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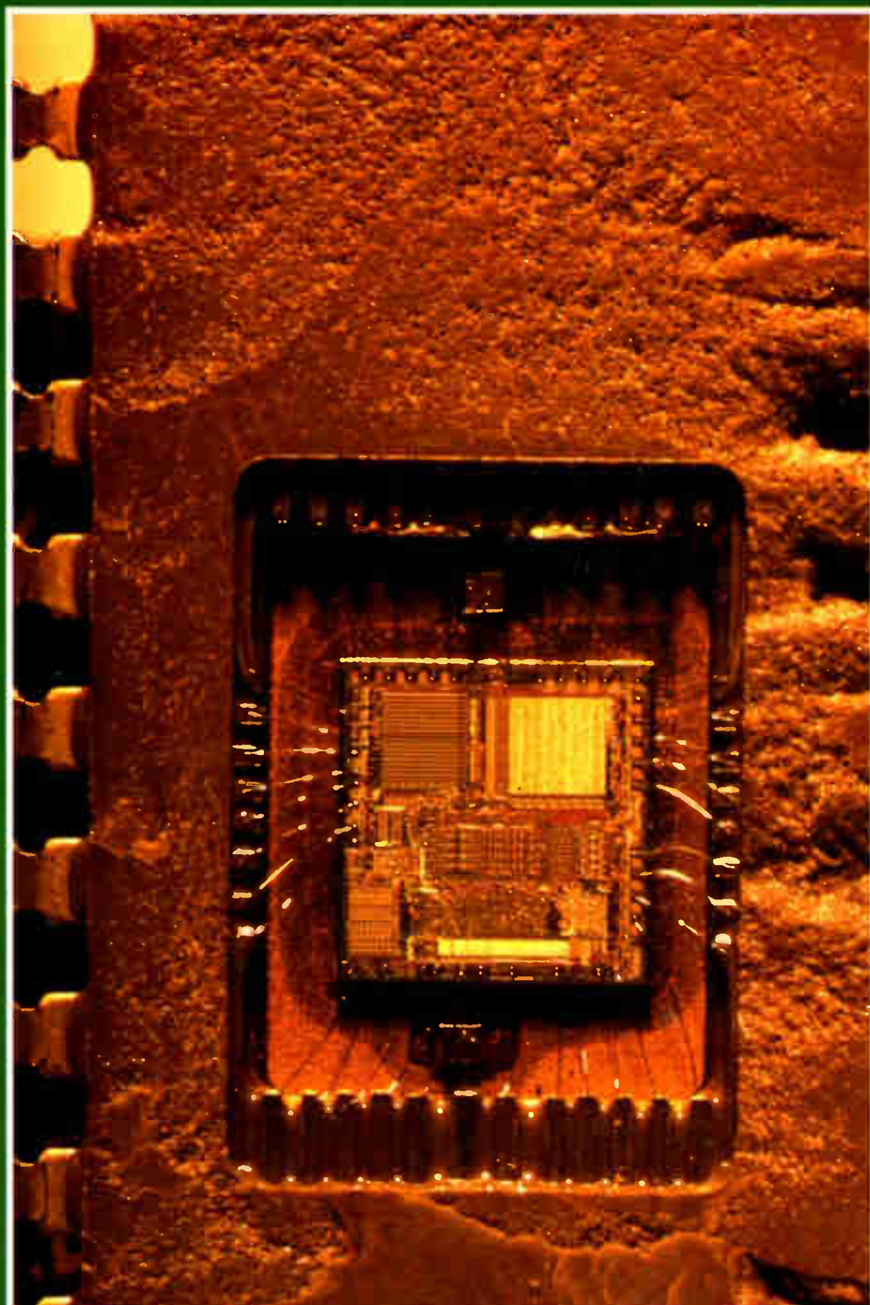

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VOL. 26 No. 9 SEPTEMBER 1997

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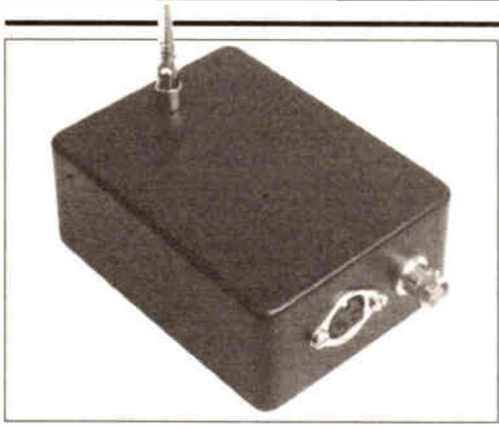

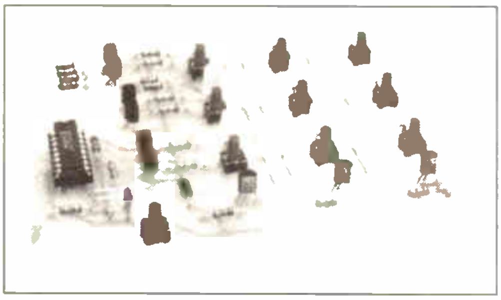

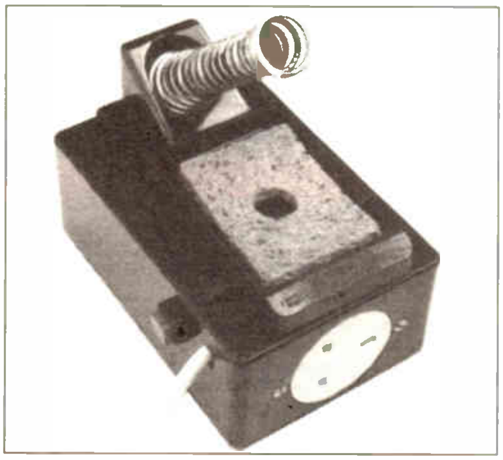

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Our October '97 issue will be published on Friday, 5 September 1997. See page 641 for details.

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BURNING IDEA

It just shows what can be achieved with a good idea and a basic understanding of logic and timers. Nothing complicated, no "new" circuit developments, just a novel application of some straightforward building blocks. Yet the design was judged to be the most commercially viable in a national competition. I'm talking about the *Iron Safety Device* featured in this issue.

Start with a problem – no-one wants their favourite shirts burned by a distracted "iron operator" – then comes the hard bit – decide how it can be overcome. In this case that meant sensing when the iron was stationary in a horizontal position for a few seconds. Finally, sort out how some sensors and a little electronics can be applied to provide a neat and simple solution.

Sounds easy and, like all great ideas, in retrospect it is. You may soon see such devices built into commercial irons but, in the meantime, we are pleased to present the *Iron Safety Device* project from Simon Todd, a pupil at Bolton School. Simon, no doubt encouraged by our contributor and his teacher Chris Walker, designed and refined the project and won honours for himself and the school in two competitions: the *Young Electronics Designer Awards* (sponsored, by Texas Instruments and Mercury Communications in association with the Institution of Electrical Engineers) and the *National Duracell Schools Competition*. The project netted a total of £3,250 in YEDA prize money for Simon and Bolton School. We also hope to publish another YEDA prizewinning project in a future issue.

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I'm sorry to say that our subscription price will increase to £26 (UK) from 1st September. Whilst this will give a saving of £5.80 on cover price, and therefore makes a subscription a worthwhile investment – no missed issues, no tramping to the newsagents in the rain, etc. – you can still achieve a saving of £7.80 if you are quick.

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Constructional Project

IRONING SAFETY DEVICE

SIMON TODD

Keep the peace in your household with this prize winning, low-cost, easy-to-build safety device.

THE first clothes iron was developed in the late 15th century and it consisted of a heavy cast-iron brick with a moulded handle and a smooth base. This raw and crude tool has been a godsend for inventors across the globe who have for centuries been modernising and building upon the device to make it into the electric iron which we take for granted so much in modern everyday life.

Have you ever had to throw away an expensive shirt/blouse or any other valuable item of clothing simply because it has been burned or singed by a hot iron? Or possibly, you have opened your drawer one morning to find a hole "the size of Cape Canaveral" glaring back at you from your favourite T-shirt? *(To help keep the peace in the Todd household we decline to commit to print Simon's comments about his mother's ironing skills!* –Ed*)*

Then this simple, cheap and easy to construct little gadget is for you.

HOT PROBLEM . . .

An iron is an essential yet extremely dangerous item of household equipment. Many people think that ironing requires very little mental power and concentration.

This is most certainly not the case. One would usually classify a solid object with 30 per cent of the surface area averaging at 250°C a dangerous object to have around the home, but to make matters worse it is often left balancing precariously on the edge of the ironing board with the wire trailing across the floor just waiting for someone to trip over it.

There are already many inventions on the market which are designed to make the iron a better and safer utensil. These include, rotating safety flexes, safety cut-off devices, limescale filters and even cordless models.

However, the majority of them are designed for *personal* safety and/or to make the process of ironing easier. None of the gadgets actually protect the *clothing* from the immense heat of the iron.

Unfortunately, ironing always has been and always will be a boring and tedious chore. When ironing, a person's mind often begins to wander in an aimless quest to seek out some form of entertainment. This often takes the form of a television or radio or in some cases an argument or conversation, all of which are considerably more interesting than the task in hand.

It is not surprising, therefore, that accidents can easily happen. A person need only be distracted for a few seconds and an item of clothing may be ruined. Any longer and a fire may result.

People can also be distracted in many ways other than the aforementioned. For example: the telephone may ring; the doorbell may ring; something may occur in the kitchen which requires immediate attention (eg. a pan may boil over); or an accident or problem involving children or pets may suddenly occur and require urgent assistance.

Taking all this into consideration it is not surprising that accidents happen when an iron serving a family of four can pass over about 50km of fabric in one year.

. . . COOL SOLUTION

The solution to the problem is to develop a device which detects whether the iron is in contact with the same part of the material for more than about five seconds, and this project does just that.

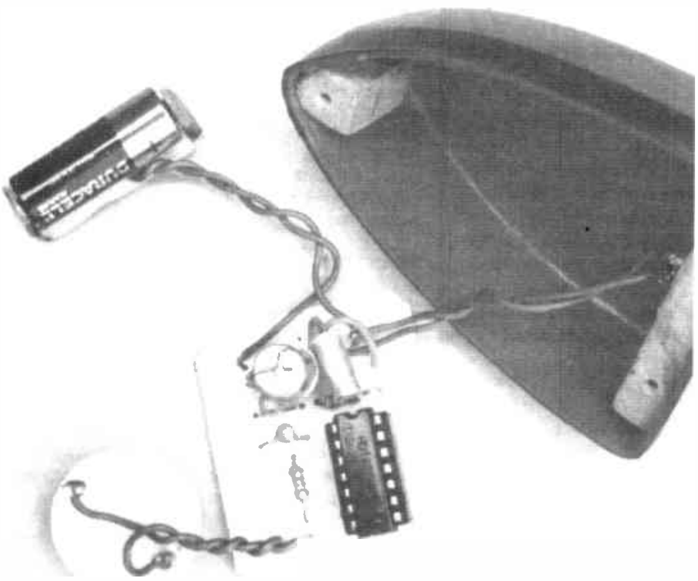
The Iron Safety Device is an extremely simple, cheap and easy to construct project which will trigger an alarm if the following two criteria are detected simultaneously:

a) If the iron is horizontal. (A mercury switch is used as the sensor)

b) If the iron does not move for more than five seconds. (A vibration detector is used as the sensor.)

HOW IT WORKS

A block diagram for the Ironing Safety Device is shown in Fig. 1. When the iron is placed in a horizontal position (i.e. on top of the ironing board) the mercury tilt switch contacts are bridged (*closed*)



AWARD WINNING DESIGN

The Iron Safety Device was developed as part of a G.C.S.E technology project at Bolton School (Lancs) and helped Simon to win a Scholarship and £500 for his school. It was entered in the *National Duracell Schools Competition* and was chosen as one of the top five winners.

Simon also entered it in the *1997 Young Electronic Designer Awards* where it came first in the Intermediate (15-17 years) Category, winning him a YEDA trophy, £750 and a cordless telephone from Mercury Com. It also scooped the Texas Instruments prize for the most commercially viable project, winning £2,500 for Simon's school.

All this for a project costing well under £20. An imaginative example of "electronics in action" – well done Simon.

which thus activates the timing device. Immediately, a five second "count-down" begins at the end of which an alarm is activated.

However, the timer is constantly being reset by the vibration detector which pulses open and closed when the iron is in motion – ironing clothes. If the iron stops moving and the mercury switch is still closed (i.e. the iron is still in a horizontal position) then the five second "count-down" will finish and the alarm will be triggered. This will alert the user to the problem. Once the alarm is triggered it can only be reset by placing the iron in a *vertical* position.

CIRCUIT DESCRIPTION

The full circuit diagram for the Iron Safety Device is shown in Fig. 2. Slide switch S1 will provide power to the circuit and will override any other switches. This allows the user to turn the device off when not in use.

The mercury tilt switch S2 is located in series with S1 in the +12V rail so that when the device is switched on, the circuit itself is only activated when the iron is placed in a horizontal position. When ironing begins the mercury switch S2 will fall closed and the circuit will be activated.

continue to do so as long as the iron is in motion.

If the iron is left stationary, in the *horizontal* position, the vibration switch will not be activated. Capacitor C1 will thus continue to charge until the voltage at pin 1 of IC1 rises to a level recognised as a logic 1 (high) by the OR-gate – approximately 6V (half the supply voltage) for a CMOS gate. At this point the output of the OR-gate (pin 3) will go high, sounding the alarm WD1.

Resistor R2 feeds back the logic high output from the gate to the other input (pin 2). This high input makes sure that the output stays high even if the other input

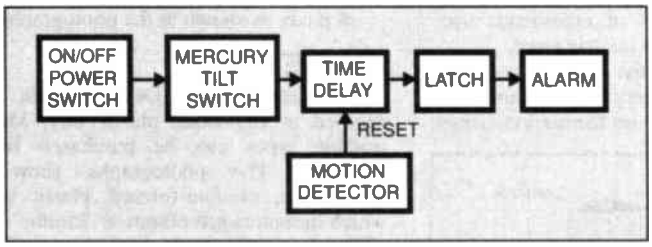


Fig.1. Block digram for the Iron Safety Device.

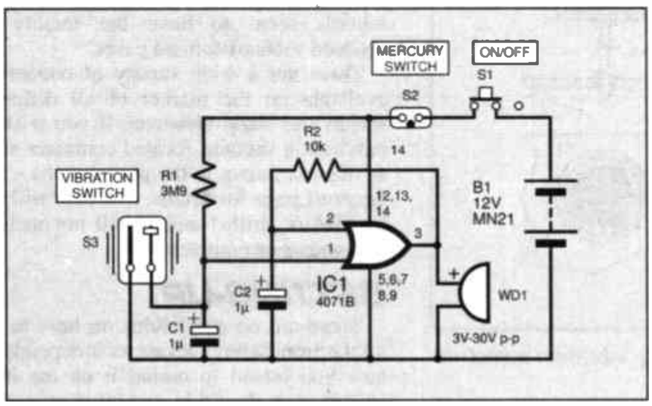
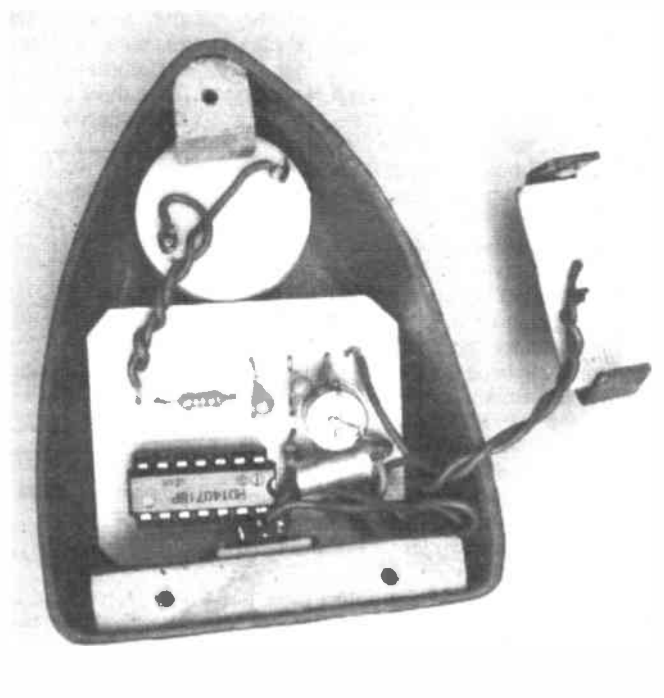


Fig.2. Complete circuit diagram for the Iron Safety Device.



Full size customised case and brass/p.c.b. battery holder.

COMPONENTS

Resistors
R1 3M9
R2 10k
All 0·25W 5% carbon film

See SHOP TALK Page

Capacitors
C1, C2 1µ tantalum bead, 16V (2 off)

Semiconductor
IC1 4071B quad 2-input OR-gate

Miscellaneous
S1 s.p.d.t. sub-min slide switch
S2 miniature mercury tilt switch
S3 miniature vibration switch
WD1 low profile piezoelectric sounder
B1 12V MN21 battery (see text)

Printed circuit board available from *EPE PCB Service*, code 167; plastic case, see text; 14-pin d.i.l. socket; approx. 30cm solid-core insulated wire; solder etc.

Approx Cost Guidance Only £15 excludes battery

When this occurs, the resistor R1 allows a small current to flow into the capacitor C1. This resistor-capacitor (*RC*) combination acts as a timing device.

As capacitor C1 begins to charge, the voltage at the input to the OR-gate (pin 1 of IC1) slowly increases. The time taken for the voltage across capacitor C1 to rise from 0V to 63 per cent of the supply voltage is called the "time constant". It is calculated by the formula: $T = R1 \times C1$.

For this circuit the *RC* combination is as follows:

R = 3M9 C = 1µF
therefore: $T = 3900000 \times 0{\cdot}000001$
$T = 3{\cdot}9$ seconds

Using this formulae you can alter the time delay of the device simply by altering the value of the capacitor or the resistor.

Note that the actual time delay will be less than the actual value of T as most CMOS chips switch at *half* the supply voltage, as opposed to the 63% associated with the *RC* calibration.

VIBRATION DETECTOR

The vibration detector "switch" S3 is located so that it short-circuits capacitor C1 and will thus discharge this capacitor when triggered. This means that the vibration switch S3 will reset the timer and will

drops low again i.e. the output is "latched" on.

Therefore, once the alarm sounds, moving the iron will have no effect. The iron must be placed in a *vertical* position so that the mercury switch S1 will fall open, thus breaking the circuit. Capacitor C2 ensures that the latch always resets when power is applied to the circuit.

CONSTRUCTION

The Ironing Safety Device is built on a miniature printed circuit board (p.c.b.) measuring just 38mm × 30mm. The component layout, wiring, and full size copper foil master pattern are shown in Fig. 3. This p.c.b. is available from the *EPC PCB Service*, code 167.

The hole labelled *Z* on the p.c.b. master must be about 1mm diameter, so that it can accommodate the shaft of the vibration switch – see later and Fig. 4.

With so few components on the board, construction is very easy and should only take a couple of hours to complete. To prevent any possible damage to the i.c., resulting from prolonged exposure to the hot tip of the soldering iron, a 14-pin i.c. socket should be fitted to the p.c.b. The socket will also allow you to replace the i.c. should it become damaged for whatever reason. Next, fit the two resistors, followed by the two capacitors – they are polarised and *must* be fitted the correct way around.

TRIP SWITCHES

The two sensor switches, S2 and S3, should be installed next. Begin with the mercury tilt switch S2. The mercury switch must be attached to the p.c.b. in a manner which allows its angle to be adjusted (see under Setting-Up).

This can be accomplished by soldering the "tilt" sensor (S2) on two short insulated wire leads which project up from the p.c.b. Cut the two legs of the mercury switch about 5mm down from where they leave the casing and solder a 30mm length of insulated solid-core wire to each leg. Solder the other ends of each wire into the appropriate hole on the p.c.b.

Referring to Fig. 4, you must now attach the vibration switch S3 to the p.c.b. Start by securing the shaft of the switch to the p.c.b. at the hole labelled *Z*, leaving the casing projecting up about 5mm from the board.

Next cut a length of wire about 50mm in length. Strip about 5mm off one end and about 20mm off the other. Wrap the longer length of exposed wire round into a loop and then solder the shorter end into the appropriate hole on the p.c.b.

If done correctly, the wire loop will just sit on top of the casing of the vibration switch. Secure the loop to the casing with excess solder. (The casing may require heating with the tip of the soldering iron for a few seconds before the solder will flow.) Solder two lengths of insulated wire (about 50/80mm each) to the power On/Off slide switch S1 and solder them to the p.c.b.

The recommended buzzer (WD1) is a miniature low profile piezoelectric device, chosen because of its compact size. In the prototype, the buzzer is not actually mounted on the p.c.b. however, but connected to it with two short lengths of insulated wire.

Observe polarity when connecting the buzzer. It should be noted that the circuit will only reliably drive miniature, low current buzzers such as the one specified.

BATTERY POWER

Any battery can be used which is rated between 5V and 12V. The one used in the model is the MN21 12V type (otherwise labelled G23A). These are fairly cheap and frequently used in car alarm key-fob remote controls. Such a battery should give about 50 hours of continuous use, assuming the alarm is not triggered.

Unfortunately, at the time of going to press, there is no battery clip for this small 12V battery available on the market. There will certainly be one released in the near future, but until then one must make do with other means of connecting the battery to the circuit.

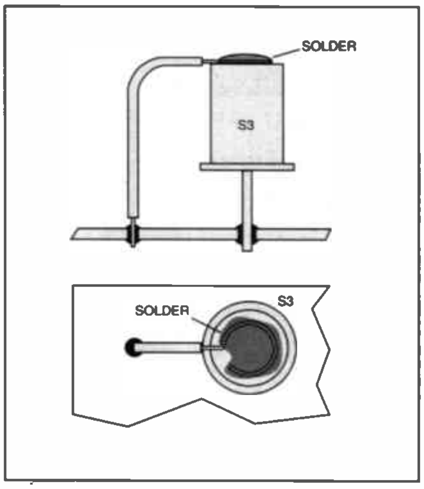


Fig.4. Soldering the vibration switch to the p.c.b.

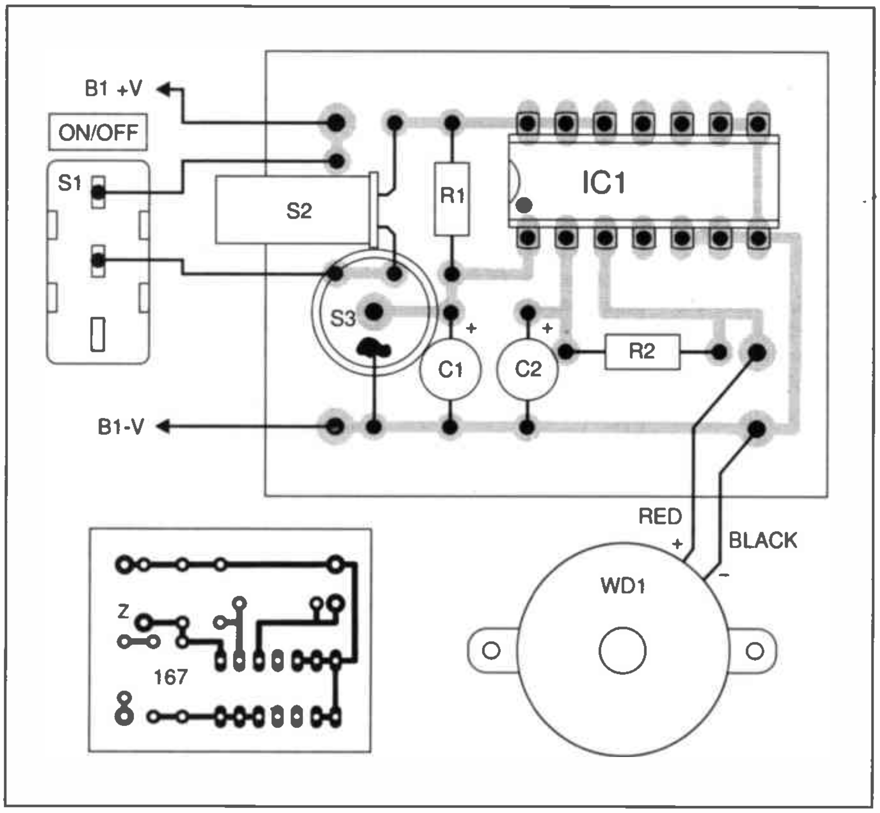


Fig.3. Printed circuit board component layout (twice size), interwiring and full size copper foil master pattern.

There are several ways of doing this. For example:

a) Solder the wires directly to the terminals of the battery *(avoid if possible)*.
b) Secure the wires to the terminals using insulation tape.
c) Place a blob of solder on the end of a wire and crush it before it solidifies using a flat surface. This should make the solder into a flat disk. Two of these disks can be secured to the terminals of the battery using an elastic band.
d) Make a holder from brass and a piece of p.c.b. as shown in the photographs.

CASE

The Iron Safety Device could be encased in any small plastic box. Many suitable types can be purchased from suppliers. The photographs show a customised, vacuum-formed, plastic case which measures just 60mm × 75mm.

There is little doubt that a customised case presents a far better finished project than a plain square black box. Most schools seem to have the facility to produce vacuum-formed cases.

There are a wide variety of containers available on the market of all different shapes and sizes. However, if you wish to purchase a vacuum formed container such as the one shown in the photographs – see *Shoptalk* page for details. The case will not be filed or drilled and it will not include any screws or graphics.

SETTING-UP

There are no strict rules on how to set up the Iron Safety Device as it depends on how you intend to mount it on the iron. However, it should be mounted on a cool part on the side of the iron with the component side of the p.c.b. facing away from the iron. Adhesive pads could be used to attach the unit to the iron or you could use self-adhesive Velcro strips, which will allow for easy removal of the case from the iron.

Once the p.c.b. is mounted inside the case, and a suitable location is found on the iron, it will be necessary to double-check that the mercury switch S2 is *open* when the iron is in the *vertical* position and *closed* when it is *horizontal*. Some trial and error will be needed here.

Stand the p.c.b. on the side which will be parallel to the base of the iron. Mark this side A. Decide which side will be facing towards the front of the iron. Mark this side B.

Adjust the angle of the mercury switch S2 so that the switch is closed when side A is facing DOWN and open when side B is facing UP. Aim for the mercury switch to changeover between 30 degrees and 60 degrees. This does not necessarily mean that the casing should be angled at 45 degrees – experimentation is needed as the switching properties vary from one manufacturer to another.

When the time comes to attach the device to the iron ensure that side A is facing down towards the sole-plate of the iron and that side B is facing towards the nose of the iron. The iron is now ready for action. □

New Technology Update

The concept of a single electron device first took industry by surprise when it was announced by Hitachi in 1993. It now seems that a number of companies are showing more than a passing interest in this "new technology" – reports Ian Poole

IN 1993 Hitachi hit the headlines when they announced their revolutionary research into single electron devices. It is claimed that these devices, which might include memories and switches that operate as a result of the movement of single electrons, will have a far reaching impact into the electronics scene as we know it today.

Initial research only included the basic concepts, and was undertaken for Hitachi at the Cavendish Laboratories in Cambridge. Since the initial announcement, work on the concept has progressed considerably. News has emerged of a number of devices which have been fabricated in the progress towards the single electron devices themselves.

Not only are Hitachi undertaking development along these lines. Other companies are also looking into this type of technology. This shows the importance people are placing on the idea.

Original Developments

At the time of the original announcements the devices that had been manufactured demonstrated the basic effect, but had many limitations. An early demonstration device was built in "delta doped" gallium arsenide. This consisted of a 20nm thin layer of GaAs doped with silicon to create a two dimensional plane in which the electrons could travel.

The cell was then contained between two multiple tunnel junctions where the gallium arsenide becomes very narrow. The transfer rate of electrons could then be tuned by applying a negative voltage to the side of the narrowing electron channel in the junction.

With suitable control of the bias voltage it was expected that a single electron could be controlled. The major problem when this was announced was that the device only operated at very low temperatures of around 0·1°K.

Transistors

The next stage in the development was to fabricate switches in the form of transistors. The first devices were announced a year after the initial announcement.

A structure was used where the presence of one electron on a small island of conducting material was used to control the flow of other electrons. This structure, similar to that in Fig.1 with two transistors was used to demonstrate a NOR function.

In this cell there were two islands acting as transistors. When both islands contained an electron the cell gave a "high" output voltage. If either island was not blockaded the cell output was "low" i.e. at ground potential. This gave the classic NOR function.

Again the temperature of this device was a problem, as it only operated at a temperature of just under 2°K.

Higher Temperatures

Naturally it was vitally important to improve the temperature of operation and one of the keys in improving the temperature performance was to reduce the size of the structure. Accordingly, a 2nm diameter island was produced. This in itself was no mean achievement and was claimed as a world record.

Along with a number of other developments to reduce the capacitance, the operational temperature was raised to 77°K. To achieve room temperature operation it was stated at that time that the dots or islands would have to be five times smaller. This could have slowed development if other ways of overcoming the problem had not been found.

The other development of importance announced at the same time was that the record had been set using silicon. Previously these single electron effects had only been seen in gallium arsenide.

MOS Transistors

In recent months further developments in single electron technology have been announced. Researchers at the University of Minnesota, Minneapolis have announced a single electron MOS memory which can operate at room temperature. In addition to this they have also claimed a number of other firsts.

Previous single electron devices needed unconventional structures, and this resulted in a large variation in device dimensions and performance. Also, these previous devices required several isolated nanocrystals and a polysilicon channel. This new device is said to be the first with a very narrow crystalline silicon channel and a nano-scale polysilicon floating gate.

The fabrication of the new device requires a number of processes. First a silicon on insulator (s.o.i.) substrate is taken. Then using electron beam lithography and reactive ion etching 35nm thick silicon channels are fabricated. These have a maximum width of 120nm but only 25nm in the middle as shown in Fig.2.

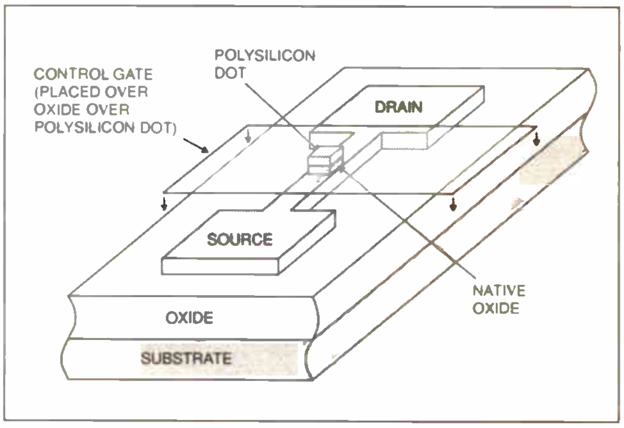


Fig.2. Structure of the single electron MOS transistor.

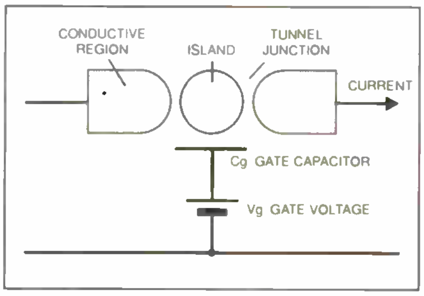


Fig.1. Principle of a single electron transistor.

With this complete, square polysilicon floating gates or "dots" are deposited onto a small area of native oxide using electron beam lithography and reactive ion etching.

The size of the channel is around 11nm which is almost the same as the gate. A layer of oxide about 18nm thick is then grown onto this structure, and this also has the effect of reducing the size of the dot to about 9nm.

A final layer of oxide is deposited using a process called plasma enhanced vapour deposition, and then the control gate is deposited over this. As the gate is just over 3µm wide, it completely covers the polysilicon dot, as shown in the diagram.

The connections are made to the various electrodes on the device for testing. This was performed at room temperature and gave very encouraging results. With a single electron stored in the floating gate a shift of over 50mV was seen on the output.

Future

Obviously there is considerably more work to be undertaken into these devices before they are commercially viable. Currently only test devices are being made and there are still many hurdles to be overcome in their development.

However, when these have been surmounted it is estimated that this technology is likely to be able to increase storage levels in memories by quantum leaps.

PIC-NOUGHTS & CROSSES GAME

PAUL HACKETT

Help make paper obsolete – let electrons save the forests and put colour into your game!

NOUGHTS AND CROSSES is known by all, and often played by young children, requiring only a pencil and paper to play. As technology advances, our aim is to move towards a paperless society, but in reality we seem to consume more paper than ever. This electronic version of the Noughts and Crosses game is a step towards that vision, using red and green light emitting diodes (l.e.d.s).

The game is laid out as a 3×3 matrix, as in normal Noughts and Crosses, with a pushswitch/key and tri-colour l.e.d. in each cell. As each key is pressed, its corresponding l.e.d. is illuminated as either red or green, alternating for each newly pressed key.

In the event that three l.e.d.s illuminated with the same colour form a straight line, the line flashes to indicate a win, after which all key presses in the matrix are ignored.

A tenth pushswitch is provided as a Reset to extinguish all l.e.d.s, ready for a new game.

In order to conserve power and extend battery life, the game goes into standby mode, extinguishing all l.e.d.s, after 20 seconds of non-use.

The project shows how to make the most out of a minimal number of I/O lines, by sharing them, to scan both the pushswitch input matrix and multiplex the tri-colour l.e.d. output matrix. It also demonstrates how interrupts are used to make these tasks perform in the background, transparent to the main program, thus keeping the main program simple.

MICROCONTROLLER

The game was designed around the PIC16C84 EEPROM (electrically erasable programmable read only memory) microcontroller from Microchip, though a PIC16C61 could be used instead. The reason for choosing the PIC16C84 rather than one of the cheaper versions of the PIC family, such as the PIC16C61, was that re-programming could be performed immediately.

The windowed EPROM versions tend to be more expensive and require a UV eraser for reprogramming, which can leave you hanging around for ten minutes! The OTP (one time programmable) versions, although very inexpensive, cannot be erased once programmed.

Because the PIC16C84 (and PIC16C61) has only 13 I/O (input/output) lines, this project makes use of multiplexing to drive the 18 l.e.d.s and read the nine pushswitches required for the game. It can be seen from the circuit diagram in Fig.1, in which IC1 is the microcontroller, that this is achieved by using only nine of the I/O lines, leaving four spare!

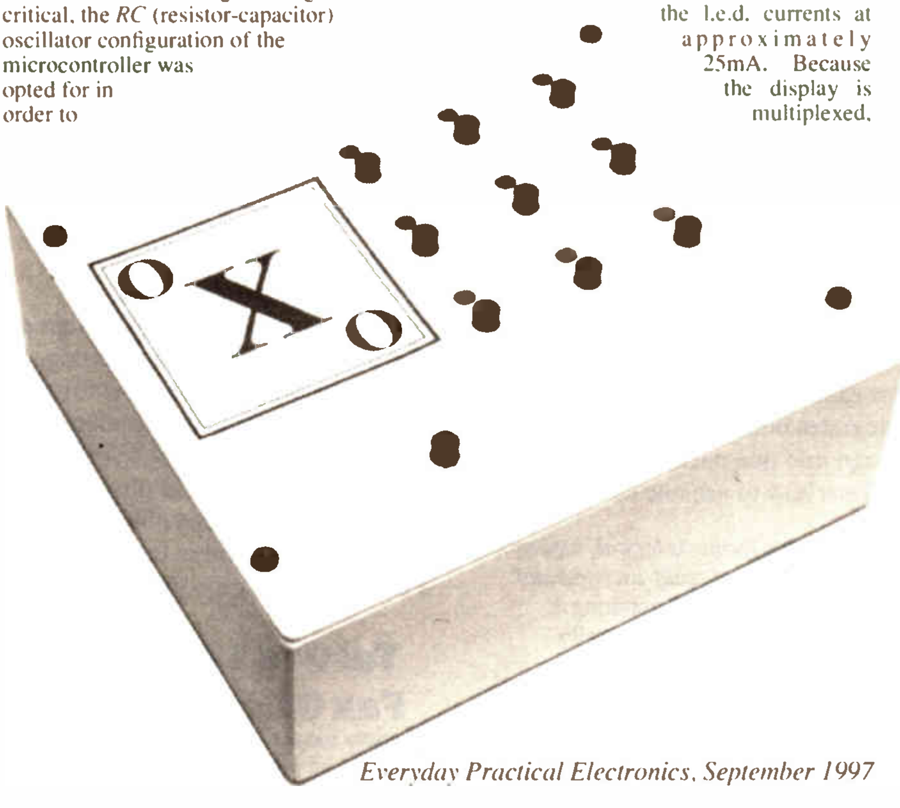
Because clock timing on the game is not critical, the *RC* (resistor-capacitor) oscillator configuration of the microcontroller was opted for in order to save the cost of a crystal. The oscillation frequency is set to approximately 620kHz by resistor R17 and capacitor C2. This frequency will vary between different units due to component tolerances.

