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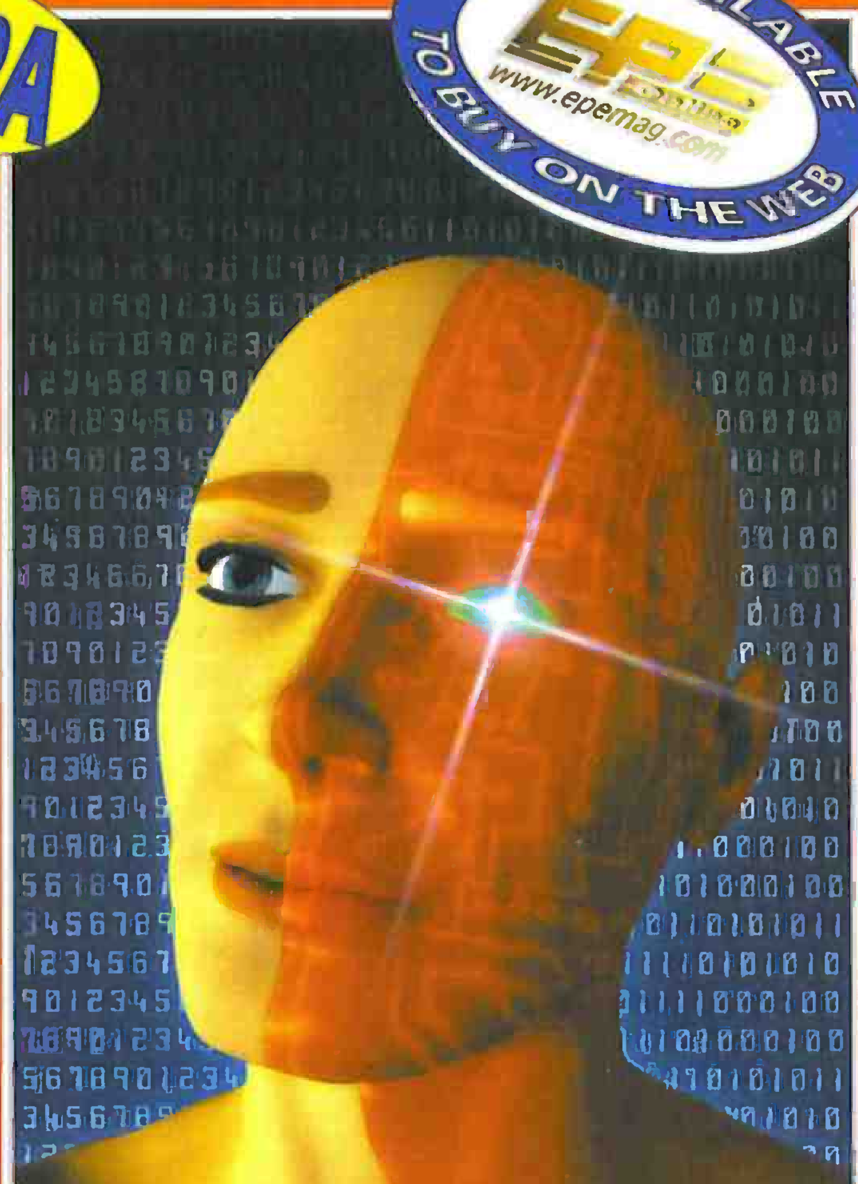

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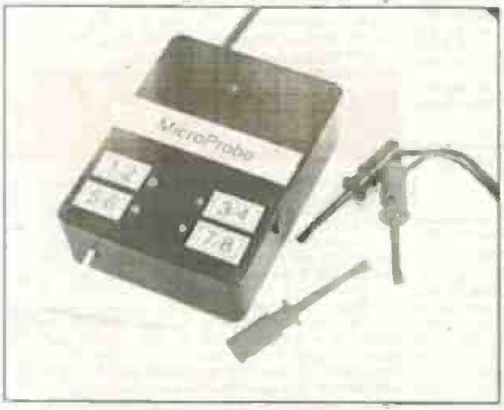
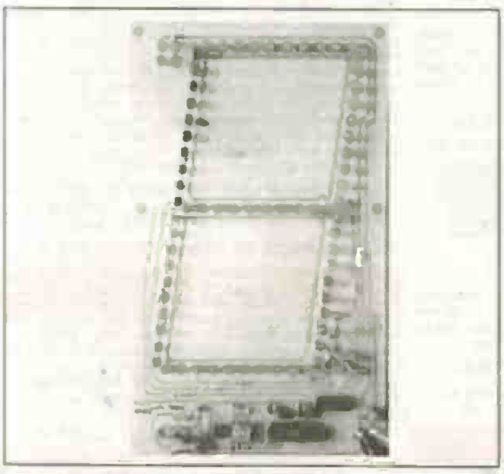
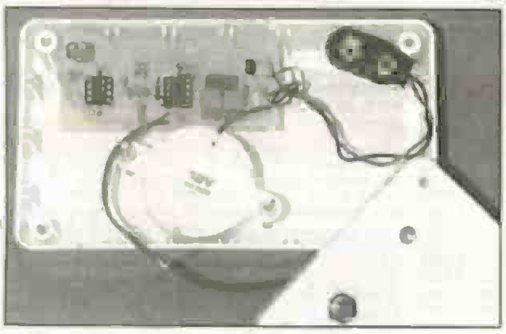
The No. 1 Magazine for Electronics Technology and Computer Projects







