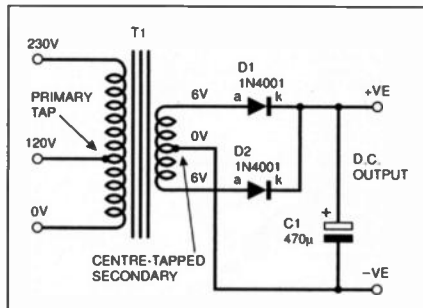


Fig.3. A multi-tapped primary, centre-tapped secondary mains transformer.

sheets. The idea is that it saves having to clutter up the circuit diagram with more lines! On checking the drawing, you will invariably see that one end of the power supply or battery has a "ground" symbol. All the grounds are thus connected together.

The same is true of a car, the chassis of which is connected to the 0V terminal of the battery (or -12V, as the auto-electrician would say). The chassis forms the main power supply return to the battery for all the electrical accessories. (There's a difference in terminology between the USA and the UK in that "ground" is also used in the USA for what we would call "earth" here in England, being the electrical earth used in mains distribution networks.)

## Current Flow

In reply to your last comment, concerning labelling of battery polarities and

current flow etc., we deliberately omit current "arrows" after the early stages in order to avoid cluttering the drawing: it's hoped that students will know the direction of current flow by then anyway.

Whilst *Teach-In '98* will move at a brisker pace in digital logic systems as you'll see in this month's discussion of Karnaugh maps, if you are seeking an all-round introduction to electronics then consider *Teach-In No.7*, which is the book form of my earlier series *Teach-In '93*. This discusses a broad variety of electronics theory, including power supplies, transistor amplifiers, the op.amp, fibre optics and radio.

It utilises the well-known *Teach-In Mini Lab* test-bed at the core of all its demonstrations. This was enormously popular at the time and is built in modular form. Several chapters are devoted to the microprocessor, which incorporates the *Micro Lab 6502*-based pre-programmed microprocessor trainer. Both the *Mini Lab* and *Micro Lab* are still available today in kit form from Magenta Electronics (advertising in *EPE* every month).

My colleague Geoff MacDonald has a *Micro Lab* web site at <http://www.pan1c.demon.co.uk/Microlab> and the popular *Teach-In No. 7* book is still available from the *EPE Direct Book Service*, see the advertisement elsewhere in this issue.

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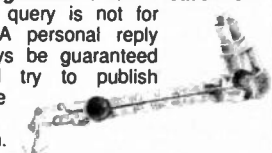
**Correction:** the formula given in Fig. 2 in February 98's column should read:-

$$V_O = 1.25 \left( R_1 + \frac{R_2}{R_1} \right)$$

We apologise for this error.

## CIRCUIT THERAPY

*Circuit Surgery* is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF, United Kingdom. E-mail [alan@epemag.demon.co.uk](mailto:alan@epemag.demon.co.uk). Please indicate if your query is not for publication. A personal reply cannot always be guaranteed but we will try to publish representative answers in this column.



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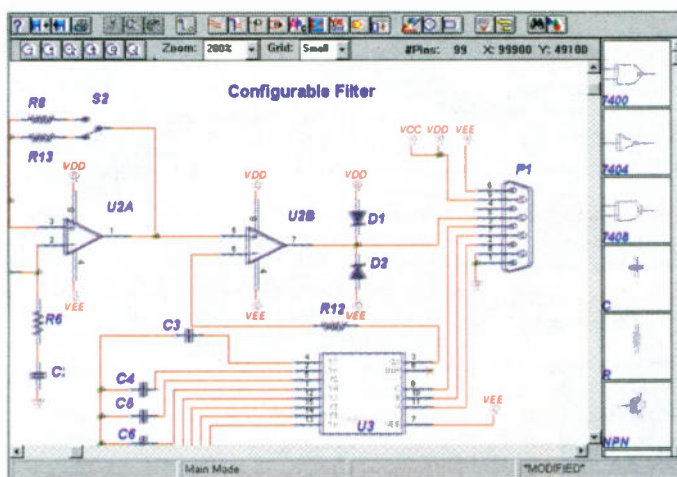


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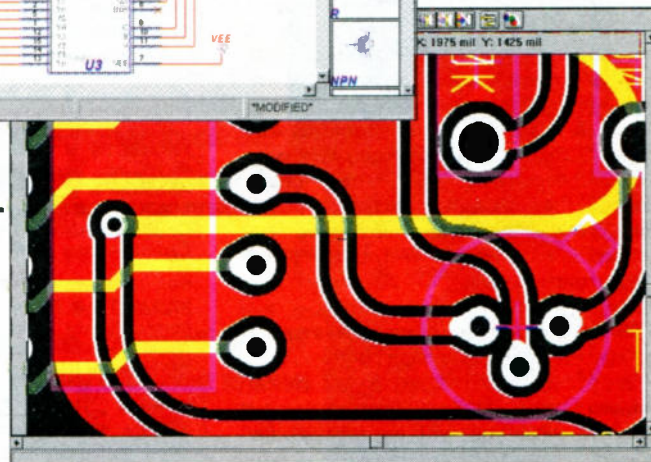


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SEPT '96

**PROJECTS** ● Analogue Delay and Flanger ● Simple Exposure Timer ● PIC-Tock Pendulum Clock ● Draught Detector ● Power Check.  
**FEATURES** ● Circuit Surgery ● Ingenuity Unlimited ● Net Work – The Internet ● MAX038 Waveform Generator.

OCT '96

**PROJECTS** ● Video Fade-To-White ● Direct Conversion Topband and 80m Receiver ● Vehicle Alert ● 10MHz Function Generator.  
**FEATURES** ● Introduction to Satellite Television ● Ingenuity Unlimited ● Circuit Surgery ● Net Work – The Internet.

NOV '96

**PROJECTS** ● D.C.-to-D.C. Converters ● Central Heating Controller ● EPE Elysian Theremin, Part 1 ● Tuneable Scratch Filter.  
**FEATURES** ● Build Your Own Projects, Part 1 ● Ingenuity Unlimited ● Circuit Surgery ● Net Work ● Interface.



DEC '96

**PROJECTS** ● Vari-Colour Christmas Tree Lights ● PIC Digital/Analogue Tachometer ● Stereo Cassette Recorder ● EPE Elysian Theremin, Part 2.  
**FEATURES** ● Build Your Own Projects, Part 2 ● Interface ● Circuit Surgery ● Ingenuity Unlimited ● Net Work – Internet News.

JAN '97

**PROJECTS** ● Earth Resistivity Meter, Part 1 ● Psycho Rat ● Theremin MIDI/CV Interface, Part 1 ● Mains-Failure Warning.  
**FEATURES** ● Ingenuity Unlimited ● Build Your Own Projects, Part 3 ● Circuit Surgery ● Interface ● Net Work – Internet News ● PCS32 Storage 'Scope Interface Review.

FEB '97

**PROJECTS** ● Pacific Waves ● How To Use Intelligent L.C.D.s, Part 1 ● PsiCom Experimental Controller ● Earth Resistivity Meter, Part 2 ● Theremin MIDI/CV Interface, Part 2.  
**FEATURES** ● Ingenuity Unlimited ● Build Your Own Projects, Part 4 ● Circuit Surgery ● Interface ● Net Work – Internet News.

MARCH '97

**PROJECTS** ● Simple Dual-Output TENS Unit ● Video Negative Viewer ● Tri-Colour NiCad Checker ● How To Use Intelligent L.C.D.s – 2 ● Oil Check Reminder.  
**FEATURES** ● Interface ● Ingenuity Unlimited ● Build Your Own Projects, Part 5 ● Digital TV – The Reality ● Circuit Surgery ● Net Work.

APRIL '97

**PROJECTS** ● 418MHz Remote Control System ● Midi Matrix ● Puppy Puddle Probe ● PIC-Agoras Wheelie Meter – 1.  
**FEATURES** ● Interface ● Ingenuity Unlimited ● Digital TV and MPEG2 ● EDWin NC Software Review ● Circuit Surgery ● Net Work.

MAY '97

**PROJECTS** ● 2 Metre F.M. Receiver ● EPE PIC-A-Tuner ● Alarm Operated Car Window Winder ● Quasi-Bell Door Alert ● PIC-Agoras – 2.  
**FEATURES** ● Ingenuity Unlimited ● Circuit Surgery ● Techniques – Actually Doing It ● Great Experimenters – 1 ● Type 7660 Voltage Converters ● Net Work.



JUNE '97

**PROJECTS** ● PIC Digilogue Clock ● Child Minder Protection Zone ● Pyrotechnic Controller ● Narrow Range Thermometer.  
**FEATURES** ● Great Experimenters – 2 ● Circuit Surgery ● Interface ● Reactobot and Virtual Reality ● Ingenuity Unlimited ● Net Work.

JULY '97

**PROJECTS** ● Micro PEST Scarer ● Karaoke Echo Unit ● Infra-Red Remote Repeater ● Computer Dual User Interface ● Micropower PIR Detector – 1.  
**FEATURES** ● Ingenuity Unlimited ● Techniques – Actually Doing It ● Circuit Surgery ● Great Experimenters – 3 ● Electronics Workbench V5.0 Review ● Net Work.

AUG. '97

**PROJECTS** ● Variable Bench Power Supply ● PIC-olo Music Maker ● Universal Input Amplifier ● Micropower PIR Detector – 2.  
**FEATURES** ● Interface ● Ingenuity Unlimited ● Colossus Recreated ● Circuit Surgery ● Great Experimenters – 4 ● Net Work.

SEPT '97

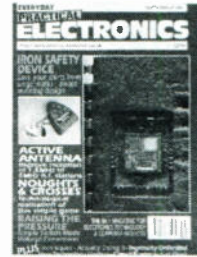
**PROJECTS** ● PIC-Noughts & Crosses Game ● Ironing Safety Device ● Active Receiving Antenna ● Soldering Iron Controller ● Micropower PIR Detector – 3.  
**FEATURES** ● Ingenuity Unlimited ● Raising the Pressure – RC4190 Switch-Mode I.C. ● Circuit Surgery ● Techniques – Actually Doing It ● Great Experimenters – 5 ● Net Work.

OCT '97

**PROJECTS** ● PIC Water Descaler ● Remote Control Finder ● Multi-Station Quiz Monitor ● Rechargeable Handlamp.  
**FEATURES** ● Ingenuity Unlimited ● It's Probably Murphy's Law ● Interface ● Circuit Surgery ● Kanda PIC Explorer Review ● Network ● Special Offer – Pico Virtual 'Scopes.

NOV '97

**PROJECTS** ● Portable 12V PSU/Charger ● Case Alarm ● Auto-Dim Bedlight ● EPE Time Machine.  
**FEATURES** ● Satellite Celebration ● Ingenuity Unlimited ● TEACH-IN '98 – An Introduction to Digital Electronics-1 ● New Technology Update ● Techniques – Actually Doing It ● Circuit Surgery ● Net Work ● Special Offer – Pico Virtual Scopes ● Free Greenweld Catalogue.



DEC '97

**PROJECTS** ● Safe and Sound – Security Bleeper ● Active Microphone ● Car Immobiliser ● Mini Organ.  
**FEATURES** ● TEACH-IN '98 – An Introduction to Digital Electronics-2 ● Circuit Surgery ● Interface ● B<sup>2</sup> Spice Review ● Ingenuity Unlimited ● Alternative and Future Technologies-1 ● Net Work – The Internet ● Free Giant Data Chart – Formulae.

JAN '98

**PROJECTS** ● Disco Lights Flasher ● Simple M.W. Radio ● EPE Virtual Scope-1 ● Surface Thermometer.  
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## An Introduction to DIGITAL ELECTRONICS

Ian Bell, Rob Miles, Dr. Tony Wilkinson, Alan Winstanley

**T**EACH-IN is a series designed to support candidates following City and Guilds (C&G) 726 Information Technology, with reference to the following specific syllabuses: \*7261/301 Introductory Digital Electronics, \*726/321 Elementary Digital Electronics, \*726/341 Intermediate Digital Electronics.

Even if you are not undertaking the City and Guilds syllabus, there is much to be learned from *Teach-In*.

### Lab Work

Throughout *Teach-In*, attempts are made to involve the student with practical "Lab Work" experiments and demonstrations, and complex mathematics and physics will be avoided unless really necessary – and even then, plenty of help is to hand! We make a point of identifying practical components in special sections of *Teach-In*, so that you will learn to recognise parts.

### Part Five: LOGIC DESIGN AIDS

**I**N THIS part of *Teach-In*, we move on to larger *combinational logic* circuits. "Combinational" logic has nothing to do with safes with dials on the front, instead it is a circuit which works by logically combining input signals to produce output signals which *do* (or *mean*) something useful.

To make use of combinational logic we must look at the input patterns given to the circuit, and then work out the collection of combinational operations we want to perform on them to get the desired outputs. Combinational circuits produce their outputs in a single step and have no "memory" of previous inputs or results.

They can be designed, for example, to add two numbers together, but not to count upwards because this would require that the circuit remembers the number it has counted to so far. We will look at circuits with *memory* next in the series.

Note: Some readers (those not taking formal courses) may find Boolean Algebra, Karnaugh Maps, etc., rather heavy going. If you understand and apply this theory you will find it helpful, although it is not essential for hobbyists. This month's Lab Work demonstrates how the theory is used in practice.

### Getting Started

So how do you design a combinational logic circuit? There are two answers: first, you may start from scratch using Boolean algebra together with the various clever techniques which have been developed to make this easy and efficient (we have a look at *Karnaugh maps* next); second, you may be able to use a pre-designed standard logic function.

The latter is obviously best if what you can obtain fits your requirements and of course the most commonly used circuits are available in this way. The

standards include adders, comparators, multiplexers, display decoders, and parity circuits.

It is also possible to use computer-aided design software which will design logic circuits from Boolean and other types of description. This is called *logic synthesis*, but is beyond the scope of this course; we also believe that it is very important that you understand what is actually going on first, before considering using tools such as these.

### Boolean Algebra - The Logic of Truth Tables

In the last part of *Teach-In*, we introduced logic statements with a "need to change clothes" Truth Table:

R (it is raining)	U (using an umbrella)	C (change my clothes)
0	0	0
0	1	0
1	0	1
1	1	0

This tells us that the need to change clothes is TRUE if it is raining AND I am NOT using an umbrella, or using the notation described earlier.

$$C = R \bullet \bar{U}$$

However, consider the situation where we want a signal which tells us when there is *no need* to change clothes. Maybe it could be needed to operate a lock on the wardrobe/closet door, so we could call this new signal "L".

R (it is raining)	U (using an umbrella)	C (change my clothes)	L (Lock the wardrobe)
0	0	0	1
0	1	0	1
1	0	1	0
1	1	0	1

There are three conditions when we want to lock the wardrobe. If we try to express this in words, we say "lock the wardrobe" is (NOT raining AND NOT using an umbrella) OR (NOT raining AND using an umbrella) OR (raining AND using an umbrella). The brackets contain the three conditions. If we translate these into an equation, we get something like this:

$$L = \bar{R} \bullet \bar{U} + \bar{R} \bullet U + R \bullet U$$

Remembering that in Boolean logic, + means OR and • means AND.

### Making the Rules

This looks rather complicated! We can apply laws for manipulating expressions like these, in order to try to simplify them. Consider the following Rules, which we've numbered 1 to 9 (don't be scared by them):

- |                       |                             |
|-----------------------|-----------------------------|
| (1) $X + 0 = X$       | (6) $X \bullet X = X$       |
| (2) $X + 1 = 1$       | (7) $\bar{\bar{X}} = X$     |
| (3) $X + X = X$       | (8) $X + \bar{X} = 1$       |
| (4) $X \bullet 1 = X$ | (9) $X \bullet \bar{X} = 0$ |
| (5) $X \bullet 0 = 0$ |                             |

These rules equate to common sense, really. Using your knowledge of basic logic functions and the basic truth tables given in the previous part of *Teach-In*, you should be able to substitute known values for X, and apply these laws to verify the result.

For example, rule 2 says that anything (X) OR 1 will give 1. Compare this with the OR gate Truth Table (Fig.4.3) to prove it. Rule 5 states that anything (X) AND 0 equals 0. Rule 7 says that if you invert X



twice (double inversion) the result is X again. Try it! It works!

Two more complicated rules called the Distribution Rules, state that:

- (10)  $A \bullet (B + C) = A \bullet B + A \bullet C$
- (11)  $A + (B \bullet C) = (A + B) \bullet (A + C)$

The best way to prove these is to work them out by hand with some known input values. Expressions which appear in brackets should be calculated first. Over to you!

Using the above rules, we can start to simplify our "lock the wardrobe door" for Lock, Raining and Umbrella, in the following way:

- $L = \bar{R} \bullet \bar{U} + \bar{R} \bullet U + R \bullet U$  – apply Rule 10 to  $\bar{R} \bullet \bar{U} + \bar{R} \bullet U$  and we get:
- $L = \bar{R} \bullet (\bar{U} + U) + R \bullet U$  – apply Rule 8 to  $(\bar{U} + U)$  and we get:
- $L = \bar{R} \bullet 1 + R \bullet U$  – apply Rule 4 to  $\bar{R} \bullet 1$  and we get:
- $L = \bar{R} + R \bullet U$  – apply Rule 11 to this and we get:
- $L = (\bar{R} + R) \bullet (\bar{R} + U)$  – apply Rule 8 to  $(\bar{R} + R)$  and we get:
- $L = 1 \bullet (\bar{R} + U)$  – finally, use Rule 4 again and we end up with:
- $L = \bar{R} + U$  – phew!

Common sense says that we would lock the wardrobe door if it is NOT raining OR I am using my umbrella, which is the expression we finally arrived at.

There are two more rules of Boolean Algebra which are often referred to as "DeMorgan's Theorems". One theorem addresses the situation where the logic to make the outcome true, uses an AND operation. The other theorem is used when the logic to make the outcome true uses an OR operation:

- (12)  $\overline{A + B} = \bar{A} \bullet \bar{B}$
- (13)  $\overline{A \bullet B} = \bar{A} + \bar{B}$

This time an overbar is seen being used to invert an entire expression, not a single variable. By inverting both sides of the equations again, we can get:

- (14)  $A + B = \overline{\bar{A} \bullet \bar{B}}$  and
- (15)  $A \bullet B = \overline{\bar{A} + \bar{B}}$

We can use these to make our life much easier! To go back to our original problem – how do we invert the "change our clothes" signal (in order to generate a "lock the wardrobe door" L signal)? We can simply use Rule 13 in the following way:

$$L = \bar{C} = \overline{R \bullet U} = \bar{R} + \bar{U}$$

The lock signal L will be generated when it is NOT raining, OR we have an umbrella. This provides a much quicker route than the long-winded reduction we used before – and it gets the same result!

### Karnaugh Maps

Boolean algebra is all very well, but it does make the head hurt somewhat! Furthermore, a simple error in the manipulation of the equations will result in the wrong circuit being described. If the number of inputs results in our truth tables becoming very large, then "reducing" the resulting equations can be very difficult.

Karnaugh Maps (pronounced "car-no") give a graphical representation of the states we are interested in. To stay with our wardrobe lock – where the door is only unlocked (to allow a

change of clothes) if it is raining AND we're not using an umbrella:

R (it is raining)	U (using an umbrella)	L (door on wardrobe is locked)
0	0	1
0	1	1
1	0	0
1	1	1

"co-ordinates" on the map to give the long-winded form of the logic equation:

$$L = \bar{R} \bullet \bar{U} + \bar{R} \bullet U + R \bullet U$$

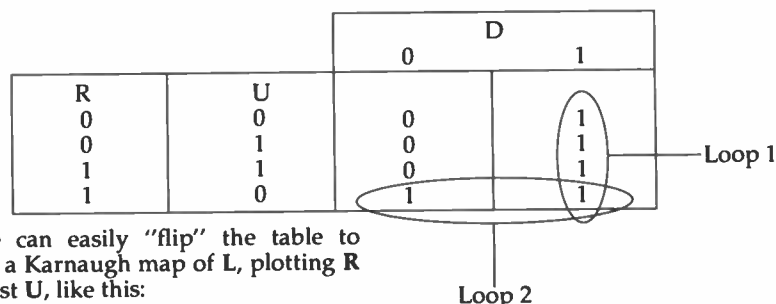
To simplify the equation we loop the 1s using the smallest number of largest loops possible which cover all the 1s. In this case two loops, each with two 1s. Loop 1 identifies  $\bar{R}$  as a variable which is common to both of its 1s, and loop 2 identifies U. We can easily combine these conditions to deduce that:

$$L = \bar{R} + U \text{ (again!)}$$

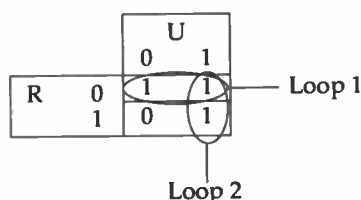
Now let's return to the full "change of clothes" Truth Table, including the "clothes dirty" variable D, which is the other occasion when we would want to change our clothes:

R (it is raining)	U (using an umbrella)	D (clothes are dirty)	C (change clothes)
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

A Karnaugh map drawn for C would look as follows:



We can easily "flip" the table to draw a Karnaugh map of L, plotting R against U, like this:



You can see two "loops", one (Loop 1) enclosing the top row and the other (Loop 2) enclosing the right-hand column. These are the areas where the output is logic 1, i.e. TRUE. We are not allowed to draw diagonal loops, but we can loop off of an edge of the map and back onto the opposite edge.

Note that neighbouring cells in the map differ by only one bit. This is true whether you move horizontally or vertically. This is what makes Karnaugh maps useful: by grouping together areas into "collections" we can see how the operation of the input variables (R and U in this case) can be simplified.

The three 1s in the basic "change of clothes" map can be read from their

Notice especially the order of the values in the left-hand columns. Each successive row is only allowed to differ from the previous row by one bit. This is not the same order as we used for the truth table for "change clothes" above. This pattern is known as the Gray Code (see later).

Loop 1 identifies D as a variable which is common to all states, and Loop 2 identifies  $R \bullet \bar{U}$ . Thus we get

$$C = D + R \bullet \bar{U}$$

### Gray Codes

Gray Codes are very important when utilising Karnaugh maps. If successive rows or columns differ by more than one bit, the map will not work. In the previous map, we need to put both R and U down the side of the map, and so we came up with a Gray code sequence of values for those inputs. If we had three inputs, we would need twice as many rows, and a Gray code sequence for the three inputs.

Table 5.1 shows a set of Gray code values for four input bits. Note that the change from decimal 15 to 0 is still only one bit. You can work out Gray codes from binary, as follows:

$$g_0 = b_1 \oplus b_0$$

$$g_1 = b_2 \oplus b_1$$

$$g_2 = b_3 \oplus b_2$$

in which the XOR function (symbol  $\oplus$ ) is used.

### Standard Combinational Logic Functions

Let's look at a variety of combinational logic circuits which frequently occur in digital electronic systems. These are also usually available as discrete chips, often with examples in the 4000 or 7400 series. We encourage you to investigate the data sheets of the chips we mention, but don't worry if you don't understand them completely yet!