DISPLAY

The game's display consists of a 3×3 matrix of tri-colour common cathode l.e.d.s, with the cathodes (k) connected in columns and the anodes (two per l.e.d.) connected in rows. Transistors TR7 to TR9 act as switches to drive to the columns of the matrix and are controlled by IC1's port lines RA0 to RA2.

Resistors R7 to R9 set the base currents for TR7 to TR9 respectively, and are of sufficiently low value to ensure that the transistors remain fully saturated for maximum collector currents – all red and green l.e.d.s in the columns illuminated.

The rows of the matrix are controlled by IC1's port lines RB0 to RB5, with transistors TR1 to TR6 acting as emitter followers. Resistors R1 to R6 are used to set the l.e.d. currents at approximately 25mA. Because the display is multiplexed,



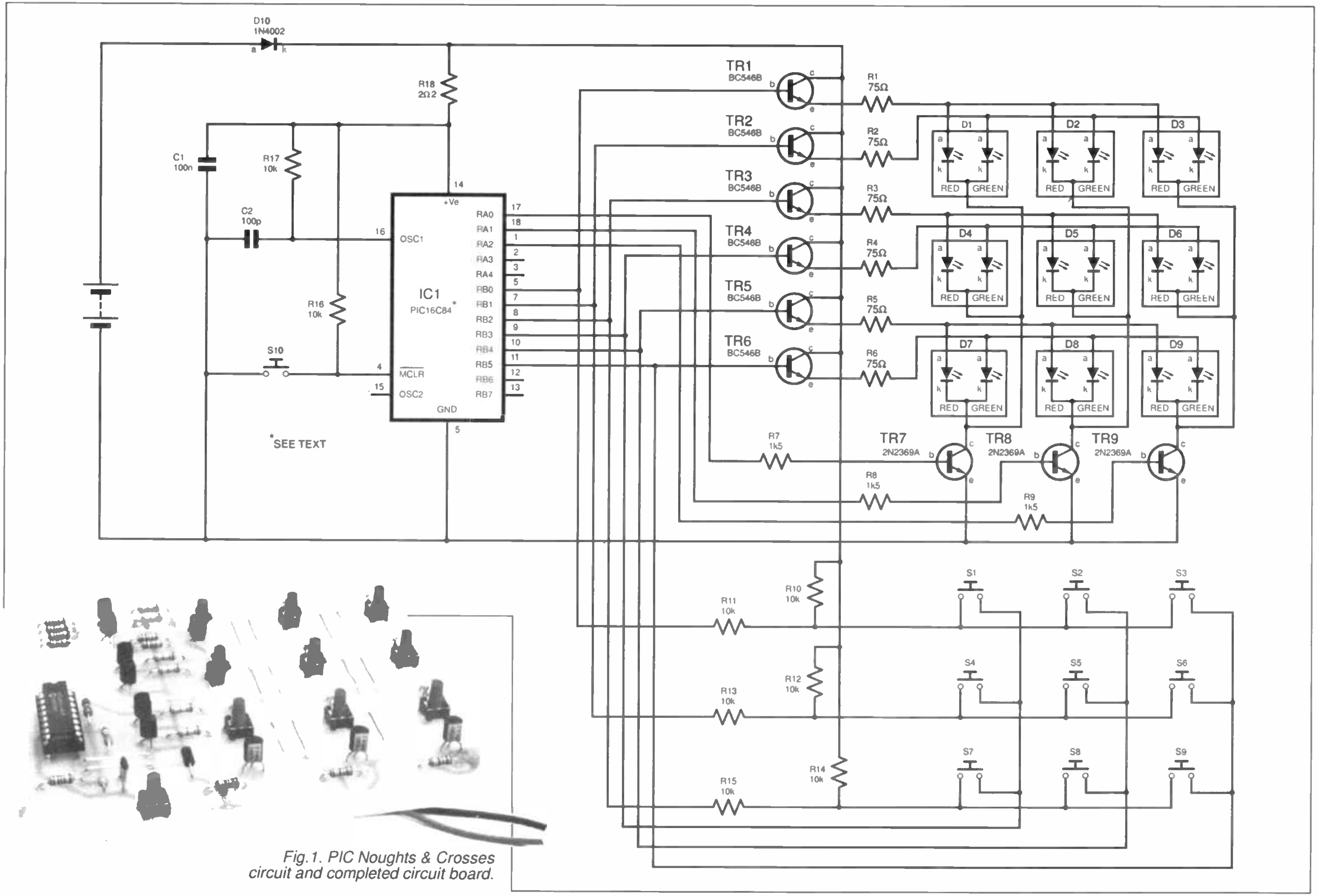


Fig.1. PIC Noughts & Crosses circuit and completed circuit board.

this current could be set at a higher level to increase the intensity of the l.e.d.s. if preferred, albeit at the cost of increased battery power consumption.

In order to illuminate a given l.e.d., a logic 1 must be present on the appropriate Port B output to drive the row. Likewise, a logic 1 must be present on the appropriate Port A output to drive the column.

For example, to illuminate l.e.d. D5 Green, both RB3 and RA1 must be set to logic 1. Other l.e.d.s in the same column can be either illuminated or extinguished depending on the logic states set for the remaining Port B outputs.

If, at any time, only one of the three Port A outputs, RA0 to RA2, is at logic 1 and the data on Port B corresponds to the column being driven, by sequencing the logic 1 through each of the Port A outputs, and at each step changing the data on Port B, the display is multiplexed, as illustrated in Fig.2.

If multiplexing is performed at a sufficiently high frequency, in this case about 250Hz, the resulting flicker produced is not apparent under normal conditions. (It might become apparent, though, if the game is moved around quickly, by shaking it from side to side, for example.)

In order to simplify the main program, display multiplexing is done under interrupt control, in the background. Because of this, Ports A and B are not written to from the main program. Instead, three variables, COL1, COL2 and COL3, are used to temporarily store the l.e.d. data between interrupt calls (see Fig.3).

Therefore, to illuminate l.e.d. D5 Green, for example, bit 3 in variable COL2 would need to be set high (logic 1), this value then being output to the relevant port line at the appropriate interrupt call.

Although not used for the game, it should be noted that yellow can be obtained by driving both the red and green diodes at the same time.

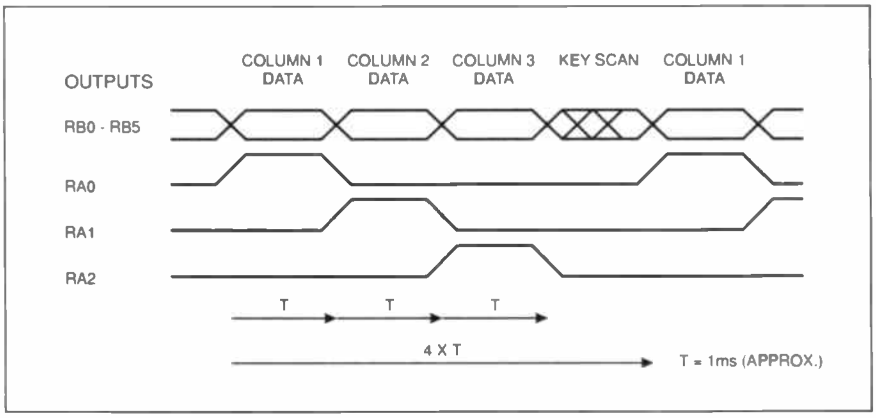


Fig.2. Display scan multiplexing.

Fig.3. Display store variables

BIT	7	6	5	4	3	2	1	0
COL.1	NOT USED		D7		D4		D1	
	0	0	G	R	G	R	G	R
COL.2	NOT USED		D8		D5		D2	
	0	0	G	R	G	R	G	R
COL.3	NOT USED		D9		D6		D3	
	0	0	G	R	G	R	G	R

LOGIC 1 = L.E.D. ILLUMINATED. LOGIC 0 = L.E.D. EXTINGUISHED.

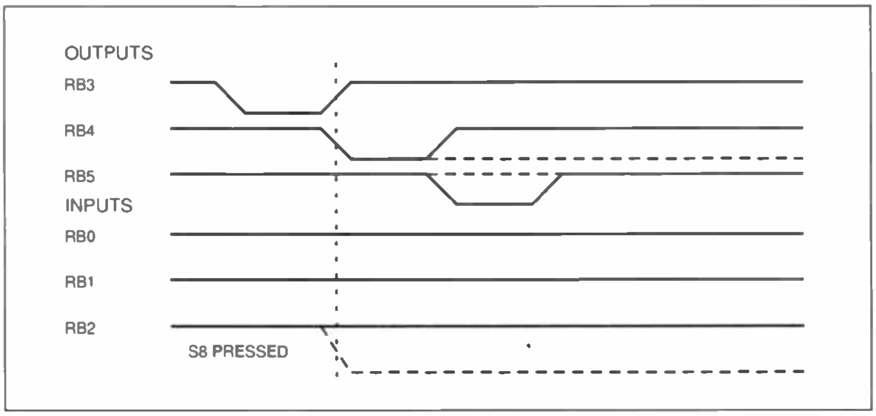


Fig.4. Keypad scanning.

KEYPAD

The game's keypad consists of nine normally open push-to-make switches, S1 to S9, which are connected to Port B in a 3×3 matrix. Each switch is located directly below the l.e.d. to which it belongs – S1 to D1, S2 to D2, and so on.

Resistors R10, R12 and R14 act as pull-ups to define the non-pressed key state (logic 1) on RB0 to RB2 when they are configured as inputs. Resistors R11, R13 and R15 are necessary to limit the current flowing from Port B I/O pins when they are all configured as outputs (during display scan) and one of the switches is pressed.

Just as the display is multiplexed, so too the keypad is scanned, but at a time when the display is not being driven (RA0 = RA1 = RA2 = 0), see Fig.4.

Keypad scanning is performed by strobing each of Port B outputs RB3 to RB5 in turn with a logic 0, and then reading the state of Port B inputs RB0 to RB2 to check if a switch in the strobed column is pressed. If a switch is pressed, the corresponding Port B input will be read as logic 0. If the switch is not pressed, a logic 1 will be read.

If switch S8 is pressed, for example, when output RB4 is at logic 0, input RB2 will read as logic 0.

The keypad scanning is also performed in the background as part of the display multiplexing, and hence is transparent to the main program.

Data about the pressed switch (S1 to S9) is passed to the main program through the variable KEY_VAL, with a flag to indicate its validity (switch bounce elimination is performed by the program).

Switch S10 is the reset to the microcontroller and is used to initialise the game.

POWER SUPPLY

The game is powered from four AA size (1·5V) cells serially connected as a 6V battery. With the voltage drop across diode D10 being approximately 0·7V, the game typically runs from a 5·3V supply. Diode D10 is included to protect the game from damage should the battery pack be connected the wrong way.

No power switch is provided on the game since its power consumption in standby mode is typically tens of microamps. You could install a switch if you preferred.

SOFTWARE HIGHLIGHTS

For a thorough understanding of the software, one should refer to the source code, which is fully commented. Details of how to obtain the source code and preprogrammed microcontrollers are given in *Shoptalk*.

Flow charts for some of the main features are shown in Fig.5a to Fig.5d.

In order to multiplex the display and scan the keypad in the background, the RTCC (real time clock counter) line in the microcontroller is configured to produce interrupts at approximately 1ms intervals. The period between these interrupts is determined by both the RTCC prescaler and the value loaded into the RTCC register during the interrupt service routine, see Fig.6 and assembly code routine in Listing 1.

An essential requirement for any interrupt service routine is that data in registers, such as WREG and STATUS, that is used by both the main program and interrupt service routine, is restored to the

FLOW CHARTS

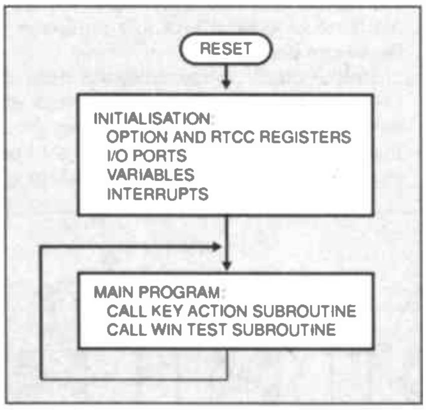


Fig.5a. Initialisation and main program.

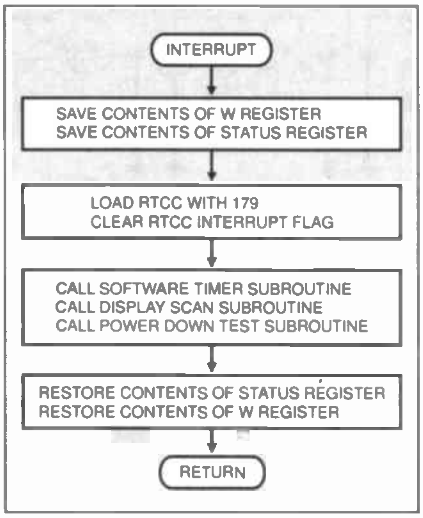


Fig.5b. Interrupt service routine.

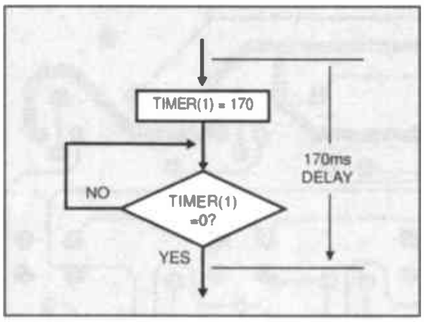


Fig.5c. Using software timers in main program.

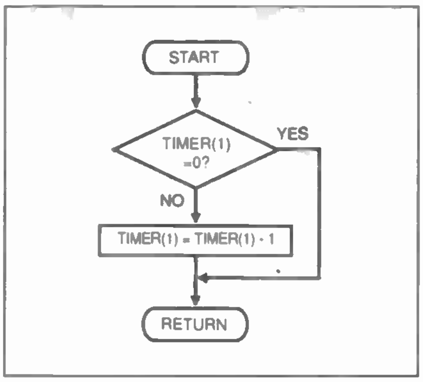


Fig.5d. Software timer subroutine (only one timer shown).

Listing 1: Interrupt service routine.

```
RTCC_INIT  equu     179          ; RTCC initialisation value
Int_Serv                         ; Interrupt service routine
           MOVWF    W_TEMP       ; store Wreg
           SWAPF    status,w     ;
           MOVWF    S_TEMP       ; store Status
           BCF      _rp0         ; select page 0
           MOVLW    RTCC_INIT    ;
           MOVWF    rtcc         ; initialise RTCC with init value
           BCF      _rtif        ; clear RTCC overflow interrupt flag
           CALL     SW_Timer     ; decrement software timers
           CALL     Disp_Scan    ; display scan control
           CALL     Pwr_Off_Tst  ; test if inactive and power off
           SWAPF    S_TEMP,w     ;
           MOVWF    status       ; restore status and page select
           SWAPF    W_TEMP,f     ;
           SWAPF    W_TEMP,w     ; restore wreg
           RETURN                ; return from interrupt service routine
```

pre-interrupt value on exiting the routine. This, of course, does not apply to registers used for passing data between the interrupt service routine and main program – software timers for example.

If this precaution is not taken, corruption of data and program control in the main program can occur. The first three and last four instructions of the interrupt service routine show how this is achieved in this application. It should be noted that the instructions chosen for performing the storing and restoration action do not affect the STATUS register.

The subroutine SW_Timer, which is called from the routine in Listing 1, provides a total of five software timers for use in the main program. One of the timers is used for controlling the flash rate when a winning line is detected, another for powering down the game after a 20 second delay.

The timers are 8-bit variables whose contents, when non-zero, are decremented each time the subroutine is called (see Fig.5d). Since the subroutine is called once every millisecond, time intervals can easily be measured in the main program (see Fig.5c).

It should be noted that not all timers are decremented every millisecond. Two of the timers are decremented every 10 milliseconds, and one every 100 milliseconds – this is how the longer time delays are achieved.

In essence, the subroutine Disp_Scan is a "state machine", with four states. Three of the states are for driving the display and the fourth for reading the keypad matrix. Each time the subroutine is called, the state is changed, and at the same time the data applied to Ports A and B is modified accordingly (see Fig.2).

MAIN PROGRAM

The main program contains two key modules, Key Action and Win Test (see Fig.5a). Key Action determines what happens when a key is pressed. Firstly, it checks to see if the l.e.d. is illuminated for the key pressed, and if not, illuminates the l.e.d. either red or green, depending on the status of the colour flag.

Each time a new l.e.d. is illuminated, the colour flag is toggled, thus alternating the colour for each valid key press.

WINNING DETECTION

Detection of a winning line is performed by the Win Test routine. In this routine, a series of simple logical tests are performed on the three column variables, COL1, COL2 and COL3. The tests are carried out in order of the columns, then the rows, and finally the diagonals.

On finding a winning line, the appropriate bits in the column mask variables, COL1_MSK, COL2_MSK and COL3_MSK, are set to indicate the win. These variables are then used to flash the winning line(s).

If a winning line is present in a column, the column variable will be equal to either 21 (Red win) or 42 (Green win). By testing for both numbers in each column variable, the presence of a winning line can be determined.

The following code shows the test for 21 in column 1:

```
                            ; NOTE x = red
                            ; o = green
; first test the columns . . .
MOVF       COL1,w       ;
XORLW      00010101B;
BTFSC      _z           ; test for x??
CALL       R_WIN_1      ;
```

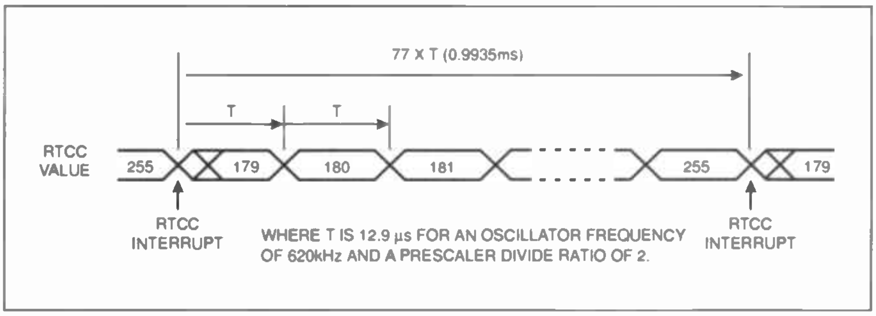


Fig.6. Internal RTCC interrupt timing.

If column 1 contains the value 21, the subroutine R_WIN_1 is called:

```
R_WIN_1   BSF    COL1_MSK,bit0
          BSF    COL1_MSK,bit2
          BSF    COL1_MSK,bit4
          RETURN
```

Testing of the rows is slightly more complicated, but not much. Firstly, a logical AND of the column variables is performed and the result stored in a temporary location. Then, each bit of the result is tested for the presence of a logic 1 which indicates a winning row, the row and colour being determined by the bit tested:

```
; ... then the rows ...
MOVF      COL1,w
ANDWF     COL2,w
ANDWF     COL3,w
MOVWF     COL_TST
BTFSC     COL_TST,bit0
CALL      R_WIN4
```

Checking of the diagonals is performed by testing the relevant bits which form a diagonal in each of the column variables. If all three bits of a tested diagonal are at logic 1 then the diagonal is a winning line, the direction and colour of the diagonal being determined by the bits tested.

```
; ... and finally the diagonals
BTFSS     COL1,bit0
GOTO      R_WIN8_TST
BTFSS     COL2,bit2
GOTO      R_WIN8_TST
BTFSS     COL3,bit4
GOTO      R_WIN8_TST
CALL      R_WIN7
```

Finally, the column mask variables are checked to see if any are non-zero, which would indicate a win. If a win is detected, the program enters a loop, which flashes the winning line. The flashing of the l.e.d.s is achieved by performing an exclusive-OR on the column variables with the column mask variables, COL1 with COL1_MSK, and so on.

Between each set of exclusive-OR operations there is a delay of 250 milliseconds. This delay determines the flash rate:

```
Toggle
  MOVF      COL1_MSK,w ;
  XORWF     COL1,f     ;
  MOVF      COL2_MSK,w ;
  XORWF     COL2,f     ;
  MOVF      COL3_MSK,w ;
  XORWF     COL3,f     ; toggle
                         winning
                         line/lines
  MOVLW     25         ;
  MOVWF     TIMER4     ; load Timer
                         4 with
                         250ms
Tog_Wait
  MOVF      TIMER4,f   ;
  BTFSS     _z         ;
  GOTO      Tog_Wait   ; wait for
                         250ms
  GOTO      Toggle
                       ; repeat
                         continuous
                         loop
```

CONSTRUCTION

For those with limited experience constructing and testing electronic circuits, the purchase of the printed circuit board (p.c.b.) is highly recommended. Although it adds to the overall component cost of the project, the time saved in construction and the expectation of the game working first time is certainly worth the extra money. The p.c.b. is available from the *EPE PCB Service*, code 165 and component layout details are shown in Fig.7.

Complete assembly of the p.c.b. should take no more than an hour, providing you have the right tools and all the components to hand. Since the electronics of the game is fairly minimal, the p.c.b. is a single-sided design. This keeps the cost of its manufacture to a minimum (no plated through holes) and provides those who wish, the option to make their own. The single-sided design, though, does require the use of zero ohm links (link wires!) – but these have been kept to a minimum in the design process.

Unlike other components, the links do not appear on the schematic diagram and have no reference names on the p.c.b. Instead, they are indicated by straight lines running between holes. Thinnish-gauge

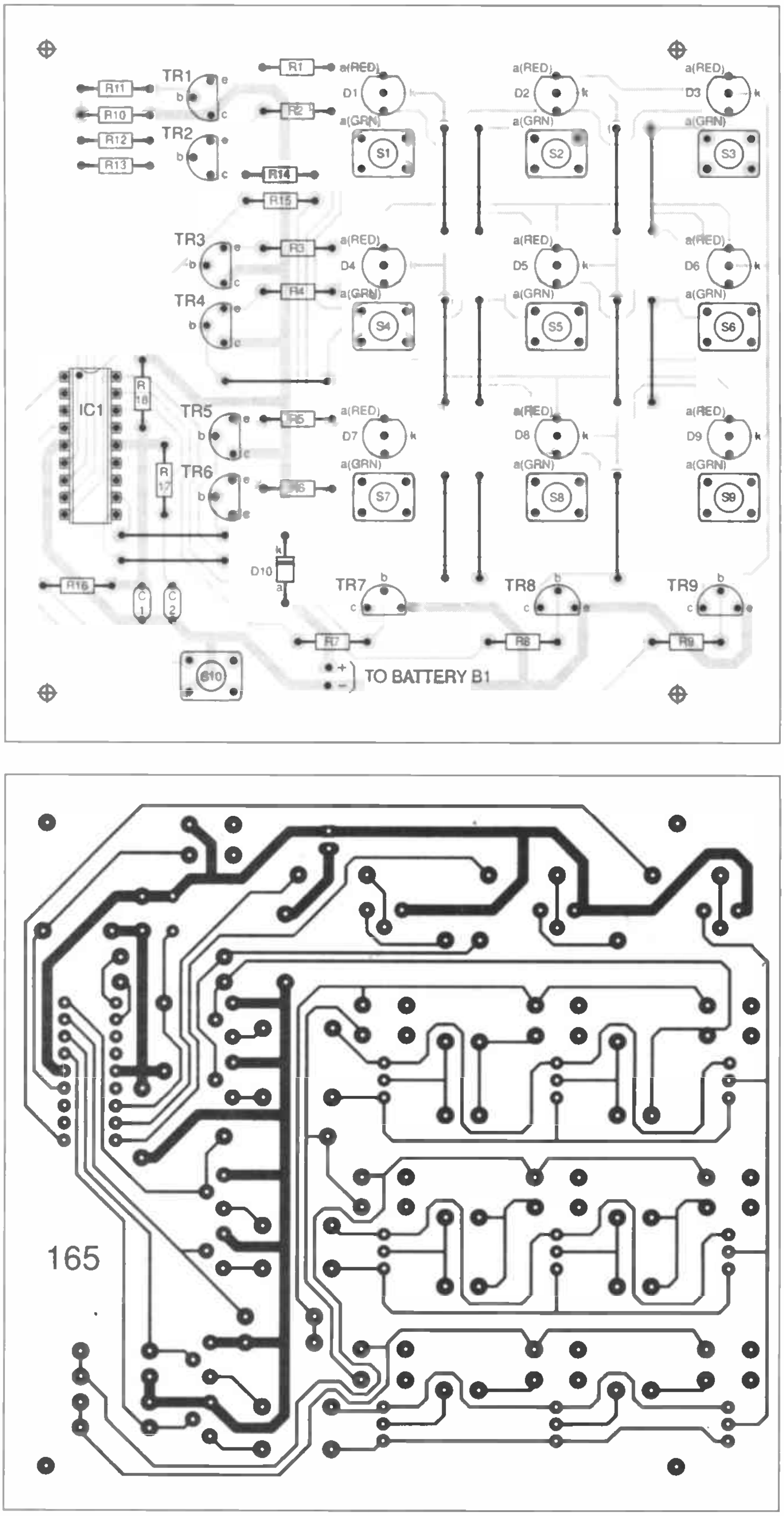
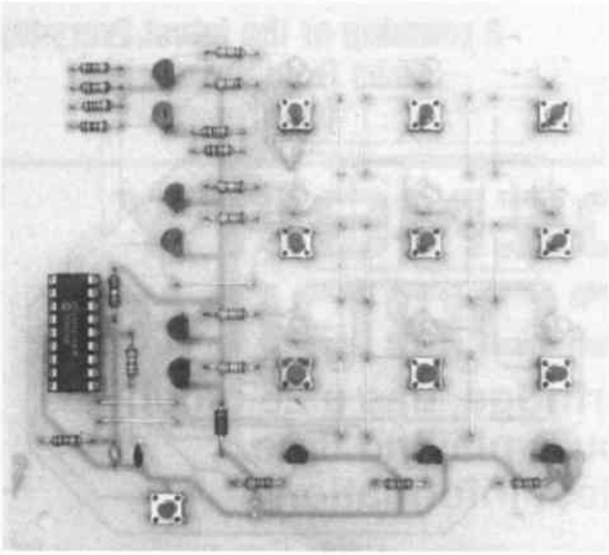


Fig.7. Printed circuit board component layout and full size underside copper foil master for the PIC Noughts & Crosses Game.



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

Table 1: Trouble Shooting

L.E.D.s do not illuminate
- ☆ Check batteries are fitted correct way in holder
- ☆ Check battery leads are soldered into correct p.c.b. holes
- ☆ Check diode D10 is fitted correctly
- ☆ Check IC1 is fitted correct way
- ☆ Check for solder bridges and dry joints around IC1
- ☆ Check correct values have been fitted for R17 and R18
- ☆ Check transistors are fitted correctly
- ☆ Check voltage between pins 14 and 5 of IC1 (above 5V)
- ☆ Check voltage between pins 4 and 5 of IC1 (should be above 5V, 0V when Reset switch is pressed)
- ☆ Check signal on pin 15 of IC1 – if you have an oscilloscope (should be a 150kHz square wave)
- ☆ Check signals on other pins as described in the text

L.E.D.s flicker and winning line flashes very slowly
- ☆ Check values of R17 and C2

Red/Green l.e.d. alternation not as expected
- ☆ Check l.e.d.s are all fitted in the same orientation

COMPONENTS

Resistors

R1 to R6	75Ω (6 off)	
R7 to R9	1k5 (3 off)	
R10 to R17	10k (8 off)	
R18	2Ω2	

All 0·25W 5% carbon film.

See SHOP TALK Page

Capacitors

C1	100n min. polyester
C2	100p polystyrene

Semiconductors

D1 to D9	tri-colour l.e.d. (9 off)
D10	1N4002 rectifier diode
TR1 to TR6	BC546B or similar *npn* transistor (6 off)
TR7 to TR9	2N2369A or similar *npn* transistor (3 off)
IC1	PIC16C84-04/P or PIC16C61-04/P pre-programmed microcontroller (see text)

Miscellaneous

S1 to S10	min. push-to-make switch (10 off)

Printed circuit board, available from the *EPE PCB Service*, code 165; 18-pin d.i.l. socket case 148mm × 138mm × 52mm, approx. (see text); AA size battery (4 off); battery holder, 4 × AA (long); connecting wire; solder, etc.

Approx Cost Guidance Only £26 excluding case

tinned copper wire should be used for the links – the off-cuts from the resistors will be suitable if long enough.

It is recommend that the PIC microcontroller is fitted last since it is a static sensitive device. Also, normal anti-static precautions should be taken at the time of fitting. The PIC should be fitted into a socket on the p.c.b.; *do not solder it*.

The sequence in which the other components are fitted is not important. However, the suggested method is: link wires, resistors, d.i.l. socket, switches, transistors, diode, capacitors, l.e.d.s.

When fitting the switches, it is important to make sure they are pushed fully home before soldering. This guarantees that the stems are all vertical and of the same height.

On the issue of height, the transistors should be pushed into the board as far as possible. If they are not, they may cause problems when trying to mount the assembled p.c.b. into its enclosure.

The mounting of the l.e.d.s will depend on how the game is to be housed, since they may need to be spaced off the board slightly. If the housing is not available at this stage of assembly, it would be wise to leave sufficient length on the leads of the l.e.d.s to allow for later repositioning.

When fitting the l.e.d.s, attention should be paid to the flat edge on both the l.e.d. and the layout in Fig.7. The tri-colour l.e.d.s (unlike "normal" l.e.d.s) will work fitted either way, but should all be fitted the same way in order for the game to operate as intended.

TESTING

Before connecting power to the board, it should be thoroughly inspected for shorts and poorly soldered component joints. At the same time, it is worth checking that the correct component values have been fitted in the right places.

Following on from the inspection and any necessary rework, the next step is to apply power. The game has been designed to run from four AA-size 1·5V cells, housed in a suitable holder, as specified in the components list.

The game should never be connected to a 9V battery. Doing so would cause the supply on the microcontroller to exceed its maximum rating of 7·5V, and this may cause permanent damage!

Once the battery holder has been connected to the p.c.b., the Reset switch (S10) should be pressed to ensure correct initialization of the microcontroller. If there are no problems, then pressing the matrix keys should cause the l.e.d.s to illuminate as intended. If not, the notes in Table 1 should be followed to help trace and rectify the problem:

Other problems that are not listed may be encountered. If so, the symptoms, along with the schematic, should be used to help determine the cause of them. It is important that a logical step-by-step approach is taken if the problems are to be resolved quickly. The chances are, though, that it will work first time.

CASING

As with all electronic constructional projects, the casing tends to be the difficult part. Whether you buy a suitable enclosure or make your own, the time taken to package the electronics will quite often exceed the assembly time of the p.c.b.

This is certainly true for this project. The more time that is spent during this stage of assembly, the better the finished product will hopefully look. The prototype enclosure, shown on the first page of this article, is home made. Basically, a wooden box with a metal plate on top, plus a few holes for the switches, l.e.d.s, and p.c.b. mounting points.

If cost is a concern, then this is by far the cheapest option for producing the game's enclosure.

Whatever your choice of casing, though (and an all-plastic casing would be fine), the accuracy of the hole drilling is fairly critical. It is suggested that you photocopy the life-size p.c.b. track pattern and use that as a drilling template, temporarily taped to the lid of the case.

GENERAL USAGE

Once the game has been tested and suitably packaged, the coffee table is possible its ideal location! It is sure to be a great hit with children, and adults, too, for that matter. Have fun!

SOFTWARE SOURCING

Pre-programmed PIC16C84 and PIC16C61 microcontrollers are being made available by the author for those readers who do not have the facilities to program these chips – see *Shoptalk* page.

Readers who wish to program their own PICs can obtain the software either on disk from the *EPE* editorial office or download it from our Web site (there is a nominal charge for the former, but the latter is free) – see *Shoptalk* page for details. The Web site files are in sub-directory PIC-NOUGHTS.

DEEPER DENSITY VIDEO RECORDING

Eagle, the new digital video cartridge, has a 26 gigabyte capacity and seven hours playing time. Barry Fox has the latest information

HOT on the heels of high density Digital Video Discs, Philips of the Netherlands will soon join with US computer companies Exabyte and Verbatim to launch a radically new, very high density digital tape recording system.

The system, called DigaMax, builds on the technology currently used by PC owners to back-up data from their hard discs onto industry standard QIC and Travan tape cartridges. But whereas these tapes have a capacity of only around one Gigabyte, the new cartridges, to be called Eagles, will store 13 Gigabytes, equivalent to twenty CD-ROMs. With compression, which reduces the storage space needed for repetitive data like spaces between text, Eagle's capacity doubles to 26 Gigabytes. The same cartridge can hold seven hours of high quality digital video, equivalent to five feature length movies on the new Digital Video Disc format.

As a bonus to consumers, the new Eagle drives will play back old QIC and Travan cartridges.

The high capacity of the new Eagle cartridges is thanks partly to work previously done by Philips for its ill-fated Digital Compact Cassette system, partly to JVC for the hi-fi sound system used with VHS and partly to completely new tape positioning and speed control techniques. The three companies wanted to avoid using the helical scan recording techniques normally used for video, because the rotary heads inflate the price.

In readiness for an official launch at the *PC Expo* exhibition in New York late in June, Exabyte prepared publicity material which reveals that DigaMax is seen as a direct competitor for D-VHS, JVC's new digital VHS video system. The technical specification for DigaMax was "driven primarily by digital video applications". Demonstrations given in Eindhoven recently proved that the system can play digital video with the same quality as DVD.

"DVD is still years away from low-cost, high capacity writable media, which eliminates it from broadcast recording or PC data storage", says the joint venture's publicity pitch. "D-VHS is being touted as the next-generation video recording technology, but its high price, large size and complex user interface are definite drawbacks in consumer electronic equipment . . . D-VHS suffers from the same limitations as analogue VHS, questionable reliability and an unfriendly user interface".

UNIVERSAL RECORDER

So "enter the universal tape recorder" which "will replace existing analogue VHS recorders, providing higher fidelity playback, lower cost and friendlier interfaces".

The new cartridge, which is similar in size to a thick floppy disc, contains 1000 feet (300 metres) of 8mm video tape. The tape is treated before sale by magnetically "embossing" it with a low frequency guide signal which is recorded deep in the tape's magnetic coating. Like the VHS hi-fi system, which records video and stereo sound at different depths in the same tape coating, DigaMax records the digital data over the guide signal and nearer the surface. The surface data can be read, erased and re-recorded without affecting the low frequency guide signal recorded below it.

The guide signal is read by servo control electronics in the Eagle drive and used to keep the recording and playback heads aligned with the tape. Alignment accuracy of one micrometre, one fiftieth the width of a human hair, is vital because the data is recorded on the tape in very narrow, parallel tracks.

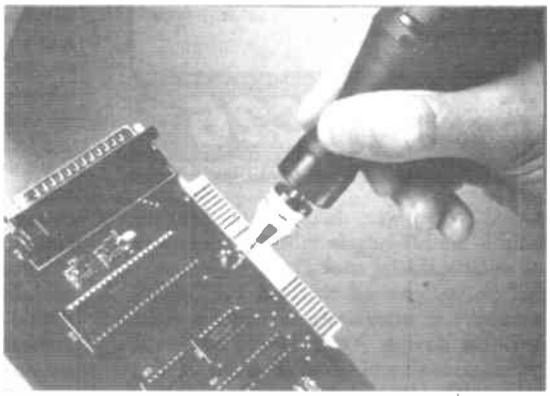
The data tracks are spread across the tape width, much like the parallel tracks used by the DCC audio system previously developed by Philips. The DigaMax recording heads are made like microchips, using a modification of the process used to manufacture DCC heads. The DigaMax heads simultaneously record eight parallel tracks as the tape runs.