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A hardware tool to help debug your PIC software

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TELCAN – Unfortunately this feature, advertised last month, has been held over due to lack of space

Our January 2000 issue will be published on Friday, 3 December 1999. See page 859 for details.

Readers Services • Editorial and Advertisement Departments — **869**

NEXT MONTH

SCRATCH BLANKER

It seems that reports of the death of vinyl discs have been somewhat exaggerated. While it is true that new vinyl records are not made in significant numbers any more, there is a thriving second-hand market. In fact many types of record are now hotly collected, including some that were manufactured quite recently. Interest in vinyl records may still be quite strong, but the drawbacks that resulted in compact discs taking over have not gone away.

Noise caused by dust getting into the grooves is one problem, but with proper care and handling this can be minimised. Physical damage to this very vulnerable form of recording is probably the main problem, and there is no easy solution to this one. Most new vinyl recordings were supplied complete with a few "clicks" and "pops", and even when handled with due care they tend to gain some more over the years.

This stereo circuit provides a delay of less than one millisecond to the audio signal so that "clicks" can be detected and removed before the listener hears them. Make listening to your old vinyl a pleasure again.

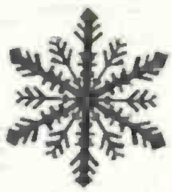
FLASHING SNOWMAN

If you wish to make an electronic project popular you give it some flashing l.e.d.s, or you do if you believe the in-joke that was popular in the electronic magazine publishing business some years ago. This joke came about because one of the magazines now incorporated into EPE published a project that was basically just a soap dish fitted with some l.e.d.s that flashed. Apart from looking pretty, it did not actually do anything, but that did not stop it from being by far the most popular project ever published by that magazine!

This project is very much in the flashing soap dish tradition. It is just a polystyrene ceiling tile fitted with some l.e.d.s that flash. It is a simple but amusing Christmas decoration that should raise a smile or two.

Starter Project

The tile is fashioned and painted to look like a snowman (or snowperson?), and it has the l.e.d.s to form the eyes, nose and mouth. The idea is to arrange the l.e.d.s so that the snowman's expression alternates between an internet style smile and frown. This is just a suggestion, and there is plenty of scope for doing your own thing. You could obviously use a different character such as Father Christmas as the basis of the project, and he could be made to wink, for example.



FROST ALERT

Vehicle manufacturers strive to make our driving experience ever more comfortable. Such items as ride control, power steering, electronic engine management, and air-conditioning now appear as standard fit on many vehicles and as a result we become more and more detached from the outside environment. One of the most important considerations would seem to be the quality of the road surface, a factor that directly affects our style of driving.

We generally notice if the road is wet, muddy, or covered in leaves and take appropriate precautions, but we can't see black ice. For this we need an external temperature sensor, warning us when the likely conditions for ice on the road are developing. A cheap solution is the l.c.d. strip attached to the driver's wing mirror, but despite looking very pretty (especially if you have heated mirrors . . .), it tells us nothing about conditions down at road level. The Frost Box gets us right there, with a simple three colour l.e.d. indicator to keep you informed.

**PLUS: EPE TEACH-IN 2000 PART 3
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JANUARY ISSUE ON SALE FRIDAY, DECEMBER 3

£1 BARGAIN PACKS – List No. 3

1 item per pack unless otherwise stated.