If you are intending to progress further into logic design, though, it will soon become a necessity to have access to a logic manufacturer's data book (increasingly available on CD-ROM): some of the larger catalogues include pinouts of the digital i.c.s concerned, which is a helpful starting point.

### Multi-Input Gates

In Part 4 we only encountered two-input gates, but in theory a gate may have any number of inputs. In practice eight inputs is the largest you usually get in one discrete package (but the 74133 is a 13-input NAND).

If you need even larger gates then it is a simple matter to combine them in a "tree" circuit, for example Fig.5.1a shows a 10-input NAND gate made from 2- and 4-input AND gates with a 3-input NAND. The same function using eight 2-input ANDs and one 2-input NAND is shown in Fig.5.1b. Note that only the final gate is inverting.

Examples of 4000-series and 7400-series NAND gates include:

- 4023 7410 triple 3-input NAND
- 4012 7420 dual 4-input NAND
- 4068 7430 single 8-input NAND
- 74133 single 13-input NAND

### Transmission Gates

Transmission gates, also known as "analogue switches", or "bilateral switches", are available in CMOS series logic, but not in TTL 7400. They make use of the switching action of the MOS transistor (see *Teach-In* Part 3) and behave like electronically-controlled on/off switches. A single MOS transistor can be used in this way as shown in Fig. 5.2a, but unfortunately the transistor switches off when the voltage being switched gets close to the control voltage, because the gate-channel voltage falls below the switch-on threshold.

This can be overcome by using two MOS transistors, one p-channel and one n-channel, as shown in Fig.5.2b, an arrangement which forms a handy

Table 5.1 Gray Code for Four Binary Inputs

Decimal value	Binary input				Gray Code			
	B3	B2	B1	B0	g3	g2	g1	g0
0	0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	1
2	0	0	1	0	0	0	1	1
3	0	0	1	1	0	0	1	0
4	0	1	0	0	0	1	1	0
5	0	1	0	1	0	1	1	1
6	0	1	1	0	0	1	0	1
7	0	1	1	1	0	1	0	0
8	1	0	0	0	1	1	0	0
9	1	0	0	1	1	1	0	1
10	1	0	1	0	1	1	1	1
11	1	0	1	1	1	1	1	0
12	1	1	0	0	1	0	1	0
13	1	1	0	1	1	0	1	1
14	1	1	1	0	1	0	0	1
15	1	1	1	1	1	0	0	0

transmission gate. Here, at least one of the transistors is ON when control is high for all input/output voltages within the supply range.

Unlike other types of logic gate, signals may pass *either way* through these switches (just like a mechanical switch), and analogue levels rather than logic levels may be passed from "input" to "output". These switches have a far higher ON resistance than mechanical switches (up to a few hundred ohms or more) and this resistance varies with the input voltage and supply voltage. The 4016 and 4066 i.c.s (integrated circuits) both contain four such switches with individual control inputs. The 4066 has lower and less variable ON resistance.

Examples:  
4016 4066 Quadruple Bilateral Switches

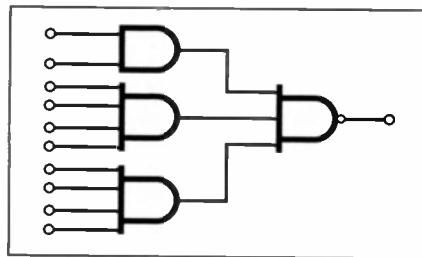


Fig.5.1a. A 10-input NAND gate.

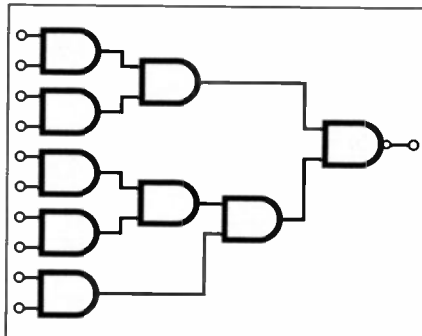


Fig.5.1b. An alternative 10-input NAND gate system.

### AND-OR-INVERT Gates

Many logic functions can be readily expressed in the regular form, thus:

(this AND this AND this ...) OR (this AND this AND this ...) OR ...

in which *thises* are very general and may mean *not this* (inversion). With the help of DeMorgan's theorem the above equation can be converted to the form:

(this OR this OR this ...) AND (this OR this OR this ...) AND ...

Some example equations of these forms are given below, noting that the second form requires brackets around the OR terms. (Remember too that a + sign means OR in Boolean logic.) In Boolean theory, the jargon for these forms of the equations are *sum-of-products* and *products-of-sums*

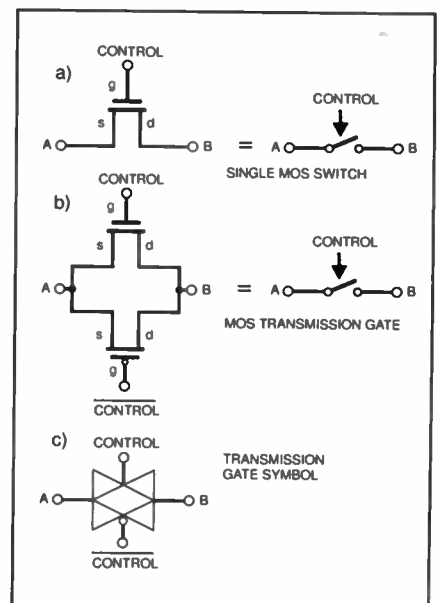


Fig.5.2a. Single MOS switch, (b) MOS transmission gate from p-channel and n-channel MOS transistors. (c) Transmission gate symbol.

respectively, sometimes abbreviated to SOP and POS (don't you just love jargon):

An SOP equation:

$$Q = \bar{A} \bullet \bar{B} \bullet C + A \bullet \bar{B} \bullet \bar{C} + A \bullet B \bullet C$$

A POS equation:

$$Q = (A + \bar{B}) \bullet (\bar{B} + C) \bullet (A + C) \bullet (\bar{A} + B + \bar{C})$$

The regular form of the logic equations translates into a regular form of circuit - for example, a set of AND gates driving an OR gate. All you need to create your logic function is one of these "AND-OR" structures, and a few NOT gates for the inputs (and maybe the output) that are inverted in your equation.

By putting the AND-OR function onto one chip, you save a dual-inline package as you no longer need both an OR chip and an AND chip. These devices are called AND-OR-Invert gates (sometimes abbreviated to AOI gate) and are described in terms of the number of AND gates (how "wide" they are), and the number of inputs each AND gate has.

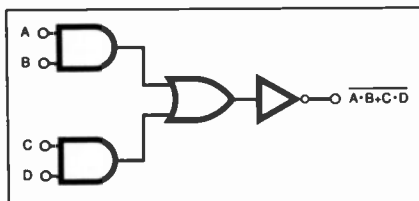


Fig.5.3. A 2-wide, 2-input AND-OR-INVERT gate.

The arrangement of such a 2-wide 2-input AOI gate is shown in Fig.5.3. (The OR gate sometimes has an extra input so that larger circuits can be easily formed using other chips.) The logic equation for the (4-wide 2-input AOI) 4086, for example, is:

$$\text{Output} = \overline{I_0 \bullet I_1 + I_2 \bullet I_3 + I_4 \bullet I_5 + I_6 \bullet I_7 + I_8 + I_9}$$

Note the invert bar over the whole equation indicating the invert part of the AOI. Also note the four sets of two ANDed inputs which are ORed together ( $I_0$  to  $I_7$ ), together with two "extra" inputs  $I_8$  and  $I_9$ . These are "override" or enable inputs which can be used when two or more 4086s are used to make wider AOIs.

Examples:

- 4085 dual 2-wide 2-input AND-OR-invert gates
- 4086 4-wide 2-input AND-OR-invert gate
- 7451 dual 2-wide 2-input AND-OR-invert gates
- 7454 4-wide 2-input AND-OR-invert gate
- 7455 2-wide 4-input AND-OR-invert gate
- 7464 4,2,3 and 2-input AND-OR -invert gate

## Multiplexers

Multiplexers select one of a set of possible inputs, and convey the data on that input to the output. Multiplexers

can also be thought of as electronic switches which can be described in terms of poles and positions, like mechanical switches.

The choice of signal being routed through the multiplexer, or the switch position, depending on how you view it, is determined by the multiplexer's select inputs. The select inputs are usually binary coded so, for example, a multiplexer with four inputs (like a four position switch) will have two select inputs on which the binary numbers 0 to 3 (00, 01, 10, 11) each result in a different one of the four inputs being routed to the output.

The most basic logic multiplexer is the 2-input multiplexer which can be made from an AND-OR gate and an inverter, as shown in Fig. 5.4a. Larger multiplexers are based on this circuit with larger AND-OR structures and more select lines.

Multiplexer i.c.s may contain more than one multiplexer with the same select signals. Some chips also have "strobe" or "enable" inputs which can switch off the whole multiplexer forcing a fixed level (0 or 1) on the output. Some of the 74 series multiplexer chips have inverted outputs (check this if you use them!).

TTL multiplexers and some CMOS multiplexers are based on logic gates like the circuit in Fig. 5.4a. However, CMOS multiplexers can be built using MOS transistors rather than gates to route the signals, as shown in Fig. 5.4b (in practice transmission gates, rather than single transistors, may be used). Note the symbol for a buffer (Fig.5.4a), not to be confused with an inverter.

Multiplexers built in this way can therefore handle analogue as well as digital signals. CMOS analogue multiplexers are available in the 4000 series and are called multiplexers/demultiplexers because their bi-directional nature means that they can be used to distribute a signal on one input onto one of a set of possible outputs (the opposite of multiplexing).

Examples:

- 4019 Quad 2-input multiplexer (non-inverting)
- 4051 8-channel analogue multiplexer/demultiplexer
- 4052 dual 4-channel analogue multiplexer/demultiplexer
- 4053 triple 2-channel analogue multiplexer/demultiplexer
- 4067 16-channel analogue multiplexer/demultiplexer

- 4539 Dual 4-input multiplexer (non-inverting)
- 74150 16-input multiplexer (inverting)
- 74151 8-input multiplexer (inverting and non-inverting outputs)
- 74152 8-input multiplexer (inverting)
- 74153 Dual 4-input multiplexer (non-inverting)
- 74157 Quad 2-input multiplexer (non-inverting)
- 74158 Quad 2-input multiplexer (inverting)

## 1-of-N Decoders and Demultiplexers

A one-of-N decoder is quite simply what it says - it has N outputs and one

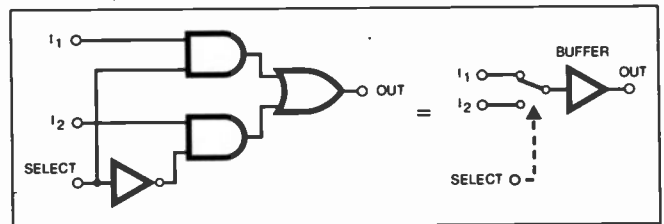


Fig.5.4a. A 2-input multiplexer using gate logic. A "selected" signal is then buffered using a buffer (no inversion takes place).

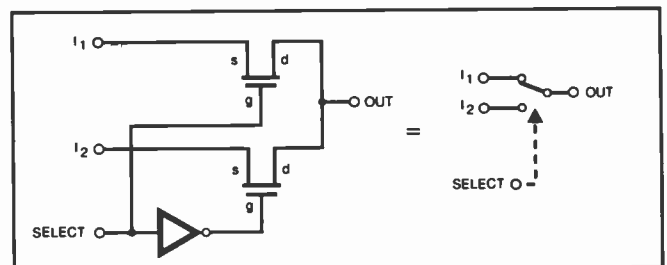


Fig.5.4b. A 2-input multiplexer using MOS switch logic.

of them is 'ON' at a time (see Fig. 5.5); this means all but one of the outputs are logic 0 and one is at logic 1 (active high), or vice versa (active low or inverted outputs). Which output is active is determined by a binary input number: if the input is, say 5 (binary 101), then output 5 will be 1 and the others 0.

Common sizes for these decoders include 1-of-4 (2-bit binary in), 1-of-8 (3-bit binary in), 1-of-16 (4-bit binary in), and 1-of-10 (BCD in). A BCD decoder can receive binary inputs greater than 9, in which case typical devices give an all-inactive output. BCD is described in the *Bits, Bytes, Words and Nibbles* panel.

Some 1-of-N decoders have "enable" inputs which can be used to force all the outputs to the inactive state. The enable can also be used as a data input. For example, assuming an active high

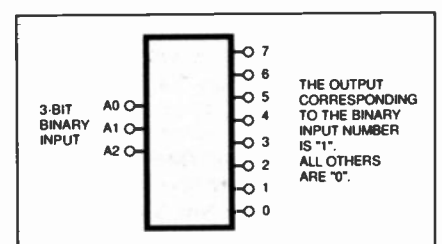


Fig.5.5. A 1-of-8 decoder.

output device, if the binary input is, say 5, then output 5 will be 1 if the enable is 1; if the enable is 0 all outputs, including output 5 will be 0. Thus, if the binary input is held at 5 the value on the enable input is effectively transferred to output 5.

This action, whereby the data on a single input can be routed to one selected output from a set of possible outputs, is opposite to that of a multiplexer. These devices are therefore also called *demultiplexers* if they have this capability.

Examples:

- 4028 1-of-10 decoder (BCD decoder with active high outputs)
- 4555 Dual 1-of-4 decoder/demultiplexer
- 4556 Dual 1-of-4 decoder/demultiplexer (active low outputs)
- 7442 4 line to 10 line decoder (1-of-10) (BCD decoder) (active low outputs)
- 7445 BCD decoder/driver (1-of-10) (active low outputs, with 80mA current sink capability)
- 74137 3-line to 8-line decoder/demultiplexer (binary input, active low outputs)
- 74138 Dual 1-of-4 decoder/demultiplexer (binary input, active low outputs)
- 74145 BCD decoder/driver (1-of-10) (active low outputs, with 80mA current sink capability)
- 74154 4-line to 16-line decoder/demultiplexer (binary input, active low outputs)

74155 Dual 1-of-4 decoder/demultiplexer (binary input, active low outputs)

## Comparators and Magnitude Comparators

In its simplest form a *comparator* compares two binary words (see the special panel *Bytes, Bits, Words and Nibbles*) and outputs a single bit to indicate if the two words are equal or not (these are known as *identity comparators*). More complex comparators, called *magnitude comparators*, indicate if a binary number on one input word is equal to, greater than, or less than a binary number on the other input word.

Magnitude comparators often have equal to, greater than, or less than inputs which can be connected to the corresponding outputs on another chip of the same type to form a comparator for binary numbers of twice the size available from a single chip. This cascading can be repeated to form very large comparators. Identity comparators may also have "expander" inputs.

The most basic identity comparator is the XOR gate, which compares two single bits and outputs a 1 if they are different and a 0 if they are the same (see the Truth Table in Part 4 (Fig.4.6)). The XNOR does the same thing, but with inverted outputs. It is a simple matter to build a multi-bit equality comparator by using as many XOR gates as there are bits connected to an OR gate, with one input for each XOR

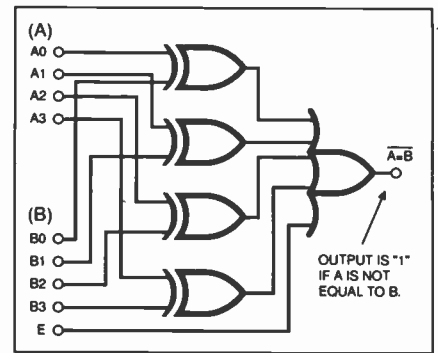


Fig.5.6a. A 4-bit identity comparator based on XOR gates.

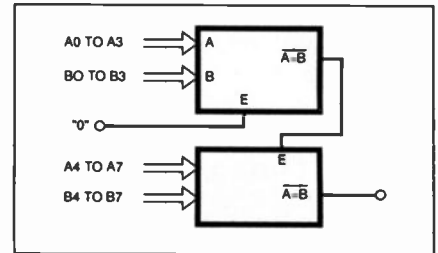


Fig.5.6b. Two 4-bit comparators connected to form an 8-bit comparator (based on 2 x Fig.5.6a).

output. The OR output will be 1 if any of the corresponding bits are not equal. An extra input to the OR gate would provide an expander input. Fig. 5.6a shows a 4-bit comparator based on this idea, and Fig. 5.6b shows two such arrangements forming an 8-bit comparator. Identity comparator chips with expander inputs are available, for example the 74521.

## Bits, Bytes, Words and Nibbles

A single binary digit, called a bit, can hold the value 1 or 0. (high or low). If a greater range of values is required, this can be achieved by grouping a number of bits together. If we have two bits, four possible patterns are available, which can be regarded as the numbers 0 to 3 in decimal:

00 > 0  
01 > 1  
10 > 2  
11 > 3

The digital circuit will always regard the information as a pattern of bits: it is the user of the system who decides to map these patterns onto particular values or meanings. By adding yet more bits, the range of values possible increases (for numbers, or for coding anything else). In fact the number of patterns available is 2 raised to the power of the number of bits you have, for example with three bits you have  $2^3$  - which gives 8 different patterns. The number of available patterns from a collection of bits can also be referred to as the number of possible *states*.

When the inputs or outputs of a digital circuit represent binary numbers then the numbers are often identified using a letter or word (e.g. A, B or DATA). The individual bits (which correspond to the actual pins or wires) are identified using these names with numerical subscripts indicating the power of 2 the bit represents. For example a 4-bit binary number called A requires 4 wires called  $A_3 A_2 A_1 A_0$  representing the 8s 4s 2s and 1s of the binary number respectively. This wire labelling is also used for data other than binary numbers, but you do also see bit numbering starting with a 1 rather than 0 so take care!

Numbers are usually coded using binary (base 2) numbers, but other numerical codes have been used. Very large and very small numbers (e.g. those used in science and engineering) and often written in a form such as  $2.3 \times 10^{42}$ , require special coding (matching the scientific notation we use to write them), for which there are recognised international stan-

dards (e.g. ANSI/IEEE Std 754-1985, for Binary Floating Point Arithmetic). The range of numbers on a typical calculator ( $1 \times 10^{-99}$  to  $9.99999999 \times 10^{99}$ ) would require something like 662 bits to code directly; we don't do this just as we don't write  $1 \times 10^{99}$  using 100 decimal digits.

Eight bits in a row gives us a *byte*. This can hold 256 different patterns ( $2^8$ ), these range from 00000000 (the binary representation of 0) to 11111111 (the binary representation of 255). Bytes are often used to hold individual characters (letter, digit or punctuation mark) in textual data (e.g. in E-mail and wordprocessor documents). Some characters are special control characters which represent a particular action you want to take whilst printing, for example move down to a new line, or return to the start of the line. Fortunately, a standard has been set up so that all computers agree on the character code values. This standard is called ASCII (American Standard Code for Information Interchange) and ensures that all machines agree that the number 65 represents the letter 'A'.

A byte is big enough to store a character, but not big enough to hold larger values. Computers hold larger values by putting even more bits together to make *words*. There is no standard for how long a word is. Some computers regard a word as 16 bits in length, others talk in terms of 32 or even 64 bits. In fact "word" can be used for any bit length as long as you qualify it, e.g. "5-bit word".

Sometimes you would like to store a small value, and you don't want to use a whole 8-bit byte to hold it. In this case you can use a *nibble*. The *nibble* is a semi-serious name for a 4-bit quantity. A 4-bit nibble can hold a value between 0 and 15, making it possible to represent the contents of a nibble by a single *hexadecimal* (base 16) digit.

Another use for 4-bit quantities is BCD (Binary Coded Decimal), which uses a group of 4 bits for each digit in a decimal number. The binary values 0 to 9 (0000 to 1001) are used for the decimal digits 0 to 9 but the binary values 10 to 15 (1010 to 1111) are not used. As an example, 237 in decimal would be represented as 0010 0011 0111 in BCD. Compare this with its true binary equivalent of 11101101.

## Carry Out Instructions

In case you have been relying on your pocket calculator and do not have a good feel for "carrying" when doing sums, an example or two may help. If we add 86 to 57 we first do  $6+7$  to obtain 13. We put the 3 in the units column and *carry* the 1 over to the 10s column. Then we add  $8+5+1$  carried in, to get 14. We put 4 in the tens column and *carry* 1 over to the 100s column. Then we put the final carried 1 in the 100s column. The result is 143. (Applause!)

Note that the result of an addition may have one more digit than the larger of the two numbers being added. A similar process is used for binary. To add 110 and 011 we do  $0+1$  to get 1 in the units, then  $1+1+0$  (0 carried in) to get 10, put 0 in the 2s and carry the 1 out, then we do  $1+0+1$  (1 carried in) to get 10, we put 0 in the 4s and carry the 1, finally we put the carried 1 in the 8s. The result is 1001.

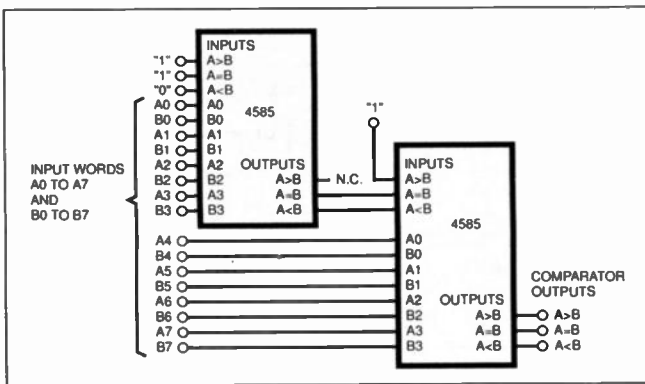


Fig.5.6.c. Two 4585 4-bit magnitude comparators used as an 8-bit magnitude comparator.

Magnitude comparators are available as devices in the 4000 and 7400 series. For example the 4585 is a 4-bit magnitude comparator with expander inputs. Fig. 5.6c shows two 4585s used to form an 8-bit comparator.

Magnitude comparators are used in arithmetic circuits (there's one somewhere in the processor in your PC...). Identity comparators are used in address decoding for computer memories (there may be few of these in your PC too...). Special comparator chips aimed at address decoding applications are available.

Examples:

- 4070 Quadruple 2-input XOR
- 4585 4-bit magnitude comparator
- 7485 4-bit magnitude comparator
- 74521 8-bit identity comparator
- 74686 8-bit magnitude comparator

## Adders and Subtractors

Arithmetic circuits such as *adders* are of great importance in digital electronics. It is these circuits which enable computers and other digital systems to "do maths". It is often said that all numerical calculations can be done using addition, after all subtraction is just negative addition, multiplication is repeated addition and division is repeated subtraction.

Making this *really* work though is a bit more difficult than the previous comment indicates, and when you mix in the requirement that the circuits have to be fast too, then it gets even more complicated!

Due to their key role in computers a considerable amount of research and development effort has been put into developing arithmetic circuits over the years since digital electronics first emerged. There is now a vast array of different types of arithmetic circuit offering varying degrees of speed, circuit size, power consumption, and types numerical coding. We only have space to introduce a few of the fundamental ideas here.