When the tape has reached the end of its run, it reverses and the heads are mechanically stepped a small distance across the tape to record another eight tracks running in the opposite direction. At the end of this run, the tape reverses again and the heads step again. This happens 24 times to lay down a total of 192 parallel tracks, in groups of eight which follow a serpentine path 24 times along the tape length and back again.

RAPID SEARCHING

The Eagle drive can search out a selected passage of recording very quickly because the tape only needs to shuttle backwards or forwards by a short distance after the heads have stepped

MINI DRILLING



THE new P3 precision cordless tool from Minicraft is compact, versatile and seems ideal for all those small DIY and hobby tasks. The tool has plenty of power and torque to drill in wood, plastic, ceramics, glass and light metals, and to cut, polish, grind and engrave as well.

Its features include: 3 × NiMH 3.6V DC power; 9500 r.p.m. no-load speed; usage time approx. 35 minutes; keyless, 0.4mm to 3.2mm chuck; fan-cooled motor; twin ball-bearing drive shaft; 25 accessories; sturdy carrying case; overnight plug-in charger. It fits the Minicraft drill stand MB540.

For more information, plus a free catalogue and list of stockists, call Minicraft on 07000 646427238.

across the tape to the correct one of its 24 positions.

The international standard for MPEG-2 video recording was designed to make the best possible use of storage capacity by continually varying the recorded data rate to suit the picture content. More bits per second are recorded when there is motion in the pictures, than when images are static. With DVD, the disc speed remains constant while large and expensive memory chips temporarily buffer the data as it streams at different rates. DigaMax saves on memory costs by continually changing the tape speed to record data at anything between four and 16 megabits/second. Philips is making the Eagle drives which Exabyte will start selling in September for under $500. Blank tapes from Verbatim will cost around $20.

Philips recognises the issues of piracy raised by a $500 tape recorder which can make perfect copies of five DVDs on a blank tape which costs less than a single pressed disc. The company is already working on an image watermarking system which will let the Hollywood studios bury a tell-tale identification code in any data stream which leaves a DVD player. This will not stop people making copies but it will enable the copyright owner to prove the source of a copied tape.

High-speed Modem Muddle Looms

Barry Fox outlines the problem

PC USERS will soon be able to buy a new generation of modem which works at near ISDN data speeds on ordinary analogue phone lines but early adopters risk being left with an obsolete product. Rival research teams have developed different and incompatible technologies. Instead of waiting for the International Telecommunications Union to finish its work on setting a single standard, the rivals are selling their proprietary solutions in the hope of creating a *de facto* market standard before the official process is finished.

An ISDN line is designed to connect direct to a PC and carry a 64 kilobit/second stream of digital pulses. But they are very expensive; BT charges £400 to install an ISDN line and over £100 a quarter on rental. An ordinary analogue line, designed for speech, can only carry computer pulses if they are first converted into rapidly changing warble tones, like those heard from a fax machine. Background noise on the network limits the rate at which warble changes can be reliably detected, and this limits data speed to around 33·6 kilobits/second.

Much of the noise comes from the equipment used by telephone companies to convert analogue speech into digital code for travel down their long distance digital lines. This equipment works to a coarse 8-bit standard. Many large companies now bypass these coarse converters and connect their digital equipment direct to digital phone lines.

The signal still has to go through one converter, to change digital signals to analogue, before they travel the last leg of copper wire into a subscriber's home. But this digital-to-analogue converter adds very little noise.

FASTER INTERNETTING

The new modems take advantage of the fact that direct connection of digital equipment to digital lines makes the signal reaching the subscriber much cleaner. In theory it should be possible to send 64 kilobits/second downstream into the subscriber's home, but in practice 56 kilobits/second is the safe limit. With one of the new modems, a PC can use an ordinary analogue phone line to suck files from the Internet at near ISDN speeds but at a fraction of the cost.

The PC cannot send files back up the line at such a high speed, because the user's analogue line must still connect to the telephone network through a coarse and noisy analogue-to-digital converter. But most people want to receive large files from the Internet, not send them.

Lucent Technologies (which spun off from US phone giant AT&T and its Bell Labs) developed a proprietary system called V.flex2. Rockwell worked on the very similar K56Plus system. Last November the two companies pooled resources to promote a single system, now known as K56Flex. Leading modem maker Hayes has now backed K56Flex. So have Compaq, Hewlett Packard and Toshiba.

Hayes' main competitor, US Robotics, has developed a rival system, known as X2. Texas Instruments has backed X2 and is making chipsets.

The main difference is that whereas USR provides a return path of 33·6Kbps, Lucent, Rockwell and Hayes claim 45Kbps. This, and other coding differences, stops the systems working with each other.

PROVIDING THE MATCH

PC users can only use their new modems if their Internet Service Provider has installed matching equipment. It is impractical for ISPs to meet both standards. An ITU committee is now considering the rival proposals. But USR is not waiting. The company is now advertising modems which can be modified to work in X2 mode and cost only around £200. .

In what it describes as a "bold move", Hayes has now said that anyone who buys a Hayes modem before May, will get a free upgrade to 56/45K working. Anyone with an older modem, even a competitor's, can pay a trade-in price of between £99 and £149 for an upgrade or replacement.

Both groups say they hope that what they sell will be upgradeable to whatever standard the ITU finally agrees. But until the ITU decides, there can be no solid guarantee that consumers will not be left holding a non-standard modem.

PIC DATA CD-ROM

MICROCHIP have announced the release of the 1997 Technical Library CD-ROM, a complete selection of technical documentation on their PIC microcontrollers and allied products.

The CD-ROM contains an extensive collection of microcontroller product specifications, applications notes, development systems and software support for embedded control applications, programming specifications and more.

All documents are readable in Adobe Acrobat Portable Document Format (.pdf) and run under Adobe Acrobat Reader 3.0 (included *free* on the disk).

The user-friendly features in the CD-ROM are: applications note source codes, development systems demonstration software, cross reference to all CD-ROM documents, World Wide Web access from the main menu. In addition, Microchip's Home Page **(http://www.microchip.com)** hyperlinks users to the latest information on related products, third-party tools and services, and literature updates.

The CD-ROM is available through any authorised Microchip distributor worldwide.

Microchip's UK headquarters are: Arizona Microchip Technology Ltd., Unit 6, The Courtyard, Meadowbank, Furlong Road, Bourne End, Bucks SL8 5AJ. Tel: 01628 851077. Fax: 01628 850259. Web: as above.

Tektronix Signs Maplin

TEKTRONIX, the leading manufacturer of electronic test and measurement instruments (their 'scopes are widely regarded as being the Roll-Royce in this market) have announced a distribution agreement with Maplin.

Maplin will distribute a range of Tektronix portable instruments, including digital oscilloscopes and digital multimeters. They will be sold throughout Maplin's 43 UK shops and in the three Mondo superstores. They will also be featured in Maplin's catalogue.

Said Trevor Smith, UK Distribution Manager for Tektronix: "It will give our marketing efforts a big boost in the hobbyist and semi-professional market, where Maplin is the market leader."

Simon Peers, Product Group Manager at Maplin is equally enthusiastic: "Tektronix products offer unprecedented value for money by combining professional quality and performance with attractive prices."

ORGAN MUSIC

Organ built by EOCS member Wilfred A. Sawyer.

FOR 40 years the Electronic Organ Constructors Society (EOCS) has been the mouthpiece and earpiece of those who delight in building electronic organs. Some of us on *EPE* have been aware of them for at least 30 years; probably longer!

Older readers will probably recall them from the days when music projects made up a hefty chunk of several electronics magazine's constructional armory, including *EE* and *PE* before we both combined forces to become *EPE*. Remember such classics as Alan Douglas's *Electronic Organ* and Doug Shaw's *Minisonic Synthesiser*?

Consequently, it's good to receive confirmation of their continued existence, and indeed of their continued *thriving*. How good, too, to see that Alan Douglas is still associated with them. This confirmation has come to us through the arrival of their latest *Electronic Organ Magazine*, number 162. It's the first we have seen for a long time.

The magazine's new editor (pro-tem), Don Bray, tells us that the aims of the EOCS are the same as they always have been – to serve as a mutual forum for anyone interested in electronic organs and their construction.

If such is *your* interest, give Don Bray a call on 01323 894909, or write to him at 34 Etherton Way, Seaford, Sussex BN25 3QB. He also has a fax: 01323 492234. Tell him that *EPE* told you about EOCS!

Pooling DVD Patents

Barry Fox reports

Philips, Pioneer and Sony have pooled all their patents on Digital Video Disc. The move follows the breakdown of negotiations between all ten members of the DVD Consortium on pooling all DVD patents and providing manufacturers with a one-stop licence shop. The three-company pool will charge a royalty of 3·5 per cent on the player, and five US cents per disc.

Even the Philips/Pioneer/Sony pool is not complete. DVA, Discovision Associates, owns a whole folio of patents on all aspects of optical recording which last into the next century. Although Pioneer owns DVA, DVA will issue its own licences separately.

So any manufacturer wanting to make DVD players must negotiate with the Philips/Pioneer/Sony pool, with DVA, with the seven other companies in the DVD Consortium, with a US company called MPEG LA which administers the patents on MPEG compression, and then with whatever other companies claim to hold key patents on other aspects of optical recording which are vital to the DVD system.

FREE AMATEUR RADIO LICENCES

AMATEUR Radio Licences became free to all users under the age of 21 from 1 July 1997. Welcoming the move by the Radiocommunications Agency, Technology Minister John Battle said: "The Agency has taken this step to encourage more people into amateur radio. Radio, in its many forms, has made a massive impact this century on all aspects of our life. We should do all we can to help young people develop an interest in one of the key technological areas for the next century."

For further information contact Radiocommunications Agency on 0171 211 0158.

RADIO RALLY

THE 3rd Northampton Radio Rally and Car Boot Sale takes place on Saturday 6 Sept. '97 at the Heart of the Shires Shopping Village Showground, on the A5 just two miles north of Weedon. There is a bring and buy sale as well. For more details, Tel: 01604 32478.

A YEN FOR THE OLD

APPARENTLY the Japanese are well into collecting ancient British audio equipment. According to the *Financial Times*, woofer and tweeter fans now pay more than £3500 for Fifties-style amplifiers with valves.

Dorset-based electronics specialist Stuart Perry is one of those who are exporting the equipment to Japan, though his company Beam-Echo.

Amazing, isn't it, yesterday's obsolescence yet again becoming today's collectables. Throw nothing away and you'll make a fortune!

POOLING PCB COSTS

BETA Layout Ltd. has established Ireland's first p.c.b. pooling service. The aim is to offer customers a cost-effective solution to their prototyping needs.

Several designs are placed together on a multi-panel and the set-up and tooling costs are shared by the participating designers. Standard delivery time is 15 working days, although a fast turn-round service of five to seven days is also offered.

For more information, contact Beta Layout Ltd., 6 College Grove, Ennis, Co. Clare, Ireland. Tel: 353(0)6566500. Fax: 353(0)6566514. Web: **http://www.pcb-pool.com.**

NEW SHAREWARE CD ROM

PDSL, the Public Domain and Shareware Library tell us that their new Scientific and Technical Library CD ROM is a library of hard to find scientific, technical and specialist working programs. The 639 megabytes of data contains 1,476 applications, the largest selection to be found anywhere on the market, say PDSL.

This CD ROM is intended for the technical and scientific user who does not want to wade through thousands of games or other unrelated software while looking for the scientific software needed.

The disc contains virtually all available technical scientific shareware programs for DOS and Windows. It also gives vast amounts of specialist source code and utilities. It comes with HTML indices to make topic searching easier for you and there is a function description for every program.

We know from personal experience that some excellent software is available inexpensively (free in some cases) from PDSL. This CD ROM costs £21 and appears to be well worth obtaining.

PDSL have also released a new CD ROM in the *Libris Brittania* series, version 6. It contains over 1800 Public Domain and Free-ware programs requiring no fee for personal use, many including source code. Priced at £10, this is a great way to obtain fee-free programs.

For further information, contact PDSL, Dept EPE, Winscombe House, Beacon Road, Crowborough, E.Sussex, TN6 1UL. Tel: 01892 663298. Fax: 01892 667473.

RAISING THE PRESSURE

ANDY FLIND

The RC4190 switch-mode device is ideal for boosting supply voltages.

THERE are often occasions where a circuit designer needs a voltage greater than that available from the supply. Two typical examples are in battery powered circuits and digital equipment where the only supply available may be 5V, but a 12V rail is needed for an analogue addition.

The common methods of increasing voltage are capacitor and diode "charge pumps", "flying capacitor" integrated devices, such as the Siliconix SI7660 or the Maxim MAX665, and switch-mode DC-DC converters. The capacitor-based circuits are simple to design but limited performance makes them suitable only where a few milliamps of current are needed.

Switch-mode power supplies are more versatile but their design is sometimes considered to be something of a black art. Recently, the introduction of "simple" dedicated switch-mode i.c.s has improved this situation.

SWITCH-MODE PRINCIPLE

The principle of the switch-mode step-up converter is shown in Fig.1. Switch S1 opens and closes repeatedly. When it is closed, the supply voltage appears across inductor L1 and a current builds up in it, storing energy in the process as a surrounding magnetic flux.

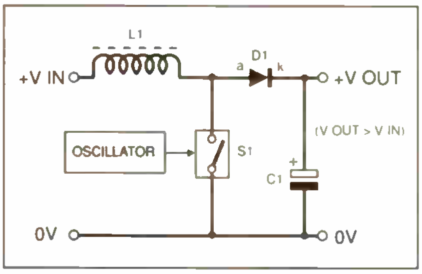


Fig.1. Principle of switch-mode step-up circuit.

When S1 opens, this flux collapses, causing the current to continue to flow through L1 and diode D1 into capacitor C1. As most readers will know, an inductor can produce a high voltage to sustain current flow during flux collapse, so, by repeatedly closing and opening S1, a voltage much higher than supply V_{in} may be generated across C1.

In practice, the switch is usually a transistor, and feedback is normally provided to control the output voltage to a value chosen by the designer. This often works by reducing the "on" time of the switch during each oscillator cycle so that the total energy stored in the coil is equal to the energy required from the output.

RC4190 SWITCH-MODE DEVICE

The Raytheon RC4190 switch-mode i.c. works in this way, and is particularly suitable for battery-powered circuits as it has a quiescent current of less than 0·5mA. A simplified block diagram of the internal structure of this i.c. is shown in Fig.2, together with the pin connections for the 8-pin d.i.p. (dual-in-line package) version.

Although the RC4190 can be used for voltage reduction (step-down), the step-up application will probably be of interest to most potential users. The basic circuit for this, together with practical component values, is shown in Fig.3.

In Fig.3, capacitor C2 sets the oscillator frequency, resistor R1 supplies a "bias" current for the internal voltage reference in the i.c., and resistors R2 and R3 provide feedback to the internal comparator to set the output voltage.

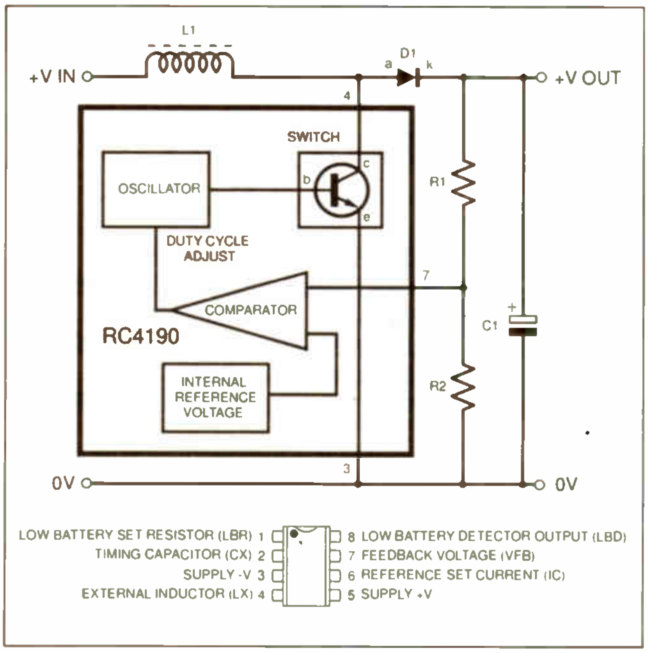


Fig.2. Internal structure of the RC4190 switch-mode i.c., together with pin function information.

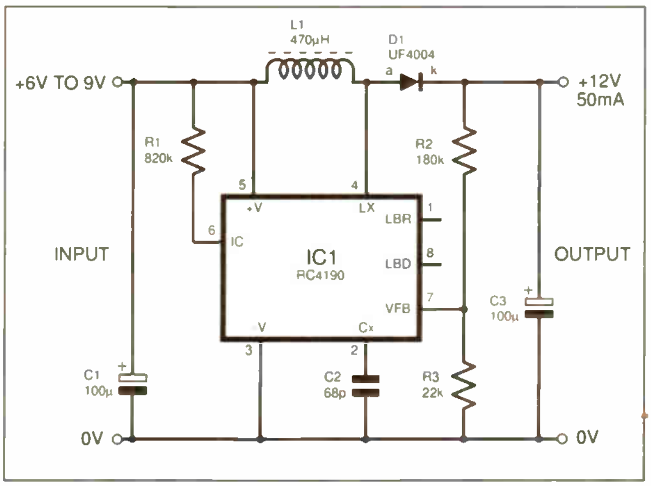


Fig.3. Basic circuit diagram for the step-up voltage application using the RC4190 switch-mode i.c.

Selection of component values can be tricky, especially for capacitor C2 and inductor L1 as both influence input and output voltages and the output current. There is also a maximum current rating of 375mA for the internal switch transistor, which should not be exceeded.

The procedure suggested by the manufacturer's data sheet involves selecting an operating frequency and then calculating the corresponding inductance, but this usually turns out to be a value unavailable "off-the-shelf". The calculations are also fairly complex, so a more simple method is called for.

COMPONENT CALCULATION

The author has devised two methods for selecting component values for this and similar switch-mode devices. The first is simple and can be carried out quickly with a calculator. A couple of design factors are ignored so the results are not precise, but they should suffice for most designs.

The second method involves use of a spreadsheet. Many readers will have computers and will therefore be familiar with such software, and the sheet shown in Table 1 is compact and simple to enter, in fact it was developed on the tiny screen of a Psion Series 3a.

The simple method begins with selection of input and output voltages and output current. These calculations should always be made for "worst-case" conditions, that is, for the lowest expected input voltage and highest required output current. With a 9V battery the lowest input might be 6V, after which the battery would normally be replaced.

The output power required from the inductor can then be calculated. As some of the output comes directly from the supply, the amount that must be supplied by the inductor can be calculated as:

$$P_{in} = (V_{out} - V_{in} + V_{diode}) \times I_{out}$$

where V_{out} is the output voltage, V_{in} is the supply voltage, and V_{diode} is the forward voltage drop across diode D1, typically about 0·6V.

It follows that (disregarding losses) the input power to the inductor is equivalent to this, so the average input current is given by:

$$I_{in} = \frac{(V_{out} - V_{in} + V_{diode}) \times I_{out}}{V_{in}}$$

In worst-case conditions, the "switch" should be on for about half of each oscillator cycle. As the inductor current builds up in a linear fashion, the average current is about quarter of the maximum value, so the peak inductor (and switch) current can be calculated from:

$$I_{max} = \frac{(V_{out} - V_{in} + V_{diode}) \times I_{out} \times 4}{V_{in}}$$

If I_{out} is entered in milliamps, I_{max} will also be in milliamps. Its value should be checked against the 375mA maximum allowed for the switch. If it is greater, an external power device will be required; this will be covered later.

Values of frequency and inductance are now required that will result in this value of current being reached. It should be noted that higher output requires less inductance and/or a lower operating frequency, so that more current can build up in the inductor.

It might be thought that half the frequency, which would result in half the pulses of twice the current, would result in the same overall output. However, the power is proportional to the *square* of the current, so it would actually be doubled.

For any two particular values of I_{max} and V_{in} there are various possible combinations of frequency and inductance, but their product, $f \times L$, will always be the same. If this is called K, then it can be calculated as:

$$K = \frac{V_{in}}{(2 \times I_{max})}$$

K can then be divided by a frequency to find the corresponding inductance, or by an inductance to find the frequency. To further simplify this process, I_{max} can be entered in mA and the formula multiplied by 10^6 as follows:

$$K = \frac{V_{in} \times 10^6}{(2 \times I_{max})}$$

The values of L and f can then be entered or read directly in kHz and µH.

Possible operating frequencies range between 1kHz and 75kHz, but for efficiency practical circuits will probably run between 10kHz and 50kHz. To recap on the complete process:

1. Choose values for the lowest expected supply voltage V_{in}, the highest required output current I_{out}, and required output voltage V_{out}.

2. Calculate maximum inductor current from:

$$I_{max} = \frac{(V_{out} - V_{in} + 0{\cdot}6) \times I_{out} \times 4}{V_{in}}$$

Check this does not exceed the switch limit of 375mA, or use an external device for switching.

3. Calculate a constant K from:

$$K = \frac{V_{in} \times 10^6}{(2 \times I_{max})}$$

then use this for selecting operating frequency or inductance, using K/L or K/f (where I_{max} is in mA, L is in µH, f is in kHz).

4. Calculate values for the remaining components as follows:

Capacitor C2 is given by $2400/f$

where f is in kHz and C2 is in pF (i.e. 20kHz requires 2400/20 = 120pF).

Resistor R1 should supply a bias current of about 5µA into pin 6, which has a potential of 1·2V. Its value is therefore:

$$R1 = \frac{(V_{in} - 1{\cdot}2)}{5 \times 10^{-6}}$$

The feedback divider resistors R2 and R3 should have a standing current of 50µA to 100µA. Since pin 7 normally has a potential of 1·31V, this means that R3 should be 18k or 22k. R2 can then be calculated from:

$$R2 = \left(\frac{V_{out} \times R3}{1{\cdot}31}\right) - R3$$

Decoupling capacitor C3 will usually be between 10µF and 470µF, a value of 100µF will be more than adequate in most designs. Capacitor C1 will usually be somewhere between 100µF and 470µF, again it is a decoupler and its value is not critical.

INDUCTOR AND DIODE CONSIDERATIONS

Most of the components are non-critical with regard to type but, for efficient operation, inductor L1 and diode D1 must be suitable for this application. Good inductor performance is especially vital.

The two main sources of loss here are through winding resistance and leakage of magnetic flux. A simple rule-of-thumb is that the inductor should consist of thick wire on a large chunk of ferrite!

Table 1: Spreadsheet layout. (Columns D and F are set to display no decimal places.)

	A	B	C	D	E	F
1	V in	<enter value>				
2	Freq (kHz)	<enter value>	I max (mA)	=B11*1E03	C1 (pF)	=2400/B2
3	L (uH)	<enter value>			R1 (k)	=(B1-1.2)/5E-03
4	V out	<enter value>	I out (mA)	=B13*1E03/(B4-B1+B5)	R2 (k)	=B4*F5/1.31-F5
5	V diode	<enter value>			R3 (k)	<enter value>
6	V switch	<enter value>				
7	t-off (uS)	<enter value>				
8						
9						
10	t-on	=1/B2/2000+B7*1E-06	(seconds)			
11	I max	=(B1-B6)*B10/B3/1E-06	(amps)			
12	Joules	=B3*5E-07*B11^2				
13	Watts	=B2*B12*1E03				

Tiny wire-ended 1mH chokes (recommended by one supplier for use with the RC4190) should be avoided as they are very inefficient. However, for small currents, tiny ferrite bobbin-type inductors work surprisingly well.

Some coils tried by the author and found satisfactory include the "low current radial lead" r.f. chokes from Electromail, the higher current versions (part numbers 228-517 to 228-545) giving much better performance than the low-current ones.

Maplin's 1mH "general purpose axial lead inductor", UM13P, works well in designs needing this value. These and most other component suppliers list larger bobbins and toroids which should give even better performance where space is not at a premium. Most circuits will need a value of inductance between 100µH and 1mH.

Diode D1 must be a Schottky or similar fast-recovery type, such as the 1N5822 or the UF4004. The slow reverse recovery of the standard 1N4000 types makes them totally unsuitable for this application.

IGNORED FACTORS

For simplicity, this calculation method ignores two factors that should really be included. One is the saturation voltage of the switch, quoted as about 0·5V, though for small currents it will be less.

The other is the switch "turn-off time", stated to be about 5µs. This effectively increases each "on" period which raises the switch current. The effect increases with frequency and can be quite substantial, but modifying the frequency/inductance formula to include it resulted in considerable complexity.

If a spreadsheet is used, these factors can be included and also made easily adjustable so that calculations may be made for other switch-mode i.c.s.

SPREADSHEET METHOD

The layout and formulae for a simple spreadsheet used by the author is shown in Table 1. This works as shown on the *Microsoft Works* sheet, and also on the Psion Series 3a and MC400 providing the "^" (raise to a power) in cell B12 is altered to "* *". Minor modifications may be required for other sheets.

Input values are placed in cells B1 to B7 and F5 (R3). Typical inputs and resulting outputs are shown in Table 2, which can be used to check that the formulae have been entered correctly.

The sheet works by calculating input wattage, assuming this will be the output wattage, and calculating the maximum output current for the given output voltage. The peak switch current I_{max} is displayed along with values for R1 (use next lower preferred value), R2 and C1.

In practice, different values of frequency and inductance are tried until the required output current is obtained, whilst keeping an eye on I_{max}, then the component values can be tried in a practical circuit.

The output in most circuits tested was found to be about 20 per cent lower than the calculated value, probably due to efficiency losses, so allowance should be made for this.

EXTERNAL DEVICES

There are two cases where an external switching device is needed with this i.c.

The first is where I_{max} will be exceeded. If this is the case, ignore it in the calculations and use an external power device which can handle the increased current.

A useful alternative is to use a CMOS i.c. for inversion and provision of active drive to a power MOSFET output device. Although a trifle expensive, the low drive power, high speed and good reverse breakdown characteristics of MOSFETs make them better for this application than bipolar types.

The IRF740 and IRF840 have both been found to give good results, others may be even better. When choosing one, look for a low "on" resistance. Various devices can be used for the inversion.

CMOS BUFFERING

For the smallest size, an ICM7555 (CMOS) timer can be used as shown in Fig.4, where it acts as an efficient inverter/driver with a useful Schmitt action. Note the use of a "pull-up" resistor R2, needed because the switch transistor in the RC4190 cannot source current.

Several of the 4000B series CMOS i.c.s can be used, so long as the arrangement

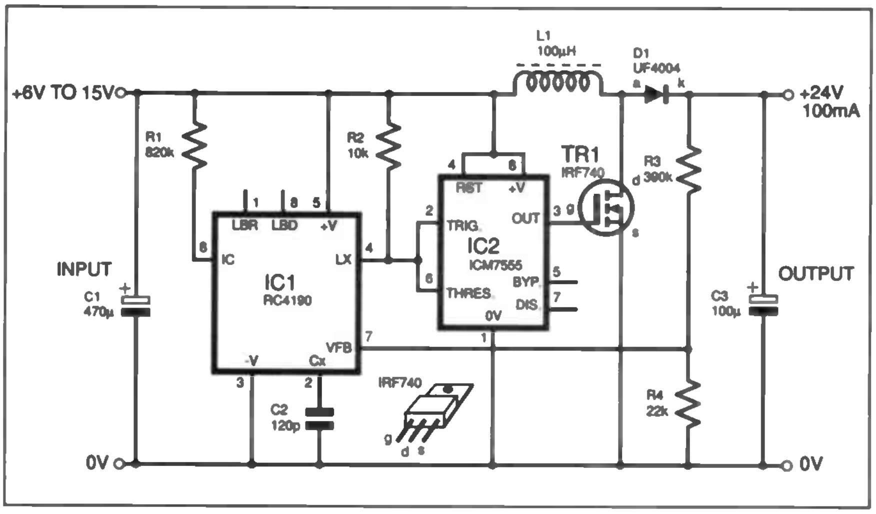


Fig.4. Circuit diagram for producing a 24V step-up using a CMOS 7555 timer and a power MOSFET.

The second is where the required output voltage is greater than about 30V. This is the collector breakdown voltage of the internal switch transistor, but, with suitable external switching, it is easy to reach 80V or even a 100V at a few milliamps.

Pin 4 cannot directly drive an external switch since most suitable devices invert the phase of the drive, requiring the addition of phase inversion to correct this. Transistors can be used for inversion and output, but the values of associated resistors have to be low to ensure rapid switching and this raises current consumption.

used inverts the signal. Connecting the outputs of several gates together gives increased drive power for the capacitance of the power MOSFET gate.

One version using a 4070B quad exclusive-OR gate is shown in Fig.5. The internal structure and pinout details for the 4070B are given in Fig.6.

Gate IC2a is connected as a non-inverting buffer, driving the remaining inverting gates in parallel. This circuit is capable of supplying 80V at 10mA with an efficiency of about 80 per cent. The inductor used by the author was a tiny ferrite bobbin. The gates can be connected in any order, as convenient.

Whilst the value of 1·3 megohms (1M3) for resistor R3 is a standard value, it could also be made up using 1MΩ and 330kΩ resistors in series.

Table 2: Typical inputs and resulting outputs spreadsheet.

V in	6				
Freq (kHz)	35.5	I max (mA)	223	C1 (pF)	68
L (uH)	470			R1 (k)	960
V out	12	I out (mA)	63	R2 (k)	180
V diode	0.6			R3 (k)	22
V switch	0.5				
t-off (uS)	5				
t-on	1.90845E-05	(seconds)			
I max	0.223329338	(amps)			
Joules	1.17209E-05				
Watts	0.416090472				

FINALLY

An optional battery monitoring facility is provided in the RC4190. If the voltage at pin 1 drops below 1·31V, pin 8 will become active and sink current up to about a milliamp. The input to pin 1 can be a simple potential divider and the output can be used for various purposes, an l.e.d. warning circuit being one obvious application.

It is hoped that these design methods will simplify calculations and enable less

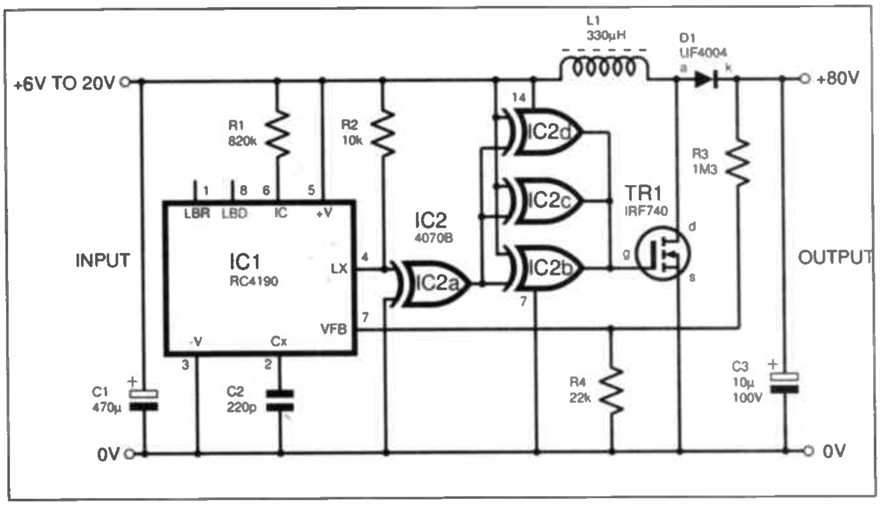


Fig.5. Circuit diagram for producing a 80V step-up by adding a 4070B quad exclusive-OR gate and power MOSFET.

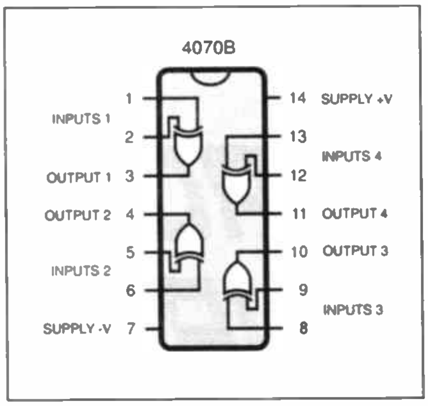


Fig.6. Internal structure and pinout details for the 4070B XOR i.c.

experienced designers to begin using this switch-mode device and similar ones in designs of their own.

The micropower RC4190 is just one of several "simple" switch-mode devices available. There are a number of others in small wire-ended packages capable of higher powers and voltages, and in some cases the oscillator frequency is internally fixed so their circuits are even simpler. These calculation methods should work just as well for these types.

READOUT

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

NZ PICS THE NET

Dear EPE,

Your *Net Work* page really makes *EPE* a versatile magazine and takes hobby electronics to new heights. Living in New Zealand meant that in the past I had to obtain free software from *EPE* at reasonable expense using the postal service. Now it's literally moments away and at a fraction of the price.

I have become very interested in the PIC micros made popular by *EPE* and have constructed Derren Crome's *Simple PIC16C84 Programmer* of Feb '96. What I feel will also really help beginners in the microcontroller field are some very simple and short learning examples that take readers step by step through learning how to write programs for the PIC. Would it be possible to publish a PIC Programming Tutorial?

Glen Nordin, New Zealand, via the Net

Our Web site is being accessed from around the globe and many readers (including those who only learned about us via the Web itself) are benefitting from our software FTP facility.

You will be pleased to know that I am in the middle of writing a detailed step-by-step tutorial on how to program PICs. Lots of readers have made this request. It is to be published as a series of practical articles – more details soon! JB

DOES THE CAP FIT?

Dear EPE,

I have experienced difficulty in obtaining the 1µF 16V tantalum capacitor specified for one of your projects. I can only buy higher voltage ones. What can I do?

Terry Birmingham, Romsey, Hants

You know now, of course Terry, since we replied to you directly. But your query is of interest to other readers so we include it here.

As far as the voltage is concerned, the value quoted is the minimum voltage that it should be. There is no problem about using a higher voltage-rated part. Generally speaking, this is true in the vast majority of cases. You can nearly always use a passive component with a higher voltage rating than that specified, providing of course, it will physically fit in the space available.

However, never use a component that has a voltage rating lower than that specified unless you are sure that the replacement has a rating that is at least one and half times that of the potential across which it will be placed. Some power supply components need to have even greater "head-room".

The type of situation that might arise is that the designer of a project may have used an electrolytic capacitor of say 1µF 63V in a circuit run at 5V. This value may have been the only one available to him from his supplier. Another supplier may only have 1µF 16V devices; another might have them at 6·3V. We nearly always quote the component voltage ratings supplied to us by authors.

Both the 63V and 16V devices are perfectly acceptable for a circuit powered at 5V (unless voltage boosting is being employed somewhere along the route that the capacitor will be placed). The 6·3V capacitor might *be OK, depending on where it's placed, but it should not be subjected to the 5V power line voltage if there is any possibility that surges or faults might take this voltage higher.* JB

HISTORICAL SHORTS

Dear EPE,

I add my hearty endorsement to the correspondence praising simpler, shorter projects. However, perhaps P. Price, the original correspondent on the subject, has missed the salient point, which is that 25 years ago we could choose between buying *Everyday Electronics* as light, simple, entertaining, hobbyist reading, and/or we could buy *Practical Electronics* for more meaty stuff. Naturally, the merger of *EE* [and] *PE* into the one publication *EPE* removed customer choice and the editorial policy eased out the *EE* style content.

In our business, we constantly meet customers whose knowledge of electronics is not matched by their interest, who do not have, or want, web addresses and whose ambitions do not include building some digital gizmo for which it is necessary to purchase a specially programmed chip! These people seem mostly to have tried *EPE*, found it to be pitched at too high a level and stopped taking it.

CPD, Stowmarket, Suffolk

All of us at EPE *were greatly involved with* PE *and* EE *and intimately know their histories and philosophies. The sad fact is that "market forces" ultimately caused the merger into the single title (with a few chunks of interesting "history" in between). In the hey-day of hobbyist electronics a situation existed that was somewhat different to that prevailing now.*

Following the pre-war establishment of Practical Wireless and its continued post war success, PE *was introduced in '64, and subsequently* EE *in '71; three sisters parented by IPC Magazines, each meeting the needs and capabilities of hordes of readers in a market craving for technology, and electronics in particular.*

During the mid '70s (and explaining it in very simplistic terms), two major situations began to emerge: the introduction of computers and a change in public attitude towards technology. Both factors drew people's interests away from electronics and the market declined. This situation was not aided by the recurrent recessions when magazine readership in general began to decline with the increase in people's uncertainty about job security and the need to economise.