SOLAR CELL, will give 100mA of free electricity. Order Ref: 631.
PLASTIC FAN BLADES. 3in. diameter, push-on spindle, pack of 2. Order Ref: 638.
PC GAMES in cases for remaking, pack of 6. Order Ref: 645.
PIEZO NOISE MAKERS, standard size, pack of 2. Order Ref: 647.
DITTO but mini, only 23mm across, pack of 2. Order Ref: 648.
COVERS, suit Piezo sounders, etc., need 22mm hole, pack of 6. Order Ref: 651.
10A MICROSWITCHES with screw terminals, mains voltage, pack of 2. Order Ref: 662.
PCB MOUNTED RELAY, 5V/6V coil, **2** changeover **5A** contacts. Order Ref: 665.
CONTROLLED 4-ROCKER SWITCH, 3 of its switches cannot be on unless the first master is on, suit 3kW blow heaters, etc. Order Ref: 666.
0·33uF 1000V CAPS, ideal to put in series with 115V 2-4W motors, pack of 4. Order Ref: 672.
COPPER CLAD PANEL, size 12in. x 9in. approximately, make your own PCB or it's strong enough to act as a chassis. Order Ref: 683.
100M COIL OF CONNECTING WIRE. Order Ref: 685.
D.C. MOTOR, extra efficient, needs little current so will work with solar cells. Order Ref: 687.
SUB MIN PUSH SWITCHES, pack of 2. Order Ref: 688.
CERAMIC BEADS, ideal insulation where heat or flame, pack of 100. Order Ref: 690.
6in. LENGTHS OF ¼in. DIAMETER PAXOLIN TUBING, make useful test prods, etc., pack of 3. Order Ref: 691.
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440V A.C. CAP, 4uF, aluminium cased. Order Ref: 702.
POWER SUPPLY UNIT, output 9V 100mA d.c. Order Ref: 733.
AM/FM TUNING CAPACITOR, air spaced with ¼in. spindle. Order Ref: 743.
13A PLUG BARGAIN OFFER. You get 3 for £1. Order Ref: GR19.
DP/DT ROCKER SWITCHES for motor reversing, etc., pack of 2. Order Ref: 745.
NOISE TRANSPARENT SPEAKER MESH, 12in. x 9in., pack of 4. Order Ref: 746.
LIGHTEST TOUCH CHANGEOVER MICROSWITCHES, mains voltage, pack of 2. Order Ref: 748.
PAIR PORCELAIN INSULATORS, pack of 4, suitable cabin aerials, etc. Order Ref: 749.
CASED PSU, A.C. output, **15V 150mA and 9·5V 60mA.** Order Ref: 751.
3 CHANGEOVER CONTACT RELAY with coil, suitable for 12V A.C. or 6V D.C. Order Ref: 753.
LEVER-OPERATED MICROSWITCHES, ex-equipment, batch tested, any faulty would be replaced, pack of 10. Order Ref: 755.
PROJECT BOX, size approximately 100mm x 75mm x 24mm, its lid is a metal heat sink. Order Ref: 759.
EX-BT INSTRUMENT in plastic case with carrying handle, has many useful parts. Order Ref: 760.
PICK-UP ARM with diamond stylus, new and unused. Order Ref: 764.
RUBBER FEET, fit corners of square chassis, pack of 20. Order Ref: 769.
24V BAKELITE ENCASED A.C. OR D.C. BUZZER. Order Ref: 774.
COMPONENT MOUNTING TAG STRIP, 32 tags each side. Order Ref: 779.
½ MEO POTS each fitted double-pole switch, pack of 2. Order Ref: 780.
C/O MICROSWITCHES operated by a wire control to spindle through side, pack of 4. Order Ref: 786.
MULTI-TAG MAINS PANEL, has 12 tags to take ¼in. push-on connectors. Order Ref: 792.
REED SWITCH, flat instead of round so many more can be stacked in a small area. Order Ref: 796.
VERY THIN DRILLS (0·3mm), pack of 12. Order Ref: 797.
ROCKER SWITCHES, spring-loaded with changeover 10A 230V contacts, pack of 2. Order Ref: 800.
MAINS CIRCUIT BREAKER, 7A, pushbutton operated. Order Ref: 802.
IN-LINE SWITCH intended for electric blanket to give variable heat, but obviously has other uses. Order Ref: 805.
PLUG FOR CAR LIGHTER SOCKETS, each having internal fuse, pack of 2. Order Ref: 809.
MAINS TRANSFORMER, 12V-0V-12V, 6W. Order Ref: 811.
10M OF MAINS VOLTAGE FLEX with screen and outer PVC insulation. Order Ref: 815.
13A ADAPTORS to each take 2 plugs, pack of 2. Order Ref: 820.
0·1uF 250V MAINS WORKING SUPPRESSOR CAPACITOR, pack of 5. Order Ref: 836.
RING MAIN JUNCTION BOXES, 13A, 230V, pack of 3. Order Ref: 801.
FLUSH PLATE LIGHT SWITCHES, 5A, white, pack of 2. Order Ref: 806.
OCTAL VALVE BASED, Paxolin, pack of 4. Order Ref: 12.
GERMANIUM TRANSISTORS, OC45 etc., pack of 52 assorted. Order Ref: 15.
LIGHT SENSITIVE TRANSISTORS, ref. OCP70, pack of 2. Order Ref: 14.
LOUDSPEAKER CROSSOVER, for tweeter mid-range and woofer. Order Ref: 23.
SUB-MIN TOGGLE SWITCH, single pole changeover so can be used for just on/off, pack of 3. Order Ref: 1066.
TELEPHONE WIRE for permanent extensions, made to BT standard and colour coded, white outer PVC, 25m. Order Ref: 1067.
TV REMOTE CONTROLS, if it does not suit your TV, you could use it for other projects, FM bug, etc., pack of 2. Order Ref: 1068.
5A BRIDGE RECTIFIERS, with fixed heatsink, ideal car battery charger, pack of 2. Order Ref: 1070.
CYCLE DYNAMO BULBS, 6V 0·5A, pack of 10. Order Ref: 1072.
3½in. 12W SPEAKER, waterproof so suitable for indoors or outdoors. Order Ref: 1073.
INTERSTAGE TRANSFORMER for transistor operation. Order Ref: 1/RC12.