The most basic arithmetic circuit is simply an XOR gate. This adds two one-bit binary numbers and gives the "units" result (there is no carry in, or carry out). For the more mathematically inclined, it actually performs modulo-2 addition. The *half adder*, which we introduced in Part 4, adds

two 1-bit binary numbers and gives a 2-bit binary (2s and units) result. The 2s output of the half adder is usually referred to as the carry-out, but note that the half adder does not have a carry-in input.

In order to build an adder for more than 1-bit numbers we need to be able to fully handle the carrying process which occurs during multi-digit addition. To do this, we use a *full adder* for which a circuit is given in Fig. 5.7a. (The half adders are as per Fig. 4.5 in Part 4.) This has two bits to be added,  $X_0$  and  $Y_0$  plus a carry-in, and the circuit outputs a 1-bit result (sum) and a carry-out.

The addition process is the same for each digit: starting at the least significant digit (the lowest bit), we add the corresponding digits from the numbers being added, plus the carry from the previous digit to get a "partial result". We put the "units"

part of the partial result into the corresponding digit of the final result and carry the more significant part of the partial result to the next digit's calculation. The process is repeated for each digit. (Be sure to read the separate topic panel "Carry Out Instructions" to see how this works.)

There is slight difference for the first digit as its carry-in is always zero, and for the last digit where the carry-out goes directly to form the most significant digit (highest bit) of the result. This is illustrated in Fig. 5.7b which also happens to be the schematic of a 4-bit binary adder made up from four full adders.

How would we add two 16-bit numbers? We could use four 4-bit adders with their carry-ins and carry-outs linked. This would, of course, work but we must remember a key issue in digital design, that of the *speed of operation* of the circuit. The carry signal arriving at the final output (bit 17 of the result) has to pass through up to 32 gates, whereas the individual digit input-to-output path is 6 gates (but these have to wait for their carry-ins). The speed of the adder will be limited by the response time of the final carry. Adders of this form are called *ripple-carry* adders, which are simple but slow.

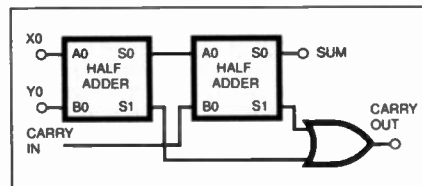


Fig.5.7a. Full adder circuit using half-adder circuit from Fig.4.5.

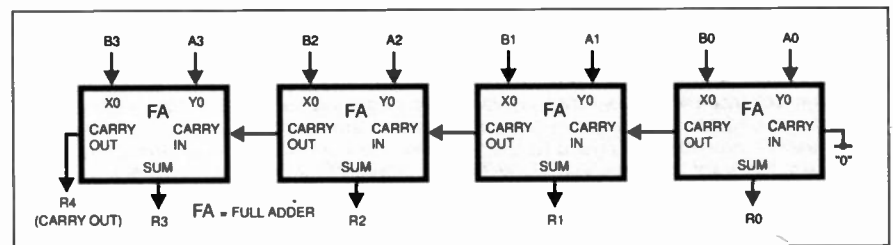


Fig.5.7b. A 4-bit adder. This adds two 4-bit numbers A and B to give a 5-bit result R. R4 can be used as a carry for constructing larger adders.

## Modulo Arithmetic

Consider *modulo 100* in base 10 ("normal" numbers) in which we have possible numbers 00 to 99 and we use 0 to 49 as positive and 50 to 99 as negative numbers. To find a number's complement we subtract it from 100. So  $-23$  is  $100 - 23 = 77$ , that is  $-23$  is represented by 77. So to do the sum  $45 - 23$  we do  $45 + 77$  which gives 122, we ignore the 1 because we are using modulo 100 and so we get 22 (the right answer!). We have just used *addition* to do *subtraction*!

We can do the same with digital adder circuits as we can also design circuits to convert numbers to their complements (which of course turns out to be easy). The type of complement we have used is called the *10s complement* and the corresponding complement in binary is called the *2s complement* which can be obtained by inverting all the bits and adding 1.

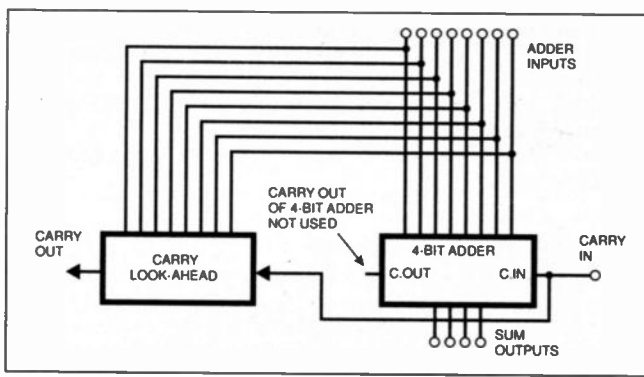


Fig. 5.7c. A 4-bit adder with "carry-look-ahead" circuit which generates a carry faster than the carry-out of the four full adders of 5.7b.

## Looking Ahead

We can make the adder go faster by using "clever" carry circuits. One example is called *carry-look-ahead*. The way this works is to use a circuit which directly (and hence quickly) works out the final carry from (say) a 4-bit adder (see Fig. 5.7c).

To design such a circuit, all that is required is the logical condition for this carry to be 1 in terms of the 8 digit inputs and carry-in to the 4-bit adder. Larger adders are then constructed by connecting the carry input of each 4-bit section to the carry-look-ahead output of the previous 4-bit section. The total delay to the final carry is then greatly reduced. The 4008 is a 4-bit adder with carry-look-ahead, the 74182 is a separate carry-look-ahead circuit.

## Negative Addition

So far we have only discussed addition and not subtraction; however subtraction can be viewed as the addition of the negative of the number being subtracted, and this is the way in which it is often done in digital arithmetic circuits. So how do we represent *negative numbers* in binary?

Well, the most obvious way is to have an extra bit for the sign (e.g. 0 for + and 1 for -) but this does not lead to easy subtractor circuits. Another method is to use what are called *complements* and *modulo arithmetic*. Basically, in this usage of modulo arithmetic all numbers are limited to  $n$ -digits and overflows beyond  $n$ -digits are ignored. Limiting the range of possible numbers may seem strange, but it inherently occurs in arithmetic circuits; once you've built a 16-bit adder you are limited to doing 16-bit additions!

Complements are basically a coding of negative and positive numbers which lead to straightforward circuits, because *adding* a number's complement results in that number being *subtracted*. To obtain complements, we use half of the available  $n$ -digit numbers as negative, and half as positive. Just to make it even more complex there are different types of complement too, but a common one is the 2s complement which is obtained by inverting all the bits and adding 1.

This is quite neat because inverting

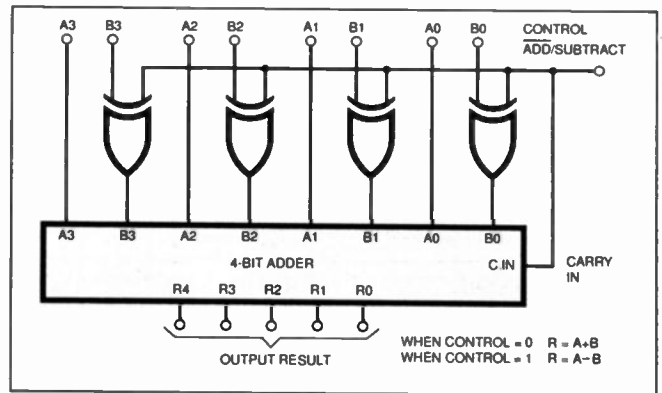


Fig. 5.7e. A 4-bit Add/Subtractor circuit.

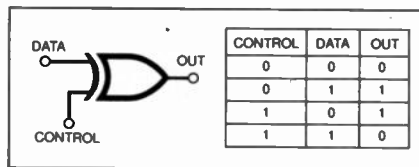


Fig. 5.7d. An XOR gate used as a controlled inverter.

is easy to do, and adding one can be readily achieved using the carry-in of the first stage of an adder circuit. The fact that we can use the same adder circuit for both addition and subtraction of both positive or negative numbers is the great advantage obtained by the use of complemented numbers. For an example of how this works check out the panel *Modulo Arithmetic!*

If we need an Adder/Subtractor circuit, i.e. one which can do either  $A+B$  or  $A-B$  under the control of a "mode-select" input, then we can make use of the versatile XOR gate again, as a controlled inverter. If one input to an XOR is considered to be the data and the other the control, then the output is equal to the data when control is zero and equal to data when control is 1 (see the Truth Table in Fig. 5.7d).

Thus in Fig. 5.7e, if we use XORs between the B input and the adders, and also connect the control input to the carry-in of the first adder (for the add-one of the 2s complement), we get a versatile adder/subtractor circuit module.

Examples:

4008	4 bit binary full adder with look-ahead carry-out
7480	Gated full adder
7482	2-bit full adder
7483/74283	4-bit binary full adder with fast carry
74182	Carry look-ahead unit
74183	Dual carry-save full adder

## ALUs

If you look at the functions which a basic microprocessor (the heart of a microcomputer and many computerised systems and gadgets) can perform then you will find a list of basic arithmetic operations (addition, subtraction, greater than, less than, etc.) and logical operations (AND,

OR, NAND etc.). We have described individual circuits which perform these functions. It is useful to have a "big" logic circuit which can do all these functions with a form of "select" input to choose which function is currently being performed on the input data.

Such a circuit is called an arithmetic logic unit (ALU). An example of this can be found in the 74 series - the 74181 which provides addition, subtraction, shift-by-one-bit (multiply by 2), magnitude comparison, AND, NAND, OR, NOR, XOR, logical comparison and 12 other arithmetic and 10 other logic operations. It can be used with the 74182 carry-look-ahead generator to give high speed operation. The arithmetic circuits in modern microprocessors are far more complex than the 74181 but it serves to illustrate the idea of multi-function arithmetic and logic circuits found in the heart of computers.

## Seven-Segment Decoders

A digital circuit will represent a number as a pattern of bits. The bigger the number, the larger the number of bits (see "Bits, Bytes, Words and Nibbles" for more on this topic). A common way of displaying numbers is by the use of a 7-segment l.e.d. display. This uses seven illuminating bars which, when lit in various combinations, can display all the digits (see Fig. 5.8). See also *Check Out: Digital Displays*.

A 7-segment display decoder takes in a bit pattern and produces an output for each bar of the l.e.d. That bar is then lit at the appropriate time. It is not uncommon to see 7-segment displays which contain the encoder as a single package. When supplied with the appropriate bit pattern such devices light the required number.

You have to choose the correct decoder to match the type of display you are using. For **common-cathode** l.e.d. displays you need an *active-high* output device, such as the 7448 or 7449, whose outputs are at logic 1 at the appropriate time and will drive the anodes of the l.e.d. display.

For **common-anode** l.e.d. displays you need *active-low* output decoders, such as the 7446 or 7447; outputs are logic 0 when they are "enabled" by the

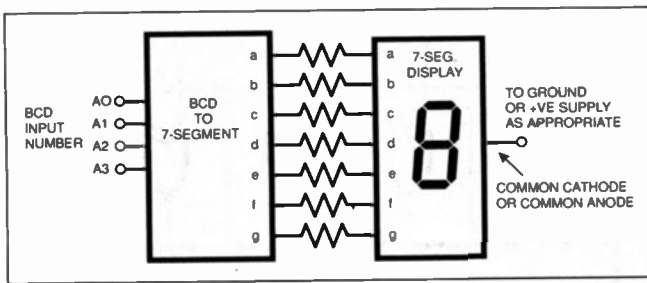


Fig. 5.8. A binary-coded decimal to 7-segment display decoder. The display is connected to 0V or positive supply, depending on whether it is a common cathode or common anode type.

internal circuitry and these connect the l.e.d. cathodes to 0V. An "open collector" decoder output has a floating output (the collector of the output driver transistor), to which the display can be connected.

Additional features that you might find on 7-segment decoders include "ripple-through zero-blanking", "override blanking", and "lamp-test" inputs. Ripple-blanking sets the leading (or trailing if desired) zeros to blanks so, for example, 0023 would be displayed as 23.

The RBI and RBO input and output of the decoders driving successive digits are connected together. The blanking input can be used to control display intensity by pulsing it on and off and varying the proportion of off-time to on-time. The lamp test input can switch on all the outputs (to check the display) whilst override blanking switches them all off.

### Priority Encoders and Majority Gates

A priority encoder is a circuit which "decides" on the highest priority input which it is given, and produces a binary number which represents this. To further explain this, we could look at the residence of Lord Faversham-Wills, which has recently been re-wired with the new, patent butler request selection system.

Various members of the family are given "butler request" buttons which they press to indicate that they need the services of the butler. However, Lord Faversham-Wills, who pays the butler, has insisted on a particular order of preference for butler requests, with himself at the top, and then various daughters, nephews and sons-in-law below.

A simple 10-input priority encoder with a BCD output is shown in Fig. 5.9.

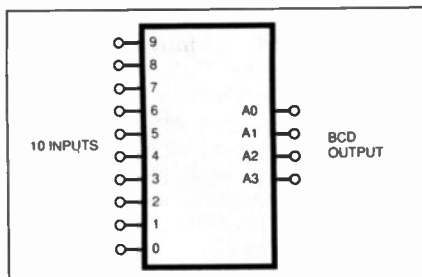
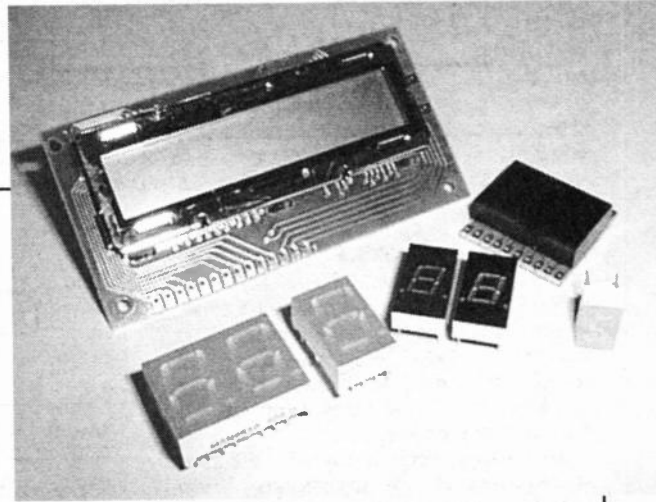


Fig. 5.9. A 10-input priority encoder with BCD output.

Examples:

- 7446 BCD to 7-segment decoder, 30V max., active low
- 7447 BCD to 7-segment decoder, 15V max., open collector, active low
- 7448 BCD to 7-segment decoder, 15V max., 2k pull-up, active high
- 7449 BCD to 7-segment decoder, 5.5V max., open collector, active high



## Check Out: Digital Displays

Light emitting diodes (l.e.d.s) are useful in producing "displays" which can show numerical data. The commonest form is the 7-segment display which everyone has seen at one time or another - look for them in the "opto-electronics" section of a catalogue.

They generate the numerical characters 0 to 9, as well as (with a little imagination) a few limited alpha characters too. Various colours are produced, with red being the most common. They are especially suitable in darker ambient conditions.

The l.e.d. bars are each lettered a to g signifying their position - see Fig. 5.11. Since each display contains seven light-emitting diodes plus an eighth for a decimal point, you might think that this involves making a total of sixteen connections to the anodes and cathodes of each l.e.d. However, in order to reduce the necessary wiring, it is usual to "common" either all the anodes or all the cathodes together, to form **common anode** and **common cathode** types.

The common anode is then connected to the supply rail, and individual cathodes are connected to 0V to illuminate specific segments. Common cathodes work in reverse, with cathodes wired to 0V and individual

anodes are driven from a positive supply instead. It is necessary to use a current limiting resistor in series with each segment, just like an ordinary l.e.d.

Seven-segment displays may be fabricated in multi-digit assemblies containing several digits. Manufacturers' data will tell you the pin-out details of the packages, which must be followed carefully for the display to function correctly.

More "intelligent" displays include a complete decoder-driver chip inside, so that you can input a binary number and the display will show the relevant decimal number. These types of device are expensive, though. At the top of the range are "dot matrix" displays, where an array of individual l.e.d.s is driven to generate alphanumeric characters.

The **liquid crystal displays** (l.c.d.) require an alternating drive signal and are much more suited to low-power applications (digital watches, mobile phones, calculators etc.). Emitting no light of their own, they need a **back-light** if they are to be seen in darker conditions. They can be manufactured in an infinite variety of character shapes and sizes (e.g. for l.c.d. games) and standard 3- or 4-digit types are commonly available from suppliers.

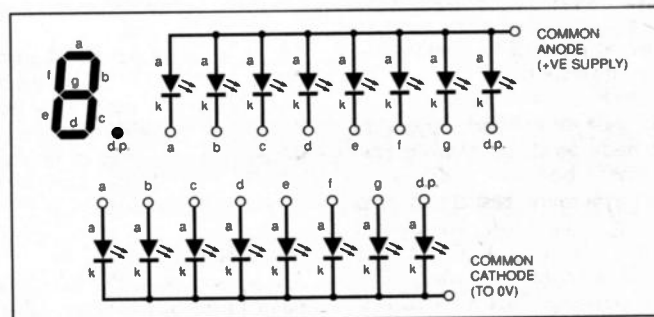


Fig. 5.11. A 7-segment l.e.d. display showing segment labels a-g, plus decimal point. The common anode and cathode set-up is also shown. The large device in the photograph is an l.c.d. module.

A priority encoder takes an input from each family member, and then produces a binary number which represents the current highest priority. This could be fed into a 7-segment decoder (see above) to drive a number display which shows the butler the number of the person he must go to.

A more serious use is inside your computer, where various devices (keyboard, disk drive, clock etc.) are competing for the attentions of the processor, and the hardware needs to determine which is currently the most urgent. An "interrupt controller chip" contains a priority encoder which is used to manage this. Another possible application is as a keyboard encoder, for example 10 switches could be used to produce a 0 to 9 binary output.

Examples:

- 4532 8-input priority encoder
- 74147 10-line to 4-line BCD (binary coded decimal) priority encoder
- 74148 8-line to 3-line binary priority encoder

A majority gate has an odd number of inputs which can be either high or low. It then produces a single output which indicates the state of the majority of inputs. Lord Faversham-Wills has one incorporated into the living room, so that when the family is watching television together they can vote on whether to watch BBC or ITV. (Of course Lord Faversham-Wills, who keeps the remote control, has the final say!). More of His Lordship in Lab Work 5.

### Parity Encoders and Decoders

Parity is a way of making sure a given bit pattern is correct. It allows single bit (i.e. one bit in the wrong state) errors to be detected. It works by adding an extra bit to the word we want to check. There are two types of parity: *even* parity means that the parity bit is set so that the number of high bits in the sequence is an even number; *odd* parity means that the parity bit is set so that the number of high bits in the sequence is an odd number. If one of the bits is incorrect (including the parity bit) the number of high bits will be incorrect for the parity regime in use.

The useful XOR gate provides an even parity bit for a 2-bit binary word.

To make larger parity generators it is simply a matter of using a tree of XOR gates, for example Fig. 5.10 shows an 8-input parity circuit. However, a faster parity circuit could be achieved by designing the logic from scratch rather than using the full XOR tree. A parity checker simply consists of a parity generator of the correct type, and an XOR gate to compare the generated parity bit with the one in the word itself.

Your PC contains memory which is nine bits wide. The ninth bit is the parity bit and is used by the hardware to make sure that your memory chips are all working correctly. If a memory parity error is detected the PC will and display an error message. (Such a PC was once seen on sale in a High Street store: it might have well said "My memory is broken. Do not buy me." The store assistant didn't know.)

Parity can be used whenever we send data from one place to another. Each sequence of eight bits (a byte) is verified by the use of an additional parity bit. The parity checking circuit is often built into the chip which sends the data down the wire, the chip will set a "bad parity" marker which the computer software can detect. It is important that both ends of the conversation agree on the parity which is to be used, or it will all end in tears!

Examples:

- 74180 9-bit odd/even parity generator/checker
- 74280 9-bit odd/even parity generator/checker

### Conclusion

This concludes our world-tour of combinational logic functions. We have come across many useful-looking functions such as adders and comparators, but actually these circuits are of relatively little use on their own. The real power of digital electronics comes with the ability to *sequence* a series of operations in order to perform a complex task or interact with changing external processes.

We could build a pocket calculator with combinational logic but it would not fit in your pocket. You would need a separate keypad for each digit of both numbers being, say, added and would have to press *all* the digit keys and the required function key (+ in this case) simultaneously. The result would only be displayed when the keys were being pressed.

Real calculators have *memory*: they store digits of the numbers to be

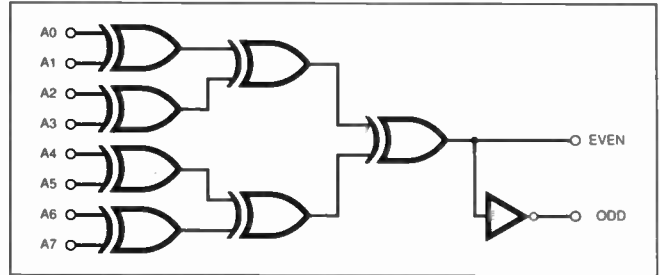


Fig.5.10. An 8-input parity generator formed from XOR gates.

added (or whatever), apply the appropriate data to the combinational logic circuits which do the arithmetic, and store the result and display it until the battery runs out or you do another calculation. Digital circuits with memory are called *sequential circuits*, and will occupy our thoughts for most of the rest of this series.

None of this means combinational logic is unimportant - it is of *critical* importance. In simplified terms many digital circuits contain sequential parts which control the flow of data through the combinational parts which perform the actual logic or calculations. Now have a look at the Lab Work section and hone your skills with combinational logic!

The Teach-In writers are delighted to receive your comments, feedback and queries. You can write to us at Teach-In c/o the Editorial address, or E-mail Teach.In98@epemag.demon.co.uk.

### PLEASE TAKE NOTE

In *Teach-In Part 4*, (Feb. '98 p.122) the 4081 should be described as an **AND** gate, not XNOR as shown in Fig.4.10. The pinout drawings and symbols are correct.

Also page 116, top of right hand column, "2-bit" binary result should be from (00 to 10) *not* (00 to 11).