By '86 all three sister magazines had become separate entities under different owners. The market continued to decline, and then in '92 PE *was taken over by* EE*, to become* EPE*. (Did you know that we also acquired ownership of the title* Electronics Monthly *– formerly* Hobby Electronics *– some years ago?) The readership of both titles had be catered for, hence the editorial policy which exists now. But we recognise that the balance between readers at both the* PE *and* EE *ends of the spectrum needs retuning from time to time.*

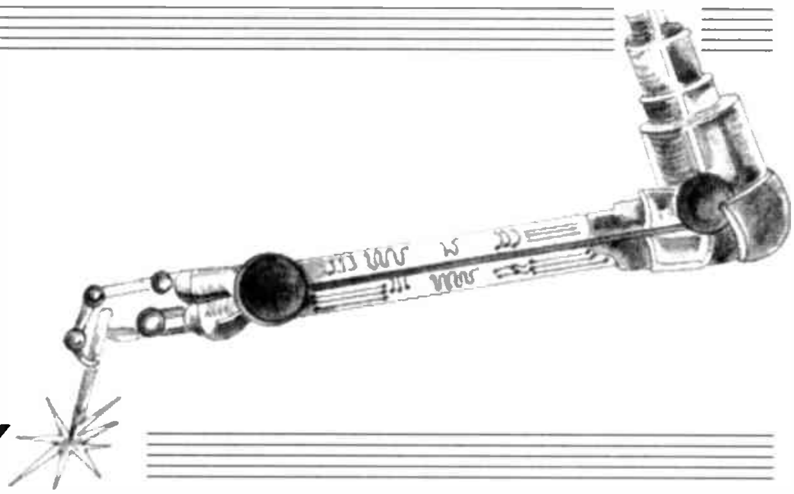
We believe that we can, and do, provide all readers with a magazine that meets their needs in terms of project simplicities/complexities, education, interest, news etc. Such series as Teach-In, Build Your Own Projects, Circuit Surgery *and* Ingenuity Unlimited *are extremely popular at one end of the spectrum. At the other end we know too, in various ways from p.c.b. sales to letters received, that the more complex projects are welcomed, and we have been very gratified with the enormous interest shown in all the PIC projects.*

Nonetheless, we do "sound-out" what readers think and take action accordingly. We had enormous feedback from our survey of last year and it has proved beneficial. The correspondence currently being received about the subject is also of great interest to us.

The electronics hobbyist market has stabilised and we are the leading publication catering to it. Although the national attitude towards science and technology seems to be one that is less prepared to enquire into the subjects than it used to be, at last Government(s) appear to be recognising that public awareness and participation in them should be encouraged.

Those of you involved in electronics, at whatever level, are a privileged group: electronics in its various forms has become the driving force behind society; you *are the ones who are intent on making your own contribution to it. Good luck to all of you, we shall do our*

CIRCUIT SURGERY



ALAN WINSTANLEY

This month, our team of surgeons helps a Bat Group to keep a count on some furry, flying mice! We describe methods of detecting direction of movement – a tricky problem!

AS EXPLAINED a month or two ago, *Circuit Surgery* is attempting to include a wider variety of queries which are now coming our way from all levels. We're grateful to the staff at the Department of Electronic Engineering at the University of Hull for volunteering to join in the fun and lend a hand: we promise an ever-wider field of interest, and something we hope which will appeal to everyone.

You may find that the material we include is more in the form of outline suggestions or "pointers" rather than fully-sorted circuits. At times, it simply isn't feasible to produce a completely debugged, 100 per cent functional circuit "to order" but we certainly hope that readers will be inspired to experiment for themselves and refine some ideas, using some of the data and information suggested here in *Circuit Surgery*.

Holy Bat Counters!

One deceptively-simple sounding problem which requires a lot of electronic ingenuity is that of directionally-sensitive counting – using an electronic circuit to count an event which occurs in one direction, but not the other. This problem could apply to, say, a "people counter" used across the doorway of a night-club, to check the actual number of customers within the club at any one time. Perhaps a football club would find this useful, too, in an attempt to gauge the total attendance at a match. Or, which way is that robot arm moving?

Here's an interesting query from ***Dave Williams*** of Kidsgrove, Stoke-on-Trent.

I work for the Staffordshire Bat Group, and I'm working on a twin-beam counter which I would like to use to count bats into and out of a roost.

My suggestion consists of two counters and two infra-red beams which are mounted side-by-side, separated by 20 to 30mm. They are placed across the exit and the distance between the light-emitting diode emitters and the photodiode receivers will vary from 20 to 75mm.

I am having difficulty obtaining IR l.e.d.s with a narrow enough beam to allow the photodiodes to receive their signal only from the appropriate l.e.d. The other more serious problem is the logic circuit needed to advance the counter depending on whether the bat is entering or leaving the roost. Both beams will be broken on every occasion but only the "first" beam each time should be used to pulse the appropriate counter.

I'm having great problems finding a circuit to accomplish this. I'd be very grateful for any help.

Ian Bell, of the Department of Electronic Engineering, University of Hull, suggests a possible solution to this batty headache! (Bats, for the benefit of overseas readers, are a highly protected species in the UK, with four-figure penalties being imposed for unauthorised interference with a bat colony.)

The problem here is that the beams from the l.e.d.s are not narrow enough to be focused onto only *one* of the detectors. This could obviously be solved optically if a narrow-angle beam can be obtained, but this will make the mechanical arrangement of the l.e.d.s much more critical.

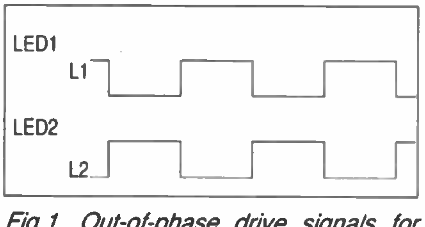


Fig. 1. Out-of-phase drive signals for two infra-red emitters.

An electronic signal is possible if the two signals from the l.e.d.s can be distinguished at the sensors. A couple of approaches spring to mind: we could switch the l.e.d.s. so that only one device is on at a time using two out-of-phase clocks (see Fig. 1).

The signal can then be passed to the receiver so that the sensor signal is only "used" when the corresponding l.e.d. is being driven. The pulsing of the l.e.d.s must be fast enough so that they are switched on and off a number of times, in the fastest time taken for a bat to fly through the beams. Logic placed after the sensors can then determine which beam is being broken, and provide a stable (i.e. non-pulsed) indication of the state of each sensor. A block diagram of this is shown in Fig. 2a.

The two infra-red emitters are toggled alternately using a flip-flop (F/F1) and a separate "sync" is sent to the receiver side. This is used to synchronise the decoding of the two signals and provide a "detected" output.

In the circuit idea of Fig. 2b, on the negative going edge of the clock signal, F/F1 toggles state and selects one of the emitters. The appropriate sensor is then sampled by the next positive clock edge by using either F/F2 or F/F3.

The timing diagram of Fig. 3 shows what happens when beam number one is broken part way through the example. Note that when IR Beam 1 is broken, both sensors (S1, S2) receive the L2 signal but the sampling clocks C1 and C2 look at the sensor signals at different times, so that the detected outputs D1 and D2 are correct.

There is some delay from the beam being broken, to detection being indicated. This is not important if the clock period is much faster than the transit time of the bat flying through the beam.

Another possible solution could be to pulse the l.e.d.s at different frequencies and use filters in the sensor circuits to isolate the signal from the appropriate l.e.d. (Fig. 4). The filters could be a narrow pass band which would amplify signals resulting from the appropriate l.e.d., and reject signals from the other. Two advantages of this approach are that the sensors would be less sensitive to changes in ambient light, and also no wiring is required between the emitter/transmitter and sensor/receiver parts of the system.

Direction Finder

The second part of the overall problem concerns *the determination of the direction* in which the bat is flying through the infra-red beams, and counting correctly as a result. I'm assuming that the physical set-up is such that the bat breaks *both beams* when it's half-way in or out of the roost, as this makes direction sensing easier.

Consider the digital signals obtained when a bat enters (Fig. 5a) and exits (Fig. 5b). You'll see that the signal pair from the detectors (D1/D2) goes through two different sequences: 00 10 11 01 00 on entering the roost, and 00 01 11 10 00 when leaving.

We could build a fool-proof circuit to detect these complete sequences, but there's altogether a much simpler – if not quite so fool-proof – technique. Take one of the signals as a reference, say D1. Now check the logic level of D2 *when D1 changes from 0 to 1*. It is logic 0 when the bat enters and logic 1 when it leaves. It is possible to use a positive edge-triggered D-type flip-flop, with the clock wired to D1 and the D input to D2, to indicate the direction, by generating a logic 0 or 1 at its Q output. See Fig. 6 – it suddenly becomes very easy when you compare the D1/D2 waveforms with those shown in Fig. 5.

Having obtained the "direction" information, we also need a signal to say "count". We can use the edge of D1 to clock a counter, as long as we delay it by

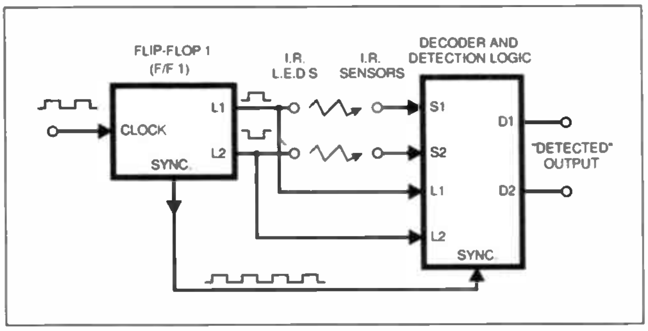


Fig.2a. Block diagram to detect direction of bat flight.

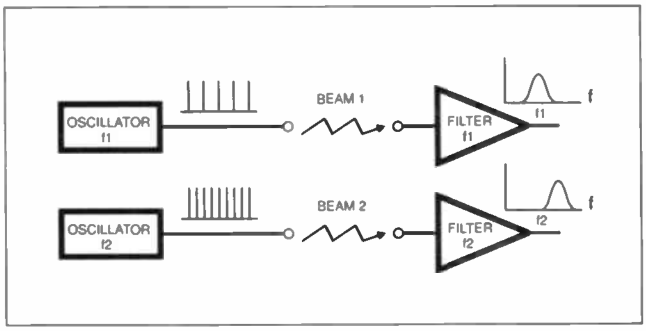


Fig.4. Alternative frequency-sensitive discrimination system.

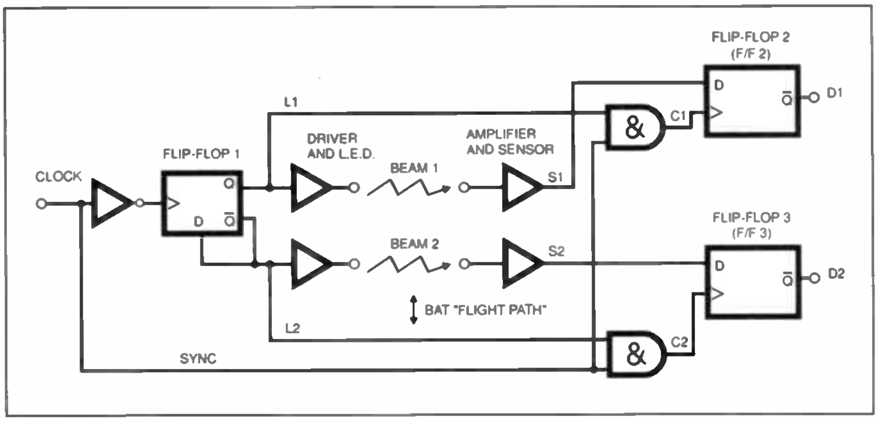


Fig.2b. Suggested outline circuit for direction/detection system.

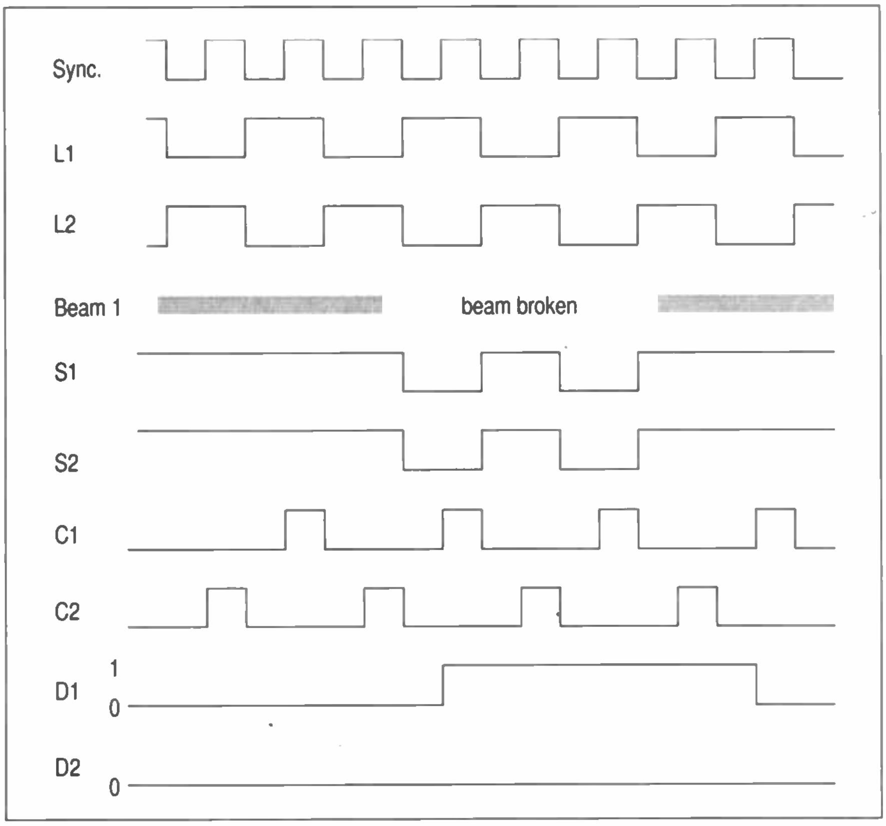


Fig.3. Timing diagram for suggested direction-sensitive detector. When IR Beam 1 is broken, both sensors (S1, S2) receive the L2 signal.

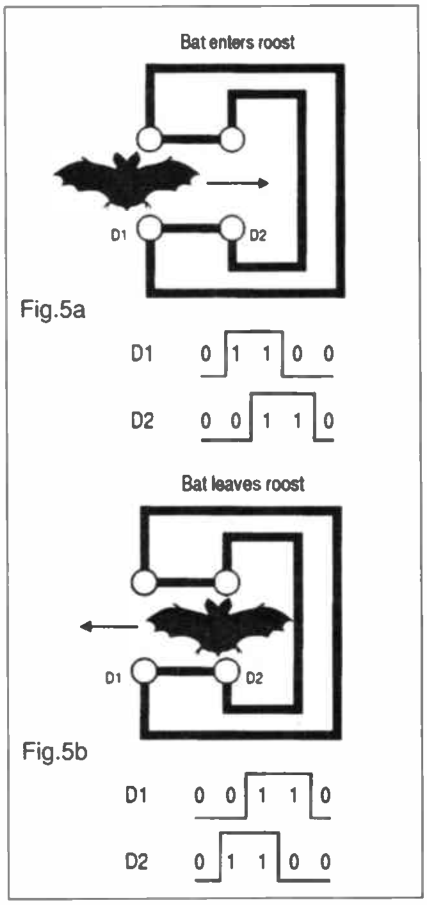


Fig.5. Direction signal outputs generated when a bat breaks each beam when entering or leaving the roost.

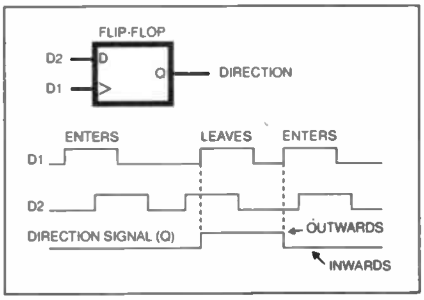


Fig.6. Direction signal logic waveforms (see also Fig.5).

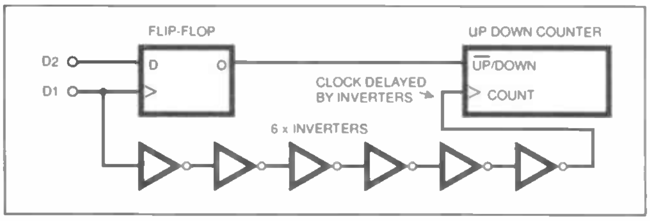
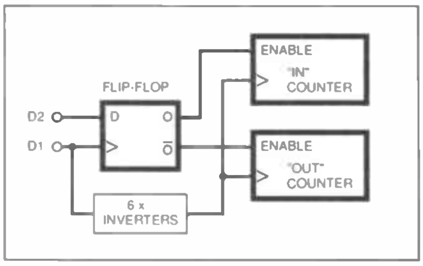


Fig.7a. Introducing a time delay with a series of inverters, to ensure the up/down signal occurs before *the count.*

Fig.7b (right). Driving two separate counters for Bat-In and Bat-Out counts.



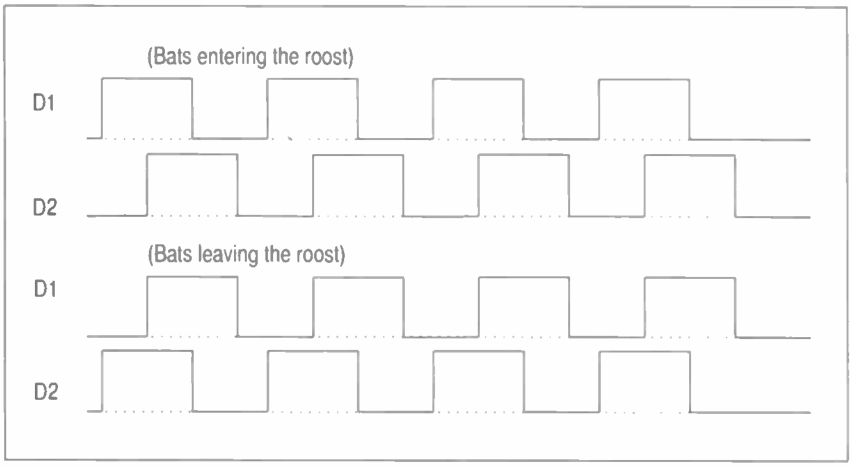


Fig.8. Quadrature signal depends on the direction of rotation of movement detected.

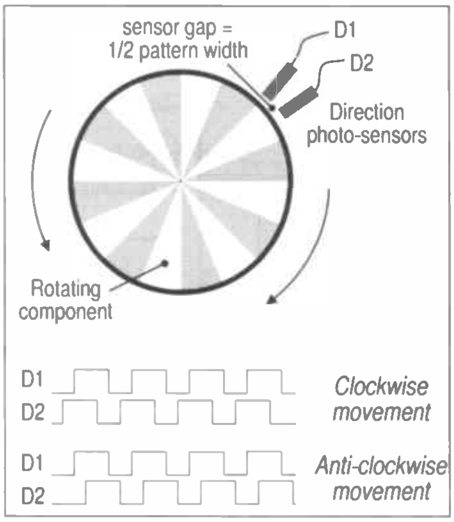


Fig.9. Sensing the direction of rotation of a rotating mechanism, e.g. a robot arm.

a period longer than the flip-flop takes to store the "direction" value.

A somewhat unofficial way of doing this is to place several inverters in series, to take deliberate advantage of their propagation delays, as shown in Fig. 7a. If you would like to have separate "in" and "out" counters then the "direction" logic signal can be connected to the counter's enable inputs, Fig. 7b.

As I said, the circuit is simple but not fool-proof! If a clever bat sat and popped its head in and out at the entrance, breaking a beam, the counter would advance but no bat would have entered the roost. We're safe provided that we assume that bats don't behave like that, though it may be undesirable in other directional counting applications.

False counting may also occur if the string of inverters is still not sufficient to slow down the D1 signal, especially if a particularly slow flip-flop is encountered. Another potential headache is that any glitches on the detect signals will get counted.

Robo-Bats

All of these problems can be overcome by a suitable integrated circuit, and indeed the Hewlett Packard HCTL-2000 is a CMOS device which is specially made for this type of application.

Now, you'll be wondering why on earth HP make a chip which counts bats! They don't, but in actual fact the directional counting problem is a common one which occurs in a number of industrial situations, such as monitoring the position of a robot arm.

Consider the signals which would result when several bats entered or exited from the roost, one after the other (Fig. 8). These are two square waves phase-shifted by +90° or −90°, depending on the direction. This is known as a *quadrature signal* and it can be utilised to monitor the movement of a mechanical part, e.g. a robotic arm or an optical shaft encoder.

For example, consider a rotating joint on a robot arm. If we fit an alternating reflective/non-reflective pattern on the fixed part and a couple of opto-sensors on the moving part, so that the opto-sensors are separated by half the width of the pattern sections, we will obtain a quadrature signal when the arm moves.

This is most easily understood by looking at diagram Fig. 9. Each time the outputs from the sensors changes, the direction of movement can be determined by looking at the "direction" of change and the state of the other sensor.

The HCTL-2000 does this and increments or decrements a 12-bit up-down counter. If the maximum speed of the mechanical part is known, then the minimum pulse width of valid signals on the inputs can be calculated. The HCTL-2000 also contains a simple Schmitt-trigger digital filter which rejects pulses that are too short to be valid inputs.

The pinouts for the chip are given in Fig. 10. The two sensor inputs from the quadrature-encoded source are presented to Channel A (pin 7) and Channel B (pin 6) which are Schmitt-trigger inputs. Sampling is controlled by a clock signal at pin 2.

Based on the "history" of the binary signals compared with their present state, the device outputs a count and direction signal to its own internal position counter.

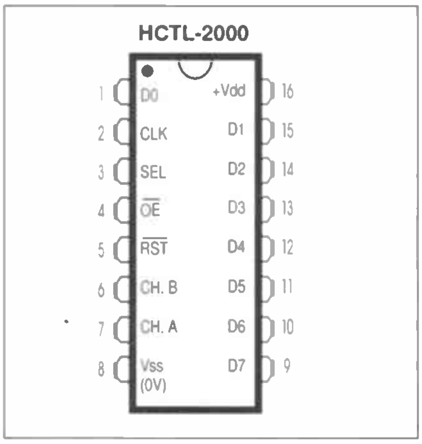


Fig.10. Pinout details for the HCTL-2000 interface i.c.

The pins D0-D7 are TTL-compatible tri-state outputs which form an 8-bit wide output that can be used to count with.

It's beyond the scope of this column to show application circuits but for those who are interested and would like to experiment further, the data sheets and device are available from Farnell Components (Tel. 0113 263 6311, Order Code 407-471, price £14.83 excl. V.A.T.)

Thanks for a very interesting question. Ian Bell, University of Hull.

We're back down to earth next month.

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.** A personal reply cannot always be guaranteed but we will try to publish representative answers in this column.

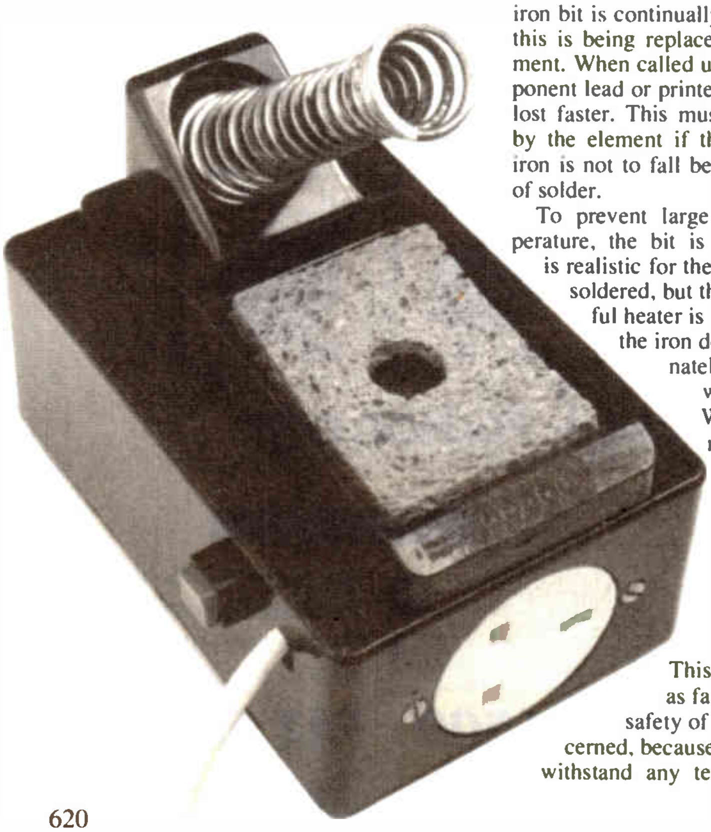
SOLDERING IRON CONTROLLER

BART TREPAK

Here's a cool cure for a hot problem, though it's not for beginners.

THE soldering iron is perhaps the most indispensable piece of equipment that any electronics enthusiast possesses. Without it, even the simplest of circuits would be impossible to build or repair.

The basic instrument consists of an insulated heating element, usually rated at between 15W and 25W, which heats a copper bit that is shaped to allow maximum contact with a component lead or printed circuit board track to enable solder to be melted. An insulated handle with a mains cable terminated in a 3-pin mains plug completes the assembly. What more could one want?



BASIC PROBLEMS

This simple tool is, of course, quite adequate even for the serious hobbyist. But, as with most basic designs, it has limitations which only become apparent when the device is used. First, there is the question of what to do with the iron when it is on but not actually in use. A hot soldering iron is not something which you can safely leave lying around on the kitchen table or even a workbench.

Then there is the problem of preventing the iron overheating when it is in this stand-by condition. When it is in use, and even if it is not actually melting solder, the iron bit is continually loosing heat, though this is being replaced by the heating element. When called upon to heat up a component lead or printed circuit track, heat is lost faster. This must be rapidly replaced by the element if the temperature of the iron is not to fall below the melting point of solder.

To prevent large fluctuations in temperature, the bit is made as massive as is realistic for the component size to be soldered, but this means that a powerful heater is required to ensure that the iron does not take an inordinately long time to heat up when first switched on. With temperature controlled irons, the power fed to the element is controlled to combat heat fluctuations, but with ordinary irons it means that the iron will run rather hot when left in a stand-by condition.

This is not such a problem as far as the element or the safety of the instrument is concerned, because these are designed to withstand any temperature which the element is likely to reach. But too high a temperature can result in poor solder joints because the flux in the solder is burned off before it can do its job.

It can also seriously reduce the life of the soldering bit and with iron plated bits now almost universally fitted in place of the plain copper ones, this can be both annoying and expensive.

FORGETFULNESS

Perhaps the most infuriating feature of the basic soldering iron is the absence of an indicator lamp to show that the unit is on. Many people, no doubt, share the author's experience of returning to the work bench after a period of some hours, or sometimes even a weekend, to find the soldering iron has been left on for all that time.

At a consumption of 25W, this is not exactly something which will cause anyone to wind up in the bankruptcy court, but it is still a waste of energy and can do nothing for the environment, especially if added to all the other items of equipment which are sometimes left on needlessly.

As well as this, it is also often discovered that the bit has been ruined and a replacement has to be ordered which results in a few more days delay before the iron can be used.

Most seriously, an unattended soldering iron is a potential fire hazard as it could come into contact with papers on a cluttered bench or be knocked over by a pet or even a child.

Many of these limitations are rectified in the more advanced models and some even have a microprocessor to not only control the temperature to within a fraction of a degree of that selected, but to display it as well.

Unless the iron is to be used "professionally", it is unlikely that the associated price tag of such instruments can be justified by the hobbyist who may only use the soldering iron occasionally and would probably feel that the money would be better spent on a better multimeter, or even on components.

IRON STAND

The first problem is easily solved by purchasing a stand which is designed to hold the iron safely when not in use. These are available at reasonable prices from most component stockists.

They usually consist of a sturdy base (the higher the price, the sturdier the base) and a metal spiral into which the hot iron is inserted. The manufacturers claim that they are also designed to prevent the iron from overheating. To a certain extent they probably do, but they seem to have little effect on the frequency with which bits need to be changed, especially if the iron is sometimes accidentally left on overnight.

SIMPLE SAVER

This problem of overheating was initially solved by the author using a very simple circuit which, in terms of aggravation and money saved against cost, he considers to be probably his top scoring circuit of all time.

Consisting of a rectifier diode and a microswitch, it can be built for less than the price of a new soldering iron bit and since building the unit some three years ago, the author has not had to replace a bit once.

The basic set-up shown in Fig. 1 consists of the microswitch and rectifier diode in parallel, and connected in series with the soldering iron element. Using a soldering iron with a hook attached enables it to be hung on an arm which operated the microswitch in such a way that when the iron is in use, the rectifier is shorted out, allowing full power to reach the element.

After a soldering operation, when the iron is replaced on the arm its weight causes the microswitch to open, re-introducing the rectifier into the circuit and effectively halving the power to the element, which therefore runs cooler. There appears to be no noticeable delay in the bit reaching a working temperature when the iron is removed, although it does take slightly longer to heat up initially.

WHAT A SAVE!

Unfortunately, this design would win no prizes from the Health and Safety Executive, as the author can readily attest: on one occasion, he absent mindedly replaced the iron on its arm after completing a tricky soldering operation but missed the hook.

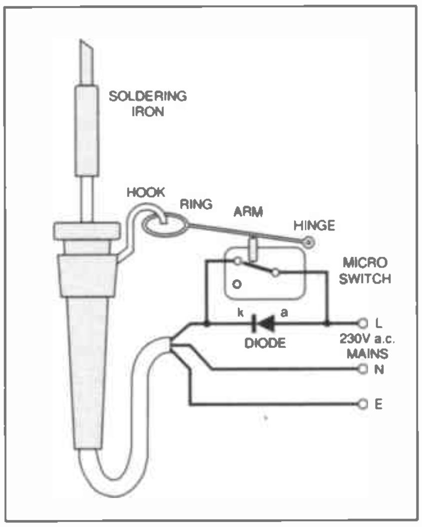


Fig. 1. The author's original bit-saver idea.

"Lightning fast reactions", as he puts it, "saved" him (he thinks that's the right word!) because he managed to catch the iron before it fell to the floor and burned a hole in the carpet – by gripping firmly on the hot element!

This experience forced a re-examination of the above arrangement and, while about it, the design of a circuit to overcome the other major problem with many soldering irons, namely, that of accidentally leaving them on for extended periods.

BACK TO THE DRAWING BOARD

It was decided to replace the arm and hook arrangement and make use of the recommended stand for the iron, but no position could be found to ensure that a microswitch would operate reliably when the iron was replaced.

A magnet/reed switch arrangement was also considered, using a small magnet mounted on the iron and a reed switch on the stand, but this was also discounted for much the same reasons.

Luckily, however, soldering iron manufacturers go to great lengths to ensure that the soldering bit and, indeed, the sheath which houses the element, are well earthed. This enabled a purely electronic solution to be found to this problem as illustrated in Fig. 2.

where a separation of perhaps even up to a few centimetres will suffice.

Because this circuit is connected directly to the mains, great care must be taken to ensure that the current resulting from touching the input is limited to a harmless value, and this is done by the total resistance of the R1 chain.

The resistor chain limits the current to about 20µA and consists of three resistors for safety, since the breakdown voltage of "normal" quarter watt (0.25W) resistors is usually 250V d.c. A chain of just two resistors would appear to provide adequate voltage protection against the mains a.c. supply, but the failure of one of these resistors could cause a dangerous voltage to appear on the spiral.

As an extra safety measure in the final circuit, one of these resistors is connected "off the board" directly to the spiral. This ensures that even if the other end of the resistor were to be connected to the wrong point in the circuit by mistake, the spiral would still be safe to touch although the circuit would obviously not work.

To convert the voltage across resistor R3 to a steady d.c. level for further processing, capacitor C1 is fitted as shown. The voltage at the emitter of TR1 will therefore rise to almost the d.c. supply voltage when the soldering iron is in its stand. It will fall to zero as the capacitor discharges via R3 when the iron is removed.

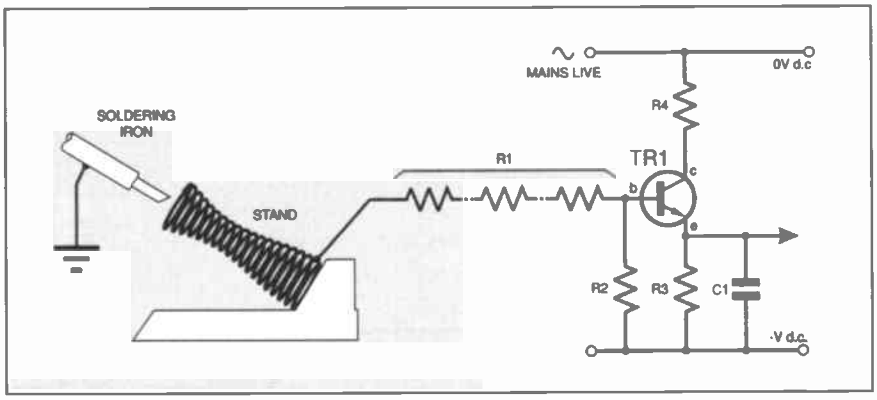


Fig. 2. The basis of a more sophisticated bit-saver.

THE SOLUTION

As shown in Fig. 2, a resistor chain (R1) is connected between the spiral spring of the soldering iron stand and the base (b) of transistor TR1. Through resistor R2, the emitter (e) of TR1 and resistor R3, there is a current path to the common negative d.c. line (Mains Neutral).

The circuit is powered from a d.c. supply, the positive terminal of which is also connected to the mains Live terminal. In this condition, TR1 will be cut off and the voltage appearing across R3 will be zero.

If, though, an earthed object (notably the soldering iron) is brought into close (inductive) proximity to R2, then, because TR1's emitter is at 230V a.c. with respect to this, the transistor will turn on each time that the emitter goes negative. This condition occurs during the negative mains half cycle and results in a voltage appearing across R3 during this time.

By changing the value of resistor R2, the sensitivity of the circuit may be adjusted from minimum, where the transistor will just turn on when the soldering iron touches the metal spiral, to maximum

CONTROL BLOCK

With a stand-by/in-use signal now available for the status of the iron, the rest of the circuit can be designed as shown in the simplified block diagram of Fig. 3. The rectifier diode in the original circuit of Fig. 1 has been replaced by a triac which allows full or half power to be switched to the element. This is achieved by triggering the triac either continuously, or only during alternate mains half cycles, or, indeed, switching it off altogether.

The heart of the system is a digital timer which is reset and held in this state each time the soldering iron is removed from its stand. In this condition, the output of the timer is high so that the AND gate is enabled and the triac will be triggered whenever the output of the half-wave/full-wave switch is high.

The output status of this stage depends in turn on the polarity of the mains signal and the output of the soldering iron detector. The switch status will be high if the output of the detector is high. It will alternate between low and high when the detector output is low (OR function).