12V 18AH RECHARGEABLE BATTERY

It is Yuasa made jelly type so maintenance-free and usable in any position. Brand new and guaranteed 12 months. The regular price of these is £40 but you can buy at £15.
Order Ref: 15P78.

12V 8A D.C. POWER SUPPLY. Totally enclosed with its own cooling fan. Normal mains operation. Price £11. Order Ref: 11P6.

D.C. MOTOR WITH GEARBOX. Size 60mm long, 30mm diameter. Very powerful, operates off any voltage between 6V and 24V d.c. Speed at 6V is 200rpm, speed controller available. Special price £3 each. Order Ref: 3P108.

MOST USEFUL POWER SUPPLY. Rated at 9V 1A, this plugs into a 13A socket. Is really nicely boxed. £1. Order Ref: 2P733.

GROWERS PLEASE NOTE: We now have a very useful 100W soil heater. This is essentially 5V 20A power supply, completely encased and with built-in cooling fan. We supply with it 10m of cable with instructions on how to couple it to give the recommended 10W per sq. ft. or 5W per sq. ft. or a very low 2·5W per sq. ft. Price for complete l.c.u. £15. Order Ref: 15P79.

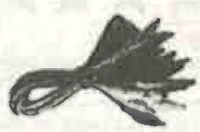
BIG 12V TRANSFORMER. It is 55VA so over 4A. Beautifully made and well insulated. Live parts are in a plastic frame so cannot be accidentally touched, £3.50. Order Ref: 3.5P20.

BIKE RADIO. In fact, it's more than a radio, it's an alarm and a spotlight. The radio is battery operated, of course, and needs 3 AA cells. Only one band but this is the FM band so will receive Radio 1 and 2. Comes complete with handlebar fixing clips. Price £4. Order Ref: 4P72.

INSULATION TESTER WITH MULTIMETER. Internally generates voltages which enable you to read insulation directly in megohms. The multimeter has four ranges AC/DC volts, 3 ranges DC milliamps, 3 ranges resistance and 5 amp range. Ex-British Telecom but in very good condition, tested and guaranteed, probably cost at least £50 each, yours for only £7.50 with leads, carrying case £2 each. Order Ref: 7.5P4.

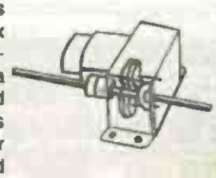
REPAIRABLE METERS. We have some of the above testers but faulty, not working on all ranges, should be repairable, we supply diagrams. £3. Order Ref: 3P176.

FOR QUICK HOOK-UPS. You can't beat leads with a croc clip each end. You can have a set of 10 leads, 2 each of 5 assorted colours with insulated crocodile clips on each end. Lead length 36cm, £2 per set. Order Ref: 2P459.



RECHARGEABLE NICAD AA BATTERIES. You can have these at a bargain price of 50p each, but you have to buy a pack of 10 which would give you a 12V rechargeable battery. However, it is quite easy to divide into 2 x 6V rechargeables or 10 x 1·2V rechargeables. Order Ref: 5P287. Made by Varta.

1.5V-6V MOTOR WITH GEARBOX. Motor is mounted on the gearbox which has interchangeable gears giving a range of speeds and motor torques. Comes with full instructions for changing gears and calculating speeds, £6. Order Ref: 7P26.



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1101	Dollar tester	4.60
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1122	Telephone call relay	3.68
1123	Morse code generator	1.84
1126	Microphone preamplifier	4.60
1127	Microphone tone control	4.60
1128a	Power flasher 12V d.c.	2.53
1133	Stereo sound to light	5.26

BUY ONE GET ONE FREE

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35V + 35V at 150VCA, price £8. Order Ref: 8PG9.
35V + 35V 220VA, price £9. Order Ref: 9PG4.
50V + 50V, price £4. Order Ref: 4P112.
110V + 110V at 220V would give 110V at 2A or 220V at 1A, price £10. Order Ref: 10PG5.
110V + 110V at 500VA would give 110V at 5A or 220V at nearly 3A, price £25. Order Ref: 25PG8.