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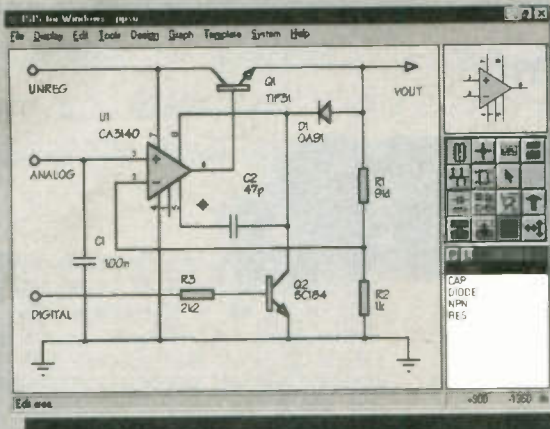
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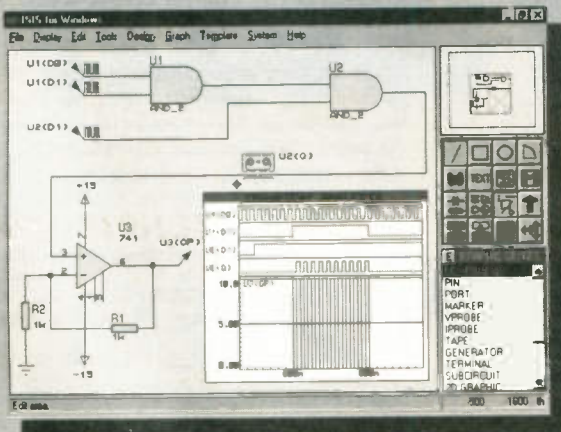
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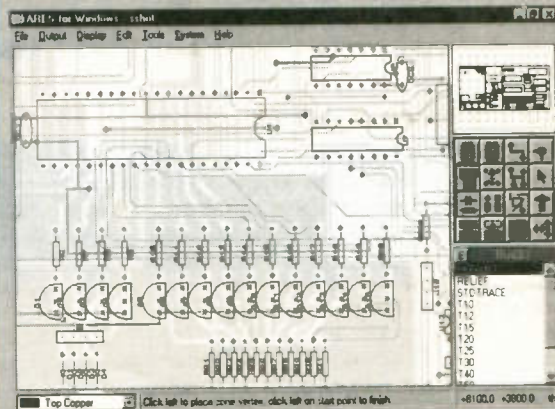
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## LAB WORK

## 5

**Objectives:** To demonstrate a practical application for Karnaugh Maps. Construct a priority encoder circuit and display the result on a 7-segment I.e.d. display.

**T**HIS section will challenge your understanding of Karnaugh Maps in a typical logic application, as we get to grips with a basic 7-segment I.e.d. display function. The text may look daunting, but we think that if you follow the text logically and refer back to the main tutorial text to refresh your memory as needed, you should be able to complete this section successfully.

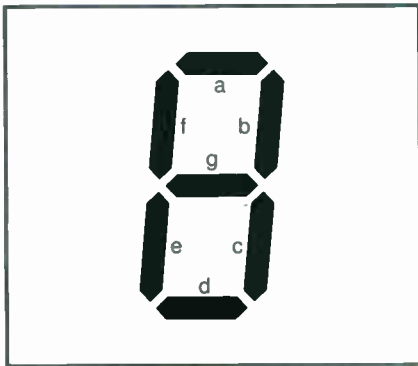


Fig.5.11. The conventional notation of a 7-segment I.e.d. display. The decimal point is not shown.

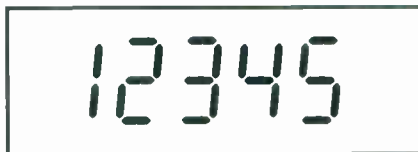


Fig.5.12. Segment displays to produce decimal numbers 1 to 5.

Karnaugh Maps can be complex-looking design aids, especially if you have never used them before. Take your time as you work through this part, and don't worry if you don't understand everything first time around.

### Lab 5.1 - Karnaugh Maps in Action

Consider a 7-segment display with I.e.d. segments which, for simplicity of understanding, are turned on by a logic 1 signal (a common cathode display – but read the important note later). Let's devise a decoder to decode a count of decimal 1 up to decimal 5, from binary input variables.

The truth table for this problem is as shown in Table 1.

The next stage is to draw a Karnaugh map for each of the seven segments a to g. The binary C and B input states are plotted against the third (A) input, and loops drawn in the resulting map. This is depicted in Fig.5.13. Note that we have identified each loop 1, 2 and 3 as necessary.

Because only the codes for decimal 1 to 5 are used, other counts do not matter and thus 'X' (don't care) states are entered and treated as 0 or 1 as is convenient in each map. This maximises the sizes of loops which can be used; if all the cells with 1s have been looped (remember – no diagonals allowed), then no further loops are needed.

Table 5.1: Producing a count of 1 to 5 from binary input variables

DECIMAL VALUE	BINARY			SEVEN SEGMENT DISPLAY						
	C (4s)	B (2s)	A (1s)	a	b	c	d	e	f	g
X	0	0	0	X	X	X	X	X	X	X
1	0	0	1	0	1	1	0	0	0	0
2	0	1	0	1	1	0	1	1	0	1
3	0	1	1	1	1	1	1	0	0	1
4	1	0	0	0	1	1	0	0	1	1
5	1	0	1	1	0	1	1	0	1	1
X	1	1	0	X	X	X	X	X	X	X
X	1	1	1	X	X	X	X	X	X	X

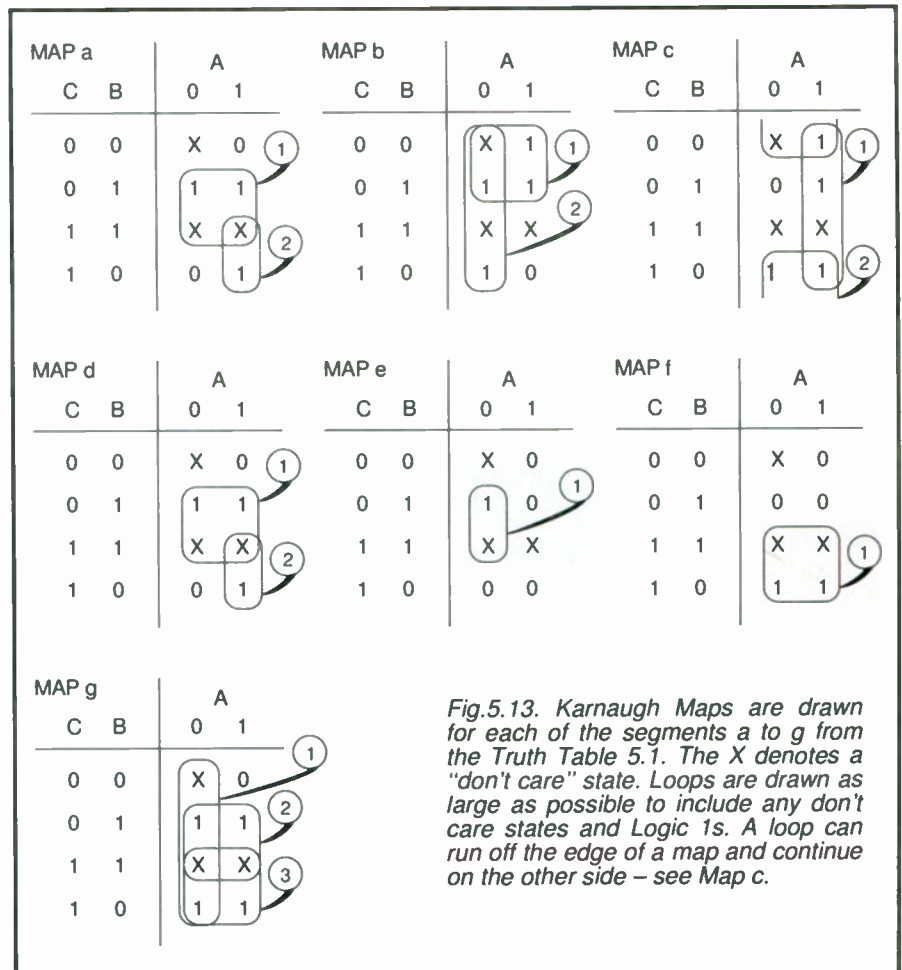


Fig.5.13. Karnaugh Maps are drawn for each of the segments a to g from the Truth Table 5.1. The X denotes a "don't care" state. Loops are drawn as large as possible to include any don't care states and Logic 1s. A loop can run off the edge of a map and continue on the other side – see Map c.

The result of these maps tells us the logic statements for each of the seven segments of the display, and are as follows:-

<b>Map a:</b> Loop 1 $\triangleright$ B	Loop 2 $\triangleright$ A $\bullet$ C'	$a = B + A \bullet C'$	
<b>Map b:</b> Loop 1 $\triangleright$ C	Loop 2 $\triangleright$ $\bar{A}$	$b = \bar{A} + C$	
<b>Map c:</b> Loop 1 $\triangleright$ A	Loop 2 $\triangleright$ B	$c = A + B$	
<b>Map d:</b> Loop 1 $\triangleright$ B	Loop 2 $\triangleright$ A $\bullet$ C	$d = B + A \bullet C$	
<b>Map e:</b> Loop 1 $\triangleright$ $\bar{A} \bullet B$		$e = \bar{A} \bullet B$	
<b>Map f:</b> Loop 1 $\triangleright$ C		$f = C$	
<b>Map g:</b> Loop 1 $\triangleright$ $\bar{A}$	Loop 2 $\triangleright$ B	Loop 3 $\triangleright$ C	$g = \bar{A} + B + C$

### Practical Circuit

You will now see how easy it is to translate this into a circuit diagram, using logic gates and inverters to represent the above formulae, see Fig. 5.14a. The three binary inputs A, B and C are shown, also with inverters on each line, and an array of OR and AND gates is used to implement the logic decoding in accordance with our logic statements. It will be seen that you would need three inverters, five OR gates plus three AND gates to realise the entire circuit.

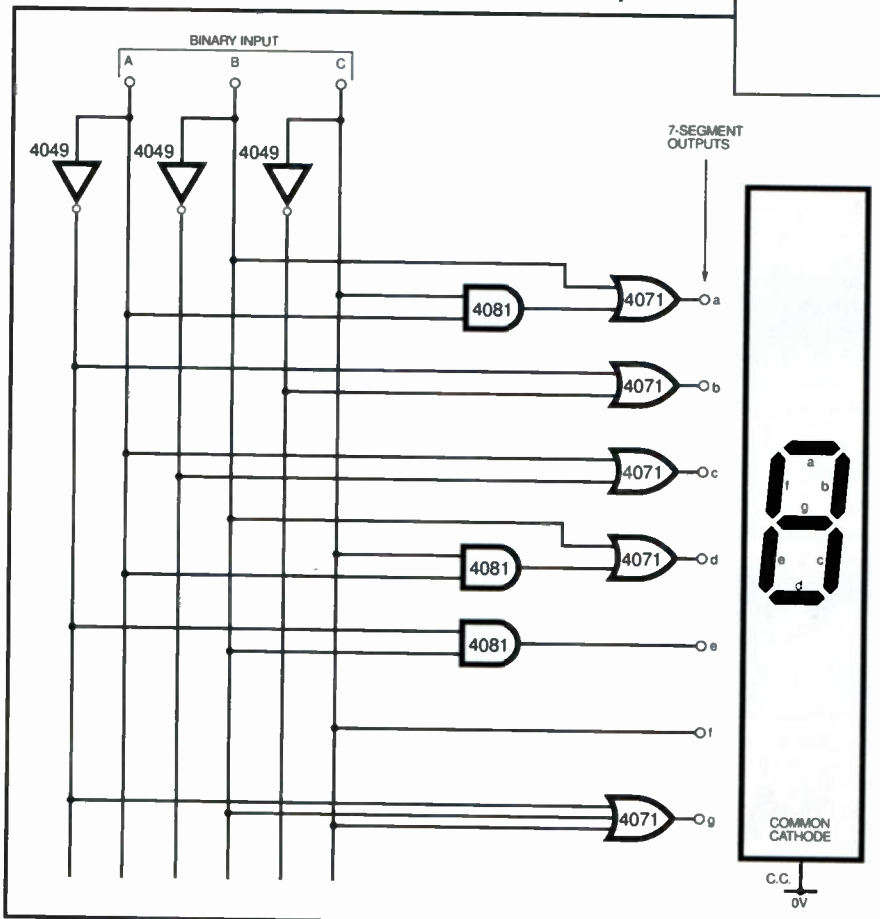


Fig. 5.14a. Circuit realisation of a 7-segment decoder driver which will display decimal 1 to 5.

In practice, we also need to provide enough current for each i.e.d. segment, the easiest way being to include an inverter buffer on each segment's drive signal as shown in Fig. 5.14b. Thus, seven more inverter buffers are also necessary. Altogether, ten inverters are used - e.g. two CMOS 4049 packages of which two inverters are unused; two quad OR gate packages (4071) would also be used, three gates being ignored; three AND gates from a 4081 are also needed.

The presence of the output inverter/buffers to boost the available current means that the output logic sequence for the display is now inverted and a common cathode display will no longer display the correct character! The logic outputs will now go low in sequence. (See *Check Out: Display Devices* in the main text for a refresher.)

The workaround is to utilise a common anode display instead, connecting the segment cathodes to the inverter buffers. The display is then connected as shown in Fig. 5.14b, with series limiting resistors R1 to R7 being inserted.

If you feel sufficiently confident, go ahead and demonstrate the operation of this circuit by constructing it on your solderless breadboard: use anti-static precautions when handling CMOS devices, ensuring unused inputs are connected to the 0V "rail". Most of the parts are very cheap and you may have some of the logic chips to hand already. It won't hurt to "source" a suitable 7-segment i.e.d. common anode display and confirm its pin-out drawings from the vendor's catalogue (see later).

There is just sufficient room to accommodate the five d.i.l. chips plus the display

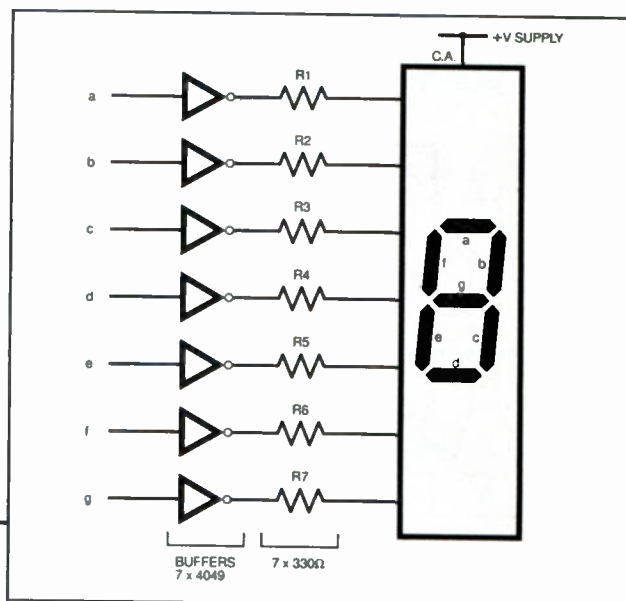
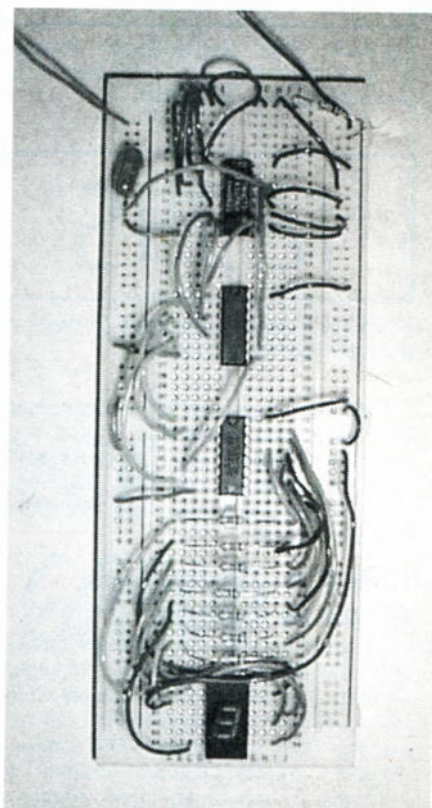


Fig. 5.14b. A practical circuit needs output buffer/inverters to drive an i.e.d. display.

on the recommended solderless breadboard. Looking further ahead, we will be investigating an alternative construction technique (wire wrapping) as an alternative way of building more complex circuits quickly and easily.

### Lab 5.2: Standard Logic Functions

So far we have only concerned ourselves with CMOS devices. These are static-sensitive, have low power consumption (ideal for battery-operated circuits) and a fairly wide operating voltage range (3V to 15V). The 7400 series TTL (transistor-transistor logic) is a competing technology - see the topic "Logic Families" in *Teach-In 4*.



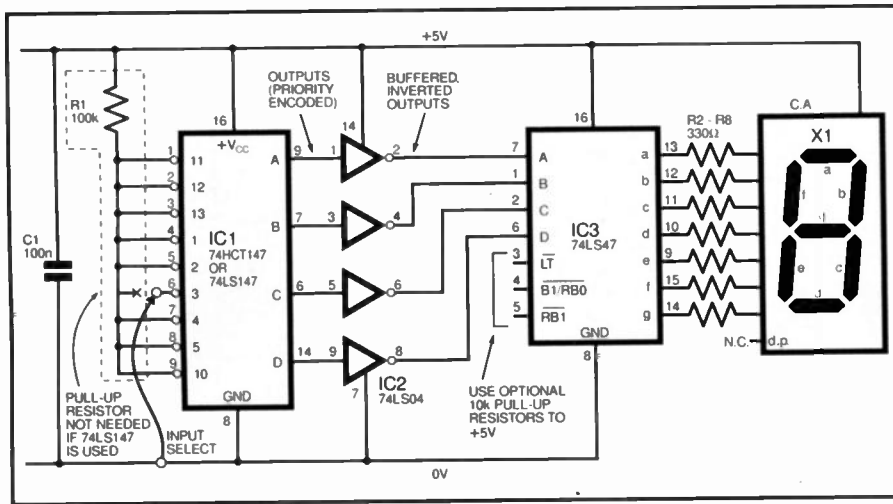


Fig.5.15a. Circuit diagram for the Priority Butler Calling system. The 74HCT147 (if used) is a CMOS device, requiring static handling. Input 6 is shown connected.

In most cases we can use either TTL or CMOS as far as the logic function is concerned, but other factors such as speed and power may influence our choice.

In this section we will build a circuit using a couple of the standard predesigned logic functions available as i.c.s. One of these will be the 74LS47, a display decoder/driver and can be used to sweep away all of the gates utilised in the binary decoder/7-segment driver circuit described earlier. This chip takes a BCD (Binary Coded Decimal) number and converts it to a form which will operate a human-recognisable 7-segment display.

Back to our country mansion and the home of Lord Faversham-Wills! His patented "Priority Butler Calling" system can be realised simply, by using a dedicated logic chip. The 74LS147 is a TTL "10-line to 4-line" priority encoder chip. It decodes the inputs to ensure that only the highest-numbered input line is encoded, producing an appropriate BCD output. So a "7" signal will output a binary 7, with any other inputs less than 7 being ignored.

Its inputs and outputs are "active low" as depicted by the circles on each input, which means that a logic 0 on, say, input 1 (pin 11) with all other inputs high, produces a 0 output on pin 9 and 1s on the other three outputs, giving binary 1110. A low on input 5 (pin 2) only, would produce binary 1010. By inverting the active low outputs, a more recognisable binary figure is generated: e.g. 0001 for input 1 and

0101 for input 5. A suitable TTL inverter is the 74LS04, a hex inverter package (IC2).

The BCD result can be converted for display on a 7-segment display if a decoder/driver chip is used. The 74LS47 (IC3) is a BCD to 7-segment decoder/driver which also has logic 0 outputs. When an output is "active", it is low. This can be used to drive a common anode display: the cathodes are taken low in order to illuminate the segment.

- Many TTL logic devices are much better at sinking current than sourcing it, hence so many "active low" inputs and outputs.
- There is no need to tie unused TTL inputs to 0V and the 74LS range is bipolar, not CMOS, so it is not static-sensitive. However, we then discovered that the 74LS147 is quite hard to obtain, so we tested using the CMOS equivalent 74HCT147 as well. This does need anti-static precautions and any unused inputs should be pulled up via R1 to +5V. One resistor can be used to tie all floating inputs together.

Now proceed to construct this on the breadboard, observing the pinout drawings for each device. Use a 5V regulated supply as before, making certain that the logic chips are correctly polarised, or you

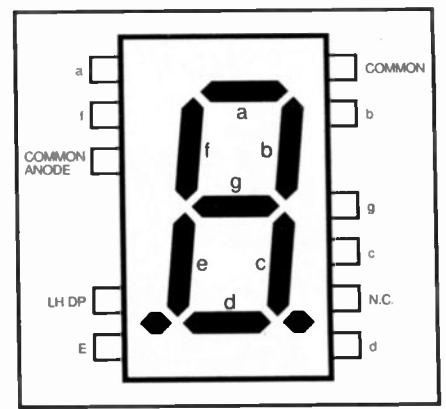


Fig.5.15b. Typical 0.3in. common anode display (e.g. HP5082-7730).

risk damaging them. The 7-segment display should fit directly to the breadboard but you must confirm the pinouts from your supplier's catalogue (a typical type is shown inset). A dual-in-line package is best as these will fit the breadboard neatly. Allow half an hour for assembly and use multi-colour solid-core hook-up wire as before.

Carefully check the circuit wiring before applying power, then confirm the operation of the display to see the "priority" operation of Lord Faversham-Wills' patent butler calling system! The input signal can be a flying lead, taken to 0V. This represents the "call buttons" in the butler call system. If you use the CMOS 74HCT device, simply switch off, unhook an input pin from R1 and re-wire it to 0V then switch on again. Otherwise, using the 74LS chip, just hook any input to 0V.

Also see what happens if several inputs are sent to 0V (grounded) at the same time. Which input has priority?

### End of Lab 5 Tasks

You have now used Karnaugh maps to analyse a combinational logic design problem, and designed a display decoder driver with logic gates. You have used a dedicated TTL decoder/driver with a 7-segment display, and have built a priority encoder circuit with digital display.

**In Lab Work 6:** We investigate the world of Sequential Logic Systems.

## You Will Need

### Resistors

- R1 100k (for 74HCT147 version)
- R2 to R8 330Ω 0.25W 5% carbon film (7 off)

### Capacitor

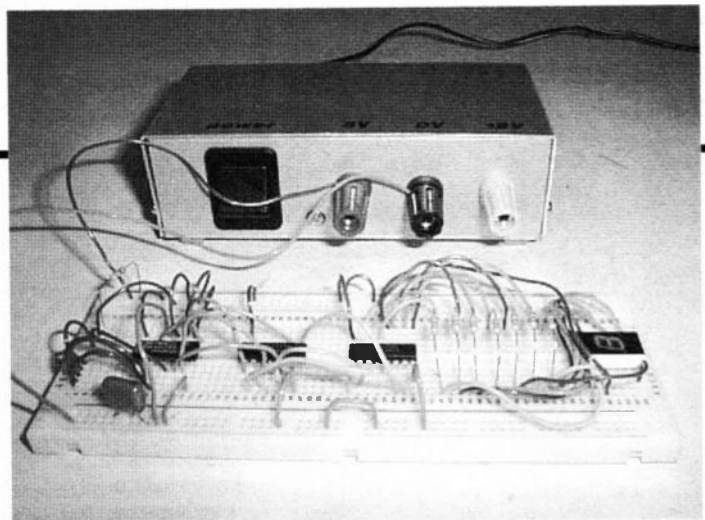
- C1 100n polyester

### Semiconductors

- (For optional experiment Lab Work 5.1)
- 4049 hex inverter (2 off)
- 4071 quad-OR gate (2 off)
- 4081 quad-AND gate
- 74LS147 TTL or 74HCT147 CMOS priority encoder
- 74LS47 TTL BCD to 7-segment decoder driver
- 74LS04 TTL hex inverter
- X1 0.3in. 7-segment common anode d.i.l. display

### Miscellaneous

- Solderless breadboard; 5V power supply; hook-up wire



Using the 5V Add-on Regulator, detailed in Lab Work 3, to power the breadboard demonstrations.