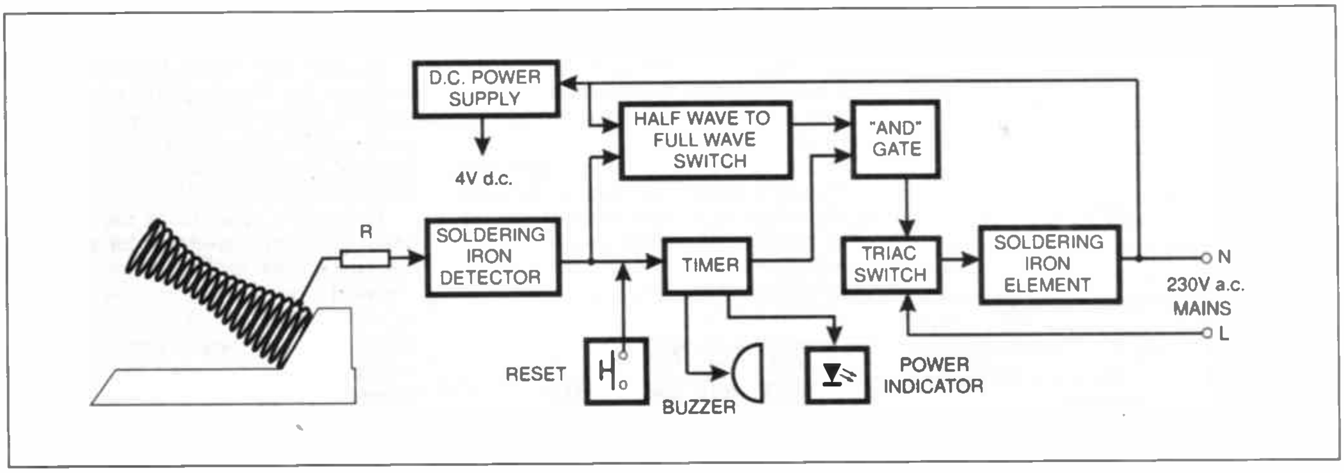


Fig. 3. Block diagram of the final Soldering Iron Controller.

The triac, therefore, will be switched on continuously (full power) when the iron is removed from its stand. When it is replaced, the triac will be switched on only during the positive mains half-cycle.

FUNCTIONAL CIRCUIT

The circuit to perform the functions in the block diagram is shown in Fig. 4. The various blocks can be easily identified, bearing in mind that due to logic considerations, both the OR and the AND functions are implemented using NOR gates.

The timer is built around a CMOS 4060 oscillator/divider whose outputs (Q4, Q8 and Q14) are low when the chip is reset. This means that, initially, point D is also low due to the action of diodes D1 and D2 and resistor R10.

Simultaneously, gates IC1a and IC1c are both enabled. In this state, IC1a and IC1c can be considered simply as logic inverters, with the output status of IC1c (pin 3) depending solely on the output of IC1b (pin 10).

Assuming that the iron is in use, and is therefore removed from the stand, transistor TR1 will be turned off. Thus, the logic level at its emitter will be low, causing IC1a output (pin 4) to be high, resetting the timer and preventing it from counting.

The steady high logic level on input pin 8 of IC1b will also cause the output of this gate to remain low and the output of IC1c to be high so that the triac will be switched on continuously and supply full power to the element.

When the soldering iron is replaced in its stand, the output of IC1a will go low, enabling the timer. The output of IC1b will now be determined by the logic level at its other input (pin 9) which will be switching

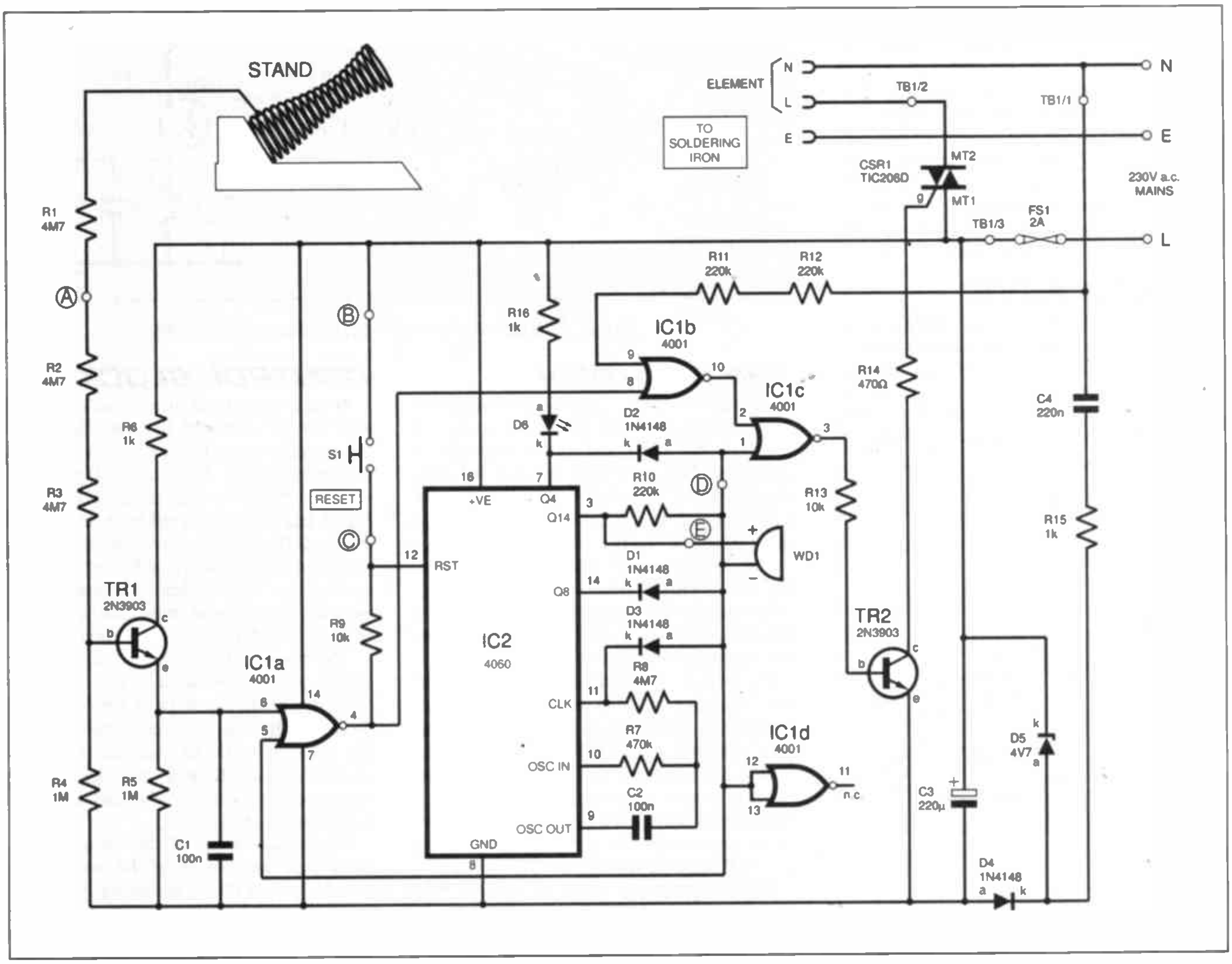


Fig. 4. Complete circuit diagram for the Soldering Iron Controller.

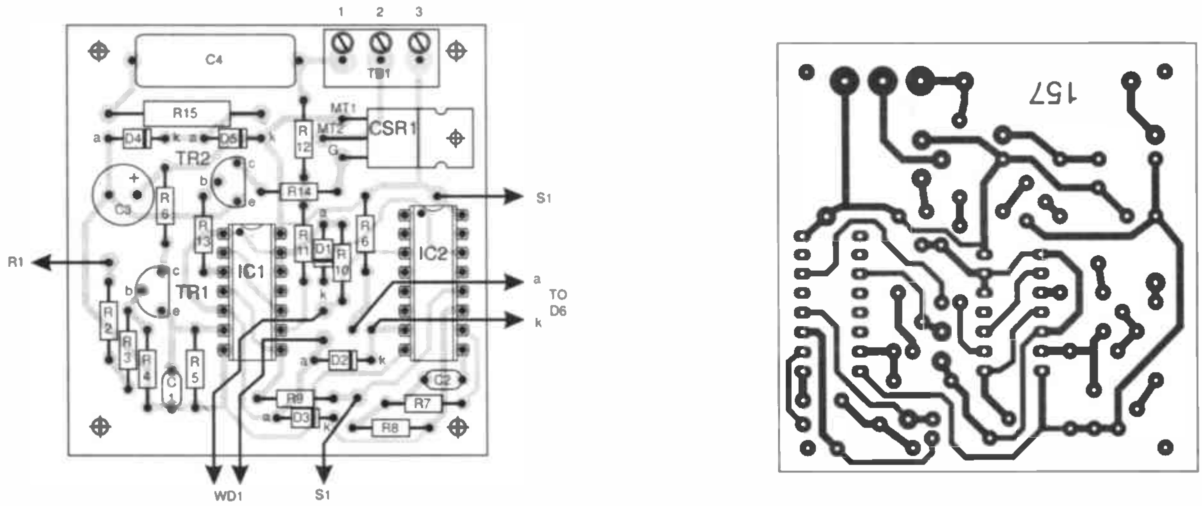


Fig. 5. Printed circuit board component layout and full size copper foil master track pattern.

high and low due to the mains signal fed to it via resistors R11 and R12.

In this situation, since the output of IC1b will be low only during the positive mains half-cycle, the triac can only be triggered during this period. Thus it will supply only half power to the element, causing it to run cooler and so extending the life of the bit.

RESET CONTROL

When the reset input on IC2 (pin 12) goes low, as it will each time the soldering iron is replaced, the chip counts up at a frequency determined by the values of resistor R7 and capacitor C2, until eventually (assuming no further reset occurs) output Q14 will go high.

Since point D will still remain low (pulled down by IC2's outputs Q4 and Q8 via diodes D2 and D1) the buzzer WD1, which is connected with its positive terminal to output Q14 via point E, will receive the correct polarity signal and sound a warning.

Counting will continue, however, and assuming no reset occurs due to the iron being removed from its stand or the reset button being pressed, outputs Q8 and Q4 will also both go high about twenty seconds later.

Light emitting diode (l.e.d.) D6 will be switched off in this condition and point D will also go high (pulled up by output Q14 via resistor R10) causing pin 11 of IC2 to go high via diode D3, so stopping the oscillator and preventing further counting, but not resetting the counter.

With point D now high, the output of IC1c will be permanently low, ensuring that the triac remains switched off. Gate IC1a will also now be inhibited with its output (pin 4) low, ensuring that the counter cannot be reset by removing the iron from its stand, thus preventing your cat from re-activating the circuit by knocking the stand over!

Once this stage is reached, the only way of switching the iron on again is to press the Reset switch, S1.

POWER INDICATOR

It will be noticed that while counting is in progress, IC2 output Q4 (and indeed Q8) will be switching repeatedly between logic low and logic high, causing l.e.d. D6 to switch on and off at about 1Hz.

Whenever the counter is reset (due to the iron being in use and at full power), output Q4 will be low and the l.e.d. will be on continuously. The l.e.d. therefore functions as a power indicator, being at full brightness for full power, flashing for half power, and off when the triac is off.

COMPONENTS

Resistors — See SHOP TALK Page

R1 to R3, R8	4M7 (4 off)
R4, R5	1M (2 off)
R6, R16	1k (2 off)
R7	470k
R9, R10, R13	10k (3 off)
R11, R12	220k (2 off)
R14	470Ω
R15	1k 0·5W 5%

All 0·25W 5% carbon film, except R15.

Capacitors

C1, C2	100n polyester (2 off)
C3	220μ elect. axial, 16V
C4	220n non-polarised, mains rated (500V a.c. class X or Y)

Semiconductors

D1 to D4	1N4148 signal diode (4 off)
D5	4V7 400mW Zener diode
D6	red l.e.d.
TR1, TR1	2N3903 *npn* transistor (2 off)
IC1	4001 quad NOR gate
IC2	4060 14-stage oscillator/counter
CSR1	TIC206D triac, 3A 400V

Miscellaneous

FS1	fuseholder, panel mounting, plus 3A fuse
S1	plastic push-to-make mains rated switch
TB1	3-way terminal block, mains rated
WD1	piezo buzzer, active

Printed circuit board, available from the *EPE PCB Service*, code 157; robust plastic case (see text); 14-pin i.c. socket; 16-pin i.c. socket; 13A mains socket, chassis mounting; connecting wire; cable; nuts and bolts; solder, etc.

Approx Cost Guidance Only £14
excl. case and mains fittings

The 4·7V d.c. supply for the circuit is obtained by a low power "capacitive dropper" and Zener diode arrangement. This comprises capacitor C4, resistor R15, Zener diode D5, together with rectifier diode D4 plus smoothing capacitor C3. Since triacs are more sensitive to negative trigger currents, a "negative supply" is thus provided.

CONSTRUCTION

SINCE THIS CIRCUIT IS OPERATED AT MAINS VOLTAGE, IT IS POTENTIALLY HAZARDOUS AND ITS CONSTRUCTION SHOULD NOT BE ATTEMPTED BY ANYONE WHO IS INEXPERIENCED IN WORKING WITH MAINS POWERED EQUIPMENT.

Details of the printed circuit board (p.c.b.) are shown in Fig. 5. This board is available from the *EPE PCB Service*, code 157.

Most of the components used are not critical and only two deserve special mention. The first is the "mains dropper" capacitor, C4, which should be rated for mains operation (i.e. 500V a.c. Class X or Y). The other components "see" only a low voltage except, of course, the triac CSR1, which should also be rated at 400V minimum.

Note that the pin configurations/outlines of transistors TR1 and TR2 are correct as shown in Fig. 5 for the 2N3903. If you are using substitute transistors, they may have different pinouts.

Because of the rather crude "mains detector" formed by resistors R11, R12 and gate IC1b, the square wave at the output of the latter (pin 10) the "half power" mode is not symmetrical and the positive cycle is slightly longer than the negative.

This has the effect of switching the triac gate current off shortly after the beginning of the negative mains half-cycle, rather than before it. Normally, this is not a problem because, due to the low power of the load (15W or 25W), the latching current is not achieved before the gate current is terminated. So, although the triac may be triggered at the beginning of the negative half-cycle, it quickly switches off again and is therefore on only during the positive half cycle.

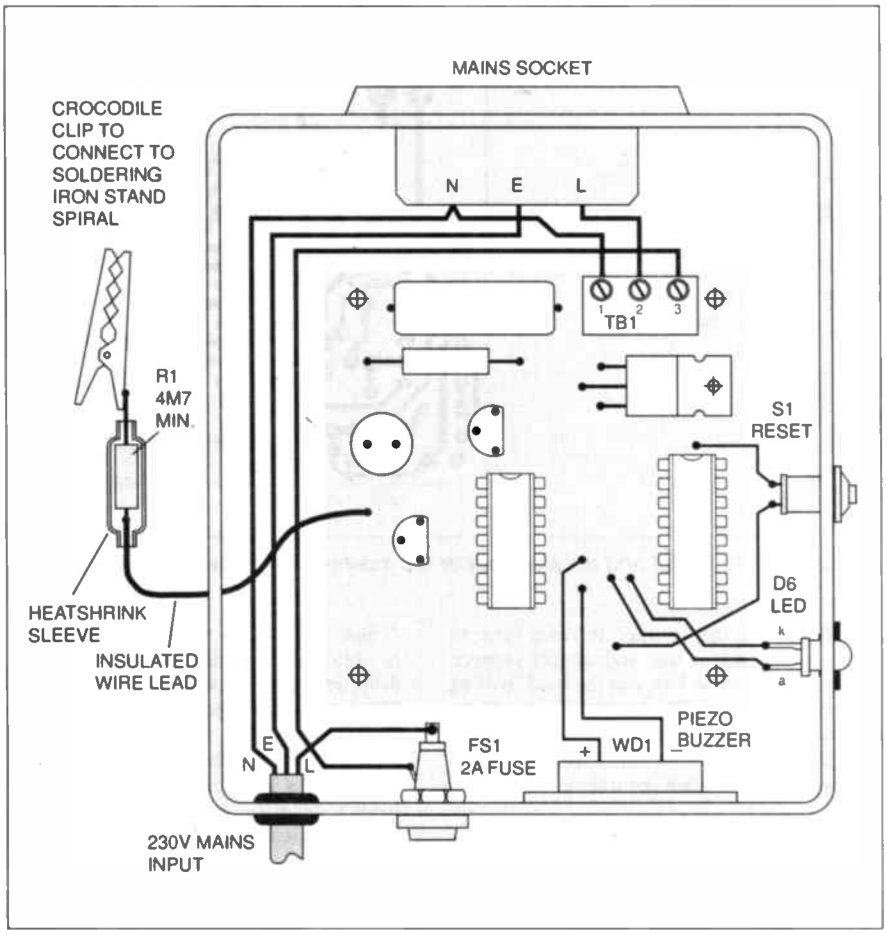
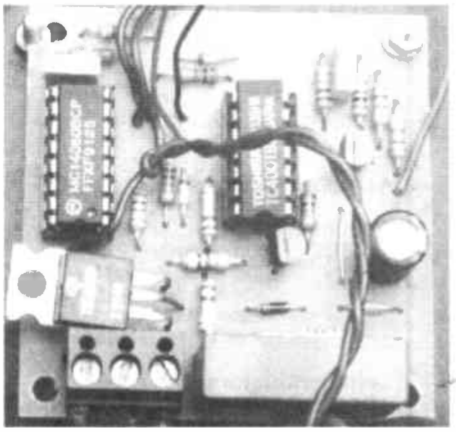


Fig. 6. Internal layout and wiring of the components within the box. This layout differs from that of the prototype as seen in the photos. It is not to scale.



To ensure correct operation, especially if a higher power soldering iron is used, a triac with a high latching current is preferable but, in any case, loads of more than 60W should not be used. The switch-off function should not be affected by this, irrespective of which type of triac is used.

For correct operation of the warning circuit, the buzzer WD1 should be a low power piezo type with built in oscillator and capable of being driven directly from the output of a CMOS i.c. These are normally rated at 12V but will work quite happily down to 3V or so. Note that electro-mechanical types are not suitable.

Assemble the components on the p.c.b. in assending order of size, ensuring their correct positioning and polarities where appropriate. Take the usual handling precautions with the CMOS chips, IC1 and IC2, discharging static electricity from your body before touching them. Use i.c. sockets with them.

Once the assembly of the printed circuit board has been completed, an insulated lead about ten centimetres long should be made up with a 4M7 resistor (R1) soldered to one end as shown in Fig. 6.

The resistor (and the solder joint) should be insulated, which is best done with a short piece of heat shrink sleeving, as shown, and the lead soldered to the printed circuit board.

A robust contact between the spiral of the soldering iron stand and resistor R1 is not necessary, so a crocodile clip is recommended as the easiest method of connection.

HOUSING IMPORTANCE

A most important aspect is to ensure that the housing of the finished unit will be safe. From this point of view, the author felt that a *robust* plastic box should be used. He does not recommend a metal box since, although it would be earthed, it might cause problems in the setting up or operation of the circuit.

The circuit was built into the box with the soldering iron stand secured to the top (see Fig. 7) by means of two small *nylon* nuts and bolts (this avoids any metal parts being exposed on the outside of the plastic box) and the insulated lead passed through a hole in the top of the box.

The size of case should be chosen to allow adequate space for the stand to be mounted on it, and for the p.c.b. and panel mounted items to fit easily without danger of them being too close.

The printed circuit board should be securely fixed to the box using *nylon* nuts and bolts or p.c.b. stand-offs. "off-board" components switch S1 and l.e.d. D6 were mounted at convenient points on the box after suitable holes had been drilled.

Note that many soldering iron stands have a space for a sponge which is used to clean the soldering iron tip during use. Take care not to drill any mounting holes in this area as the sponge is normally kept damp and making holes here would allow water to seep into the box.

The circuit board and all other "live" components should be mounted in such a way that it is impossible to touch any part of them when they are inside the box. It is also particularly important to ensure that the two resistors R2 and R3 are connected in series *inside* the case, with resistor R1 *fully insulated* and connected directly to the soldering iron stand spiral.

WIRING UP

On no account should any point on the circuit be connected to earth as this would cause the instant destruction of most of the components on the board and severely damage the p.c.b.

As shown in the wiring diagram a 13A panel-mounting mains socket is mounted in the side of the box to enable the soldering

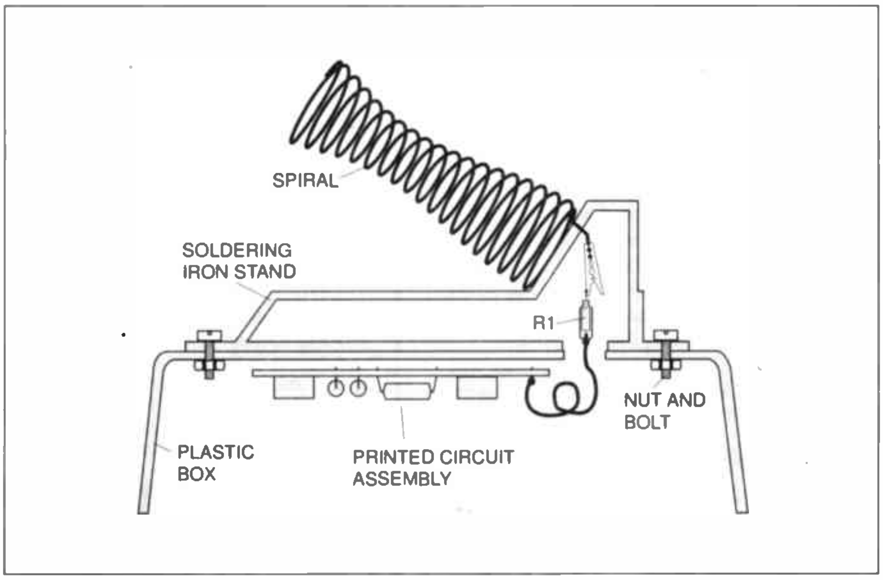


Fig. 7. Showing how a soldering iron stand can be fitted to the case.

iron to be plugged into the unit, rather than wired directly to it. The fuseholder should be mounted in the case as shown. Its fuse should be rated at 2A. The mains cable should be terminated in a 3-pin fused (3A) plug.

It is imperative to get the mains polarity (i.e. live and neutral) correct. Failure to observe this will not damage the circuit but it will prevent the detector from operating correctly.

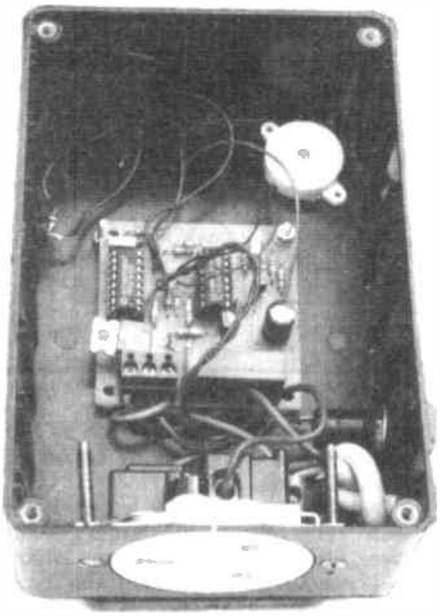
The buzzer was mounted inside the box by means of double-sided adhesive tape.

TESTING

NOTE THAT DANGEROUS MAINS VOLTAGES EXIST ON THE PRINTED CIRCUIT BOARD. DO NOT TOUCH ANY PART OF THE BOARD OR OTHER COMPONENTS WHEN THEY ARE CONNECTED TO THE MAINS SUPPLY. SWITCH OFF AND DISCONNECT FROM THE SUPPLY BEFORE ATTEMPTING ANY SOLDERING OF COMPONENTS ON THE BOARD.

When assembly has been completed, check your wiring thoroughly and ensure in particular that the resistors R1, R2 and R3 are in place **and have the correct values.** Because the operational safety of the unit depends on these resistors, it is advisable to check their values using a multimeter in case the colour code has been misread and lower values fitted inadvertently.

Once all checks have been made, the unit is ready for testing. At this stage, a small table lamp would probably be better to use



as a temporary load instead of the soldering iron. It will then be immediately obvious if the triac is switching on or not.

Note that fluorescent lamps or those containing a transformer should not be used for this test.

The lamp should be plugged into the socket on the unit and the unit switched on at the mains. For correct operation, a 15W or 25W bulb (similar to the soldering iron rating) should be fitted. The lamp should light at full brightness and the l.e.d. stay on without flashing.

Next, the soldering iron should be plugged into a nearby mains socket (which need not be switched on) and inserted into the stand. The l.e.d. should begin to flash and the lamp dim slightly. A slight flicker may be observed, showing that the lamp is being switched on only during alternate mains half cycles.

If the lamp remains in the dimmed condition when the iron is removed from the stand, the value of resistor R4 should be reduced. If the lamp remains at full brightness, check that the circuit is connected to the mains with the correct polarity (i.e. live to the circuit positive rail) and that the triac has not been shorted out.

Remember to unplug the unit from the mains before soldering or adjusting any components.

Ensuring that the unit will switch off if it has not been used for a certain period is more difficult, unless you are prepared to wait for the fifteen minutes or so. One way around this would be to temporarily connect a 4k7 resistor in parallel with resistor R7 to make the counter run faster.

If this is done, the total time before switching off will be about 18 seconds, but the l.e.d. should still be observed to flicker and the buzzer heard, although, of course, all timings will be much shorter than with the correct value of R7.

If all is well, the lamp can be replaced by your soldering iron and you can look forward to long service from it.

Happy soldering!

SHOP TALK
with David Barrington

Ironing Safety Device

Just a few minor points need some clarification for constructors about to undertake the *Ironing Safety Device* project. Although there are only a few components on the small printed circuit board, it is most important that extra care be taken when mounting the mercury filled tilt switch on the p.c.b. They may be hermetically sealed inside a metal "can", but the lead entry point can be a weak spot and ***mercury is a highly dangerous substance*** – so take care.

Both the miniature mercury tilt and vibration switches should be available from your usual local supplier. Some may be slightly different in appearance, but there is no reason why they should not work in this circuit.

If problems do arise finding suitable switches, the ones used in the model came from **Maplin**, codes FE11M (Tilt Sw.) and UK57M (Vibration Sw.). Regarding the tilt switch, for a slightly cheaper outlay the above company also list a "non-mercury" version (code DP50E) which may be worth considering.

The recommended warning sounder is a miniature low-profile piezoelectric type, chosen for its physical size and low operating current capability. (It should be noted that this circuit will only drive low-current buzzers.) These miniature low-profile piezo devices should be readily available from most of our components advertisers, and the one used in the model came from Maplin, code KU57M.

There are a wide variety of small cases/boxes, of all shapes and sizes, on the market that could be used to take the p.c.b. and it will finally come down to individual choice. However, if any reader wishes to purchase a vacuum formed case, as depicted in the article (minus screws, graphics and finishing off), one can be obtained from Bolton School for the sum of £5 inclusive. Overseas readers add £2 for post and packing.

All cheques, P.O.s or money orders should be made payable to Bolton School Boys Division. Address all orders to: S. Todd, **Bolton School Boys Division, Chorley New Road, Bolton, Lancs, BL1 4PA.**

The small, approx. 38mm x 30mm, printed circuit board is available from the *EPE PCB Service*, code 167 (see page 651).

PIC-Noughts & Crosses Game

Nearly all the components specified for the *PIC-Noughts & Crosses Game* are RS types and were purchased through **Electromail** (☎ *01536 204555*), their mail order outlet. The Siemens LU5351-JM 60mA (20 mA typical) tri-colour, common cathode, l.e.d.s came from them, quote code 578-294.

The miniature p.c.b. mounting, push-to-make, switches used in the model are manufactured by Alps and were obtained from **ElectroSpeed** (☎ ***01703 644555***), quote part code 63-61432K. Some of our advertisers stock a similar switch which is listed as being a p.c.b. mounting "click-effect" type, but check that they will fit on the circuit board before making a purchase.

For those readers who do not have their own facilities to program PIC chips, a ready-programmed PIC16C84-04/P (£14 each) and/or PIC16C61-04/P (£11 each) can be purchased from **PH Research, 32-34 School Lane, Swavey, Cambridge, CB4 5RL.** (☎ ***01954 200411***). Email: **paul@ph-research.prestel.co.uk**). *Make cheques payable to PH Research (allow 28 days for delivery).*

The Noughts & Crosses printed circuit board is available from the *EPE PCB Service*, code 165.

Soldering Iron Controller

It is most important that only a ***new*** Class X or Class Y non-polarised capacitor, rated at 500V a.c. or *greater*, be used for C4 in the *Soldering Iron Controller* circuit. This type of capacitor is usually of metallised polypropylene construction and should be stocked by most of our component advertisers.

Due to the presence of dangerous mains voltages within this unit, it is not a project for beginners to tackle.

The remaining components for the Controller appear to be standard parts and should not cause any purchasing problems. The printed circuit board is available from the *EPE PCB Service*, code 157.

Active Receiving Antenna

Only the inductor and varicap diode could cause problems when putting together parts for the *Active Receiving Antenna*. The "telescopic" whip aerial should be carried by quite a few of our components advertisers, such as **Cirkit, Bull Electrical, Maplin and J&N Factors**.

You have a choice regarding the varicap diodes, **Cirkit** list a dual and a triple version of the required varicaps for the same price. The dual (KV1236) version stock code is 12-12365 and the triple (KV1235) is 12-12355. They also stock the Toko (B)KANK3333R inductor, code 35-33330.

The small double-sided printed circuit board is available from the *EPE PCB Service*, code 140.

Micropower PIR Detector – Alarm Disarm/Reset Switch

The miniature 18mm glass-encapsulated reed switch for the *Alarm Disarm/Reset Switch* module was obtained from Maplin, code CL38R. They also stock a range of small magnets and choice will depend on final installation.

Of course, you do not have to use a reed switch, a pushbutton, key-operated or even a keypad switch will do the job. The problem is hiding them out of sight. The printed circuit board is available from the *EPE PCB Service*, code 166.

Incidentally, if you intend experimenting with the circuits contained in the *Raising the Pressure* feature, the Raytheon RC4190N switch-mode i.c. is currently stocked by Maplin, code UR15R.

Techniques

ACTUALLY DOING IT!

by Robert Penfold

IN THE previous *Actually Doing It* article (July '97) we considered passive components and their methods of value marking. This month we progress to semiconductors, which do not have values, but are instead identified by type numbers. The circuit designer selects devices which have suitable parameters, and provided you use the specified components, the project is more or less guaranteed to function correctly.

"Old hands" often use substitute semiconductors and usually get away with it, but this is definitely not to be recommended for beginners. Initially you should avoid any unnecessary complications, and should definitely not tempt fate by using components that may or may not perform adequately.

Numbers Game

Beginners sometimes enquire whether or not semiconductor type numbers tell you anything about the components. In most cases they are not purely arbitrary, and do tell you something about the components, but not very much.

For example, with a European type number such as BC549, the "B" indicates that it is a silicon device, and the "C" shows that it is a low power transistor intended for audio applications. The "549" is simply a serial number, and I think I am correct in saying that devices are numbered from 100 upwards.

With the American and Japanese systems the first digit of the type number is one less than the number of leadout wires that the component has. Devices having 2N*** and 2S*** type numbers therefore have three leadout wires, and are mostly transistors. 1N*** series devices have two leads, and are mostly rectifiers and diodes.

In general, any information of this kind is of limited value, and simply tells you what you know already. It is best to concentrate on obtaining components having the right type numbers, and do not worry too much about any coded information contained within these numbers.

The type numbers of integrated circuits are mostly those chosen by the manufacturers, and apart from the name of the manufacturer they do not necessarily tell you anything of significance anyway. The same is true of some transistors, such as the Texas Instruments TIP*** series of power devices.

Over the years many letters have been received from readers who have obtained components which have markings other than the type number. The usual worry is that there are several versions of the components and that they might not have the right one.

It is a point that has been made several times in the past, but worth making again. A large percentage of electronic components are marked with manufacturers logos, batch numbers, the date of manufacture in some form of cryptic code, and characters that seem to be purely random.

Semiconductors often seem to carry more than their fair share of these markings. Presumably the additional characters mean something to someone somewhere, but as far as the home constructor is concerned they are purely extraneous and should be ignored.

Making the Grade

With some devices there is more than one version available, and the different versions are usually identified by different suffix letters on the type numbers. Transistors are sometimes graded into gain groups, and have the suffix letter "A", "B", or "C". These correspond to *low*, *middle* and *high* gain groups respectively.

If a components list specifies a certain gain group, then you should certainly try to obtain a component which has the appropriate suffix letter. If no gain group is specified, the design should work using a device from any gain group, or one that is not graded and does not have a suffix letter.

Integrated circuit (i.c.) type numbers often include a suffix letter which denotes the type of encapsulation used. In the past some integrated circuits were readily available with two or even three different encapsulations, but these days there is usually only one version available through normal retail outlets.

However, with the increasing use of surface mount devices you do need to ensure that you do not accidentally order one of these when you require a device having ordinary printed circuit pins. Surface mount devices are much smaller than their conventional counterparts, and are designed to be soldered directly onto the copper side of the circuit board.

Physically, the two types are totally incompatible. Most component catalogues now have surface mount components in a separate section in order to reduce the risk of ordering the wrong type.

There are some integrated circuits where a suffix letter or letters indicate electrical rather than physical differences between different versions of the same device. CMOS logic devices having 4000 series type numbers usually have a "BE" suffix which indicates that they are modern devices that have slightly superior specifications to the original "AE" components. You are unlikely to encounter the "AE" components now as they have not been manufactured for many years, but it is worth noting that they cannot be guaranteed to operate in place of "BE" types.

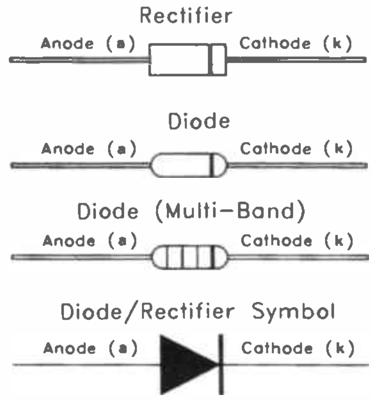


Fig. 1. Common method of indicating polarity of diodes and small rectifiers.

Some CMOS devices have a UBE suffix, and these are "unbuffered" devices. Few of these devices are available to amateur users, and the only one you are likely to encounter in a components list is the 4007UBE. It is important to use the UBE version where appropriate, but this is the only version that you are likely to encounter in components catalogues.

One Way Only

The most simple type of semiconductor device is the **Diode**, and this is a two-terminal component. The basic function of a diode is to enable a current to flow in one direction, but to block a flow in the opposite direction. Incidentally, diodes for operation at relatively high currents (about one amp or more) are called rectifiers.

The two terminals of a rectifier or diode are called the cathode and anode, but these names are often abbreviated to "k" and "a" respectively. Also, on some circuit diagrams and component layouts the cathode and anode are often indicated by "+" and "−" signs respectively. When building projects that use rectifiers or diodes it is clearly necessary to get them connected around the right way. In fact, there can be disastrous consequences if you should accidentally get one of these components connected the wrong way round! The polarity of diodes and small rectifiers is usually indicated via a white band at the cathode (k) end of each component, as shown in Fig.1.

At one time there were plenty of diodes on sale which had several bands marked around their bodies, and these indicated the type number using a sort of simplified resistor colour coding. These now seem to be much less common, but there are still a few of them in circulation. If you should come across any multi-band diodes, one of the end bands should be much thicker than the others and this is the one which indicates the cathode end of the component.

In practice this is sometimes less than obvious, and you may need to look very carefully to find the wider band. This method of marking is most common on 1N4148 diodes, and with these the band at one end is yellow, and the band at the other end is grey. The yellow band is the one at the cathode end of the component.

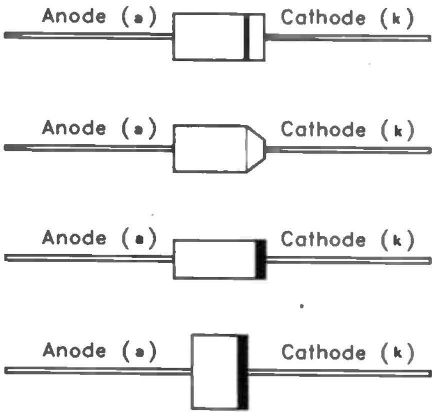


Fig.2. Common methods of indicating the polarity of larger rectifiers.

Many of the higher current rectifiers look just like outsize low power types, but some have a totally different type of encapsulation. Probably the most common form of encapsulation for high power rectifiers is the type which has a narrowing of the body at the cathode end. This type is shown together with three others in Fig.2.

Getting high current rectifiers connected round the wrong way is likely to result in major damage to the circuit and could even be dangerous. Therefore, never connect a component of this type unless you are *absolutely certain* that you know the correct orientation.

Beginners would be well advised to avoid any projects that use large rectifiers, or involve the use of high currents. There are plenty of interesting and safe projects to choose from, so there is no need to opt for a project that involves any risk.