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A 10in. 4 ohm with power rating of 250W music and normal 150W. Normal selling price for this is £55 + VAT, you can buy at £29 including VAT and carriage. Order Ref: 29P7. The second one is an 8in. 4 ohm, 200W music, 200W normal, again by Challenger, price £18. Order Ref: 18P9.
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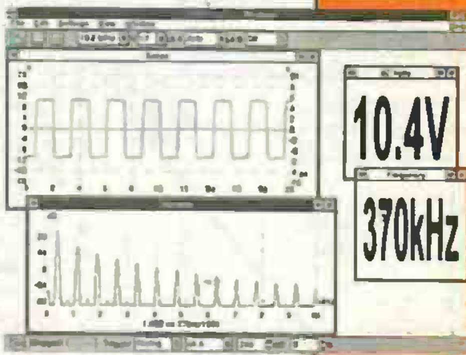

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Connection to a PC gives the ADC-200 the edge over traditional oscilloscopes: the ability to print and save waveforms is just one example. Units are supplied with PicoScope for Windows which is powerful, yet simple to use, with comprehensive on line help.

Applications

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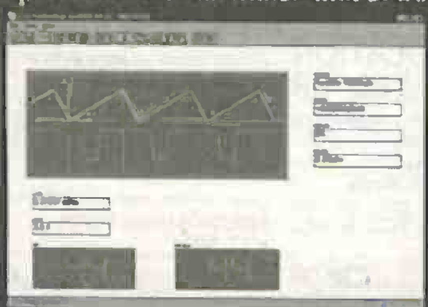

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VOL. 28 No. 12 DECEMBER '99

TIME LINE

With the millennium fast approaching (or maybe you feel we should be accurate and wait for the end of 2000 to celebrate?) we have decided to produce a series of articles describing the development of electronics over the last 100 years. Our friends and Editors of *EPE Online*, Max and Alvin in the USA, are producing it for us and they asked a number of people to suggest significant developments they thought worthy of inclusion. We passed this request on to some regular contributors in the UK and their responses just about covered everything we could think of. It should make a fascinating series and it should expose one or two myths about who invented what first.

We are also planning to produce a "Time Line" wall chart, showing all the significant events/developments etc., which will be given away with one of the spring issues of *EPE*. This series should start in the Feb '00 issue (on sale Jan. 7).

Max and Alvin have already secured a fascinating article from Horst Zuse about his father, Konrad, who invented the first large-scale digital computer in Germany in 1941. You can read all about it and see some fascinating, never previously published, photos of the computer on our *Online* edition web site at www.epemag.com.

ON-LINE CONTACT

As many readers will know, we have a Chat Zone on our UK *EPE* web-site at www.epemag.wimborne.co.uk. This is so that readers can "chat" to each other, and help each other with information, advice, etc. However, we have noticed one or two readers asking questions that would be better put to us at the editorial department. Whilst we keep an eye on what is happening on the Chat Zone, you should not be trying to ask us editorial questions on it. If you want to ask when something was published, if we can supply a back issue, or to direct a question at one of the editorial staff, you should do this via our E-mail address: editorial@epemag.wimborne.co.uk.

We do try to respond to both letters and emails within a few days but if something needs researching and we are tied up with getting the magazine out it may take a little longer.

Mike Kenward

AVAILABILITY

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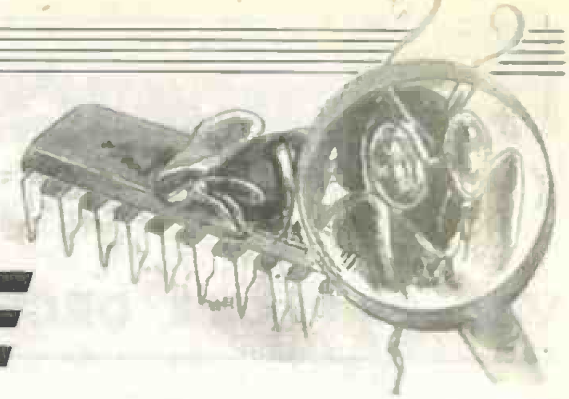


PIC MICRO-PROBE

JIM MAIN

A neat little tool to help debug your PIC microcontroller code!

IF there's one thing which irks most when developing PIC microcontroller software, it's that sinking feeling when you apply power for the first time and the thing just sits there smugly doing (apparently) nothing.

In fact, your PIC chip is probably whizzing away inside some loop or other, or resetting itself several thousand times a second. You'll be none the wiser.

BUGS AND OPTIONS

There are various solutions to debugging your code and indicating what's going on inside your chip. You could be using a software simulator, such as MPSIM. You might have some l.e.d.s attached to a spare port and be lighting them up at various stages of your code to see how far you're getting. You might, perhaps, have a serial port in your project and be sending the odd character to indicate position – you might even be fortunate enough to have an in circuit emulator (you wish . . .).

All these debugging methods are well and good, but suffer from disadvantages. MPSIM requires time and effort to set up, and if you're running on-chip peripherals such as serial ports, PWM, I2C, SPI etc., then its use becomes very limited.