# AUDIO SYSTEM REMOTE CONTROLLER



MARK SKEETE

*Adding infra-red remote control facilities to your audio system is easier than you might think.*

IN AN AGE where most TVs, videos and satellite receivers can be remotely controlled, it can become quite frustrating to have to leave your armchair or bed to adjust your hi-fi system because it lacks remote control.

This is the situation the author found himself in before he designed this circuit. Apart from the lack of remote control, he was quite happy with his hi-fi set-up and did not want to replace it with a cheap sounding Midi system just to gain remote control.

Instead, he decided to develop a circuit that could be connected to the existing hi-fi set-up to provide remote control of the line level signals before they reached the main power amplifier.

The circuit can be controlled either by an existing universal remote control handset, or by its own keypad.

## SYSTEM BLOCK DIAGRAM

As can be seen from the system block diagram shown in Fig.1, the design is based around two main chips. A microcontroller is used to process commands from a remote control or local keypad and transmit them to the audio chip in a form that it can understand.

The microcontroller chosen for the job is the PIC16C84, which is well known to many EPE readers. This chip was chosen for a number of reasons. It can be reprogrammed in seconds (allowing software changes to be implemented quickly). It also has a 64-byte EEPROM (Electrically Erasable Read Only Memory) data memory whose contents are retained when the power is removed and, in this application, is used to store user-settings.

Another feature of this chip is the

interrupt facilities which provide an easy way of generating accurate timing intervals to decode infra-red signals. Finally, there is an 8-level deep hardware stack which makes it easier to write software as a number of small routines that call each other.

## AUDIO CHIP

The audio chip used in this circuit is the LMC1983 device. A block diagram of this

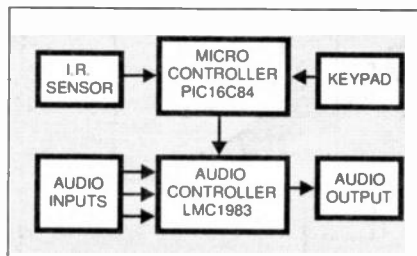


Fig.1. Block diagram of the Audio System Remote Controller

chip is shown in Fig.2. An input selector selects one of the three stereo line inputs for further processing. A mute position can also be selected. The selected input then goes through an input mode selector switch before appearing at the select-out pins. Three input modes are possible:

**Left Mono:** The left channel of the selected input is connected to both select-out pins

**Right Mono:** The right channel of the selected input is connected to both select-out pins

**Stereo:** Normal stereo operation

The select-out and the select-in pins provide a "gap" in the signal path so that external signal processors such as a noise reduction unit can be connected. The level at the select-out pins is not affected by the volume or tone control settings. If no external processing is required then the select-out and select-in pins should be linked via capacitors.

The select-in signals pass through a tone control and volume circuit before



appearing at the left and right outputs. Loudness compensation can be applied to the volume setting but this feature is not used in the present circuit and the relevant pins are left open circuit.

The position of the switches and variable resistors within the LMC1983 are controlled via a three-wire serial interface. The three wires are called ID, CLOCK and DATA. In the idle state, all three lines should be at logic 1 (5V).

To transmit a command to the audio chip, the ID line must be driven low. After a minimum pause of 250ns, the CLOCK line should also be driven low. Eight address bits are then sent to the chip using the CLOCK and DATA lines. The bits are transmitted least significant bit first. The DATA line is set to the correct logic level for the current bit of the address and then the CLOCK line is pulsed high and then set low again. This is repeated for all eight bits.

After another pause of at least 250ns, the ID line is driven high and eight data bits can now be transmitted using the CLOCK and DATA lines as before. After the last data bit, the DATA and CLOCK lines must be returned to a high state. The end of the transmission is indicated by waiting at least 6µs and then pulsing the ID line low for at least 1µs.

In Fig.3 and Table 1 are shown the timing diagram and the list of address codes and data ranges that the LMC1983 can understand. The values are shown in binary format with their decimal equivalents in brackets.

The LMC1983 also has two digital inputs that are held high by

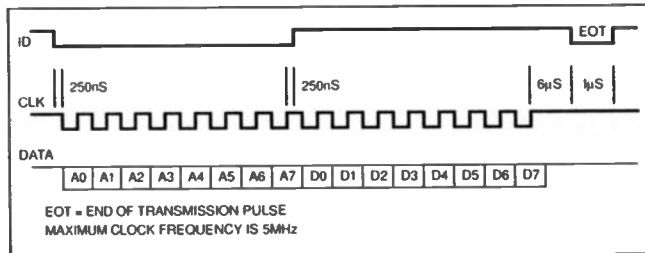


Table 1. LMC1983 Programming Codes

Address	Function	Data	Function Selected
01000000 (64)	Input select	xxxxxxx0 (0) xxxxxxx1 (1) xxxxxx10 (2) xxxxxx11 (3)	Input 1 Input 2 Input 3 Mute
01000001 (65)	Loudness	xxxxxxx0 (0) xxxxxxx1 (1)	Loudness OFF Loudness ON
01000010 (66)	Bass	xxxx0000 (0) xxxx0110 (6) xxxx1100 (12)	- 12dB 0dB (Flat) + 12dB
01000011 (67)	Treble	xxxx0000 (0) xxxx0110 (6) xxxx1100 (12)	- 12dB 0dB (Flat) + 12dB
01000100 (68)	Left Volume	xx000000 (0) xx010100 (20) xx101xxx (40)	0dB - 40dB - 80dB
01000101 (69)	Right Volume	xx000000 (0) xx010100 (20) xx101xxx (40)	0dB - 40dB - 80dB
01000110 (70)	Mode Select	xxxxx100 (4) xxxxx101 (5) xxxxx11x (6)	Left Mono Stereo Right Mono
01000111 (71)	Read Digital Inputs 1 & 2	xxxxxxD1D0	D0 = D.Input 1 D1 = D.Input 2

Fig.3 (left). Timing diagram of the LMC1983 audio controller.

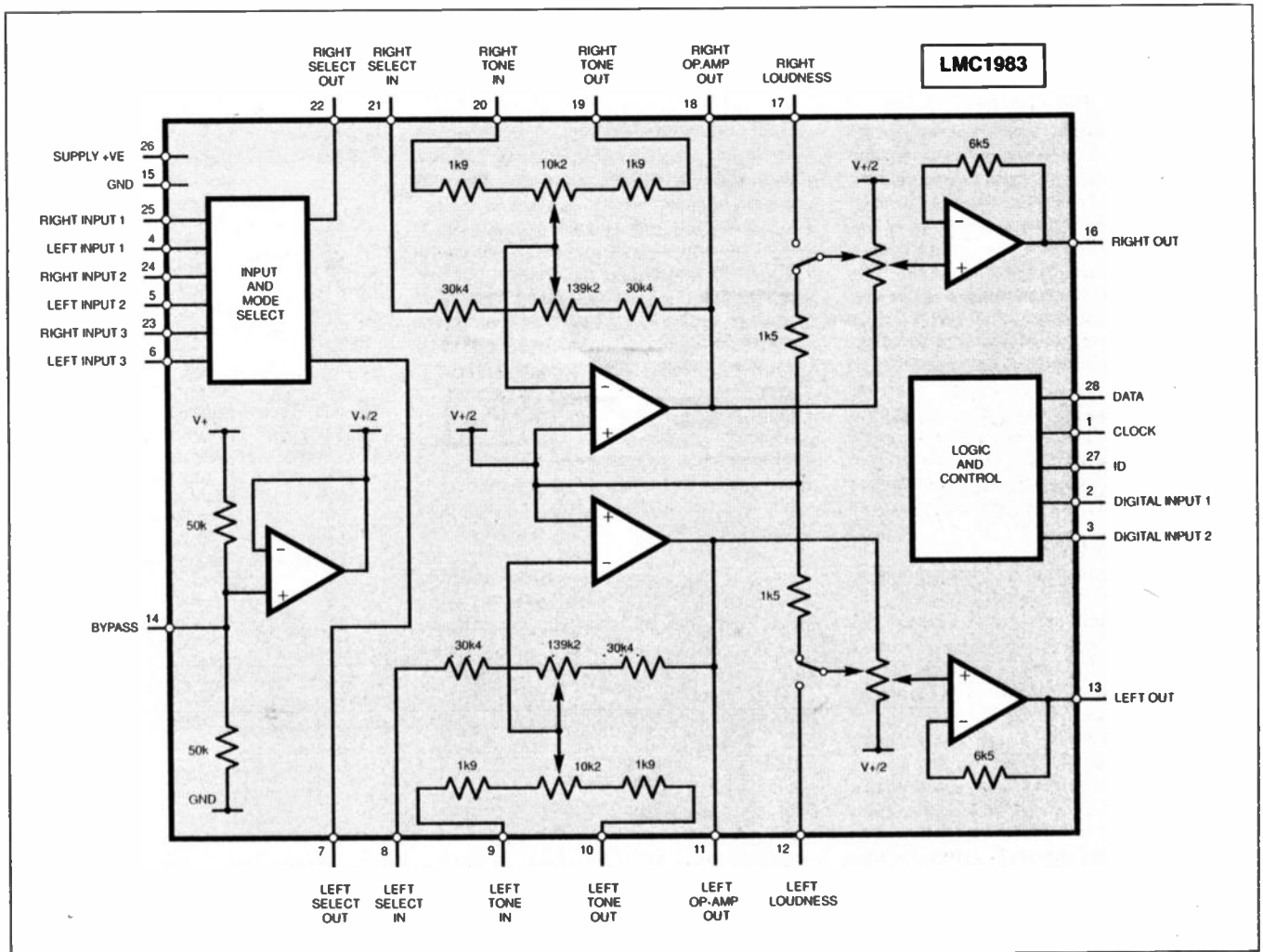


Fig.2. Block diagram of the LMC1983 audio controller chip.

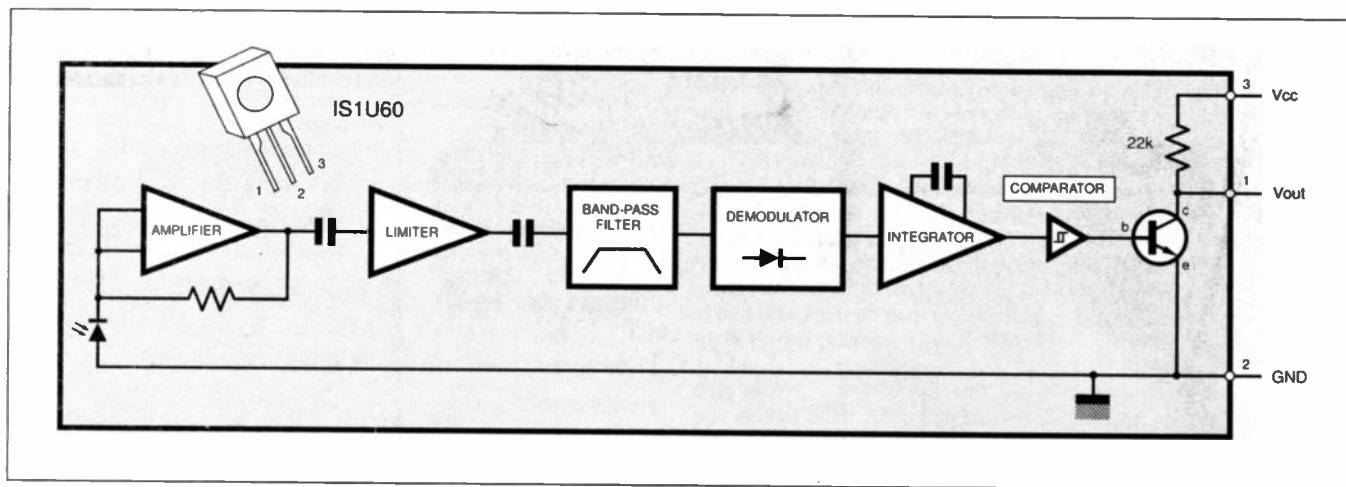


Fig.4. Block diagram of the IR receiver and amplifier i.c.

internal pull-up resistors. The state of the two inputs can be read via address 71. After this address is sent, the DATA line becomes an output for the rest of the transmission.

The data sheet recommends that the DATA line is connected to an open collector/drain output of the controlling device with a pull-up resistor used to provide the high logic level. However, in the present circuit the state of the digital inputs is never read and so the DATA line remains in input mode only. For this reason it is safe to connect the DATA line to a normal PIC output.

## INFRA-RED DETECTION

Implementing an on-board keypad is straight forward as it consists only of switches and a few resistors, as will be shown shortly. Receiving infra-red signals from a remote control handset is slightly more difficult. A photodiode can be used to detect the raw signal but there are a few things to watch out for. The output from a photodiode will be at a very low amplitude and will need a lot of amplification before it reaches a useful level.

The raw signal will also contain 50Hz interference from household lights which needs to be filtered out. Some form of automatic gain control is also needed to cope with the wide range of signal levels produced when the distance between the transmitter and receiver is varied. Because of the high amplification factor, the receiver circuit must be screened to avoid interference from other items of equipment.

All this circuitry also takes up board space. The best (and easiest) solution is to use a dedicated device, such as the IS1U60. This is a 3-pin sensor with a built-in lens and several processing stages designed to amplify infra-red signals and provide a clean output suitable for a microcontroller. A block diagram is shown in Fig.4.

Most remote control units emit pulses of infra-red light modulated by a high frequency oscillator. The oscillator frequency is usually between 36kHz and 40kHz. For this reason, the IS1U60 contains a bandpass filter centred at 38kHz. Received oscillations are demodulated and integrated before finally being squared using a comparator. The output from the sensor is normally high and goes low

whenever a signal is detected. This sensor and others like it are also used by commercial manufacturers.

Rather than design and build a dedicated remote control unit, it was decided to use an existing one. This approach also helped during the software debugging stage since it confirmed that the remote control was working.

## RC5 TRANSMISSION CODE

Software for the PIC was written to decode signals that conform to the RC5 standard. This is a standard that is used by Philips and a few other manufacturers.

An RC5 code consists of two main parts, an address and a command. Each type of remote control will always transmit the same address, but will transmit a different command code depending on which key is pressed, e.g. a remote control unit for a video-recorder will always transmit address 5.

A complete RC5 code consists of a serial transmission of 14 bits structured as follows: two start bits, one control bit, five address bits and six command bits. This structure allows for 32 different addresses and 64 commands. The control bit is used to indicate when a key is auto-repeating.

## ERROR CHECKING

Each bit in the code is transmitted using bi-phase coding. Instead of transmitting a bit using a single logic level, the bit time is split into two and each half is transmitted using opposite logic levels. This fact can be used within the receiver to check for errors. If the receiver detects that the first and second half of a bit have the same logic level than an error has occurred and the receiver can reset itself. Fig.5 shows how a logic 0 and a logic 1 are transmitted.

The example in the diagram shows the output from a TV remote control (address 0) when the volume-up key (command code 16) is pressed. One thing to note from this diagram is that by the time the first start bit is detected, half of it has already gone.

Table 2. RC5 Address/Command Summary

Address	Device
0	Television
2	Teletext
5	Video Recorder
7	Experimental
8	Satellite Receiver
16	Preamplifier
17	Receiver/Tuner
18	Tape Recorder
19	Experimental

Command Function

Command	Function
0-9	0-9
10	-
11	C/P
12	Stand-by
13	Mute
14	Presets (normalise)
16	Volume +
17	Volume -
18	Brightness +
19	Brightness -
20	Colour +
21	Colour -
22	Bass +
23	Bass -
24	Treble +
25	Treble -
26	Balance Right
27	Balance Left
32	Channel +
33	Channel -
41	Pause
46	Mix TV/Teletext
50	Fast Reverse
51	Fast Forward
53	Play
54	Stop
55	Record
56	A/V Sources (1)
57	A/V Sources (2)
60	Teletext On
63	Teletext Off

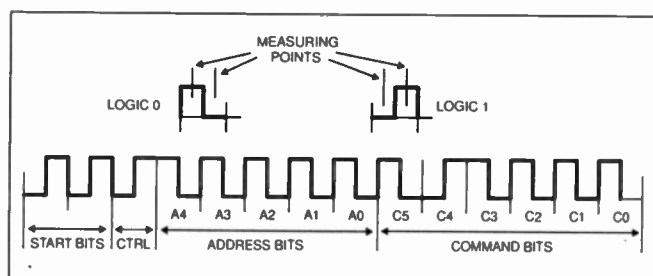
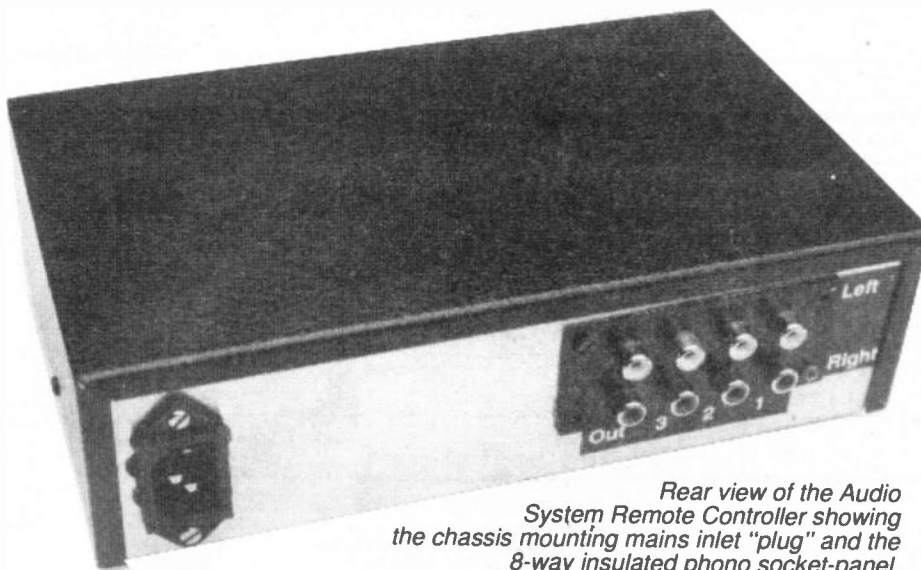


Fig.5. IR remote control transmission codes.





Rear view of the Audio System Remote Controller showing the chassis mounting mains inlet "plug" and the 8-way insulated phono socket-panel.

Within the PIC software, this first start bit is used to trigger the decoding process and is not checked for bi-phase coding. The second start bit contains no useful information and is simply ignored after a complete transmission has been received. Note also that the address and command bits are transmitted most significant bit first.

Each type of equipment has its own address and will only respond to the command part of an RC5 code if the address part of the code matches. For example, if the power button on a TV remote control is pressed, then a video-recorder will not respond because the transmitted address (0 for a TV) does not match the equipment address (5 for a video-recorder).

As expected, a TV will respond to the transmission from the remote control as the transmitted address will match the equipment address. A list of commonly used commands and addresses is given in Table 2.

## POWER SUPPLY

Details of the power supply and the relay control circuits are shown in Fig.6. The secondary voltage of transformer T1 is rectified by the bridge rectifier REC1 and smoothed by capacitor C20. This voltage is applied to the two voltage regulators IC1 and IC5 (in Fig.7).

When power is first applied, capacitor C22 slowly charges via resistor R15. After a few seconds, transistor TR1 turns on and energises the relay coil, RLA. When power

is removed from the circuit, the relay will turn off almost instantly due to the low value of capacitor C21. Resistor R13 reduces the voltage that is applied to the relay. This relay is used to short the audio outputs of the unit at switch on and off.

Diode D4 protects TR1 from any back e.m.f. produced by the relay when it switches off. Diode D2 is included to prevent the relay from being powered from the voltage across C20.

The mains earth is linked to the 0V line of the power supply circuit via resistor R12. If the mains earth was connected directly, then an earth loop might be formed between the circuit and the rest of the hifi system, causing a hum to be heard from the loudspeakers; R12 prevents this situation from arising.

## SYSTEM CIRCUIT DIAGRAM

The circuit diagram for the Audio System Remote Controller is shown in Fig.7 and, as can be seen, is quite simple as most of the work is done by software.

The d.c. output from the power supply is regulated down to 5V by IC1, providing stabilised power for IC2 and IC3. The supply to IC2 needs to be decoupled for reliable operation and this is done by resistor R2 and capacitor C1.

The output from IC2 is connected directly to IC3 for decoding. IC3's port lines RB4 to RB7, along with RA0, RA1 and RA4, provide the connections for the

## COMPONENTS

### Resistors

R1	470Ω
R2	100Ω
R3, R4, R7	10k (3 off)
R5, R6, R8,	
R11, R12	1k (5 off)
R9, R10	100k (2 off)
R13	56Ω
R14	2k2
R15	82k
R16	8k2

See  
SHOP  
TALK  
Page

All 0.25W 5% carbon film or better.

### Capacitors

C1, C16 to C19	10μ radial elect. 16V (5 off)
C2, C3	15p polystyrene (2 off)
C4 to C11	1μ radial elect. 6V (8 off)
C12 to C15	8n2 ceramic disc (4 off)
C20	1000μ radial elect. 35V
C21	47μ radial elect. 25V
C22	470μ radial elect. 16V

### Semiconductors

D1, D3	red l.e.d. (2 off)
D2, D4	1N4001 rectifier diode (2 off)
REC1	W005 bridge rectifier
TR1	BC109C n.p.n. transistor
IC1	7805 5V 1A regulator
IC2	IS1U60 infra-red receiver
IC3	PIC16C84 microcontroller, preprogrammed
IC4	LMC1983 audio controller
IC5	7812 12V 1A regulator

### Miscellaneous

S1 to S9	s.p. push-to-make switch (9 off)
T1	12V 1A transformer
X1	4MHz ceramic resonator
RLA	12V 280 ohm coil d.p.d.t. relay
SK1 to SK8	phono socket (8 off) (see text)
SK9	Euro-connector mains inlet chassis plug

Printed circuit boards, available from the EPE PCB Service, codes 185 (PSU) and 186 (Control); 18-pin d.i.l. sockets; 28-pin d.i.l. socket; metal case, vinyl effect, type WB4; connecting wire; solder, etc.