Cracking Up

Most diodes and rectifiers are physically quite tough, and are no more vulnerable to damage than most other components. However, some diodes have glass encapsulations which render them far less durable than other two lead components such as resistors and capacitors.

It is mainly the older devices such as the OA90 and OA91 that fall into this category. Components such as these should obviously be treated with greater care than normal, and it is advisable to take great care when bending the leadout wires close to the glass encapsulation. It will usually be necessary to form the leadout wires in this way so that the diode can be fitted onto the circuit board, but any lack of care can easily result in bits of the glass casing breaking off.

Do not use the obvious approach of holding the case of the diode and then pushing or pulling the leads into shape. Use tweezers, small long-nosed pliers or your fingernails to hold one of the leadout wires next to the body of the component, and then bend the wire to shape. Then repeat the process for the other leadout wire.

Heated Exchange

All semiconductors are relatively easily damaged by heat, and extra care must be taken when soldering them to a circuit board. It is advisable to use i.c. holders for integrated circuits, so that they are simply plugged into place. It is the holder that is soldered to the circuit board, and it is the holder that gets hot.

Germanium diodes are more vulnerable to heat damage than silicon semiconductors, and even more care must be taken when connecting these. The ultra-safe approach is to use a heatshunt, which is basically just a small piece of metal that clips onto the leadout wire close to the body of the diode. The heatshunt absorbs most of the heat that flows up the lead when it is soldered into place, and prevents the diode from overheating.

It is not too difficult to improvise a heatshunt using a crocodile clip or a pair of tweezers, but a heatshunt is not essential. Modern germanium diodes should not be damaged provided the soldered joints are completed quickly.

Light Work

Light emitting diodes (l.e.d.s) are used in a fair percentage of projects, and it is important to realise that these are true diodes. Unlike filament bulbs, they will only work if they are connected the right way round. If they are connected with the wrong polarity they block any significant current flow, and fail to light up.

The two standard methods of indicating l.e.d. polarity are to have the cathode (k) lead shorter than the anode (a) lead, and to have the case or body of the component flattened slightly next to the cathode lead. Most l.e.d.s have at least one of these, but a few types lack either form of polarity indication. Having been caught out on more than one occasion by l.e.d.s which did not have the expected polarity, it is wise to always check l.e.d.s prior to connecting them into circuit.

Virtually all multimeters have a diode checking facility, and this will usually show the polarity of l.e.d.s. However, some digital multimeters cannot be used to determine l.e.d. polarity as they use a test voltage that is too low to switch on a l.e.d.

L.E.D. Tester

A very basic tester of the type outlined in Fig.3 is all that is needed to perform this task. A three volt battery (e.g. two HP7 size cells in a plastic battery holder) is connected to the l.e.d. with one polarity, and then the other. When the l.e.d. switches on, the cathode (k) lead is the one connected to the negative battery terminal.

The resistor limits the current flow to a safe level, and it ***must not*** be omitted. Connecting an l.e.d. straight across a power source results in a heavy current flow and the almost instant destruction of the l.e.d.

This test circuit will operate using a 9V battery, but the value of the resistor should then be increased to 1k (one kilohm). Using a nine volt supply will result in the reverse breakdown voltage of the l.e.d. being exceeded when it is connected with the wrong polarity, but the series resistor will prevent it from coming to any harm.

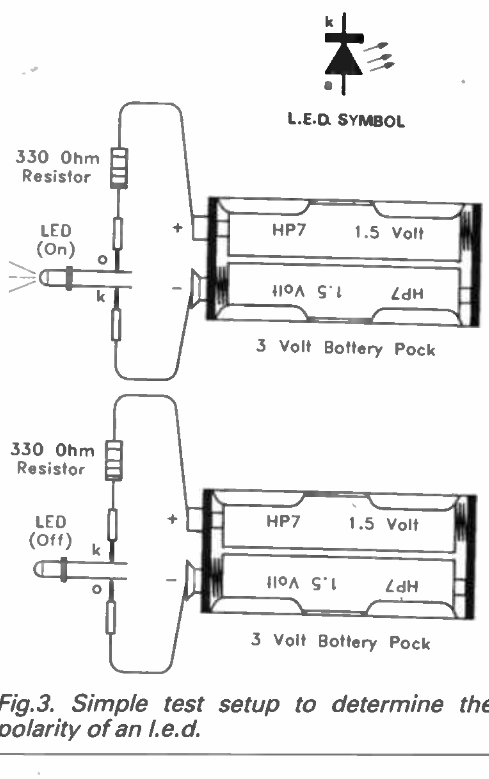


Fig.3. Simple test setup to determine the polarity of an l.e.d.

READOUT

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

RUFFLED FEATHERS?

Dear EPE

I fancy that John Becker may have ruffled a few feathers in South Africa with his comments in *Readout* June '97 (*Pin Board Wizard*). Your Tech Ed was, it seems to me, rather dismissive of your SA correspondent Freddie Clifford with regard to pinboard construction.

Whilst there is no disputing the merit of a p.c.b. for reproducing a completed design which is fixed for all time, the need also arises for a base which, while capable of carrying a permanent layout, can be used for development work and is capable of accepting modifications.

A pinboard scores by placing all components and wiring on one side of the board. Circuit checking is easy and every pin provides a handy test point. With a little experience it is possible to draw a circuit diagram in such a way that it can serve as a component layout and wiring guide. Such a diagram is simply laid over the baseboard. Pins are driven in at each connecting point. Wiring up follows the diagram which remains there for future reference. The layout is virtually self-checking and easy to fault find on.

There are still people who want to develop their own circuitry and construct it at minimum cost. Mr Clifford and I belong to this group. We know that, clumsy though they may be, pinboards work.

George Short, Brighton

Curiously, George, although I must continue to deny the suitability of pinboards (of the type referred to by Freddie Clifford) for published EPE *projects, I do actually find use for a more-electronic version of them.*

As part of my workshop group of essential tools, I have the largest strip of 0·1 inch matrix Stripboard that RS could supply, and which is now a couple of decades old. On it I mounted numerous d.i.l. sockets of various pin counts, made hundreds of appropriate track cuts and inserted an equivalent quantity of 1mm double-sided terminal pins, one for each i.c. socket pin.

The immediate result of this arduous task was RWSI (repetitive wrist-strain injury) and blisters! However, the pains have proved to have been worth it – that pinboard still finds use in any situation where I want to check out the logic of a complex circuit before commiting it to a p.c.b. layout, or if I need a sub-circuit temporarily connected to an existing p.c.b. At times, the term bird's nest *is thoroughly inadequate to describe the wiring and component positionings that sometimes build up on the board!*

Also, whilst I have never used brass pins or similar in boards for purely electronic circuit building, they have been found useful when making up lengthy and complex wiring harnesses.

There is, I agree, a place for temporary assemblies (who can deny the merits of a good bodge?!*). Nonetheless, one of our roles at* EPE *is to try to educate people in the* right *way of doing things. The wrong way may be perfectly acceptable in some situations, but our public image must be that which people can trust as being correctly informative. If asked privately, though, I might well comment about the merits of learning the rule book, and then discarding it and doing* your own thing!

That's where a column like Readout *comes in handy, it can highlight matters that would be inappropriate elsewhere in* EPE *– such as the fact that chipboard-pinboards are used by* some *people as a legitimate constructional technology!*

However, there is one constructional technique related to pinboards that we are about to publish, and that is wire-wrapping. *It will be discussed in the forthcoming new* Teach-In '98 *series (late '97).*

George, dear Readers, is a long-time contributor and friend of EPE, *albeit under a nom-de-plume (a* feathered friend, *perhaps?). Nice to hear from you George.* *JB*

TEACHER TEACH-IN

Dear EPE,

I am an avid reader of *EPE* (having bought it religiously every month for more years than I care to remember). I am always interested to buy it in order to keep up with current trends and developments, as well as identifying suitable projects for my pupils to build and investigate at Queen Elizabeth's High School in Gainsborough, Lincs.

My reasons for writing are two-fold: Firstly, I note with interest comments made by yourself and some of your readers regarding the complexity of projects. As Head of Technology in a school where pupils are very able and interested in electronics, I can fully appreciate both sides of the argument. The interests of the A Level student *and* the pupil coming to us from Primary school need to be catered for.

However, I know that many of my pupils would be attracted to *EPE* if you were to run a series of projects similar to the *GCSE Teacher Project* articles written for *Practical Electronics* by Tim Pike during 1987/88.

I do not suggest the clock should be "wound back", but I do feel that there is a real need for similar articles to be produced which begin with the basics, but then move on to encompass many of the new developments and components introduced in the last ten years. Technology is now a compulsory subject in all Secondary schools and many pupils are opting to follow Electronics courses, but they are often "turned off" the essential research of their project by the very steep learning curve which all electronic publications seem to portray.

Secondly, your various articles on PICs are very stimulating for my A Level students and I have this year bought a "PICSTART" development system for the department. I am often asked by students for circuit ideas for "running message" displays, but I usually discourage them, saying that such ideas are too involved for their A Level projects. Could *EPE* come up with such a project, using multi-segment l.e.d. displays?

W. Shaw, Gainsborough, Lincs

Tim Pike's Teacher Project *series in* PE *was indeed well received. We at* EPE *are, of course, presently running a range of "simple" projects which are suitable for GCSE students, of which* IR Remote Control Repeater *(July),* Regulated PSU *(Aug),* Quiz Monitor *(Oct) and* Case Alarm *(Nov) are/will be examples. It is recognised that they are not written from the basic viewpoint that you suggest, but we shall, though, actively pursue your idea in due course; as we shall your suggestion for the Message Display. You are not alone with such requests!* *JB*

GHOSTLY SHORTS

Dear EPE,

I feel that *EPE* could do with more simple articles, particularly from the constructional point of view. Hobby electronics is there for *enjoyment*, and enjoyment can often be best achieved by one evening's soldering on a simple yet interesting circuit.

Ingenuity Unlimited every now and then has an outstanding idea. Why not get someone to ghost-write articles around these ideas?

Rev. Thomas Scarborough, South Africa

Reverend, I feel honoured that you should write to me instead of my inveterate problem-solving friend Alan W, which I know is what you often do!

Yes, there are good ideas which come through that column and the wonder is that more inventive readers do not seem to be using them as the basis for their own more detailed projects. Perhaps it's because many inventors like to develop their own brain-waves rather than someone else's.

Whilst, from time to time, we do suggest ideas to our regular authors, by and large we prefer to let their creative imagination come into play without prompting from us.

However, if readers do develop IU ideas further, they are welcome to offer them to us for possible more-formal publication. *JB*

ANOTHER TASM!

Dear EPE,

I had an interesting E-mail from a man trying to compile the *PIC-Tock* project PIC code (Sept '96). He said he was using TASM but it wouldn't compile. I tried it and it worked fine, so I sent him the PIC16C84 table file. Still wouldn't compile. Eventually, the mystery was solved when he sent in a screen shot showing his command options. It turned out he was using Borland Turbo Assembler, also called TASM! I sent him your TASM on disk and it worked.

Gareth (Anon), via the Net.

Astonishing! We had no idea that there was another TASM around. Ours originated from the Public Domain Shareware Library (PDSL) and for which a Send program was written and appended by Derren Crome for our use. We are extremely grateful to you, Gareth, for this information. Readers beware, only our version of TASM will work with our TASM-written PIC programs!

If you would like to know more about the PDSL, and they have masses of shareware software you should know about, ask them for their catalogue: PDSL, Dept EPE, Winscombe House, Beacon Road, Crowborough, Sussex TN6 1UL. Tel: 01892 663298.

Incidentally, you may freely copy and distribute among your friends any of the programs on our PIC disk. If you want to use them commercially, though, you need to get written permission from us first. *JB*

EMULATING LENNARD

Dear EPE,

I design electronic units for handicapped use for a sheltered workshop and handicapped college. I use a lot of PICs in my designs and I have just tried a real-time emulator from Lennard Research in Newcastle. Mr Lennard was very helpful and knowledgeable, and it was pleasant to deal with the designer of the product. The emulator works excellently and cost just £149·95. I think it would make an excellent hobbyist and educational unit.

Stephen Alsop, via the Net

We know from other sources about the helpfulness of our respected advertiser Lennard Research. We have a review of some of their products coming up soon. The unit referred to by Stephen is "TRICE", the PIC Real-Time In-Circuit Emulator. Lennard Research can be contacted at Tel: 0191 273 2233. Fax: 0191 226 0876. Web: http://www.lennardresearch.demon.co.uk. *JB*

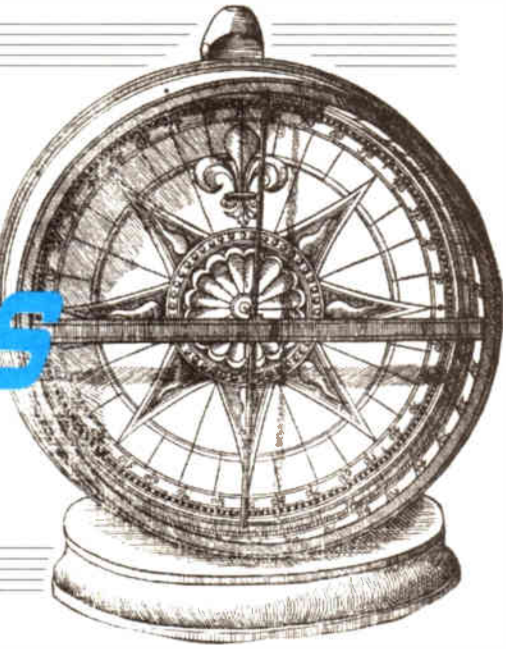
SCHOOL SHORTS

Dear EPE,

I am Head of Electronics at Tonbridge School, Kent, where I teach the subject to A Level. I take *EPE* at the school, and very much value the contribution that it makes to the enrichment of the subject at Tonbridge and the enthusing of my students. Finding projects for the most eager students is never easy; a ready supply of interesting ideas is always most welcome!

David L. Faithfull, BTech, MSC, CEng, MIEE

Thank you. *JB*



THE GREAT EXPERIMENTERS

A short history - Part Five

STEVE KNIGHT

Even in the latter part of the Great Experimental Age, many more names were added to the list of those whose researches helped shape modern technology.

THE LATTER years of the nineteenth century and the early decades of the twentieth probably saw the demise of the great individual experimenters. With today's huge impersonal research conglomerates, the work of the lone physicist or natural philosopher, as the people we have met so far in this series called themselves, is over.

The years following the endeavours of people like Ohm, Ampere and Faraday did, however, go out with a bang with a number of famous men extending the basic discoveries to new and higher levels; men like William Thomson, Heinrich Hertz, James Clerk Maxwell, Helmholtz, Rutherford, Fleming, Lodge and Marconi, to name just a few of the more well known.

Perhaps, for the purpose of illustrating some of the work of this illustrious parade, it is best to take the work of one of them and build around his achievements. This man is William Thomson (who was later to be Lord Kelvin) for his work influenced, and was influenced by, many of these other physicists. Thus he provides us with a central connecting thread, bringing together the outstanding characters of the period over the decades when our modern industrial world was created.

WILLIAM THOMSON

Like Faraday, the number and importance of William Thomson's contributions to original research are truly outstanding. Unlike Faraday, however, Thomson was a brilliant mathematician and most of his output, bound up as it was upon the arguments derived from mathematics, made him what we might call an "applied" physicist, as opposed to Faraday's "practical" approach.

Further, whereas Faraday was an enthusiastic and popular lecturer, Thomson apparently had little of a natural lecturer about him, being too deeply steeped in the theoretical and abstract problems of his researches to put over his views in a manner attractive to those whose abilities were lesser than his own.

William was born in 1824, the second son of James Thomson who was Professor of Mathematics at the Royal Institute in Belfast. He was part of a large family of four sons and three daughters, and the upbringing of these depended for most of their childhood and adolescent years upon their father, their mother having died whilst they were all relatively young.

James made a great success of this stern job, combining affection and discipline in those proportions which eventually brought all of his four sons to distinction in their respective spheres of industry.

William Thomson, Lord Kelvin (1824-1907)

In 1832, the family left Belfast for Glasgow where James had obtained the post of Professor of Mathematics at the University; and it was in Glasgow that William did the work which, in one form or another, lasted until his death in 1907.

In 1840 the professor went to Germany with his two eldest sons for a holiday tour. His main concern was for the boys to study the language, but while they were there, William came into possession of the book that had been the inspiration for Georg Ohm in his electrical researches some twenty years earlier: *The Analytical Theory of Heat* by the Frenchman, Jean Baptiste Fourier.

William was particularly attracted by the rigorous mathematical methods that Fourier employed in the book, and the story goes that at that time he learned a great deal more about the analysis of heat than he did about the German language. The book certainly made a great impression on William, for much of his later career shows the way in which his scientific approach was continually influenced by Fourier's methods.

In October 1841, William became a student at St Peter's College in Cambridge. He became second Wrangler in the Mathematical Tripos, and after completing his examinations in the early part of 1845, went to London where he made the acquaintance of Michael Faraday. Later, he went on to Paris to study physics under the tutelage of the famous Henri Regnault who was a member of the French Academy of Sciences.

In all this time, William's father had been ambitious for his son's advancement into an academic career, and the opportunity came when, in 1846, the then Professor of Natural Philosophy at Glasgow University died. It would be quite unfair and almost certainly untrue to suggest that William's father pulled strings in his son's favour with the University faculty, but on the 11th of September of that year, the Faculty met and unanimously appointed William to the vacant professorship. From this point onwards, William at the age of twenty-two embarked on a professional career which was to last for the next sixty-odd years and bring him worldwide recognition.

EARLY ELECTRICAL RESEARCH

Although Thomson in his lifetime covered a vast range of scientific disciplines, our concern here is with his researches into those subjects which have an electrical flavour. These led all the way to the submarine cable, the telegraph and the theoretical statements upon which Marconi based his famous invention, radio.

As the academic year at Glasgow University in those days covered only some six months of the year, Thomson found plenty of time for research. Initially, he looked into the problems of electrostatics, particularly to support Coulomb in his well-known laws of electric attraction against a challenge from another experimentalist who, at that time, had a high reputation among his colleagues, and whose views could not therefore be readily ignored.

The upshot of the controversy was that Thomson developed a new approach to this class of problem which enabled him to vindicate Coulomb's original calculations.

With this success, William went on to derive methods of determining an "absolute" or universal standard magnitude for the ampere and the volt, which up to then had not been established in any particular form. We have seen how Faraday and others had investigated the attractive force between two plates or surfaces when a potential difference existed between them, and how the introduction of a dielectric modified this force.

William now applied his mathematical strength to determine the value of this attraction in terms of the applied voltage, the distance between the plates and their surface area. If under any given conditions there corresponds a definite force for a given potential difference, then by measuring this force, the corresponding voltage difference can at once be found.

Here, then, was a mechanical means of measuring an electrical parameter, a method we use to this day; for instance, the ampere is defined by the attractive force between two parallel conductors carrying equal currents.

ELECTROMETER

What William now did was to devise an apparatus to turn his theory into a practical form. A device which he called the "attracted disc electrometer" (and we now call an electrostatic voltmeter) was one of two arrangements he set up, the other being the "quadrant electrometer".

Thomson justified his insistence on having a knowledge of absolute values a number of times in his career, declaring on one occasion: "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge but you have scarcely, in your thoughts, advanced to the stage of Science, whatever the matter may be".

Wise words, indeed, for though some scientists (quite justifiably) may deny that they should deal only with theories and ideas that are strictly and rigorously measurable, no one can deny the necessity and importance of an accurately measurable basis for scientific study and advancement.

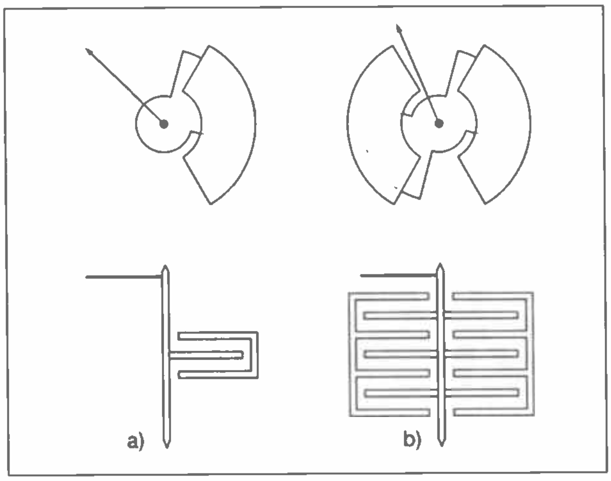


Fig.1. Principle of Thomson's quadrant electrometer.

Thomson's attracted disc electrometer had, in its basic form, two parallel plates; the lower of these was charged up to the voltage it was desired to measure, and the upper plate (which was connected to earth and therefore at zero potential) was attracted towards the lower with a force which could be directly measured by springs and counterweights such that they just balanced the electric field force between the plates.

This arrangement was not a good one from the point of view of a practical instrument, but the quadrant electrometer overcame this problem by an arrangement of a number of interleaving plates which produced a rotation, and a basic example of Thomson's instrument is shown in Fig.1a.

A light rigid aluminium vane is attached to a spindle and positioned partially within a hollow metal quadrant or between two interconnected fixed vanes. When the vane and quadrant are oppositely charged by the applied potential difference which is to be measured, the moving vane is attracted further into the fixed quadrant and the instrument spindle, together with attached pointer, is caused to rotate.

In his original design, Thomson used a torsion fibre as the spindle; this acted as a restoring agent and the vane continued to move until the counter force provided by the fibre just balanced the attractive force acting between the plates. The position of the pointer or, what is the same thing, the twist of the fibre, was then a measure of the applied voltage.

The general principle of the quadrant electrometer is shown in Fig.1b. The sensitivity of the device can be increased by increasing the number of fixed and moving vanes, but in its basic form it is not suitable for measuring very small potentials.

Thomson, and others, later made many modifications of the original instrument, including mirror systems, and these led to the development of both ammeters and voltmeters which have survived to the present day.

Kelvin's absolute attracted disc electrometer.

WIRELESS TELEGRAPHY

There was one other important piece of work amongst Thomson's earlier researches in electricity; although he was unconscious of its later applications, this was the base pioneering work which led to wireless telegraphy.

In 1847, the German physicist, Hermann von Helmholtz, known for his work on the generation of electric current within the galvanic battery, drew attention to some curious behaviour in connection with the discharge of the Leyden jar.

A contemporary of Helmholtz, Professor Riess, had wound a coil of wire around a steel rod and had passed the discharge current from a Leyden jar through the coil. Riess naturally expected to find that the rod had become magnetized as a result, but what he did not expect to find was that through a trial run of the same experiment, and with the direction of connection the same in all cases, the rod sometimes exhibited a north-seeking pole at one end and at other times at the opposite end.

Now Ampere had shown that the polarity of an electromagnet depended upon the direction of the current through the solenoid and that the poles would only reverse if this direction changed. This suggested that the discharge current from the Leyden jar was not just one-directional but could be bidirectional so that the polarity of the steel core was a matter of chance.

Helmholtz, with the intuitive approach that men of his calibre displayed, suggested that the effect could be explained by the assumption that the jar discharge was actually an *oscillating* current, which changed direction a number of times during the period over which the discharge took place.

Taking up this suggestion, Thomson delivered a paper to the Glasgow Philosophical Society in 1853 entitled *The Oscillating Discharge of the Leyden Jar*, not only proving mathematically that such oscillations existed, but also giving a

Hermann Helmholtz (1821-1894).

formula for the rate (or the frequency) at which they took place.

What was actually taking place was the discharge of a capacitor (the jar) through an inductance (the solenoid). The capacitor stores energy in an electric field, and on being connected to a solenoid (see Fig.2a) begins to discharge; the electric field energy decreases and is transferred to the magnetic field that appears around the solenoid because the current is increasing there (Fig.2b).

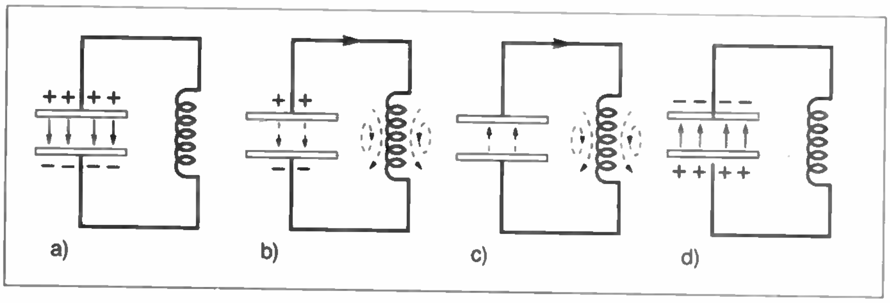


Fig.2. Showing four stages in the first half-cycle of the oscillations created in an LC circuit.

At some instant after the connection is made, the electric field will have disappeared and its energy will have been transferred entirely to the magnetic field. The solenoid current is now at a maximum, but although the capacitor charge q is zero, the current is not zero at this time. The solenoid current continues to transport positive charges (in the conventional sense) from the top plate of the capacitor to the bottom plate, as Fig.2c shows, so that energy now flows from the solenoid field back to the capacitor, where the electric field builds up again but with opposite sign.

Eventually, the energy will have been transferred completely back to the capacitor, as in Fig.2d. The situation is now similar to the initial one, except for the signs of the charge on the capacitor plates; hence one-half cycle of the oscillation is completed, and the action then repeats to provide the following half.

In a real life situation, the oscillation cannot go on indefinitely because of the inevitable circuit resistance which absorbs the electrical energy and produces heat.

Our knowledge of all this comes from the work of William Thomson and the ultimate outcome over the following decades of the nineteenth century would have surprised him. For looking into the problem further, James Clerk Maxwell showed that if the oscillations were rapid enough (that is, of a sufficiently high frequency), much of the energy stored in the jar could be radiated in the form of electromagnetic waves. Hertz, following on from this, not only produced such waves but devised a method of detecting them. The practical applications made by Marconi and Fleming later on established wireless telegraphy.

LAND AND OCEAN TELEGRAPHY

Much of Thomson's later work had a strongly nautical flavour; principally, this work involved the development of the marine compass and the establishment of a trans-Atlantic cable link to the United States.

We turn for a moment to two other experimenters of the time who were concerning themselves with the problems of telegraphy, Charles Wheatstone and William Cooke, though perhaps we ought to include the name of the American, Samuel Morse, for many allied contributions to the subject.

We have already looked at the researches of Ampere in Part 2 of this series and seen how the French experimenter had made suggestions for an electrical communications system; though his proposed method had itself been of no practical value, nevertheless, the idea had sowed the seeds of the five-needle instrument which was developed and patented in 1837 by Wheatstone and Cooke.

The principle of this device was essentially a feasible redesign of the twenty-six wire system envisaged by Ampere, compressed into a five-wire system which then had practical applications. The principle is illustrated in Fig.3 which shows the panel of the Wheatstone-Cooke design.

Here the letters of the alphabet (neglecting the least used) were arranged at the crossing points of a lattice; across the centre of the lattice were five equally spaced needles which, on receipt of the appropriate signal, could deflect either to the left or to the right and direct the eye along one of the diagonals of the pattern.

Where two such deflections crossed, the letter then being transmitted was observed. For example, if the first needle deflected to the right and the fourth needle deflected to the left, the required letter was B, and so on.

The method may sound a bit primitive to us today, but remember the period was the 1830s, and if you care to look around at the contemporary scene of the art, you will find many instances of such a technique disguised under "cross-bar", "matrix" and "multiplexing" technologies, being used in telephone, calculator and computer routing systems.

Can you suggest, by way of a short mental exercise for a bit of variety, any ways in which the "missing" letters might have been indicated, and what about numbers? Can you think of a simple way of coding each of the letters in binary input signals?

Mental designing apart, Wheatstone and Cooke's electric telegraph provided commercial telegraphic undertakings by the end of 1840 in both England and America; and by 1850 improvements had been so generally perfected that land telegraphy was spread over hundreds of route miles.

At about the same time, Thomas Russell Crampton, an English engineer, successfully laid the first cross-channel submarine cable between Dover and Calais, to be followed soon afterwards by similar short lines connecting England with Ireland and then Holland. As an aside, it might be of interest that Wheatstone invented the concertina in 1827!

LONG LINE PROBLEMS

In the 1850s, the natural ambition of all telegraph engineers was that of establishing communication links over very long distances, particularly across the Atlantic. An apparently insurmountable problem, however, appeared to be in the way of such enterprises; this problem had manifested itself in the first instance over the relatively short lines like the Dover to Calais connection, and the effect it would have on the Atlantic line seemed to rule out such a cable link as a possibility.

It had been noticed that the signals transmitted along the marine cables were very "sluggish" or "retarded" when compared with the clear signals received by overland routes. In May 1855, William Thomson, who had looked into the problem, communicated to the Royal Society a paper entitled *On the Theory of*

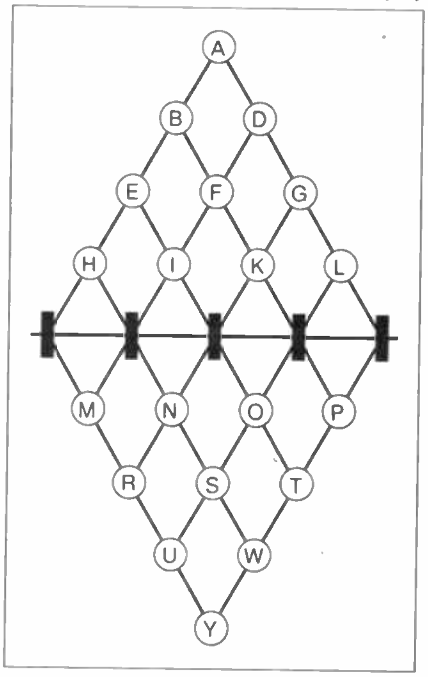


Fig.3. The five-needle telegraph of Cooke and Wheatstone.

the Electric Telegraph, in which he gave the reasons for the observed retardation effect on long cables, along with an important scientific law governing the behaviour.

What Thomson said was that a cable was, in effect, an "elongated" Leyden jar (or capacitor) of very large capacity, the copper wires acting as one of the plates, the salt water as the other plate, and the insulation of the cable (which was gutta-percha in those days) as the dielectric. Also, the wire itself had an inductance which was distributed, like the capacitance, throughout the length of the cable.

The line can therefore be viewed as a perfectly uniform network made up of elemental sections, each section having resistance, inductance and capacitance, yet so uniformly distributed throughout the length of the cable that at no point is there a discontinuity in the form of a "lumped" component. Neglecting the resistance (which is not wholly the guilty party here), the line therefore behaves as a low-pass filter as shown in Fig.4.

Much of this was pointed out by Thomson who, however, was without suitable amplifying equipment; because of this and the resultant weakness of signals at the receiving end of long lines, he devoted his time to the invention of the mirror galvanometer which was very sensitive to small current changes.

These instruments can be found in most college laboratories. In them, the magnet at the centre of the coil in an ordinary galvanometer is attached to a vertically suspended small plane (or spherical) mirror which, of course, swings with the magnet whenever a current is passed through the coil. A spot of light from a focussed lamp is reflected from this mirror on to a distance scale, and with a large spacing between the mirror and the scale, a very small deflection on the part of the mirror will cause a very large change in the position of the spot along the scale.

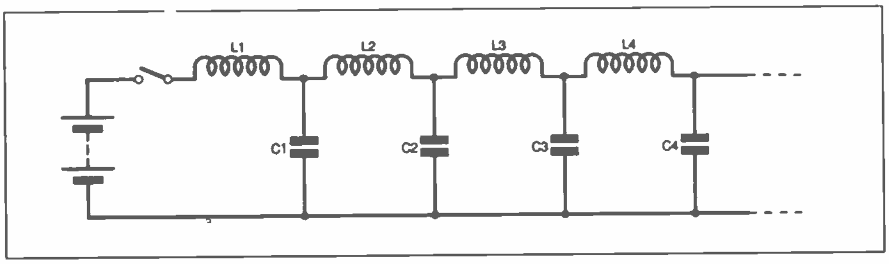


Fig.4. A cable can be represented as a low-pass filter which delays the propagation of a signal.

When a signal, assumed for simplicity to be a battery, is connected to one end of the line, the following sequence of events, said Thomson, occurs:

1. A current will begin to flow through L1 into C1
2. C1 will charge up and a voltage will develop across it
3. This voltage will send a current through L2 into C2
4. C2 will charge in turn, and the process will repeat

Since an inductance will not allow a current to rise instantaneously and a capacitance will not allow a voltage to rise instantaneously, the battery voltage will only move along the cable at a definite speed which may be far below the often accepted (quite erroneously) speed of light. In this way, any signal on the line is retarded or delayed.

In his paper, Thomson showed mathematically that the slowing of the signal was a function of the capacitance, the inductance and (as a consequence) the frequency of the signal. There were also undesirable phase shifts between the frequency components of the signals since different frequencies were propagated at different speeds. The lines not only attenuated but distorted; as most telephone engineers will know (if they have done their City & Guilds examinations properly!) that by inductive loading and getting the relative proportions of *L*, *C*, and *R* per unit line length correct, the distortionless line is possible, and by the addition of amplifiers, the attenuation is overcome.

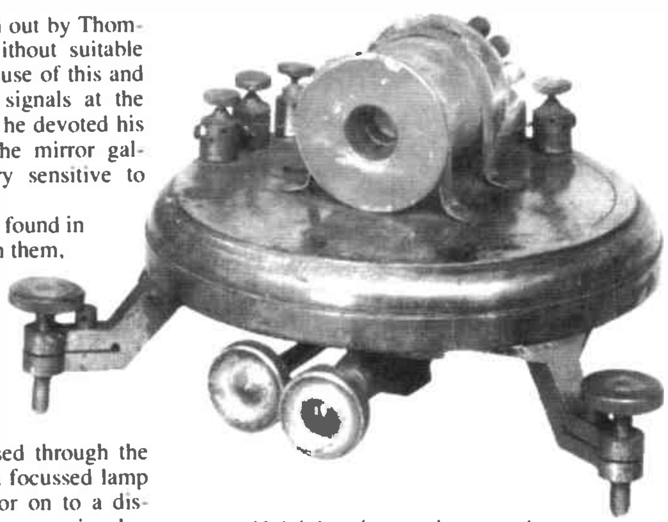
ATLANTIC CABLES

The first Atlantic cable was laid in 1858 by the newly formed Atlantic Telegraph Company, of which Thomson was a director. *(The same year that the first lighthouse, the Foreland in Kent, was equipped with electrically powered arc lights. Ed.)* Over a period of a few weeks more than 700 messages were successfully transmitted over the line, but the cable then failed and it was decided to replace it with a second length rather than to attempt to recover and repair the first.

A cable ship, the *Great Eastern* was designed to carry the whole required length of new cable and to have the necessary freedom of movement which was essential to the successful laying operation. In 1866, after two attempts, not only was the cable successfully laid but the earlier line was investigated and put back into operation. As the engineer in charge of the work, Thomson was knighted and on his return to Scotland was given the freedom of the city of Glasgow.

Not very long after this, Thomson designed what was known as the Siphon recorder in which the message was written as a series of coded marks on a strip of paper tape drawn under the non-contacting pen by an electric motor. This replaced the mirror galvanometer as a receiving device and was the forerunner of the ticker-tape machine which was in general use up to and beyond the Second World War.

Thomson was a man who successfully combined pure and applied science and, unlike some of the other experimenters we have discussed, he had a great mathematical



Kelvin's mirror galvanometer.

ability. Of the many contributions he made to science we have no space to cover them all in this short survey of his life.

Reference must, of course, be made to his work on the marine compass and his sounding machine for measuring the depth of the ocean. There is also the furnishing of lighthouses with distinguishing distinctive lights and his invention of a tide predictor, together with work on wave motion in general and the design of many electrical instruments. His home in Glasgow was the first to be lit by electricity.

LORD KELVIN

In England, apart from the many honours bestowed an him by the international scientific community, further recognition came in 1892 when Queen Victoria conferred upon him a peerage. He took the title of Baron Kelvin of Netherall, this name being taken from the Kelvin river which flowed beside the new university buildings in Glasgow.

He is, perhaps, best remembered today on the subject of thermometry. In 1848 he proposed the scale of absolute temperature, where 0°C corresponds to 273°A (absolute) or 273°K (Kelvin). This scale is the definitive temperature range for scientific investigation.