Using l.e.d.s attached to a spare port is an excellent idea, and the author always try to incorporate a bank of them on a printed circuit board wherever possible. This gives you an on-board debugger straight away – but only if you have the port pins to spare. This is chip-dependant, and remember some of the smaller 8-pin PICs only have one or two input/output pins to begin with.

SINGLE PIN SOLUTION

An answer to this situation is to use an existing output pin to output a very short duration Debug word (of around 64μs). There are two advantages to this:

1. The code is held-up outputting the Debug word for a minimum amount of time.

2. It may be possible to use a pin that is currently being used for other output duties.

Advantage 2 needs some further explanation. Ideally, this output pin will be something like a processor status l.e.d. pin – or at least a pin where a short duration word isn't going to upset whatever is connected to it (a relay, for instance, should ignore a word of less than 100 microseconds or so). In this way, the debug word is transparently output on the pin.

The Micro-Probe described here is connected to the target output pin and "listens" for any valid debug words coming from that pin. There are eight possible Flag codes. It does not matter whether the output pin is held high or low before the word is output – the probe will pick up the pattern in each case.

CIRCUIT DESCRIPTION

The Micro-Probe has a very simple circuit and uses the ever-popular PIC16F84 in its 10MHz version. It is such a simple circuit, in fact, that it does not really warrant a printed circuit board. Consequently, it has been designed onto a piece of stripboard.

With reference to the circuit diagram in Fig.1, the PIC, IC1, is set up in a crystal-timed configuration with a 10MHz crystal, X1, and two 15pF capacitors, C3 and C4. Note that because the PIC is to be operated at 10MHz, it must be configured for the HS crystal option prior to it being programmed.

The 5V power supply for the PIC is connected to the circuit by means of two flying leads with test clips on the ends. The clips allow the power to be obtained from the supply of the circuit under test. Since it would be very easy to mix up the polarity when connecting into a target circuit, diode D1 is included to protect the PIC.

A power-on l.e.d., D3, is taken across the supply in series with ballast resistor R1. You can then tell straight away if one of the power clips has fallen off!

The signal from the target circuit comes in via diode D2. This drops the incoming signal voltage level by the same amount as D1 (so that you are not over-volting the PIC with respect to the supply). R2 is a pull-down resistor for the PIC's input pin RA4. All other Port A pins are configured as outputs in the software and can be left unconnected.

Four bi-colour l.e.d.s are connected to Port B via ballast resistors R3 to R6. These l.e.d.s are actually two l.e.d.s in one package, connected back-to-back across each other. Depending on the direction of the current, the l.e.d. illuminates either red or green, so with four l.e.d.s, eight signal indications can be displayed.

If you prefer, you can replace the bi-colour l.e.d.s with eight individual l.e.d.s, remembering to add a ballast resistor to each.

When a valid word is received by the Micro-Probe, one or more of the l.e.d.s will light.

SOFTWARE

The software for the Micro-Probe is split into two-parts – the code run by the Micro-Probe itself, and the Target code you have to add to the target application to output the debug words.

It should be noted that the Target program has been written specifically for use within programs that are intended to be assembled through MPASM (Microchip's own assembler software).

The Target code cannot be used with programs written in TASM (the Shareware assembler language used in many *EPE* projects). Nor can the *EPE PIC Toolkit* (both Mk1 and Mk2) interpret the Include instruction embodied in the Target