Approx Cost  
Guidance Only

£75

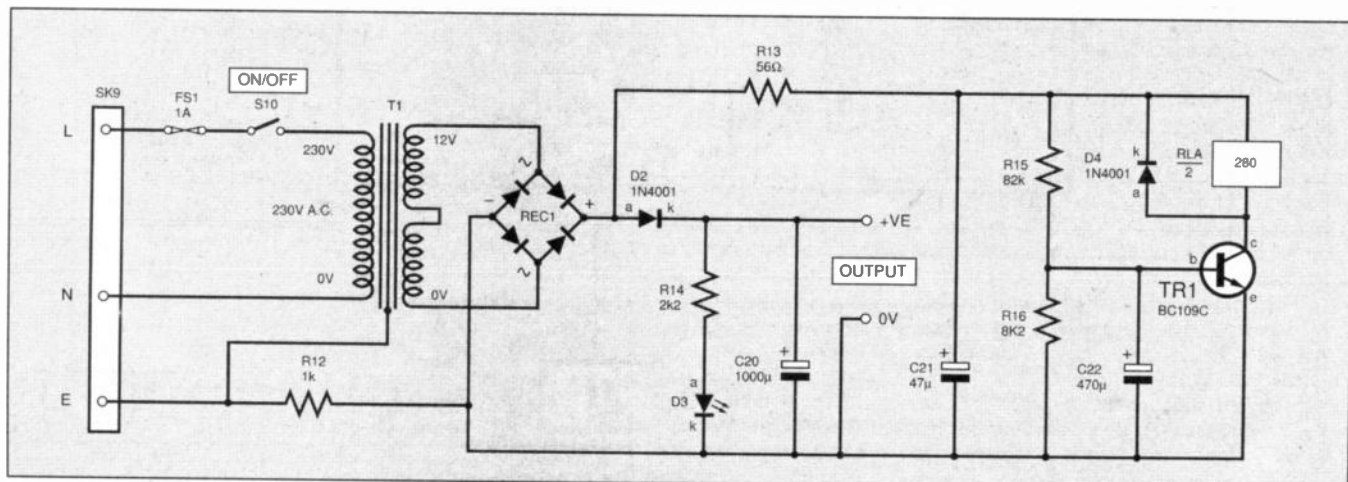


Fig.6. Power supply and relay control circuit for the Audio System Remote Controller.

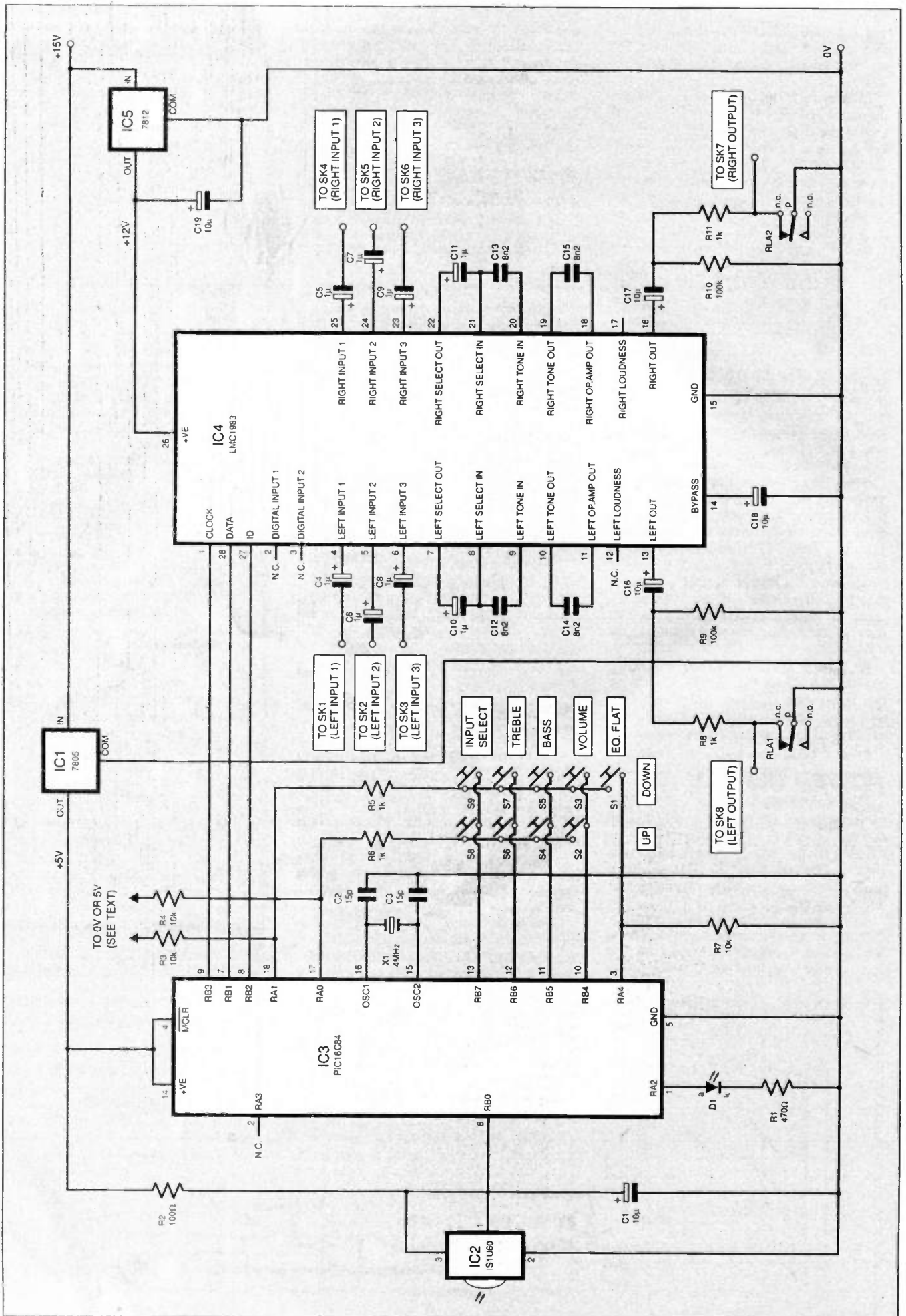


Fig.7. Main circuit diagram of the Audio System Remote Controller.

on-board keypad switches S1 to S9. RA0 and RA1 are outputs that spend most of their time at 5V. RB4 to RB7 are inputs that are held high by internal pull-up resistors within IC3.

Once every 200ms, RA0 is taken low and the status of inputs RB4 to RB7 is read. If any of these pins are low, then an "up" key has been pressed and the appropriate software routine will be called. RA0 is then taken high and RA1 is taken low and the inputs are re-read.

This time, if any of the inputs are low then a "down" key has been pressed. RA1 is then returned to its high state. Finally, the status of input RA4 is checked. This input is normally held low by resistor R7 but a high level on it means that the Eq. Flat key is being pressed.

Resistors R5 and R6 are included to prevent damage occurring to IC3 if an "up" key and a "down" are pressed simultaneously.

When IC3 is first powered up, RA0 and RA1 are used as inputs and the logic levels provided by resistors R3 and R4 are used to select the type of remote control that the software will respond to.

Three choices are available. These are TV, Video Recorder or Pre-amplifier. After the logic levels have been read by the software, RA0 and RA1 are switched to outputs and R3 and R4 have no further effect on the circuit.

Light emitting diode (l.e.d.) D1 flashes whenever a valid infra-red signal is received. Further details on selecting the type of remote control to use are given later.

## AUDIO CONTROLLER

Capacitors C4 to C9 a.c. couple audio signals into IC4. As no external processing is used, the select-out pins are linked to the select-in pins via C10 and C11. Capacitors C12 to C15 set the response of the tone control stage. With the values shown, the control range is  $\pm 12\text{dB}$  at 100Hz and 10kHz.

The final output signal is a.c. coupled to the outside world via capacitors C16 and C17. As IC4 is a moderately expensive chip, resistors R8 and R11 are included to help protect the chip from short circuits. These resistors are also used as part of the

relay circuit, RLA, jointly shown in Fig.6 and Fig.7. The relay contacts short the output signal until the relay coil is energised by the power supply circuit. This stops power on/off clicks from being heard.

The internal bias voltage of IC4 is decoupled by C18. A 12V supply is required by IC4 and is supplied via regulator IC5.

## SOFTWARE PROCEDURE

One of the first things that the processor does is to wait for the audio chip (IC4) to initialise itself. Without this delay, IC4 would not be ready to receive the user's last settings when they are recalled from the data memory.

An interrupt routine is called every half bit-time (889ns) and, in the absence of any infra-red signal, the counter used for reading the keypad is decremented and the routine returns. The main software loop checks the value of this counter and whenever it reaches 0, the keypad is read.

The main loop also checks for the start of an infra-red signal. If a signal is detected a decoding flag is set, then the interrupt timer is reloaded with a value that causes the next interrupt to occur during the middle of the first half of the second start bit.

This action causes the following interrupts to be synchronised to the incoming transmission in such a way that possible timing errors are reduced to a minimum.

Once decoding has started, each time the interrupt routine is called, it reads the output from the sensor and stores the result in a temporary location. Each pair of measurements is compared to see if they are at opposite logic levels. If this is the case then the logic level of the first measurement (first half-bit) in each pair is stored using a combination of two registers.

The first measurement is used because the output from the sensor is inverted. If no errors are detected then, after 26 interrupts (two per bit), the final bit pattern in the registers will represent the transmitted address and command code. If the transmitted address corresponds to the type of remote control that was selected during the initialisation routine, l.e.d. D1 will be turned on.

Next, the command part of the transmission is compared to all the "known" commands that the software can respond to. If a match is found, then the appropriate software routine is called. The current value associated with that command is stored in the PIC's EEPROM data memory. In this way the data memory is always up-to-date if the power is removed.

If the transmitted address does not match, or an error is detected, then all the registers associated with receiving an infra-red transmission are cleared and no further action is taken. Approximately 200ms later, l.e.d. D1 will be turned off by the main program.

## CONSTRUCTION

The circuit is constructed on two printed circuit boards (p.c.b.s) as shown in Fig.8 and Fig.9. These boards are available from the *EPE PCB Service*, codes 185 and 186.

The prototype was housed in a vinyl effect metal case, type WB4. Before adding any components to the boards, use them as templates to mark out the fixing holes in the case.

A line of sight path needs to be provided from the sensor (IC2) to the remote control. This can be achieved by drilling a large hole in the front panel and mounting the main circuit board close to the front of the case to allow the infra-red signals to reach the sensor. The hole can be covered with a piece of transparent plastic.

On the prototype, the sensor was glued to the outside of the case with a small hole drilled underneath to pass connecting wires through to the main circuit board. This approach provides the greatest reception angle but has the disadvantage that the sensor cannot be moved or readily replaced should it become damaged.

## POWER SUPPLY BOARD

Start by building and testing the power supply board first (Fig.8). Make sure that the rectifier, diodes, capacitors and the transistor are fitted the right way round.

In the interest of safety, mount the transformer securely and make sure that all mains connections are properly insulated before applying power. A metal case *must*

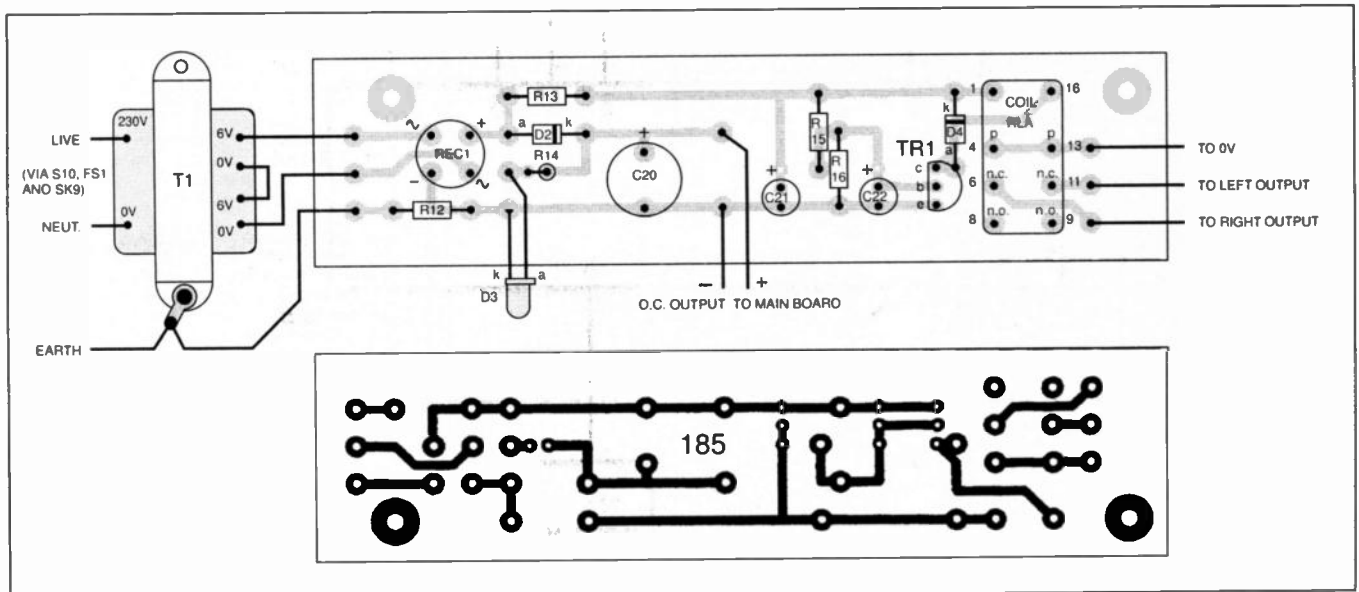


Fig.8. P.C.B. layout and full size track master for the power supply board.

be used for this circuit, and it is *essential that it is earthed*.

If you are in any doubt about the mains connections, consult a qualified electrician.

The mains connection on the prototype were wired directly to a Euro-socket (as used on electric kettles) covered with an insulating boot. These sockets are available with a built-in switch and fuseholder. Using one of them will keep the mains wiring to a minimum.

As soon as power is applied, i.e.d. D3 should turn on. After a few seconds, you should hear the relay click. The d.c. output across C20 should be approximately 15V.

## CONTROL BOARD CONSTRUCTION

If everything is okay, turn the power off and begin construction of the control circuit board (Fig.9). There is one wire link to fit on this board. The rest of the components can be mounted in order of height. Once again, make sure that all polarity sensitive components are fitted correctly.

Use good quality i.c. sockets for IC3 and IC4. Note that IC3 must be programmed before use (more details later). If you decide to program the chip yourself then make sure that the Watchdog Timer is off and that the Power-on Reset timer is on. Select the XT or HS oscillator option and if your programmer allows, program the EEPROM data memory with zeros.

The two voltage regulators do not need heatsinks as they will not get hot in normal operation. Solder pins should be used for all off-board connections as this will make life easier when it comes to the final assembly.

## CUSTOM TAILORING

As stated before, R3 and R4 are fitted according to which type of remote control

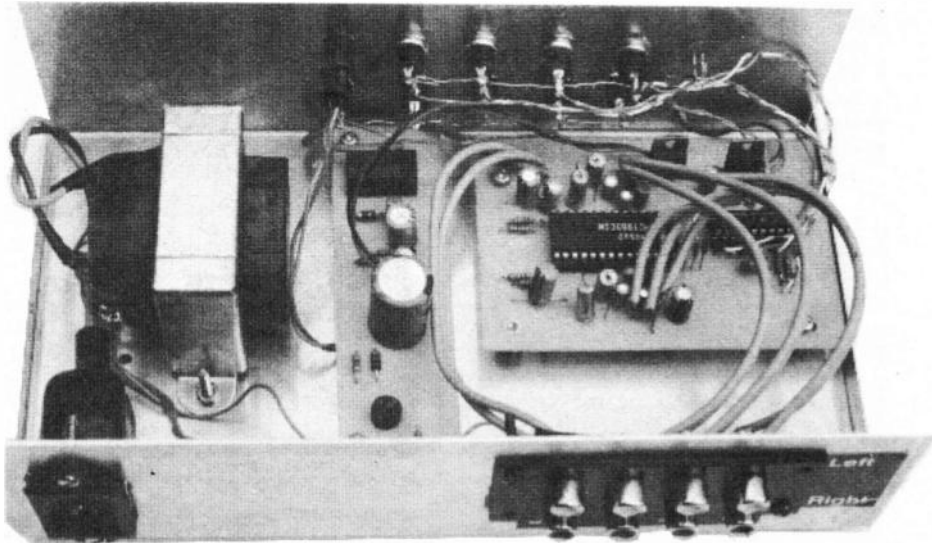


Fig.10 (below right). Connection of R3 and R4 for different remote controls.

that you wish to use. The options are shown in Fig.10. To make it easier to change the position of these resistors at a later date, they can be fitted to solder pins instead of being soldered directly to the p.c.b.

If the circuit is going to be used in the same room as other infra-red remote controlled devices, then obtain an RC5 compatible remote control unit and check that it does not accidentally control any of these devices as well. In the author's case, the television is an RC5 compatible device and so the amplifier was configured to respond to a video remote control unit.

If your television and video turn out to be RC5 compatible devices then you will have to position the finished circuit in a such a way that it can be operated independently of the other device.

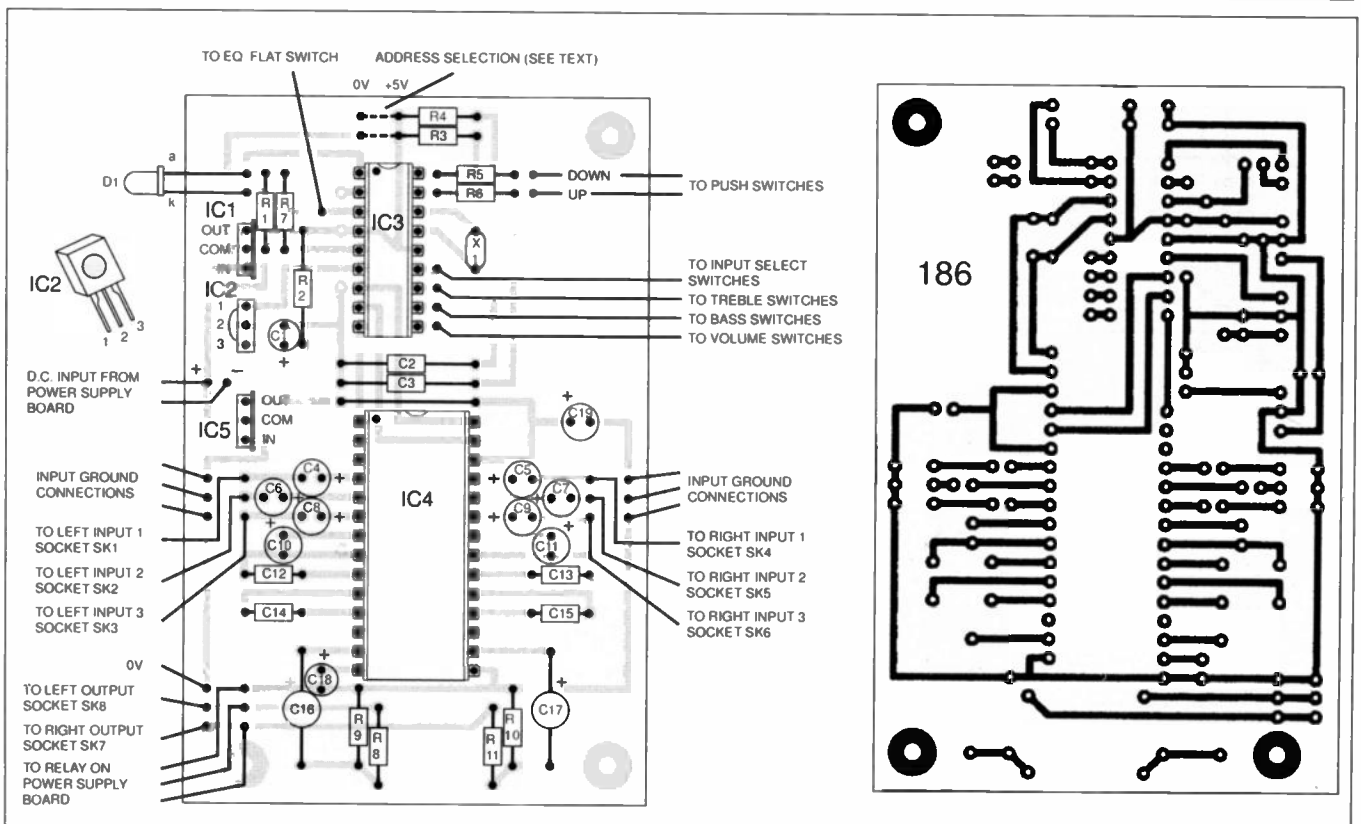
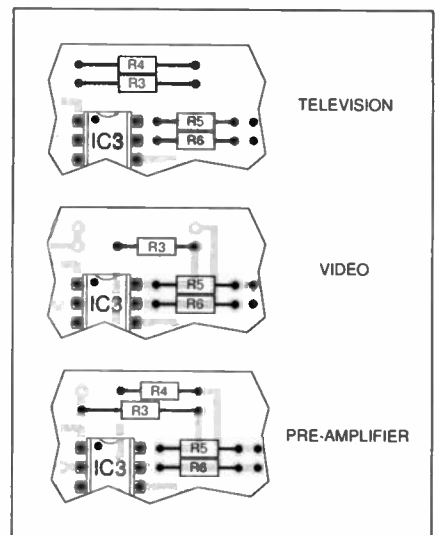


Fig.9. Control board layout and full size track master for the Audio System Remote Controller.

The prototype has been tested with the following three models of remote control:

- Philips TV remote control, model RC5420
- PRC 8-way universal remote control
- One-For-All universal remote control, model URC-2250

The last two types need to be configured before use.

To configure the PRC 8-way remote control, use the following procedure:

- hold down the power and mute keys until the indicator lights up
- press the TV or VCR device key at the top of the remote control
- a 4-digit code now needs to be entered - 0101 for a TV, or 0052 for a video

The PRC remote control is now ready for use with the amplifier.

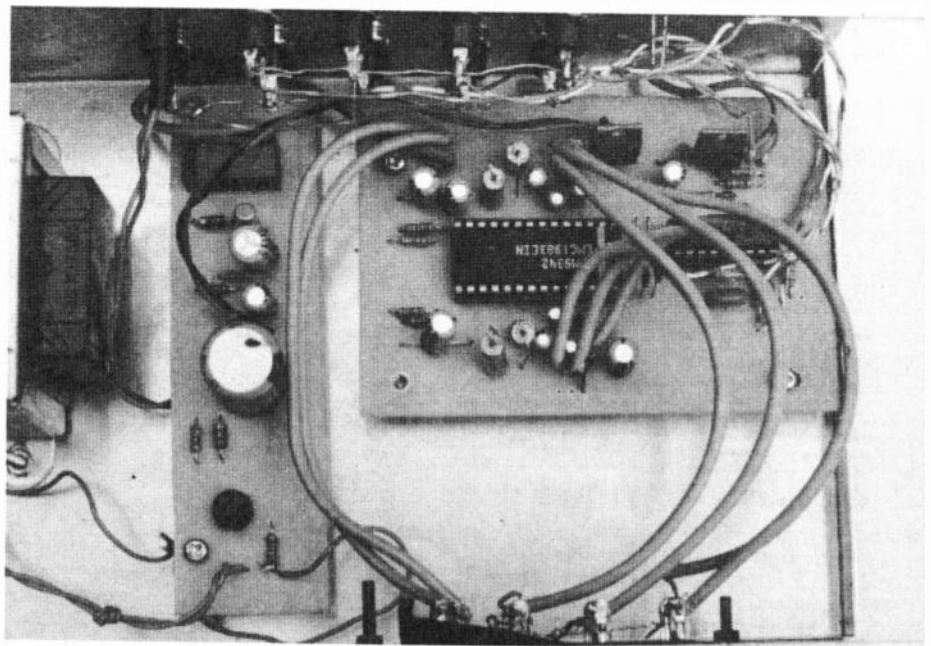
To configure the One-For-All remote control, use the following procedure:

- press the TV or VCR device button at the top of the remote control
- press A then B then C
- a 3-digit code now needs to be entered - 037 for a TV, or 081 for a video

The One-For-All remote control is now ready for use with the amplifier.