Lord Kelvin resigned his professorship at Glasgow in 1899, having completed half a century of outstanding scientific research. He died eight years later at the age of 83 and is buried in Westminster Abbey next to the grave of that other great scientific genius, Isaac Newton.

TO CONCLUDE

This, then, concludes our all too brief survey of some of the great experimenters; the list is far from complete. Hopefully, the series of articles may perhaps have stimulated you to "mess around in electronics" a bit more than you do.

There aren't going to be any earth-shaking discoveries, but experimentation, even if you blow up a few components in the process, is the way to learn and enjoy this fascinating hobby.

As the Chinese proverb tells us: "When you are hungry, it is no use painting a picture of a loaf of bread". □

ACKNOWLEDGEMENT

The illustrations used in this article have been kindly supplied by The Science Museum, *London*

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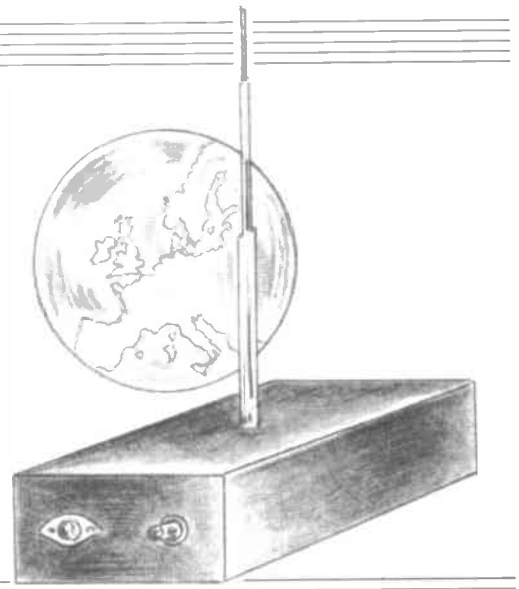


ACTIVE RECEIVING ANTENNA

ADRIAN KNOTT G6KSN

A low cost, "masthead" or "stand-alone" tuned active receiving antenna for 1·5MHz to 5MHz.

HAVING lived mainly in high rise accommodation for many years, the author has found that indoor antennas for h.f. receivers *do NOT work* in high rise buildings due to lots of attenuation from concrete and steel. Interference from TV timebases, and the like is also much worse indoors.

During the past few years experiments with frame aerials, ferrite rod aerials, and even, at one point, the building lightning arrestor has been tried (slightly lethal in a thunderstorm!). Of all the receiving antenna designs that have been tried by far the most compact, and effective has been found to be the "active whip antenna".

IN THEORY

A one metre whip in free space will develop a good percentage of the signal voltage that would be developed by a full sized dipole on h.f. but there is next to no current available. In other words the feed impedance of the antenna, which is electrically very small in comparison to a wavelength, is very high.

A means of matching to 50 ohms (the characteristic impedance of communications type coaxial cable) is required. This can be accomplished by transformer matching but results will not be as good as amplifying the signal at source.

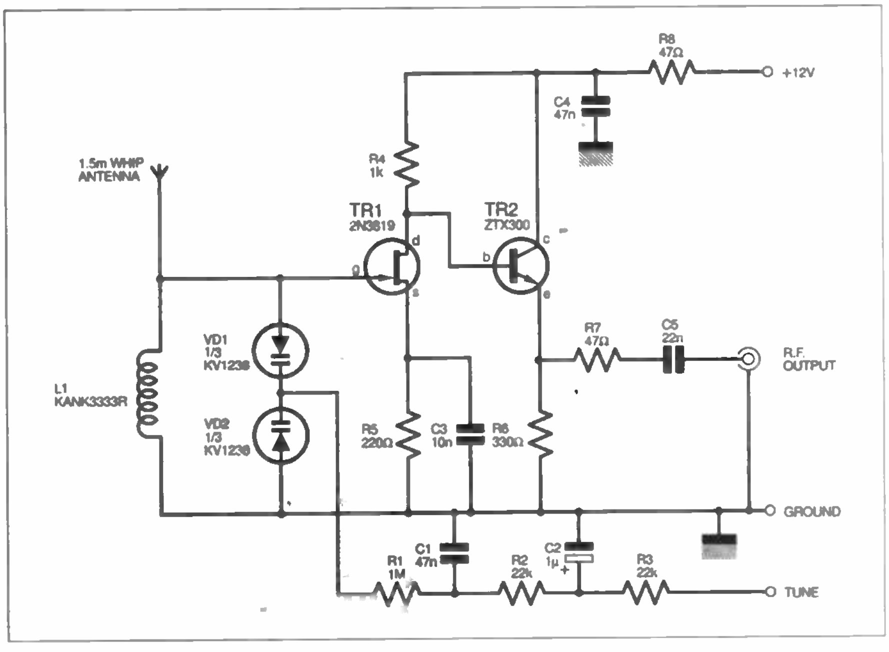


Fig. 1. Complete circuit diagram for the Tuned Active Receiving Antenna.

Although the actual power level developed by the whip is much less than a resonant half-wave dipole, the actual signal-to-noise ratio will be much the same and possibly better. This is because the natural and man-made noise levels on lower h.f. bands are very high, and secondly the antenna can be placed as far away as possible from known sources of interference.

Tuning the whip to resonance is also desirable since any non linearities in the amplifier stage will tend to cause cross modulation. If the whip is brought to resonance then it will respond best to the wanted (and often much weaker) amateur station and tend to reject the more powerful commercial traffic on adjacent frequencies. If the system is tuned then indifferent receivers with a poor image response and a tendency to overload will show a remarkable improvement.

The design featured here is ideal for enthusiasts who simply do not have the space to erect a long wire or dipole type antenna but offers a comparable performance. It is compatible with any communications or broadcast receiver but is especially well suited to the *Direct Conversion Topband and 80m Receiver* featured in the October '96 issue of *EPE*.

CIRCUIT DESCRIPTION

The full circuit diagram for the Tuned Active Receiving Antenna is shown in Fig. 1. The "whip aerial", which is 1 to 1·5 metres in length, is connected to the "hot end" of a tuned circuit formed by r.f./antenna coil L1 and two back-to-back varicap diodes VD1, VD2. These "varicaps" are biased by a variable voltage (one to nine volts) fed remotely to the unit via resistors R1, R2, R3 and capacitors C1, C2.

This network maintains the Q of the tuned circuit and also filters out any hum and noise picked up en-route. The tuning voltage can either be derived from a potentiometer or if used in conjunction with the DCRx (Direct Conversion Receiver) it can be extracted from the pre-selector line.

The tuned circuit feeds the gate (g) of TR1, a field effect transistor (f.e.t.) in common source mode which has a very high input impedance and a moderately low output impedance (around one kilohm in this case). The amplified r.f. is developed across resistor R4. Resistor R5 biases f.e.t. TR1 and the source (s) is bypassed at r.f. by capacitor C3.

The output at the drain (d) of TR1 feeds the emitter follower transistor TR2. This stage has a voltage gain of just less than one but a high current gain such that the output impedance is lowered to a few ohms. Feed to 50 ohm coaxial cable is taken from the emitter of TR2 via R7 and C5, resistive matching and d.c. blocking respectively.

POWER SUPPLY

A 12V supply is fed to the amplifier via resistor R8 and capacitor C4, another line noise filter. Obviously, the unit either needs a remote 12V PSU (Power Supply Unit) or can be powered from the regulated line of the DCR.

The Active Antenna only draws a few milliamperes and so a power supply based around a 78L12 voltage regulator should be more than adequate.

CONSTRUCTION

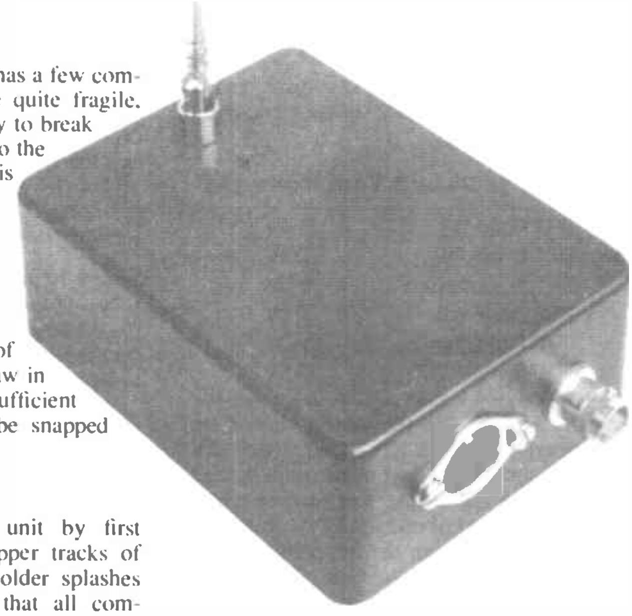
The Active Receiving Antenna is built on a small double-sided printed circuit board (p.c.b.) and the topside component layout and full size copper track master pattern are shown in Fig. 2. This board is available from the *EPE PCB Service*, code 140.

Note the topside (not shown) copper surface acts as a "ground plane" for screening and the component entry holes should be cleared (except for 0V pins) using a large twist drill to lightly countersink the holes, removing some copper to "isolate" the hole. Do not countersink too deeply, this could fracture the board.)

Start construction by inserting and soldering the six solder pins around the periphery of the board. Next solder in position the resistors, capacitors, semiconductors and finally inductor coil/transformer L1.

Although the board only has a few components, some of these are quite fragile, especially L1. It is very easy to break the very fine wires leading to the connection pins unless care is exercised.

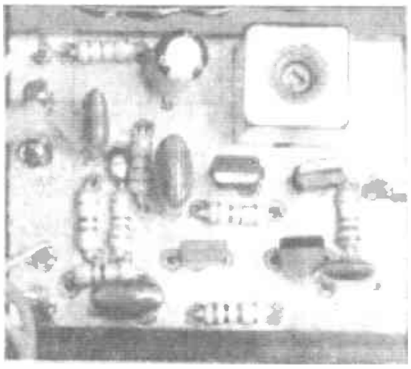
The KV1235 is a triple varicap diode in a single package. It is necessary to literally saw the device into three (be careful) individual components. A couple of strokes with a junior hacksaw in the two notches should be sufficient and enable the device to be snapped into three "segments".



TESTING

Commence testing the unit by first checking the underside copper tracks of the board thoroughly for solder splashes and "dry" joints. Check that all components are positioned correctly on the board (see Fig. 2) and also that they are the right way round. The semiconductors are polarity conscious as is the electrolytic capacitor C2.

If all is well, connect a multimeter switched to the two kilohm (2k) range across the supply lines. A reading of around 1·5 kilohms should be noted. If the reading is very low then you probably have a short or a defective component. Check the circuit again thoroughly.



Component layout on the completed p.c.b. Note the isolating holes for components.

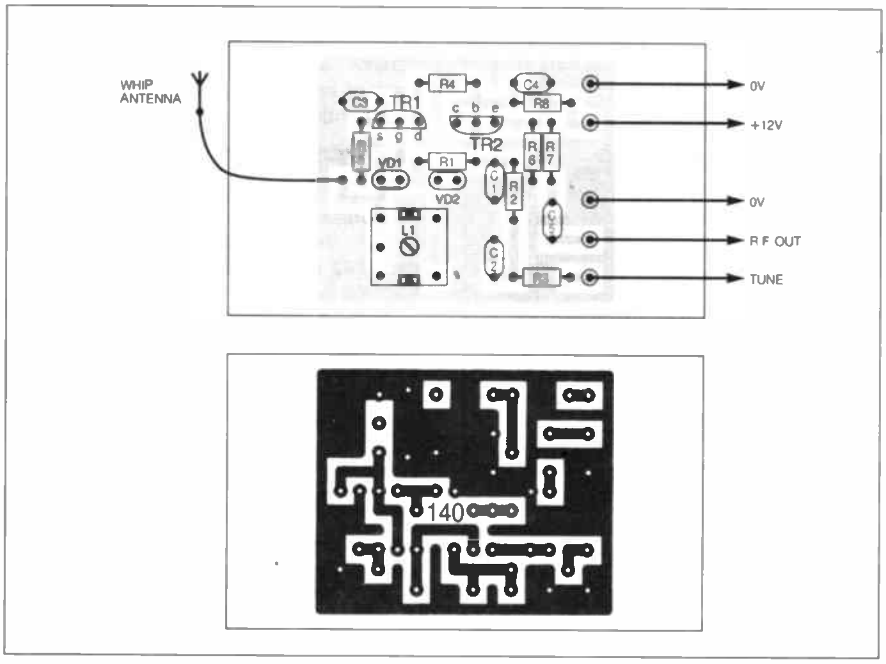


Fig. 2. Printed circuit board component layout and full size underside copper foil master pattern. The topside copper foil layer is not shown for clarity. The 0V connections should be soldered to both sides of the p.c.b.

COMPONENTS

Resistors

R1	1M	See SHOP TALK Page
R2, R3	22k (2 off)	
R4	1k	
R5	220Ω	
R6	330Ω	
R7, R8	47Ω (2 off)	

All 0·6W 1% metal film

Capacitors

C1, C4	47n mylar film (2 off)
C2	1µ radial elect. 16V
C3	10n mylar
C5	22n mylar

Semiconductors

VD1, VD2	KV1235 triple a.m. tuning varicap diode – see text
TR1	2N3819 *n*-channel field effect transistor
TR2	ZTX300 *npn* silicon transistor

Miscellaneous

L1 Toko KANK3333R inductor

Printed circuit board available from the *EPE PCB Service*, code 140; plastic or metal box, size 100mm × 76mm × 41mm approx.; telescopic "whip" aerial, size approx. 1m to 1·5m when extended; BNC chassis socket; 5-pin DIN chassis socket; equal lengths 50ohm coaxial cable and 3-core low voltage cable; multistrand connecting wire, solder etc.

OPTIONAL ATTENUATOR

Resistors

R1 to R3	75Ω (3 off)
R4, R6	68Ω (2 off)
R5	220Ω

All 0·6W 1% metal film

Miscellaneous

S1, S2 d.p.d.t. toggle switch (2 off)

Small metal box, size to suit; coaxial socket (2 off); length of 50ohm coaxial cable; multistrand connecting wire, solder etc.

Approx Cost Guidance Only £19 excluding Attenuator

If all is well connect a 12V supply to the unit. Some typical test voltages are given in Table 1.

Table 1: Circuit Test Voltages

TR1 Gate (g)	0V
TR1 Drain (d)	7·1V
TR1 Source (s)	0·5V
TR2 Base (b)	7·1V
TR2 Collector (c)	11·0V
TR2 Emitter (e)	6·5V

As a check that the varicap diodes are inserted the correct way round, apply 12V to the tuning rail and check with a high impedance multimeter that the voltage at the varicap end of resistor R1 is around 9V (this will vary with the impedance of the multimeter). If one or both varicaps are inserted incorrectly then this voltage will be nearer to one volt.

ALIGNMENT

When performing alignment it is necessary to have the telescopic whip aerial fully extended and positioned away from other objects. Be careful not to touch the whip antenna because you will add extra capacitance to the system and totally detune it.

Make sure that a proper trimming tool is used to adjust aerial coil L1. A screwdriver is NOT suitable as detuning will occur, it is also quite likely that the very brittle ferrite core, within L1, will be cracked resulting in L1 requiring replacement!

Depending on whether you are using the unit with the DCRx (Oct '96) or not affects the alignment procedure.

With the DCRx

For alignment using the DCRx, connect a signal generator set to 1·9MHz or, alternatively, connect a piece of wire (about 20 to 30 feet) to the antenna socket. Set the receiver to topband, adjust and tune the receiver to the signal generator frequency or adjust the Tuning potentiometer to midrange position.

Now adjust the receiver Preselect control for maximum level of tone or noise depending on the signal source. Disconnect the signal generator (or wire) and connect up the Active Antenna. Adjust the ferrite "slug" within the coil former of L1 for maximum received noise.

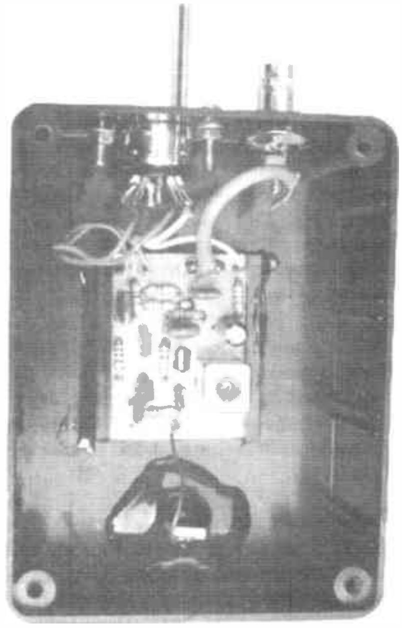
Stand-Alone

The alignment procedure for using as a "stand-alone" unit, for use with a communications receiver is very straightforward and is as follows:

With the tuning voltage set to one volt, simply adjust the slug of L1 for maximum noise or "S" meter reading on a receiver tuned to 1·5MHz.

INSTALLATION

The unit should, preferably, be mounted outdoors in order to gain the best signal-to-interference ratio. The board thus needs to be totally waterproofed. Melted candle wax poured over the board provides a very effective solution to this problem.



Antenna internal layout. Solder the short lead to the telescopic aerial before (due to heat) bonding to box.

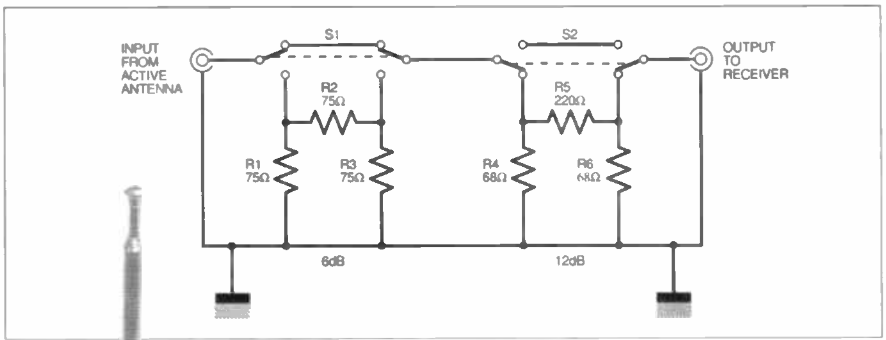
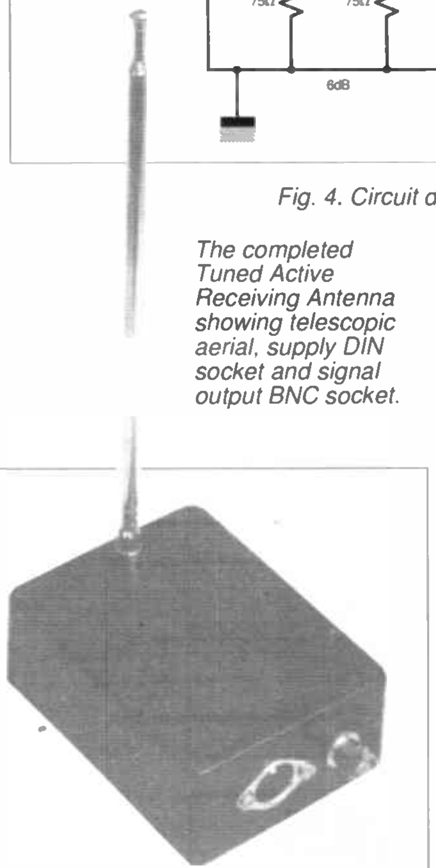


Fig. 4. Circuit diagram for the optional Attenuator unit.



The completed Tuned Active Receiving Antenna showing telescopic aerial, supply DIN socket and signal output BNC socket.

Reliability of the unit should be very high and so this approach can be quite successful. If a repair does become necessary it is possible (but messy) to remove the wax without subjecting the board to further damage by heating the unit until the wax just starts to melt and then scraping it away.

If the unit is mounted on a metallic mast or pole then this should be connected to "Earth" at the aerial end (see Fig. 3). Beware of contact oxidisation problems with aluminium.

ATTENUATOR

A circuit diagram for an optional Attenuator is given in Fig. 4. After going to all the trouble of amplifying and matching the signal, why attenuate it you may ask?

Well a receiver only has so much "dynamic range" that is to say its ability to handle weak signals in the presence of much stronger ones on adjacent frequencies. An attenuator lets you adjust the "dynamic window" to suit prevailing conditions and can be of enormous benefit. A switched unit offering 6dB, 12dB and 18dB of attenuation and a nominal input and output impedance of 50 ohms is shown here.

Only six resistors, two double-pole, double-throw toggle switches and a suitable box with input and output connectors are required. For optimum performance the box should be metal, although plastic can be used with only marginal degradation.

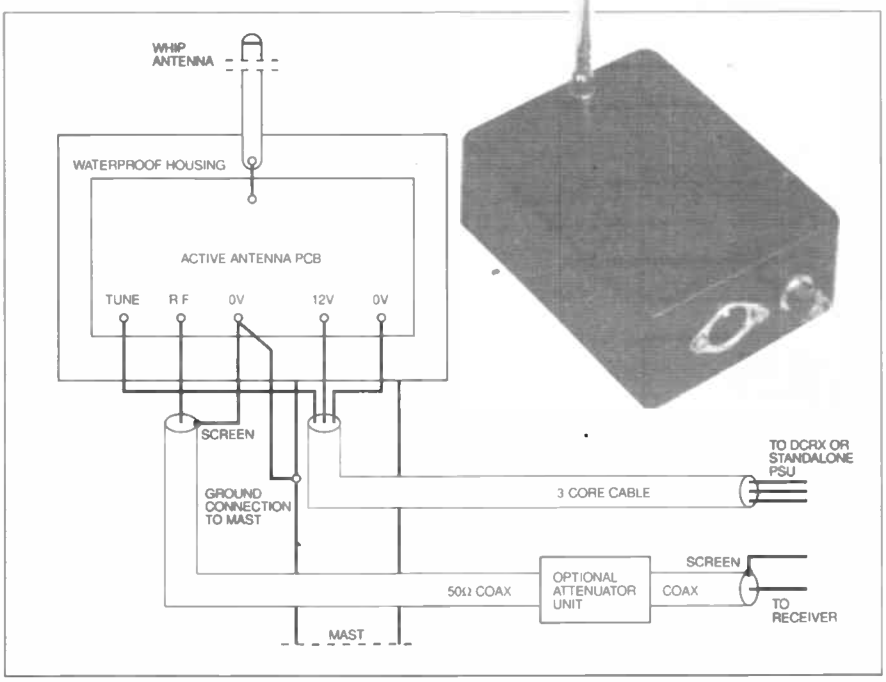


Fig. 3. Interwiring connection details for linking to DCRx, power supply unit or connection to Attenuator unit.

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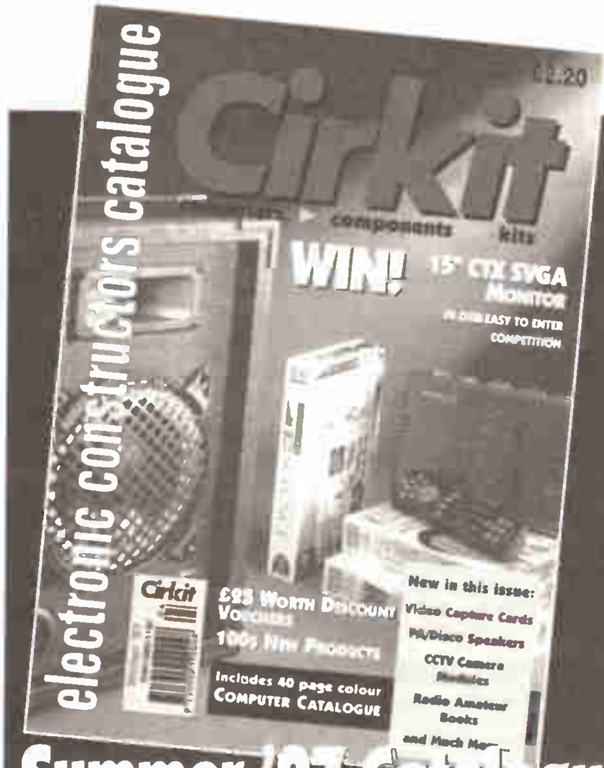

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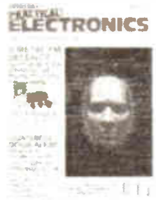

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Building on our experience with the Experimental Electronic Pipe Descaler back in August '93 (one of our most popular projects) we are now pleased to present an improved PIC-based design. These water treatment devices have, over the past few years, proved their effectiveness and this easy to build unit cuts the cost of a commercial design dramatically and has audio and visual monitoring. It will, over a period of time, reduce the level of scale build-up in kettles, boilers, shower heads and around taps etc. By keeping scale to a minimum it should eventually save you money.

RECHARGEABLE HANDLAMP

This article describes how to convert a battery-operated handlamp to a sealed lead/acid rechargeable design. Where the lamp is used more than occasionally, the conversion will be worthwhile and will soon pay for itself in terms of the savings made. By using a sealed lead/acid battery the problems encountered with NiCads are overcome.

REMOTE CONTROL FINDER

If you misplace your TV, Video, Satellite or Audio remote control it can be very frustrating. This little circuit will provide the means to find it. Just whistle and your remote control handset will bleep back at you, telling you exactly where it is!.

MURPHY'S LAW

The all too common outcome of a seemingly predictable chain of events is catastrophe. The more you attempt to avoid it, the worse it appears to get. Thus has Murphy's Law been recognised. We surmise that the Murphy Syndrome occurs too frequently to be pure chance, though reason counsels otherwise. Is Murphy's Law a satanic malevolence, an unseen and fiendish conspiracy to create chaos? Or is this interpretation of adverse phenomena irrational and more properly explained in the simple innocence of probability theory?

Though lighthearted, this article expects to challenge current beliefs. In this respect, readers are forewarned that it is written and structured so as to be convincing. Readers who believe they discern disingenuity, non-sequiturs and syllogisms are invited to rebut – if appropriate.

EVERYDAY PRACTICAL ELECTRONICS

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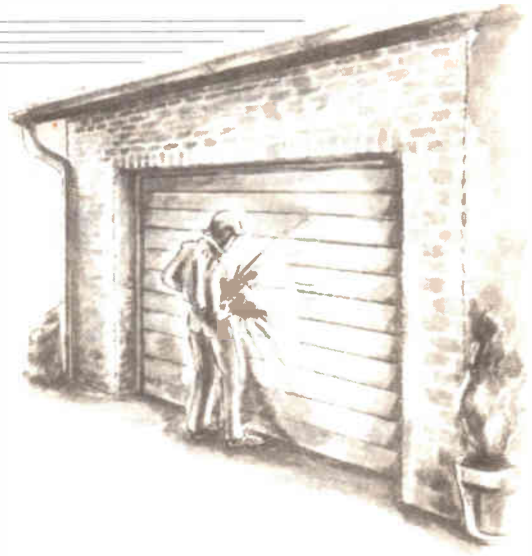
Constructional Project

MICROPOWER PIR DETECTOR



ANDY FLIND

Part 3

Magnetically-Operated, "secret" Alarm Disarm and Reset Switch, with delay-on feature.

THE problems of disarming and resetting a burglar alarm system were mentioned briefly in the Control System project described last month. The pulse-counting circuit provided by this, for use with a PIR sensor covering external areas, gives a brief delay before the alarm siren is activated.

If the user is able to disarm the system before this delay ends it will be possible to enter the property without setting off the alarm. However, access to the disarm switch will probably need to be from outside as the time taken to unlock and enter is likely to be more than sufficient to activate the alarm.

DELAY SWITCH

This raises some difficulties. The first is simply the provision of a waterproof and inconspicuous switch. A reed switch can be used as it may be operated with a small magnet through a window or even a wooden shed wall, but if the magnet has to be left in place observant thieves may figure out how the switch operates and bring their own magnets!

A better method is to use a circuit with a "toggle" action, so that a brief and inconspicuous "touch" with the magnet turns it on and off, but this will need an indicator to show that it has operated and whether the system has been disarmed or reset. The Alarm Disarm/Reset Switch circuit of this project has a toggle action and uses an l.e.d. which gives a brief flash as the system is reset and a slightly longer one to indicate when it becomes disarmed. Like the other two projects of this series it uses virtually no supply current at all in the quiescent state, so it is ideally suited for use in battery operated systems.

An extra facility required when resetting an alarm system is a delay that will give the user time to leave the area and let the PIR sensor settle to the "ready" state. A delay is built into this project, and can be easily adjusted to the user's preference by altering the value of a single resistor.

HOW IT WORKS

The circuit is based around a simple toggle switch built with two CMOS inverters as shown in a simplified form in Fig.1. If it is assumed that the input to the gate G1 is negative, its output will be positive, thereby causing the output of gate G2 to be negative. Feedback is taken from the output of G2 through resistor R1 to the input of G1 so that this state will be maintained indefinitely.

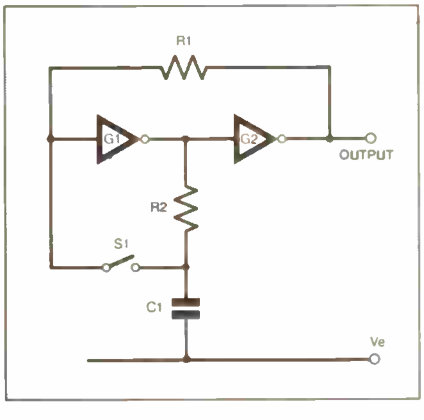


Fig.1. Circuit diagram for demonstrating the principle of the electronic toggle switch.

Meanwhile, capacitor C1 is charged to the positive supply voltage through resistor R2. If the switch S1 is now closed, this positive charge will override the negative input from R1 and the circuit will change state, with the output from G2 becoming positive.

If the switch is held closed, sufficient positive current from R1 will flow through it into C1 to prevent discharge of this capacitor through R2 into G1's output, which is now negative, so the new state is maintained. When S1 is released C1 is discharged by R2 so that the next operation of the switch will cause the circuit to change back to the original state.

The switch therefore toggles the output between positive and negative, and since it operates immediately when pressed but cannot operate again until released for sufficient time to allow C1 to charge or discharge, the problem of contact bounce is eliminated.

CIRCUIT DESCRIPTION

The full circuit diagram for the Alarm Disarm/Reset Switch is shown in Fig.2. In this IC1a and IC1d, two of the four NAND gates in a CMOS 4011B, are used as inverters to build the toggle-action switch.

The outputs of both gates are coupled through time constants, capacitor C2 with resistor R3 and C3 with R4, into the two inputs of gate IC1b. Each time the switch toggles one of these inputs goes negative briefly, causing the output of IC1b to supply a positive drive pulse to the l.e.d. D1.

Capacitor C2 has a higher value than C3 so that when the output of IC1d goes negative the l.e.d. flash is longer than that given when the output of IC1a goes negative. This is the "Disarmed" state, with a positive output from inverter IC1c, which holds the 4060B counter-oscillator IC2 in its "Reset" condition.

Whilst this reset input is present the oscillator of IC2 cannot operate and all its outputs are negative. The negative output from the final output, pin 3, is inverted and buffered by IC3c and IC3d to give a positive output signal for disarming the Control board (last month).

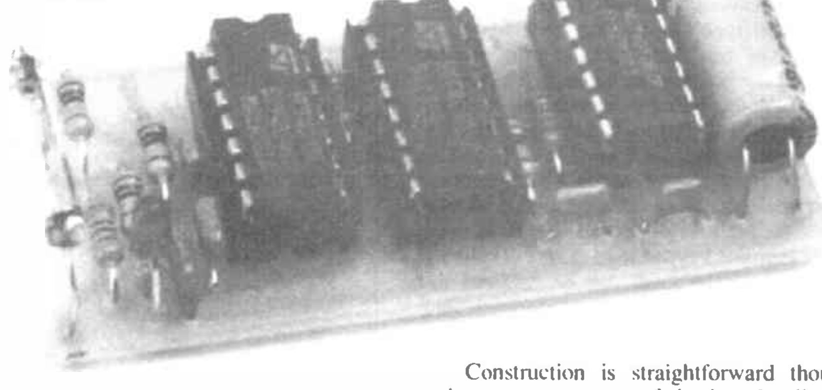
DELAYED ACTION

When the switch is toggled back into the alarm Reset state, the output of IC1d goes positive so the output of IC1c goes negative and the internal oscillator of IC2 begins operating. The oscillator connections of IC2 are pins 9, 10 and 11, and the output from pin 10 is usually connected through a resistor directly to the junction of R6 and C4. In this circuit it first passes through the exclusive-OR gate IC3a.

Whilst pin 3 of IC2 is negative the signal from pin 10 passes unaltered to resistor R7. When the count reaches the value where pin 3 goes positive, IC3a inverts the signal from pin 10 so the oscillator stops. This causes the output from pin 3 to remains positive until the switch is toggled again to reset it, and this positive output is inverted and buffered by IC3c and IC3d to give the negative output condition to reset the alarm.

This circuit action provides a delay between the circuit being switched to the alarm Reset state and the negative "reset" output actually appearing. The length of the delay is set by the values of capacitor C4 and resistor R7, those shown giving a time of about twenty seconds. If R7 is increased to 56k (kilohms) the delay will increase to about fifty seconds.

Completed Alarm Disarm/Reset Switch board. including the magnet operated reed switch.



CONSTRUCTION

The components for the Alarm Disarm/Reset Switch are all mounted on a small printed circuit board and the component layout and full size copper foil master are shown in Fig.3. This board is available from the *EPE PCB Service*, code 166.

Construction is straightforward though the compact nature of the board calls for careful assembly and soldering. D.I.L. sockets should be used for the three i.c.s as they reduce the amount of handling and the consequent risk of damage by static electricity or heat during soldering. They also make testing and trouble shooting much easier.

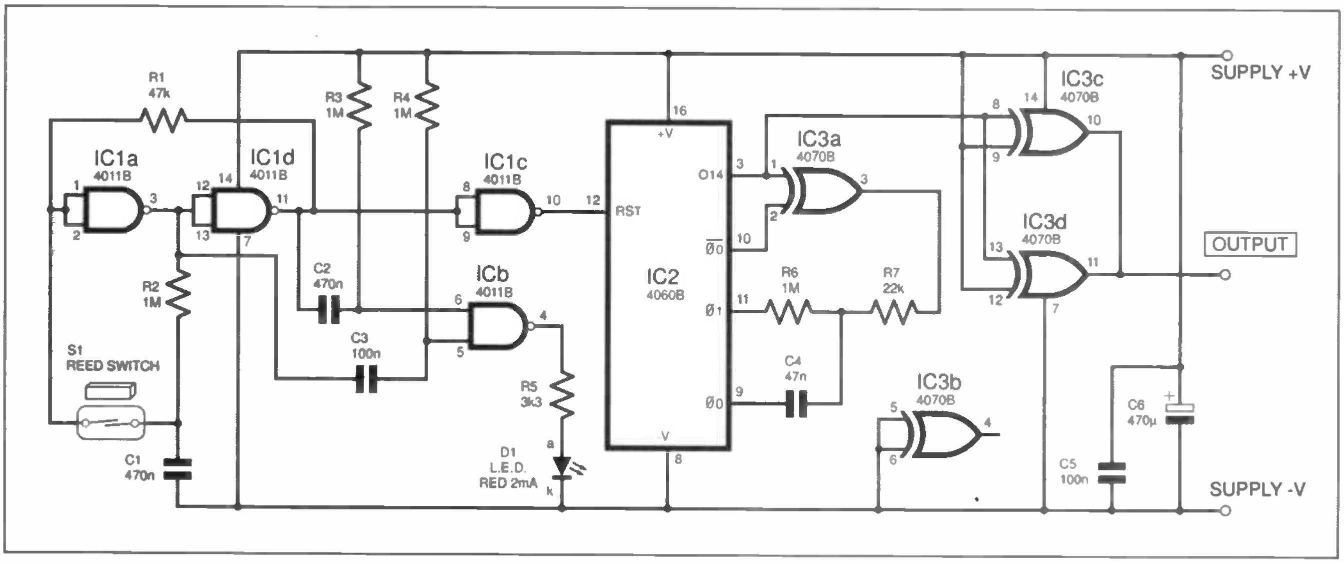


Fig.2. Complete circuit diagram for the Alarm Disarm/Reset Switch. The supply voltage can be from 6V to 15V d.c.