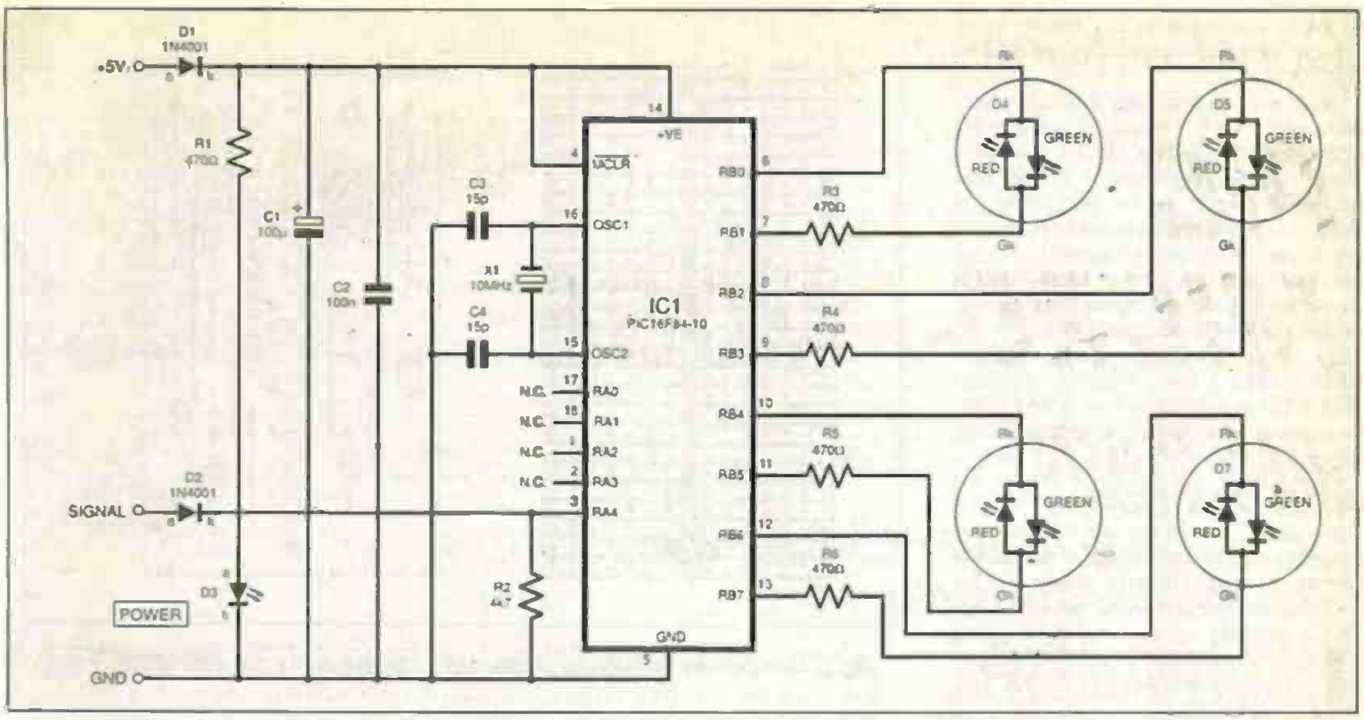


Fig.1. Complete circuit diagram for the PIC Micro-Probe.

program. Experienced programmers, however, should have no difficulty in re-writing the small amount of code involved to suit the TASM/*Toolkit* structures.

TARGET MACROS

Looking at the Target code first, this allows you to add macro-routines to your program. Macros are very powerful and flexible batch-type commands which consist of instructions to the compiler to generate code at compilation time. An example of using the macros to generate the debug words is shown in program file ***YOURPROG.ASM***.

First of all, it is important to be able to generate the correct duration of pulse for a number of target clock frequencies. The macros generate the correct duration of pulse for an integer number of megahertz frequency (1, 2, 3 etc.). It is necessary to point out that your target processor should be crystal or ceramic resonator clocked – RC (resistor-capacitor) clock generation is not really accurate or stable enough for the Micro-Probe.

In ***YOURPROG.ASM*** it will be seen that the clock speed (CLK) is defined for 16MHz:

#DEFINE CLK .16 ;SPEED IN MHz

Note that a decimal point is placed in front of the 16, which signifies to the compiler (MPASM or compatible), that the value is in decimal. The appropriate value for the speed of your target circuit should be substituted in place of the 16.

The pin of the target circuit which the Micro-Probe is to monitor is defined in ***YOURPROG.ASM*** as Port C pin 7:

#DEFINE DEBUGPIN PORTC,7

Any Port and any pin can be substituted in place of PORTC,7 as required.

MACRO ROUTINES

There are three distinct Macros: PIN X, SYNCWORD and DEBUG X.

At the lowest level is the macro **PIN X**. This takes an argument of 0 or 1 and sets or clears the selected output pin accordingly. It then loops for a number of times according to the clock frequency (defined by CLK) to time the length of the pulse.

The macro **SYNCWORD** starts with a 0 for the start bit, followed by binary 101 to uniquely identify that this is a debug word. It does this by calling **PIN X** four times (e.g. PIN 0, PIN 1, PIN 0, PIN 1).

Macro **DEBUG X** is the one you call from the body of your code with the relevant argument, where you want to signal that the code has reached that particular point. **DEBUG** first calls **SYNCWORD**, and then adds the 3-bit code for the relevant Flag point. Finally, a stop bit **0** is added to the end.

USING MICRO-PROBE

Where you want to signal a point having been reached in your code (say entering a subroutine), then add the line:

DEBUG X (where X = 1 to 8)

For example:

DEBUG 1 lights the first l.e.d. green
DEBUG 2 lights the first l.e.d. red
DEBUG 7 lights the fourth l.e.d. green

If your target application makes use of interrupts, then make sure that you disable the global interrupt enable bit (**INTCON,GIE**) before calling the Macro. This is to ensure that an interrupt does not happen halfway through a debug word, destroying its timing. Re-enable it as required afterwards (see ***YOURPROG.ASM***).

When you want to reset and turn off all the l.e.d.s, just remove one of the power leads temporarily (or fit a Reset switch if you like).

INCLUDE FILES

Keep things tidy by putting the body of all the aforementioned macros into an Include file. To do this, open up a blank page within MPLAB, type in the Macros, and save as:

DEBUG.INC
into **C:\PROGRAM FILES\MPLAB**

When you want to add debug code to an application, just put the command:

INCLUDE DEBUG.INC

below your processor-specific Include line, and then add the **CLK** and **DEBUGPIN** definitions.