More detailed instructions concerning the use of the universal remote controls can be found in the handbook that comes with them.

With IC3 and IC4 removed, connect the main circuit board to the power supply board (refer to Fig.11) and re-apply power.



P.C.B. mounting and keypad switch wiring.

Fig.12. Interconnection of the keypad switches mounted on the front panel of the unit.

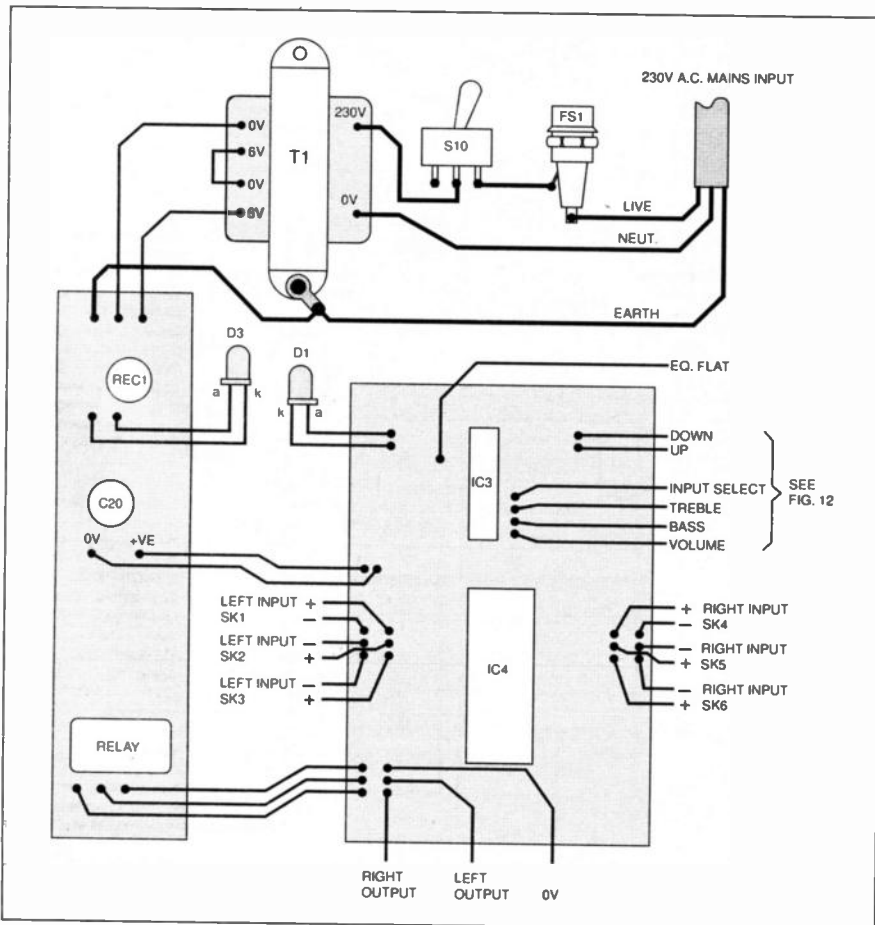
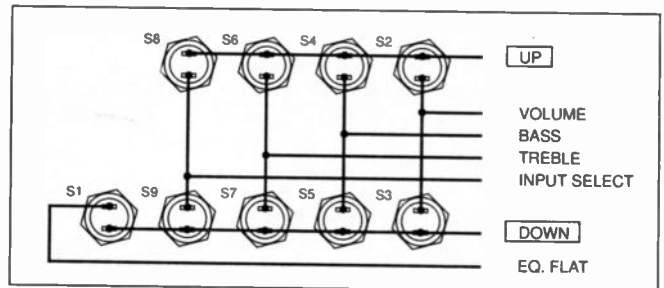


Fig.11. Off-board connections and interwiring between the two p.c.b.s.

Check for the following voltages between these pins:

IC3	pin 5 to pin 14	5V
IC3	pin 5 to pin 4	5V
IC3	pin 5 to pin 6	5V
IC4	pin 15 to pin 26	12V

If the correct voltages are present, insert IC3 and IC4 into their sockets (with the power turned off) and mount the two circuit boards inside the case.

The switches and input/output sockets can now be connected. Use screened wire for the input/output connections as this will reduce the possibility of interference being picked up. Phono sockets are the most common type of connector to be found on hifi equipment. An 8-way type was used on the prototype. This was mounted on the outside of the case to hide the rough edges of the cutout.

Make sure that the earth of the socket(s) is not in contact with the case as this would short circuit R12. With phono sockets, the earth is the outer connection.

Before fitting the keypad switches, make sure that they are the normally-open type. Fig.12 shows how the switches are interconnected.

## UNIT TESTING

Begin testing the unit by connecting a line-level source, such as the output from a tape deck to Input 1. Connect the output from the circuit to a suitable amplifier and turn the power on; i.e.d. D1 will flash once, indicating that IC3 has powered up and the software is executing.

Press the Input-Select-Down button five times and press the Volume-up button on the keypad for a few seconds. At this point you should be able to hear music passing through the unit and into the amplifier. The signal may be lacking in bass and treble until the Eq. Flat button is pressed. Check that all the switches work as expected.

Test Inputs 2 and 3 by applying a signal to each input socket and selecting it via the Input-Select switches. To test the PIC's data memory, remove power from the circuit, wait a few seconds and then re-apply power. The last settings will be restored if the memory is working.

At this stage you can also check that no loud clicks are produced as the circuit is switched on or off.

## REMOTE TESTING

Finally, the remote control can be tested. Point the remote control towards the sensor and press the "1" key. If resistors R3 and R4 have been configured correctly, i.e.d. D1 will flash to indicate that a valid transmission has been received.

The way in which the Controller responds to the keys on the remote control depends on the type of remote control in use. Table 3 shows how the keys are assigned.

In each case, keys 1 to 3 select the required input. Note that i.e.d. D1 will still flash if other keys (such as the power key) on the remote control are pressed.

The two universal remote controls that the circuit has been tested with have a feature known as *punch-through*. This means that the Volume keys and the Mute key are permanently assigned to the TV and cannot be used to control a video or any other device. For this reason, this Controller uses the numeric keys if it has been configured to respond to a video remote. Another reason for this choice of keys is that most video remote controls do not have Volume and Mute keys.

## INSTALLATION

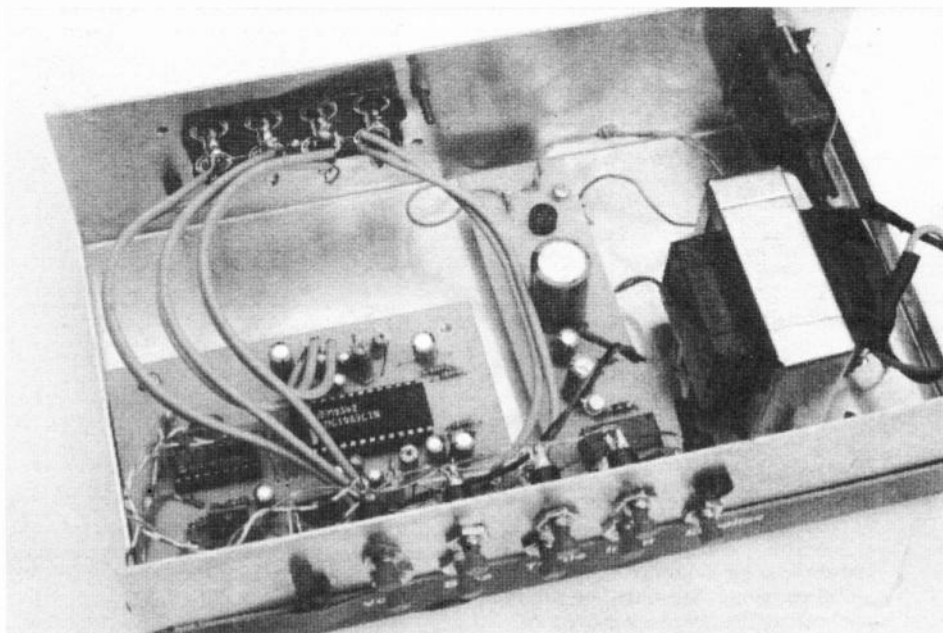
Once all the remote control functions have been tested, the Controller can be connected to the rest of your hifi system. A typical set-up using an integrated amplifier is shown in Fig.13.

In this example, the circuit is wired to the tape monitor sockets. The Tape Out signal from the integrated amplifier is fed to the circuit and the tape deck at the same time using a Y adapter or a specially made lead. The tape switch on the integrated amplifier can be permanently left in the tape position.

Inputs 1 and 2 of the circuit can then be used to switch between source and tape signals. Input 3 could be connected to the audio output of the TV. In Fig.14 is shown how the circuit may be connected between a separate preamplifier and power amplifier.

These diagrams are for guidance only and you may use any reasonable connection scheme that comes to mind. Note that the output from a turntable cannot be directly connected to the circuit as the signal will need equalisation and boosting to bring it up to line level.

The output from a microphone will also need boosting before it can be applied to one of the inputs.



The complete unit showing panel mounted controls, i.e.d. and IR receiver and input/output socket wiring.

Table 3. Remote control key assignment

Controller – Function	Remote Control Key		
	Video Remote	Television Remote	Preamplifier Remote
Volume-up	4	Volume +	Volume +
Volume-down	7	Volume –	Volume –
Bass-up	5	Colour +	Bass +
Bass-down	8	Colour –	Bass –
Treble-up	6	Brightness +	Treble +
Treble-down	9	Brightness –	Treble –
Mute	0	Mute	Mute

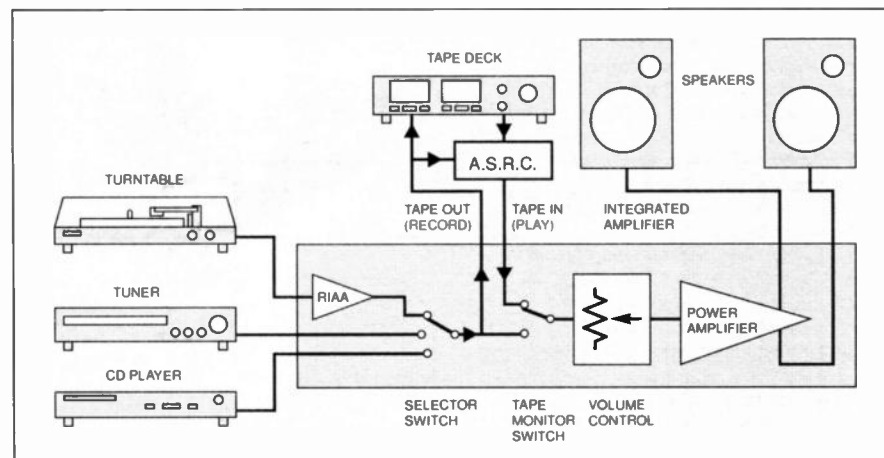


Fig.13. Typical set-up with an integrated amplifier hifi system.

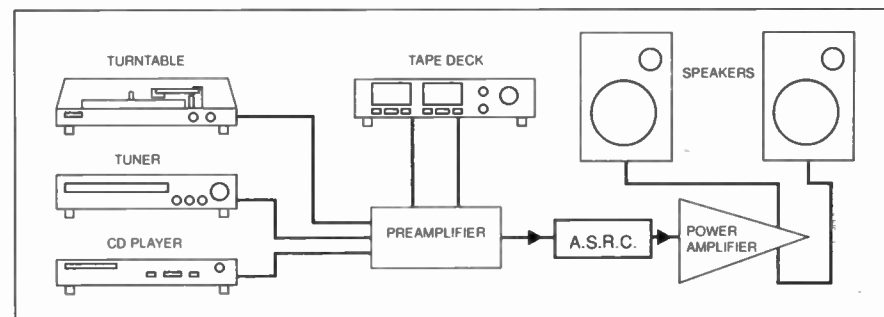


Fig.14. Connecting the controller between a separate preamplifier and amplifier.

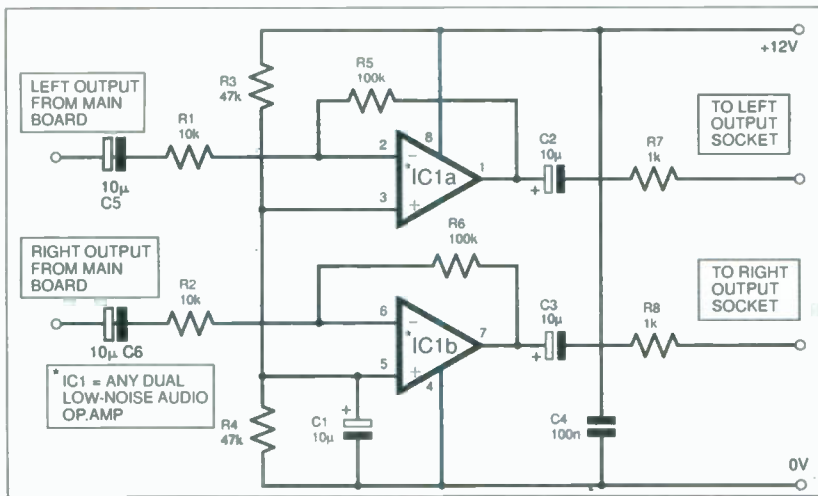


Fig. 15. Circuit to provide additional gain to the output if required.

Although the Controller circuit could be described as an amplifier, at the maximum volume setting no gain is actually provided. In other words, the input and output levels will be the same. If the circuit is used with an integrated amplifier or preamp/power-amp combination then this will not cause any problems.

If required, additional gain can be

provided by boosting the output level. A suitable circuit which can be built on a small piece of stripboard is shown in Fig. 15, along with the relevant connection details in Fig. 16.

### RESOURCES

Suitable remote controls can be obtained from most TV repair shops. *Make sure*

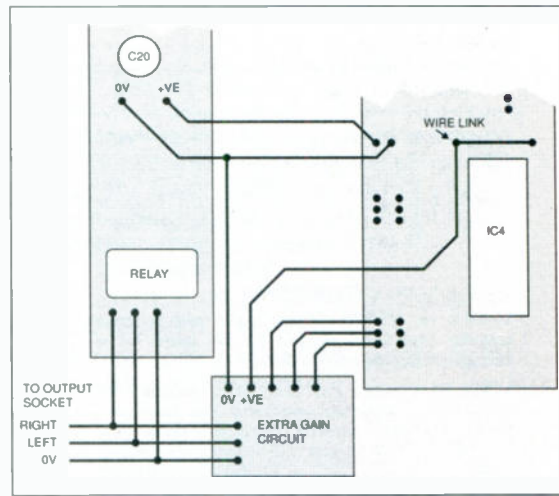


Fig. 16. Connecting the circuit of Fig. 15 into the unit.

that the remote control you are buying is RC5 compatible before you part with your money!

Details of how to obtain the free software and/or preprogrammed PIC16C84 chips are given in the *Shoptalk* column elsewhere in this issue. *Shoptalk* also gives guidance on where to obtain other components for this design. □

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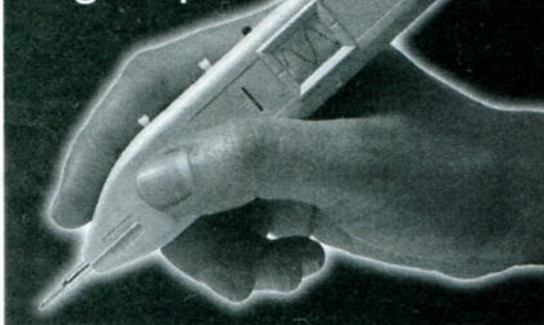
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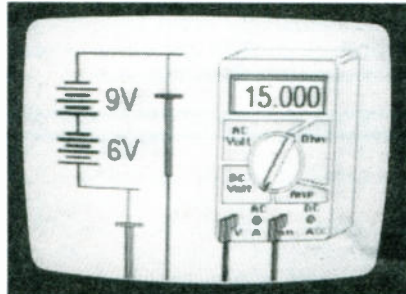
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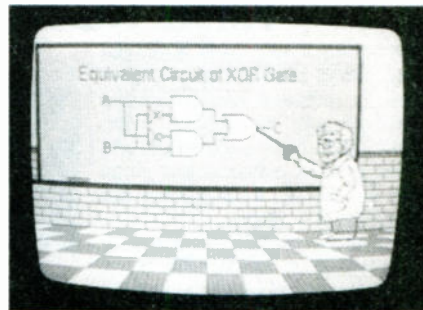


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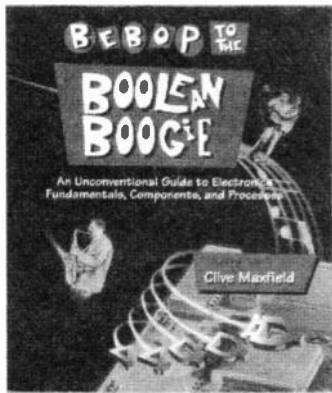
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My first exposure to the unique writing style of Clive (call me Max) Maxfield was a magazine article that he co-wrote with an associate. The article was technically brilliant (he paid me to say that) and very informative, but it was the short biography at the end of the piece



that I enjoyed the most. I say enjoyed the most because, as you will soon learn, Max does not necessarily follow the herd or dance to the same drummer as the masses. Trade journals have a reputation for being informative and educational but also as dry as West Texas real estate.

Anyway, Max's personally submitted biography not only included a message from his mom, but also made mention of the fact that he (Max) is taller than his co-author, who just happened to be his boss at the time. Now to some people this may seem irrelevant, but to our readers (and Max's boss), these kind of things – trivial as they

may seem to the uninitiated – are what helps us to maintain our off-grid sense of the world. Max has become, for better or worse, a part of that alternate life experience.

So now it's a couple of years later, and Max has asked me to write a few words by way of introduction. Personally, I think that the title of this tome alone (hmmm, a movie?) should provide some input as to what you can expect. But, for those who require a bit more: be forewarned, dear reader, you will probably learn far more than you could hope to expect from *Bebop to the Boolean Boogie*, just because of the unique approach Max has to technical material. The author will guide you from the basics through a minefield of potentially boring theoretical mish-mash, to a Nirvana of understanding. You will not suffer that fate familiar to every reader: re-reading paragraphs over and over wondering what in the world the author was trying to say. For a limey, Max shoots amazingly well and from the hip, but in a way that will keep you interested and amused. If you are not vigilant, you may not only learn something, but you may even enjoy the process. The only further advice I can give is to "expect the unexpected."

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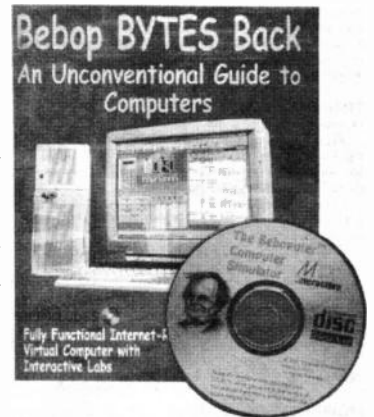
2. The labs work on two levels: on and under the surface. When you're performing the labs you'll need to look for patterns that build up from individual events.

3. When you're done, you won't look any different. You won't get a trophy or a certificate to hang on your wall. You'll have some knowledge, and some skill, and you'll be ready to find more knowledge and develop more skill. Much of this will be recognisable only to someone who has the same knowledge and skill.

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Video Fade-to-White Direct Conversion 80m Receiver Vehicle Alert 10MHz Function Generator– Main Board – PSU	OCT '96 114 116 117 118 119	£6.98 £7.52 £6.55 £7.33 £5.39
Tuneable Scratch Filter *Central Heating Controller D.C. to D.C. Converters – Negative Supply Generator – Step-Down Regulator – Step-Up Regulator	NOV '96 115 120 122 123 124	£7.83 £7.85 £5.96 £6.01 £6.12
EPE Elysian Theremin (double-sided p.t.h.) *PIC Digital/Analogue Tachometer Stereo Cassette Recorder Playback/PSU Record/Erase	DEC '96 121 127 128 129	£22.00 £7.23 £7.94 £9.04
*Earth Resistivity Meter Current Gen. – Amp/Rect. Theremin MIDI/CV Interface (double-sided p.t.h.) Mains Failure Warning	JAN '97 131/132 (pr) 130 (set) 126	£12.70 £40.00 £6.77
Pacific Waves PsiCom Experimental Controller	FEB '97 136 137	£9.00 £6.78
Oil Check Reminder Video Negative Viewer Tri-Colour NiCad Checker Dual-Output TENS Unit (plus Free TENS info.)	MAR '97 125 135 138 139	£7.16 £6.75 £6.45 £7.20
*PIC-Agoras – Wheelie Meter 418MHz Remote Control – Transmitter – Receiver	APRIL '97 141 142 143	£6.90 £5.36 £6.04
Puppy Puddle Probe MIDI Matrix – PSU – Interface	145 147 148	£6.10 £5.42 £5.91
Quasi-Bell Door Alert 2M F.M. Receiver *PIC-A-Tuner Window Closer – Trigger – Closer	MAY '97 133 144 149 150 151	£6.59 £7.69 £7.83 £4.91 £4.47

PROJECT TITLE	Order Code	Cost
Child Minder Protection Zone – Transmitter – Receiver	JUN '97 153 154	£6.58 £6.42
Pyrotechnic Controller *PIC Digilogue Clock Narrow Range Thermometer	155 156 158	£6.93 £7.39 £6.37
Micropower PIR Detector – 1 Infra-Red Remote Control Repeater (Multi-project P.C.B.) Karaoke Echo Unit – Echo Board – Mixer Board Computer Dual User Interface *PEST Scarer	JULY '97 152 932 159 160 161 162	£6.69 £3.00 £6.40 £6.75 £6.70 £6.60
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*EPE PIC Tutorial The Handy Thing (Double-Sided) Lighting-Up Reminder *Audio System Remote Controller – PSU Main Board	MAR '98 182 183 184 185 186	£7.99 £6.58 £5.90 £7.05 £8.29

## EPE SOFTWARE

Software programs for EPE projects are available on 3.5 inch PC-compatible disks or via our Internet site. Those marked with a single asterisk \* are all on one disk, order code PIC-DISK1, this disk also contains the *Simple PIC16C84 Programmer* (Feb '96). The *EPE PIC Tutorial* (\*\*) files are on their own disk, order code PIC-TUTOR. The disks are obtainable from the *EPE PCB Service* at £2.75 each (UK) to cover our admin costs (the software itself is free). Overseas (each): £3.35 surface mail, £4.35 airmail. All files can be downloaded free from our Internet FTP site: <ftp://ftp.epemag.wimborne.co.uk>.