COMPONENTS

µPIR Disarm/Reset Switch

Resistors
R1 47k
R2, R3, R4, R6 1M (4 off)
R5 3k3
R7 22k
All 0·6W 1% metal film

See SHOP TALK Page

Capacitors
C1, C2 470n resin-dipped ceramic (2 off)
C3, C5 100n resin-dipped ceramic (2 off)
C4 47n resin-dipped ceramic
C6 470µ radial elec. 16V

Semiconductors
D1 3mm, low-current, l.e.d. red
IC1 4011B CMOS quad NAND gate
IC2 4060B CMOS 14-stage ripple counter with internal oscillator
IC3 4070B CMOS quad Exclusive-OR gate

Miscellaneous
S1 miniature reed switch, with magnet (see text)
Printed circuit board, available from *EPE PCB Service*, code 166; 14-pin d.i.l. socket (2 off); 16-pin d.i.l. socket; multistrand connecting wire; solder pins (3 off); solder etc.

Approx Cost Guidance Only **£12**

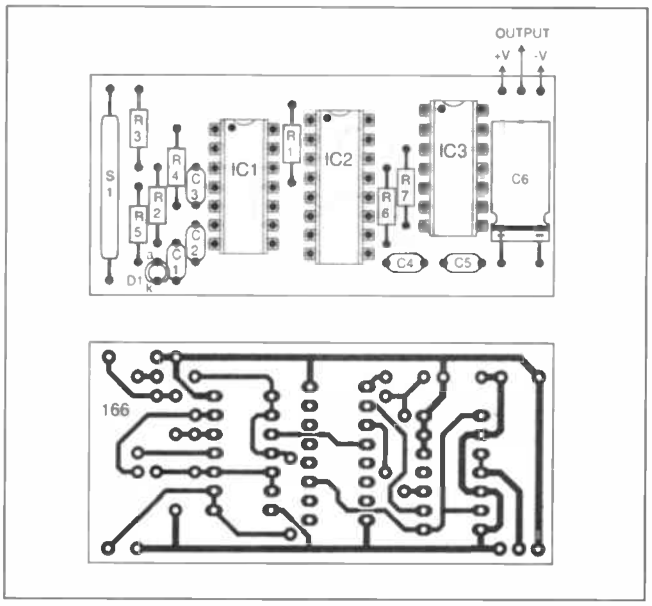
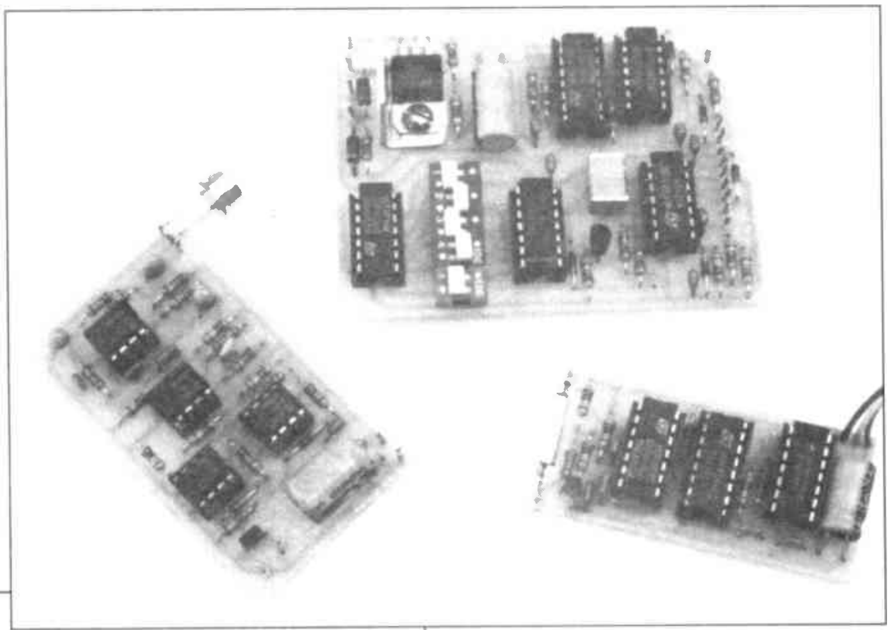


Fig.3. Printed circuit board component layout and full size underside copper foil master pattern.

The switch used for S1 doesn't have to be a reed type, although in the majority of applications this will probably be the preferred type. A miniature one having a length of less than about 18mm can be placed directly on the board if required. If this is done, extreme care should be taken when bending the leads to avoid cracking the glass body.

Any other type of switch with a momentary-make action can also be used, such as a pushbutton, a key-operated switch or even an electronic keypad if its output is suitably interfaced. The l.e.d. can be soldered directly to the board or situated elsewhere and wired to it.



TESTING

The action of the "toggle switch" based on IC1 can be tested independently before insertion of IC2 and IC3. The power supply to the circuit is intended to be about 12V, taken from the Control board described last month, but any supply between 6V and 15V can be used.

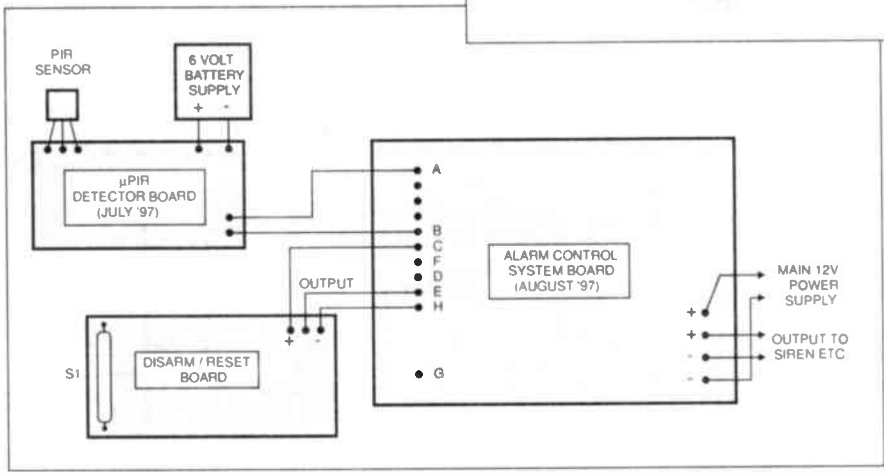


Fig.4. Linking the three modules together to form an integrated alarm system. The three boards are shown in the photograph above.

Shorting the connections for S1 should cause the l.e.d. to flash and the difference between long and short flashes should be readily visible, with the output of IC1c, pin 10, being positive following a long flash.

Since the delay timer uses IC2 and IC3, both must be inserted in order to test this part of the circuit. Following a long flash of the l.e.d. D1 the output from IC3c and IC3d should go positive immediately and remain there. After a short flash, it should remain positive for the period set by the value of resistor R7 before going negative.

During the timing period the oscillator will be running so a squarewave signal will be present on pins 9 and 10 of IC2. Most meters will give an apparent reading of about half the supply voltage if connected to these, indicating operation of the oscillator.

IN USE

Connection to the Control project circuit board (last month) is shown in Fig.4, though it is possible that this little circuit will find many uses in other systems and applications. Constructors will no doubt be able to think of many ingenious methods of installation.

Depending on the type of reed switch and strength of magnet used the reliable operating range can be over 20mm, so operation through a window pane is no problem. It can also be operated through the wooden walls of many sheds, perhaps with an inconspicuous mark (a knot?) to show the owner where to touch with the magnet.

One simple suggestion is to disguise the board by placing it in a matchbox to be left on a window sill. The l.e.d. should be visible of course, to confirm the "Disarm" and "Reset" action, but a 3mm l.e.d. can be very inconspicuous.

A final suggestion which may be useful is to assemble all three parts of this series together with an alarm siren as a self-contained portable unit. This could be placed and armed anywhere, in a vehicle, a tent, a garden, or anywhere else where there is a need for immediate protection from intrusion or theft. □

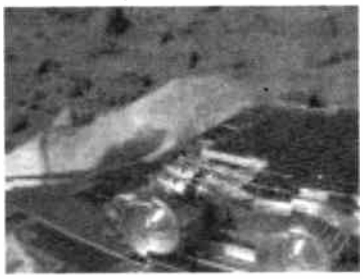
UFO LANDING?

Air Force denies stories of UFO crash

Story and surveillance photos from our Special Correspondent

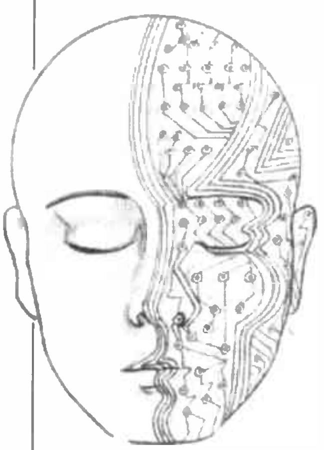
VALLES Marineris (MPI) – A spokesthing for Mars Air Force denounced as false rumours that an alien space craft has crashed in the desert, outside of Ares Vallis. Appearing at a press conference, General Rgrmrmy The Lesser stated that "the object was, in fact, a harmless high-altitude weather balloon, not an alien space craft".

The story broke when a major stationed at nearby Ares Vallis Air Force Base contacted the Valles Marineris *Daily Record* with a story about a strange balloon shaped object which allegedly came down in the nearby desert, "bouncing" several times before coming to a stop, "deflating in a sudden explosion of alien gases".



Minutes later, General Rgrmrmy The Lesser contacted the *Daily Record* telepathically to contradict the earlier report.

General Rgrmrmy The Lesser stated that hysterical stories of a detachable vehicle roaming across the Martian desert were blatant fiction, provoked by incidences involving swamp gas. But the general public has been slow to accept the Air Force's explanation of recent events, preferring to speculate on the "other-worldly" nature of the crash debris. Conspiracy theorists have condemned Rgrmrmy's statements as evidence of "an obvious government cover-up", pointing out that Mars has no swamps.



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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) 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!**

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- Multimeter • Frequency Meter
- Signal Generator

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19kHz Reference Source - Name That Tone

When constructing certain types of test or measurement gear, it can be difficult to ascertain its accuracy without the help of a precision reference source. The circuit of Fig. 1 was constructed to help with setting up a frequency meter, and it provides a 19kHz TTL-compatible signal which is derived from an FM stereo pilot tone.

A pilot tone is transmitted with a tolerance of 2Hz (0·0105%), 20dB below peak audio level (at a reference of 400Hz); de-emphasis in the receiver (50μs) reduces this by 15dB. The pilot tone should be present at the Headphone socket of a mono radio as the manufacturer would have no reason to remove it!

Resistor R1, capacitor C1 and inductor coil L1 form a bandpass filter tuned to 19kHz. L1 is a low-cost 4,700μH choke; the circuit "Q" measured 6·7 resulting in the output being 10dB down at 15kHz and 23kHz, thereby filtering out the A+B and A-B signals. The insertion loss is 15dB, and as it is, C1 needs no trimming.

The op.amp IC1 is configured as a non-inverting amplifier running from a single supply rail. The gain is set at 29dB. IC2 is an LM567 phase-locked loop (tone) decoder i.c. with filter capacitors C6 and C8 being selected empirically for best results.

The light-emitting diode D1 will illuminate when the i.c. is locked into the incoming 19kHz signal. The VCO (voltage controlled oscillator) output of IC2 (pin 5) is then equal to 19kHz and this is buffered by emitter follower TR1. TR2 level-shifts this to a TTL-compatible 5V signal.

Sensitivity is −45dBu at 19kHz at the point where IC2 just locks. Assuming that the radio used is set to give 0dBu at the headphone socket – a reasonable listening volume – and that the pilot tone is then −35dBu, there will thus be 10dB in hand. These levels were chosen so that the radio volume control does not have to be set deafeningly high if the headphone jack is pulled out before reducing the volume.

As regards accuracy, when measured with a 10-second gate period, the spread in pilot tone frequency from ten different stations was only 0·8Hz, so it would appear that the tolerance could be as good as 0·002% which is very satisfactory for setting up home-made gear.

Setting up involves tuning a radio to a strong FM stereo signal; slowly adjust VR1 until the l.e.d. lights and continue to adjust until, with the radio's volume control as low as possible, the l.e.d. lights within 0·5s of connecting the radio. The circuit was built in a metal box due to its sensitivity. Four different radios were successfully used with the prototype.

B. J. Taylor, Rickmansworth, Herts.

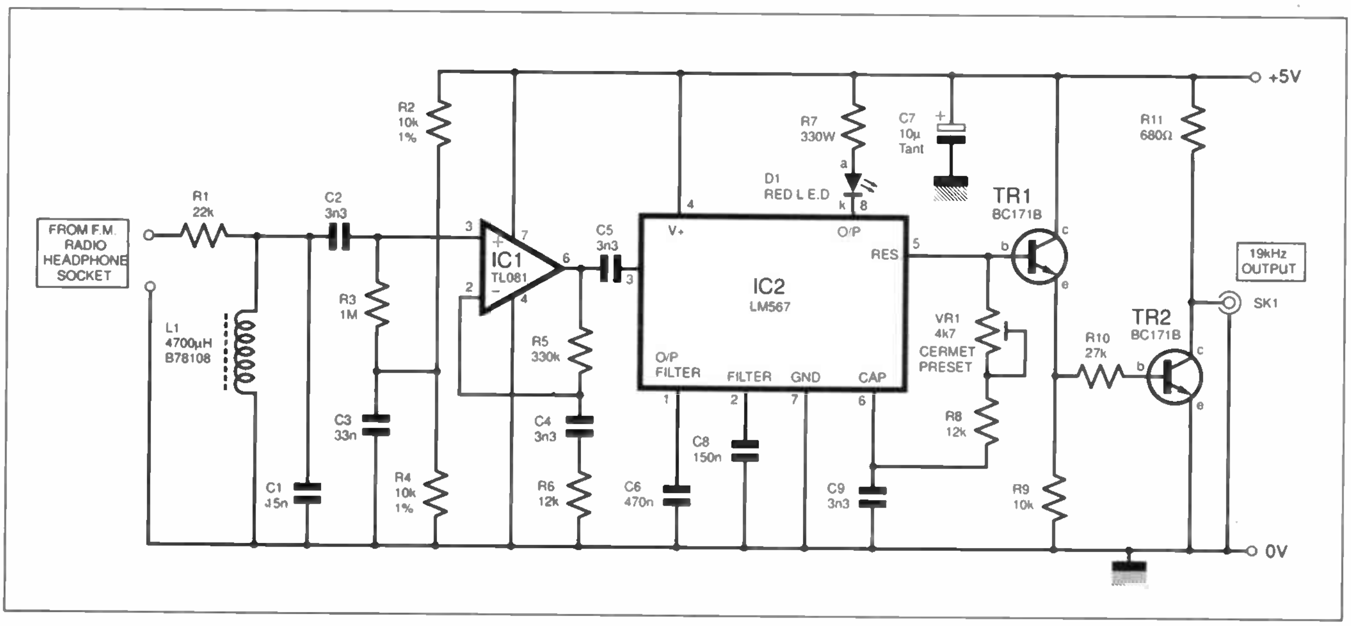

Fig. 1. Full circuit diagram for a 19kHz Reference Source. Coil L1 is from the Siemens B78108S series of miniature r.f. chokes and is currently listed by Cirkit, code 35-71475 and Electrovalue, code B78108S1475J.

Non-Linear Amplifier - Fantastic Fuzz!

CONVENTIONAL amplifier circuits are all linear: their outputs are directly proportional to the inputs. Conventional fuzz-box circuits all require amplification. The non-linear amplifier of Fig. 2 differs in both of these respects.

The circuit comprises a small-signal *pnp* transistor TR1 connected as an inverting amplifier, with a voltage gain of about 100. This drives IC1, a 555 connected – unusually – as a Schmitt trigger. This is achieved by tying the trigger and threshold comparator inputs together in order to provide hysteresis.

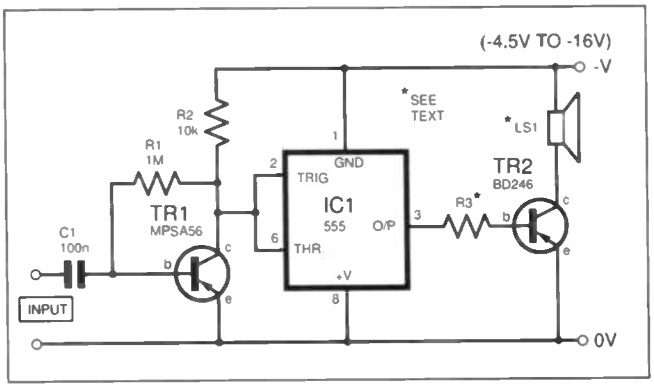

Fig.2. Circuit diagram for a Non-Linear Amplifier (Fuzz). Note the "reversed" supply rail voltages.

Pin 3 of the 555 drives a *pnp* power transistor, TR2, via a current-limiting resistor R3, which is selected to provide 200mA drive current. TR2 drives the loudspeaker directly, and since the rise and fall times are only a few microseconds, during the transition time power is dissipated by the transistor only for a very short period. At other times, the dissipation is virtually nil: either the voltage across the device is high but the current is zero, or the voltage across it is near zero and the current is high (negligible dissipation).

If the switching rate is kept fairly low, the safe operating area of TR2 changes from its familiar hyperbolic curve to a rectangle. This allows considerable output power to be delivered with only a single output device and a small heatsink.

When delivering a square wave, the total output power is $V^2/2R$, but half of this can be shown with Fourier analysis to be d.c., the actual signal being $V^2/4R$. When driving a speaker, the d.c. component must be taken into account – use a speaker much larger than the ratings suggest.

The prototype was built into a small enclosure and provided 18 watts of signal into 2 ohms when powered from an external 12V supply. The heatsink measured only 45mm x 40mm x 16mm. By utilising a large number of high voltage power transistors in a parallel Darlington configuration, the author is constructing a 5kW version (!), at a nominal cost. Experimenting with different inputs, the author found that music by the electronic group *Kraftwerk* emerged curiously unaffected!

Nick Sheldon, Norwich.

"Squeakie" Practical Joke - Drives Folks Bats!

A DESIGN for an alternative type of bug – the annoying type – is shown in Fig.3. This little circuit has caused endless hours of amusement amongst friends and family. It emits a periodic "squeak" by combining two oscillators built around an LM393 dual comparator i.c.

A slow-running oscillator is built around IC1a. Resistors R2 and R3 set an upper threshold of about 2·5V and R1 slowly charges capacitor C1. Resistor R5 pulls TR1 base (b) to the +3V rail and switches it off.

When C1 reaches 2·5V, R5 is pulled low by IC1a and switches TR1 on, discharging the capacitor to a lower threshold voltage of about 0·6V, as set by R2 and R4. R1 sets the "off" period, and with the value shown produces a delay of about 90 seconds between squeaks. This can be varied if desired.

The audio oscillator based around IC1b operates on a similar principle, but the threshold is varied by the voltage from C1's discharge via TR1 and R6, which produces the pitch change of the "squeak" (high to low). Resistors R9 and R10 set the frequency of operation. R7 sets the amount of pitch shift in the squeak whilst R6 sets the duration and rate of change of the squeak. Transistor TR2 drives loudspeaker LS1 directly.

The circuit uses just two AA size batteries to produce a 3V rail at 3·5mA. A set of batteries will last for about three weeks of continuous squeaking. Battery life can be extended by substituting an inductor and piezoelectric sounder for LS1 and increasing resistor R10 to about 100k, in which case a 3V lithium battery can be used and the construction miniaturised.

(Note, the transistors used are standard general-purpose small-signal which can be substituted with many alternatives. Readers should take especial care with the reversed-style of transistors specified - check the connection data closely - A.W.)

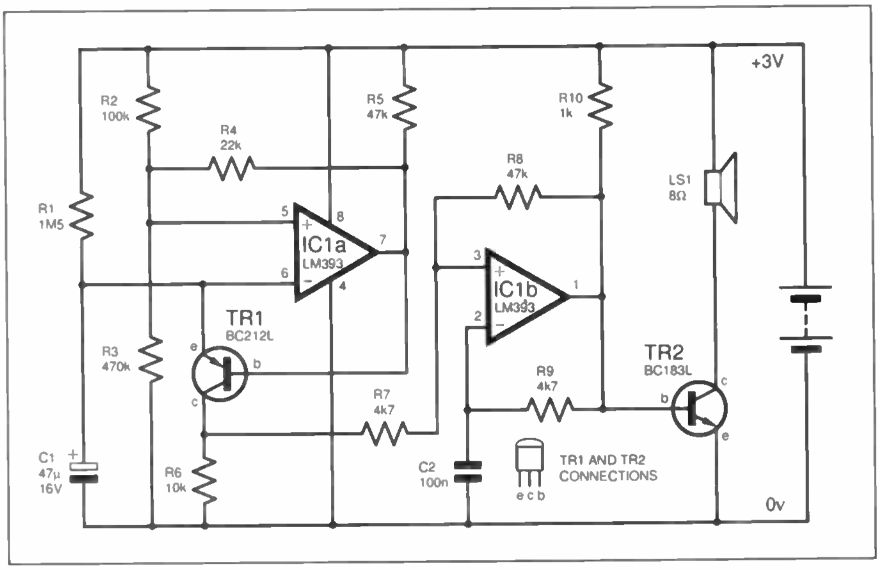

Fig.3. Circuit diagram for Squeakie, the Practical Joke!

Here are my Top Ten locations to "bug" people with Squeakie: ● Underneath an associate's desk ● In a shoe in a bedroom cupboard ● Underneath a regularly moved chair ● In the pocket of a Lab. Technician's white coat ● Stuck to the underside of a public bar ● On top of a light fitting in an examination hall ● Underneath the driver's seat of a new R-registered car (*dangerous*) ● Inside the liner of a kitchen bin ● Inside an ornamental pot or vase ● Stuck to the back of a book in a book shelf.

Also, multiple Squeak placement can have devastating results when they each have a different time constant and pitch!

Adam Fullerton, Salisbury, Wilts.

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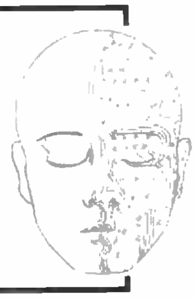

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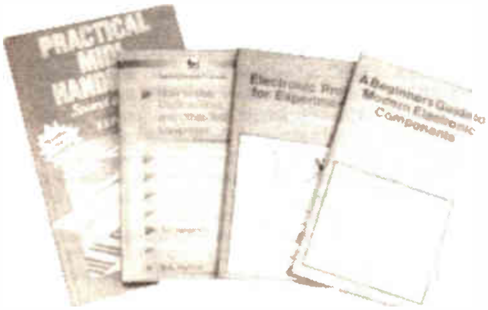

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R. A. Penfold

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Computing

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P. R. M. Oliver and N. Kantaris

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179 pages **Order code BP385** £4.95

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R. A. Penfold

Not only are PC and compatible computers very expandable, but before long most users actually wish to take advantage of that expandability and start upgrading their PC system. Some aspects of PC upgrading can be a bit confusing, but this book provides advice and guidance on the popular forms of internal PC expansion, and should help to make things reasonably straightforward and painless. Little knowledge of computing is assumed. The only assumption is that you can operate a standard PC of some kind (PC, PC XT, PC AT, or an 80386 based PC).

The subjects covered include: PC overview; Memory upgrades; Adding a hard disk drive; Adding a floppy disk drive; Display adaptors and monitors; Fitting a maths co-processor; Keyboards; Ports; Mice and digitisers; Maintenance (including preventative maintenance) and Repairs, and the increasingly popular subject of d.i.y. PCs.

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Testing, Theory, Data and Reference

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Ian Sinclair
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Contents: waves and pulses, passive components, active components and ICs, linear circuits, block and circuit diagrams, how radio works, disc and tape recording, elements of TV and radar, digital signals, gating and logic circuits, counting and correcting, microprocessors, calculators and computers, miscellaneous systems.
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R. A. Penfold

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Have you ever wished for a concise and comprehensive guide to electronics concepts and rules of thumb? Have you ever been unable to source a component, or choose between two alternatives for a particular application? How much time do you spend searching for basic facts or manufacturer's specifications? This book is the answer, it covers resistors, capacitors, inductors, semiconductors, logic circuits, EMC, audio, electronics and music, telephones, electronics in lighting, thermal considerations, connections, reference data.
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This book is in effect more than just a dictionary of practical electronics terms, it goes a stage further in also getting down to fundamentals. Accordingly the number of terms may be limited but the explanations of the many which are included are designed to leave the reader more competent and satisfied – and this is without the use of complicated mathematics.
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The book covers: **Basics** – Voltage, current and resistance; Capacitance, inductance and impedance; Diodes and transistors; Op-amps and negative feedback; **Fault finding** – Analogue fault finding; Digital fault finding; Memory; Binary and hexadecimal; Addressing; Discrete logic; Microprocessor action; I/O control, CRT control; Dynamic RAM, Fault finding digital systems, Dual trace oscilloscope; IC replacement.
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EPE SOFTWARE

Software programs for the *EPE* projects marked above with an asterisk (*) are available altogether on a *single* 3.5 inch PC-compatible disk, or as needed via our Internet site. The same disk also contains the following additional software: Simple PIC16C84 Programmer (Feb '96). The disk (order as "PIC-disk") is available from the *EPE PCB Service* at £2.75 (UK) to cover our admin costs (the software itself is *free*). Overseas £3.35 surface mail, £4.35 airmail. Alternatively, the files can be downloaded *free* from our Internet FTP site: **ftp://ftp.epemag.wimborne.co.uk.**

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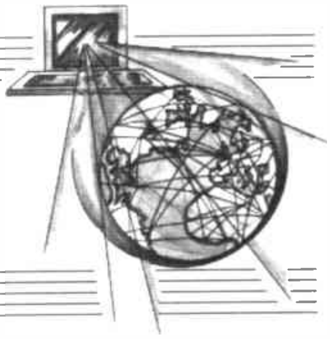

ALAN WINSTANLEY

THIS is our monthly column specially written for readers having access to the Internet – perhaps through your firm or school/college, or with a personal dial-up account used at home. *Net Work* is all about helping you to get the most out of your time on-line, keeping you posted with any updates to our web pages **(http://www.epemag.wimborne.co.uk)** and our own FTP site **(ftp://ftp.epemag.wimborne.co.uk),** and bringing you any topical chat. This month's *PIC Noughts & Crosses* software is at sub-directory **/pub/PICS/PICnoughts.**

The on-line version of *Net Work* provides a very large selection of links which we hope will interest fellow electronics fans – remember that we are always keen to share any interesting web and FTP URL's (Uniform Resource Locator) with our readers – let us know your favourites and you'll receive a mention on our web site. Don't forget to look out for the *Net Work A-Z Index* of all the URL's we've linked to so far – all you need to do is point and click!

New Addition

A new addition to our FTP site is a document *Guidance Notes for Newcomers to Usenet or 'Newsgroups'*. It gives a detailed insight into the philosophy of Usenet (Unix User Network) and how to behave properly. Newsgroups – there are 25,000 or more of them – are meeting places in cyberspace where you can exchange views and information on a particular topic. It's a great place to discuss computing and programming issues, for instance, but you can select from a massive variety of hobbies, recreations, scientific and technical areas. It was felt that this guidance document would be worth uploading to our FTP site, at **../pub/docs/usenet.txt** (42K).

Each newsgroup is usually dedicated to one particular discipline or subject, from the most fundamental or mundane, right up to the highest technical levels. Using some newsreader software, or even your web browser, you can "post an article" into the newsgroup which will be circulated electronically to everyone else who "subscribes" to the same newsgroup.

They, in turn, might post a "follow-up" response, which you'll receive next time you connect to the Internet. Thus, it is possible that a contentious subject will result in a long "thread" developing, with dozens or more replies arising. Sometimes, there may be no response at all, occasionally the thread will have grown into 100 follow-ups or more.

Netiquette

Usenet is an amazing example of self-regulation on a global community scale. It is unfair on everyone else to stray very far from the "charter" of the Newsgroup – the very reason for its existence – by posting something which is completely "off topic". If you create "noise" by posting something which is irrelevant to a particular newsgroup, then if you're lucky it will merely be ignored, but otherwise you can expect to attract "flames" – abusive postings from others which vary in intensity from polite reminders to total thermo-nuclear meltdown!

It's also against the established rules of "netiquette" to post binary files to any group which exists for discussion only (e.g. the sci.electronics.* groups). The difference is that many newsgroups are simply open-standard "chat" facilitators in which text messages are posted – a very economical form of global communication.

Occasionally though, some users decide to post binary files – such as .zip files of demo software, or .gif or .jpg image files, because it is simple to convert such computer images and programs, by UUencoding them – whereby data can be translated into plain ASCII, as used in E-mail or news posting. Thus, binary computer files can be transmitted as (incomprehensible) text.

Sometimes, folks genuinely think they are doing us all a favour by sharing e.g. demo software with us in a newsgroup, but they're not: each file can take 100K or more, and in the worst cases they reduce a subscriber's newsfeed to a crawl. It is a waste of bandwidth which costs everyone time, money and general aggravation. There are however many groups in which you *should* expect to receive binary postings – **alt.binaries.schematics.electronic** for example (yes, in *that* notorious part of Usenet . . .).

If you'd like to try your hand at news, take a tip: it's much better to subscribe to the newsgroup for a week or two and simply read it, in order to get an idea of the flavour and level, before trying to post something yourself. Be warned that Usenet is extremely addictive, but if you read the **usenet.txt** file from our FTP site, you're sure to have a happy time chatting with like-minded people from all around the planet! I have made many friends this way around the world.

More Junk

More on **junk E-mail**, following on from last month's column: it continues to dribble through, two or three mails every time I connect. I eventually found a ***free*** name removal filter to which I subscribed on-line, but it still has not eliminated junk yet! I'll report how effective it really is, next month.

Hot Links

To save you time, the following sites are all "enabled" on our on-line *Net Work page*. First, more information on "name removal" to combat unsolicited mail is stashed away at the [American] Internet E-mail Marketing Council at **http://www.iemmc.org.** For a search engine to check what's what on Usenet posts – see the essential **http://dejanews.com.** (For a test, use it to find my recipe for Lemon Meringue!) Then move on to the Bebop Site – **http://sh1.ro.com/~bebopbb**, a book and multimedia computer educational package (the *Beboputer*) which I shall be reviewing separately. If you enjoyed the excellent book *Bebop to the Boolean Boogie* you'll be delirious about this follow-up book and CD ROM, just out.

Those into GPS (Global Positioning System) navigational devices really must see the informative site **http://www.vancouver-webpages.com/peter/** where there is a massive variety of GPS links, FAQ's and software galore – even a yacht race scoring program!

The UK and Europe now have their own versions of a few popular web sites: starting with two essential search engines, the trendy and ubiquitous *Yahoo!* at **http://www.yahoo.co.uk** and my preferred, and more powerful Alta Vista at **http://www.altavista.telia.com.** Likewise, UK Apple Macintosh users will appreciate **http://www.alwaysapple.com** which has some UK search engines.

A listing service for robotics and electronics sites called *Electron-Surf* is under heavy construction at **http://www.electronics2000.com.** On a more scientific basis, the American site **http://www.scicentral.com** has been created for scientists and engineers as a gateway to some 50,000 sites in over 120 scientific disciplines. They plan to include chat rooms and news in the future.

Meantime, over in Belgium, Rudi Logghe suggests his new updated electronics pages at **http://club.innet.be/~year2138/electro.htm** and Peter Johnson recommends his site where he's posted links to some 100 circuit schematics which are freely available on the web: **http://www.web-span.com/pjohnson/schematics.htm.**

Elsewhere, a 30 day trial shareware program MMLogic Multimedia Logic System, a PC simulator for logic, can be fetched from **http://www.softronix.com.** If you're interested in power electronics, check Frank Greenhalgh's *Power Corner* at **http://www.fgl.com/power1.htm**, complete with background ragtime music!

I'm always delighted to hear from you – E-mail me at **alan@epemag.demon.co.uk.** See you next month for more *Net Work!*

VIDEOS ON ELECTRONICS

A range of videos (selected by EPE editorial staff) designed to provide instruction on electronics theory. Each video gives a sound introduction and grounding in a specialised area of the subject. The tapes make learning both easier and more enjoyable than pure textbook or magazine study. Each video uses a mixture of animated current flow in circuits plus text, plus cartoon instruction etc., and a very full commentary to get the points across. The tapes originate from VCR Educational Products Co. an American supplier.
(All videos are to the UK PAL standard on VHS tapes.)

BASICS

VT201 to VT206 is a basic electronics course and is designed to be used as a complete series, if required.

VT201 54 minutes. Part One; **D.C. Circuits**. This video is an absolute must for the beginner. Series circuits, parallel circuits, Ohms law, how to use the digital multimeter and much more. **Order Code VT201**

VT202 62 minutes. Part Two; **A.C. Circuits**. This is your next step in understanding the basics of electronics. You will learn about how coils, transformers, capacitors, etc are used in common circuits. **Order Code VT202**

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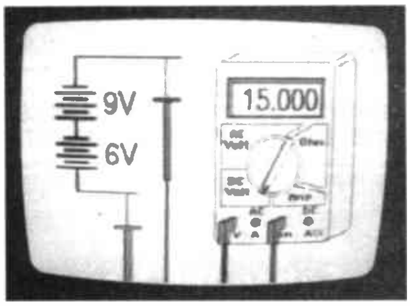

VT204 56 minutes. Part Four; **Power Supplies**. Guides you step-by-step through different sections of a power supply. **Order Code VT204**

VT205 57 minutes. Part Five; **Amplifiers**. Shows you how amplifiers work as you have never seen them before. Class A, class B, class C, op.amps. etc. **Order Code VT205**

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VCR MAINTENANCE

VT102 84 minutes: Introduction to VCR Repair. Warning, not for the beginner. Through the use of block diagrams this video will take you through the various circuits found in the NTSC VHS system. You will follow the signal from the input to the audio/video heads then from the heads back to the output. **Order Code VT102**

VT103 35 minutes: A step-by-step easy to follow procedure for professionally cleaning the tape path and replacing many of the belts in most VHS VCR's. The viewer will also become familiar with the various parts found in the tape path. **Order Code VT103**

DIGITAL

Now for the digital series of six videos. This series is designed to provide a good grounding in digital and computer technology.

VT301 54 minutes. Digital One; **Gates** begins with the basics as you learn about seven of the most common gates which are used in almost every digital circuit, plus Binary notation. **Order Code VT301**

VT302 55 minutes. Digital Two; **Flip Flops** will further enhance your knowledge of digital basics. You will learn about Octal and Hexadecimal notation groups, flip-flops, counters, etc. **Order Code VT302**

VT303 54 minutes. Digital Three; **Registers and Displays** is your next step in obtaining a solid understanding of the basic circuits found in today's digital designs. Gets into multiplexers, registers, display devices, etc. **Order Code VT303**

VT304 59 minutes. Digital Four; **DAC and ADC** shows you how the computer is able to communicate with the real world. You will learn about digital-to-analogue and analogue-to-digital converter circuits. **Order Code VT304**

VT305 56 minutes. Digital Five; **Memory Devices** introduces you to the technology used in many of today's memory devices. You will learn all about ROM devices and then proceed into PROM, EPROM, EEPROM, SRAM, DRAM, and MBM devices. **Order Code VT305**

VT306 56 minutes. Digital Six; **The CPU** gives you a thorough understanding in the basics of the central processing unit and the input/output circuits used to make the system work. **Order Code VT306**

RADIO

VT401 61 minutes. **A.M. Radio Theory**. The most complete video ever produced on a.m. radio. Begins with the basics of a.m. transmission and proceeds to the five major stages of a.m. reception. Learn how the signal is detected, converted and reproduced. Also covers the Motorola C-QUAM a.m. stereo system. **Order Code VT401**

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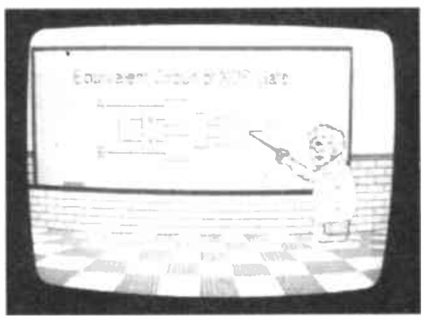

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