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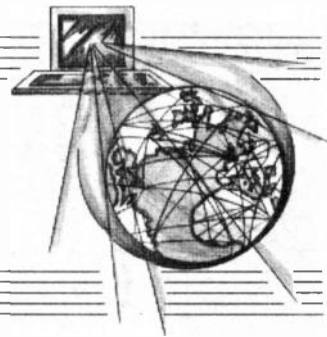
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# SURFING THE INTERNET

# NET WORK

## ALAN WINSTANLEY



### ESR Components get Kitted Out!

ONE of the perpetual headaches for electronics constructors is that of locating components for projects. Occasionally it is necessary to deal with more than one supplier in order to source the parts for your latest constructional project, which brings unwelcome extra postage charges for those operating on a limited budget. If you've checked the *EPE* web site (<http://www.epemag.wimborne.co.uk>) recently, you will have noticed a new announcement on the Home Page – we've linked to the pages of ESR Components (<http://www.esr.co.uk/epe.html>) a components distributor based in Cullercoats, Tyne & Wear.

ESR have just opened a new section of their web site which will be of special interest to *EPE* project builders. Their new on-line service has been specially designed to make it easy to obtain kits of parts for our projects. "Readers, customers, in fact anyone can now view a complete component list for recent *EPE* projects, including all prices and a discount for a complete 'kit' of parts," say ESR. Furthermore, they promise to update the web site as soon as possible – hopefully within a day or so – after a new issue of *EPE* is launched.

Those hard-working folks at ESR currently plan a "rolling" program of publishing the components listing details of the last four or five issues, we're told. Of course, ESR's new site includes a reciprocal link to the *EPE* web site plus our on-line Back Issue & PCB order forms held on our secure server. All in all, an excellent Internet resource for the *EPE* project builder which we heartily commend! Be sure to take a look.

### The QWERTY Generation

One problem in having a namesake (viz. Alan Winstanley, the music producer) is that I sometimes receive E-mail from youngsters in the USA ("Can you get me tickets for the next Bush concert?", "Are you the Alan Winstanley working in Riverside Studios, London?" etc.). This usually resulted from a young American music lover tapping my name into an Internet search engine, and then E-mailing me "on spec." It occurred to me that it seems to be perfectly ordinary to an American 10-year old to try an Internet search engine, of which there are hundreds, or to have an E-mail address, and they treat all this as a matter of routine.

Meantime, the British government is hard at work over here, playing catch-up. It's open season on Information and Computer Technology. It has designated 1998 as UK NetYear, and with the help of Bill Gates it wants to wire up all 32,000 of Britain's school to the information superhighway by the year 2002. Most schools seem to have at least some IT equipment, some schools having an enviable array of very modern personal computers – the cutting edge in some private schools, old legacy equipment and software in others.

If they're lucky then a member of staff may already have a head start with a requisite interest in IT systems, and may be able to introduce his or her personal skills into the school (just as happens in the industrial sector): up springs a school web site, E-mail addresses, even a school Intranet. Chat areas and on-line E-zines follow and clip art and colour printers brighten up the school output. Excellent stuff.

Without the technical know-how needed to run a network of computers, I suspect that most schools will have a problem, and one of the main areas highlighted in the Government's ambitions to hook up every school to the Internet is the need to train staff accordingly. (Another requirement is to encourage the availability of good quality British software.) The new "infogrid" will interconnect libraries, schools, museums, hospitals, galleries, universities and more. An Internet "kiosk" will become as common as a payphone, they hope.

In the new IT strategy every pupil and teacher is offered a free E-mail address – that's ten million addresses in all. Teachers should visit [www.excite.co.uk](http://www.excite.co.uk) for more information, or send an A4 SAE to ExcitePost, 23 Kingly Court, London W1R 5LE.

It seems to me that there is, however, a bit of a paradox in all this. The UK educational establishment is slowly waking to the fact that giving a pocket calculator to a ten-year old rather than honing basic skills in mental arithmetic is maybe not such a good idea, and perhaps multiplication is better learned by rote after all. Judging by DfEE (Dept. of Education & Employment) consultation papers, the present regime appears to be dazzled with Internet connectivity and computing, as though using a wordprocessor or Internet kiosk is a panacea for all educational ills. Once the novelty has worn off it all, I fear I can see a new QWERTY generation being created, afflicted with a short attention span and carpal tunnel syndrome, and still unable to do percentages on a factory floor.

The thinking behind the government's desire to create a "learning society" can be found on-line, in the form of Dept. of Education & Employment press releases which are published on the UK Government web site. You can browse the Prime Minister's foreword, by going to the DfEE web pages at [www.open.gov.uk/dfec/dfeehome.htm](http://www.open.gov.uk/dfec/dfeehome.htm).

The entire consultation paper is available for download in Adobe Acrobat format. Unfortunately my flaky Adobe Acrobat 3.0 reader crashed my PC when it pondered 32 pages of governmental policy. I find the best way, using Explorer, is to point the mouse at the filename on the web site, right-click Save Target As, choose a filename and save it to hard disk without opening Acrobat. Then browse it when off-line, or print it by right-clicking over the file name and selecting Print. Preferably dump it on a laser printer.

For light entertainment in a spare moment, readers might like to check the UK Government Information Service (GIS) web site at [www.open.gov.uk](http://www.open.gov.uk) which, it must be said, is quite impressive. From there you can link to various Governmental departments plus, of course, [www.royal.gov.uk](http://www.royal.gov.uk), the site providing much official and historical information on the British Monarchy.

### Links

Time for a round-up of this month's suggested links (as usual, all URLs are preceded with <http://>). Jonathan Stott maintains the Constants and Equations Pages (TCAEP), and the site includes hundreds of scientific constants, equations, a periodic Table, Greek and mathematical symbols and a large section of maths on [www.stott.demon.co.uk](http://www.stott.demon.co.uk). Some new tutorials from Iguana Labs, are now on-line at [www.proaxis.com/~iguanalabs/1stled.htm](http://www.proaxis.com/~iguanalabs/1stled.htm) (first-led.htm) describing using transistors and l.e.d.s, and [www.proaxis.com/~iguanalabs/maintut.htm](http://www.proaxis.com/~iguanalabs/maintut.htm), a very good all-round beginner's tutorial in electronics. There are some demo circuits on-line, including breadboard layouts – one for the *Teach-In '98* student to check, for sure.

Another excellent-looking site is "Jughead's Information Station" at [www.teleport.com/~jughead](http://www.teleport.com/~jughead) with pages for electronics, wireless, computers, modems and more. Texas Instruments has divested its discrete power semiconductor products to Power Innovations Ltd., a management buyout team whose new web site is [www.powinv.com](http://www.powinv.com). A new site called Short Circuit on [www.zip.com.au/~troy](http://www.zip.com.au/~troy) is a great-looking resource which claims to include a real-time message board, circuits, manufacturers and more. Finally, have a look at Laser Optics-UK, based at [members.aol.com/WSRNet/optics.htm](http://members.aol.com/WSRNet/optics.htm). This is a first-rate resource on lasers and opto-electronics, with a link to its USA equivalent, and it includes a laser tutorial plus dozens of links to research groups in the UK. Definitely one to bookmark.

You can E-mail me at [alan@epemag.demon.co.uk](mailto:alan@epemag.demon.co.uk).

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### VXT Voice-Activated Transmitter

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### HVX400 Mains Powered Room Transmitter

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### SCRX Subcarrier Scrambled Room Transmitter

Scrambled output from this transmitter cannot be monitored without the SCDM decoder connected to the receiver. Size 20mm x 67mm. 9V operation. 1000m range..... £22.95

### SCLX Subcarrier Telephone Transmitter

Connects to telephone line anywhere, requires no batteries. Output scrambled so requires SCDM connected to receiver. Size 32mm x 37mm. 1000m range..... £23.95

### SCDM Subcarrier Decoder Unit for SCRX

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### ATR2 Micro-Size Telephone Recording Interface

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### UTLX Ultra-miniature Telephone Transmitter

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### QTX180 Crystal Controlled Room Transmitter

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### QLX180 Crystal Controlled Telephone Transmitter

As per QTX180 but connects to telephone line to monitor both sides of conversations. 20mm x 67mm. 9V operation. 1000m range..... £40.95

### QSX180 Line Powered Crystal Controlled Phone Transmitter

As per QLX180 but draws power requirements from line. No batteries required. Size 32mm x 37mm. Range 500m..... £35.95

### QRX 180 Crystal Controlled FM Receiver

For monitoring any of the 'Q' range transmitters. High sensitivity unit. All RF section supplied as pre-built and aligned module ready to connect on board so no difficulty setting up. Output to headphones. 60mm x 75mm. 9V operation..... £60.95

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Individual Receiver DLRX..... £37.95

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**EPE NET ADDRESSES**

**EPE FTP site:** <ftp://ftp.epemag.wimborne.co.uk>

Access the FTP site by typing the above into your web browser, or by setting up an FTP session using appropriate FTP software, then go into quoted sub-directories:

PIC-project source code files: /pub/PICS

PIC projects each have their own folder; navigate to the correct folder and open it, then fetch all the files contained within. *Do not try to download the folder itself!*

EPE text files: /pub/docs

Basic Soldering Guide: solder.txt

EPE TENS Unit user advice: tens.doc and tens.txt

Ingenuity Unlimited submission guidance: ing\_unlt.txt

New readers and subscribers info: epe\_info.txt

Newsletters or Usenet users advice: usenet.txt

Ni-Cad discussion: nicadfaq.zip and nicad2.zip

UK Sources FAQ: uksource.zip

Writing for EPE advice: write4us.txt

Ensure you set your FTP software to ASCII transfer when fetching text files, or they may be unreadable.

**EPE Website:** <http://www.epemag.wimborne.co.uk>

Check it for up-to-date information on FAQs, subscribing, buying PCBs and Back Issues via our new Secure Server.

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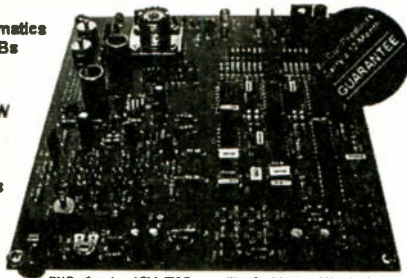
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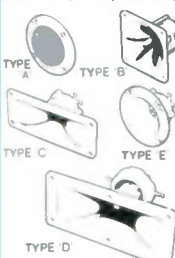


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- 8" 100 WATT R.M.S. MEB-100 GEN. PURPOSE, LEAD GUITAR, EXCELLENT MID, DISCO. RES. FREQ. 72Hz, FREQ. RESP. TO 4kHz, SENS 97dB. PRICE £32.71 + £2.00 P&P
  - 10" 100 WATT R.M.S. ME10-100 GUITAR, VOCAL, KEYBOARD, DISCO, EXCELLENT MID. RES. FREQ. 71Hz, FREQ. RESP. TO 7kHz, SENS 97dB. PRICE £33.74 + £2.50 P&P
  - 10" 200 WATT R.M.S. ME10-200 GUITAR, KEY'D, DISCO, VOCAL, EXCELLENT HIGH POWER MID. RES. FREQ. 65Hz, FREQ. RESP. TO 3.5kHz, SENS 99dB. PRICE £43.47 + £2.50 P&P
  - 12" 100 WATT R.M.S. ME12-100LE GEN. PURPOSE, LEAD GUITAR, DISCO, STAGE MONITOR. RES. FREQ. 49Hz, FREQ. RESP. TO 6kHz, SENS 100dB. PRICE £35.64 + £3.50 P&P
  - 12" 100 WATT R.M.S. ME12-100LT (TWIN CONE) WIDE RESPONSE, P.A., VOCAL, STAGE MONITOR. RES. FREQ. 42Hz, FREQ. RESP. TO 10kHz, SENS 98dB. PRICE £36.67 + £3.50 P&P
  - 12" 200 WATT R.M.S. ME12-200 GEN. PURPOSE, GUITAR, DISCO, VOCAL, EXCELLENT MID. RES. FREQ. 58Hz, FREQ. RESP. TO 6kHz, SENS 98dB. PRICE £46.71 + £3.50 P&P
  - 12" 300 WATT R.M.S. ME12-300GP HIGH POWER BASS, LEAD GUITAR, KEYBOARD, DISCO ETC. RES. FREQ. 47Hz, FREQ. RESP. TO 5kHz, SENS 103dB. PRICE £70.19 + £3.50 P&P
  - 15" 200 WATT R.M.S. ME15-200 GEN. PURPOSE BASS, INCLUDING BASS GUITAR. RES. FREQ. 46Hz, FREQ. RESP. TO 5kHz, SENS 99dB. PRICE £50.72 + £4.00 P&P
  - 15" 300 WATT R.M.S. ME15-300 HIGH POWER BASS, INCLUDING BASS GUITAR. RES. FREQ. 39Hz, FREQ. RESP. TO 3kHz, SENS 103dB. PRICE £73.34 + £4.00 P&P

**EARBENDERS:- HI-FI, STUDIO, IN-CAR, ETC**

- ALL EARBENDER UNITS 8 OHMS** (Except EB8-50 & EB10-50 which are dual impedance tapped @ 4 & 8 ohms)
- BASS, SINGLE CONE, HIGH COMPLIANCE, ROLLED SURROUND**
  - 8" 50watt EB8-50 DUAL IMPEDANCE, TAPPED 4/8 OHM BASS, HI-FI, IN-CAR. RES. FREQ. 40Hz, FREQ. RESP. TO 7kHz SENS 97dB. PRICE £8.90 + £2.00 P&P
  - 10" 50watt EB10-50 DUAL IMPEDANCE, TAPPED 4/8 OHM BASS, HI-FI, IN-CAR. RES. FREQ. 40Hz, FREQ. RESP. TO 5kHz, SENS 99dB. PRICE £13.65 + £2.50 P&P
  - 10" 100watt EB10-100 BASS, HI-FI, STUDIO. RES. FREQ. 35Hz, FREQ. RESP. TO 3kHz, SENS 96dB. PRICE £30.39 + £3.50 P&P
  - 12" 100watt EB12-100 BASS, STUDIO, HI-FI, EXCELLENT DISCO. RES. FREQ. 26Hz, FREQ. RESP. TO 3 kHz, SENS 93dB. PRICE £42.12 + £3.50 P&P
  - FULL RANGE TWIN CONE, HIGH COMPLIANCE, ROLLED SURROUND**
  - 5 1/2" 60watt EB5-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC. RES. FREQ. 63Hz, FREQ. RESP. TO 20kHz, SENS 92dB. PRICE £9.99 + £1.50 P&P
  - 6 1/2" 60watt EB6-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC. RES. FREQ. 38Hz, FREQ. RESP. TO 20kHz, SENS 94dB. PRICE £10.99 + 1.50 P&P
  - 8" 60watt EB8-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC. RES. FREQ. 40Hz, FREQ. RESP. TO 18kHz, SENS 89dB. PRICE £12.99 + £1.50 P&P
  - 10" 60watt EB10-60TC (TWIN CONE) HI-FI, MULTI ARRAY DISCO ETC. RES. FREQ. 35Hz, FREQ. RESP. TO 12kHz, SENS 98dB. PRICE £16.49 + £2.00 P&P

**ibf FLIGHT CASED LOUDSPEAKERS**

A new range of quality loudspeakers, designed to take advantage of the latest speaker technology and enclosure designs. Both models utilize studio quality 12" cast aluminium loudspeakers with factory fitted grilles, wide dispersion constant directivity horns, extruded aluminium corner protection and steel ball corners, complimented with heavy duty black covering. The enclosures are fitted as standard with top hats for optional loudspeaker stands.



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**OPTIONAL STANDS PRICE PER PAIR £49.00**  
Delivery £6.00 per pair

**IN-CAR STEREO BOOSTER AMP**



**PRICES: 150W £49.99 250W £99.99**  
**400W £109.95 P&P £2.00 EACH**

**THREE SUPERB HIGH POWER CAR STEREO BOOSTER AMPLIFIERS**

- 150 WATTS (75 + 75) Stereo, 150W Bridged Mono
- 250 WATTS (125 + 125) Stereo, 250W Bridged Mono
- 400 WATTS (200 + 200) Stereo, 400W Bridged Mono

**ALL POWERS INTO 4 OHMS**

**Features:**

- \* Stereo, bridgable mono
- \* Choice of high & low level inputs
- \* L & R level controls
- \* Remote on-off
- \* Speaker & thermal protection.

**TRANSMITTER HOBBY KIT**

**PROVEN TRANSMITTER DESIGNS INCLUDING GLASS FIBRE PRINTED CIRCUIT BOARD AND HIGH QUALITY COMPONENTS COMPLETE WITH CIRCUIT AND INSTRUCTIONS**

**3W TRANSMITTER** 80-108MHz, VARICAP CONTROLLED PROFESSIONAL PERFORMANCE, RANGE UP TO 3 MILES, SIZE 38 x 123mm, SUPPLY 12V @ 0.5AMP. PRICE £14.85 - £1.00 P&P

**FM MICRO TRANSMITTER** 100-108MHz, VARICAP TUNED, COMPLETE WITH VERY SENS FET MIC, RANGE 100-300m, SIZE 56 x 46mm, SUPPLY 9V BATTERY. PRICE £8.80 - £1.00 P&P



PHOTO: 3W FM TRANSMITTER

# New Project Kits from Maplin

## AUDIO LEAD CHECKER KIT

- No home or professional studio should be without one!

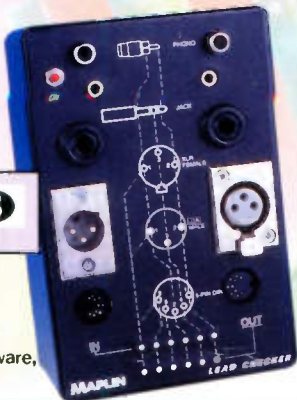
### FEATURES:

- Rapidly and clearly identifies connections on most audio cables
- Will test very long cables
- Clear led readout
- Robust design

### IDEAL FOR:

- PA/Sound engineers
- Gigging bands
- Fault diagnosis

Kit includes all components, PCB, fixing hardware, case, front panel label and full Instructions.



**PROJECT RATING 3**  
Average

**AUDIO LEAD CHECKER KIT LU26D £19.99**  
Construction details: Audio Lead Checker Leaflet XZ20W 80p  
Issue 114 / June 1997 Electronics & Beyond XD14Q £2.25

**PROJECT RATING 1**  
Simple

## NATIONAL LOTTERY PREDICTOR KIT

### FEATURES

- Ideal beginners project
- Simple to use - one switch operation
- Automatic switch off saves batteries
- Full source code available

### APPLICATIONS

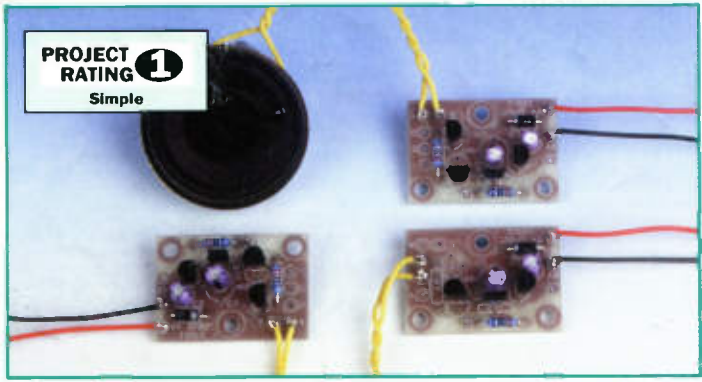
- Use to choose your lottery numbers!
- Excellent introduction to microcontrollers
- Use in other games

Kit Includes all components, PCB, fixing hardware and full instructions. Two AAA batteries are required (not supplied).



**NATIONAL LOTTERY PREDICTOR KIT LU61R £9.99**  
Construction details: National Lottery Predictor Leaflet XZ46A 50p  
Issue 120 / December 1997 Electronics & beyond XD20W £2.65

## MELODY GENERATOR KIT



**PROJECT RATING 1**  
Simple

### FEATURES

- Ideal beginners project
- Safe, low voltage operation
- Low current giving long battery life
- Directly drives speakers (included) or piezo sounders
- Large range of melodies supported (15 available)

### APPLICATIONS

- Children's toys
- Teaching nursery rhymes
- Turn ordinary cards and gifts into novel presents

Kit includes all components, PCB, speaker, connecting wire and full instructions. One or two 1.5V batteries are required (not supplied).

**MELODY GENERATOR KIT:**

LU64U Happy Birthday	LU66W London Bridge	LU67 Old McDonald
LU68 Greensleeves	LU69 Love Me Tender	LU70 Jingle Bells
LU75 Merry Christmas	LU76 12 Days of Christmas	LU77 You Are My Sunshine
LU80 I Just Called	LU81 Twinkle Twinkle	LU84 I'd Like To Teach
LU90 White Christmas	LU91 Warning Tone	LU92 Wedding March

All at £4.99

Construction details: Melody Generator Leaflet XZ47B 50p  
Issue 120 / December 1997 Electronics & beyond XD20W £2.65

## PAL COLOUR ENCODER KIT

### FEATURES

- PAL and NTSC compatible
- TTL compatible inputs
- 64 colour palette
- Composite video and UHF outputs
- Analogue or digital RGB inputs
- Optional S-video output

### APPLICATIONS

- Colour bar generation
- RGB to composite and UHF conversion
- Computer displays

Kit includes all components, PCB, Modulator, hardware to connect the Maplin Colour Bar Generator LT50E and full instructions. A +12V DC @ 300mA, regulated supply is required (not supplied).



**PROJECT RATING 3**  
Average

**PAL COLOUR ENCODER KIT LU74R £24.99**  
Construction details: PAL Colour Encoder Leaflet XZ41U 80p  
Issue 115 / July 1997 Electronics & beyond XD15R

## .....ORDER NOW!.....

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Or write to Maplin Electronics, P.O. Box 777, Rayleigh, Essex, SS6 8LU  
Or Tel: 01702 554002 for details of your nearest Maplin or Mondo store.  
Please quote **Priority Reference Code MA043** When ordering.



For orders over £30.00 inc VAT goods are dispatched free of handling charges. A small order charge of £2.95 inc VAT is applied to orders less than £30.00 inc VAT. All items subject to availability. All prices are inclusive of VAT and are subject to change. E&OE.



Internet Web Site:  
<http://www.maplin.co.uk>

These kits are:

- Supplied with high-quality fibre-glass PCBs - pre-tinned, with printed legend and solder resist
- Supplied with comprehensive instructions and a constructors' guide
- Covered by the Maplin Get-You-Working Service and 12-month warranty

Kits do not include tools or test equipment. Kits may require additional components or products, depending on application, please refer to construction details or contact the Maplin Technical Support Helpline (Tel: 01702 556001) if in doubt.