When you want to take out or disable the debug code generation, then just "comment-out", with a semicolon as usual, the Include line (as well as commenting out the various invocations of ***DEBUG*** in your code).

The **CLK** and **DEBUGPIN** definitions can safely stay in your application.

BIT-BANGING

The Micro-Probe works by what is known as "Bit-Banging" – that is, it constantly samples an input pin (RA4) and looks for changes in its logic states. To do this, you have to time the instructions carefully so that you are always sampling in the correct part of the incoming bit (interrupts are of no use here because of the short duration of the incoming pulse train).

When the level is unchanging, then a sample loop occurs every ten instruction cycles (1 cycle = 0·4μs at 10MHz), or every 4μs. It compares this level with the previous sampled level by XORing them together. If the result = 1, then a change in level has occurred.

Assuming that the output started off low, then the first sample will occur somewhere inside the first "1" of "101" (the Syncword). The pin is resampled six cycles later (2·4μs) to make sure that the sample point is not too near the leading edge of the first pulse. Thereafter, the pin is sampled every 8μs to sample each pulse in the same place.

If the Syncword is wrong, then the process is abandoned and the sampling process starts from the top.

Once the three bits of data have been obtained, we have a number between 0 and 7. This is multiplied by four (by performing the **RLF** instruction twice) before being added to the program counter (a computed **GOTO**).

Using as an example the situation where the data is **0**, 4 × 0 = 0, which is then added to the program counter (**PCL**). The program counter always points to the next instruction that is to be performed, so adding **0** to it just results in the next instruction being performed as normal. In this case that means that bit **0** of **LED_REG** is set, and bit 1 is cleared before jumping forward to the Port writing section.

In the Port writing section (**LED_EXIT**), the shadow register **LED_REG** is written to Port B and lights the relevant l.e.d. before looping back to the top.

CONSTRUCTION

Stripboard is used for the Micro-Probe construction. The type used in the prototype is that specifically designed for mounting integrated circuits and which has a break running up the middle. If using ordinary stripboard, cut the tracks appropriately to keep the two sides of the PIC isolated from each other.

The component layout and underside track view are shown in Fig.2.

It is likely that the stripboard will be larger than you need. If so, use a sharp knife to score the stripboard where you want to cut it (on the copper side). It should crack cleanly over the score when you bend it with a pair of pliers. File down the rough edges.

Drill two 3mm mounting holes in the positions indicated, and make the various breaks in the copper using the same drill bit.

Use an 18-pin d.i.l. socket (turned-pin is best) for the PIC.

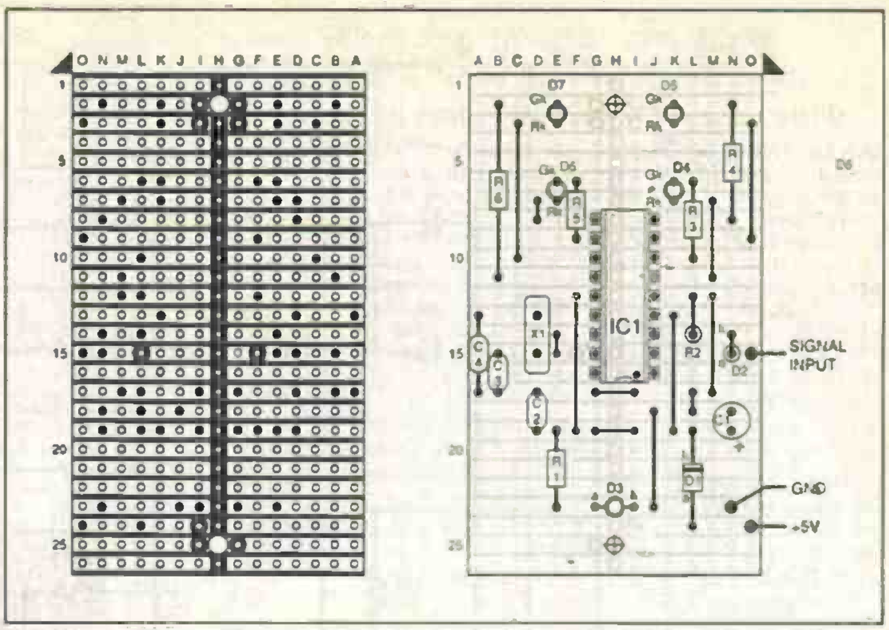


Fig.2. Component layout and stripboard track details for the PIC Micro-Probe.

COMPONENTS

See **SHOP TALK** page

Resistors

R1, R3 to R6	470Ω (5 off)
R2	4k7

All 0.25W 5% carbon film or better.

Capacitors

C1	100µ radial elect. 16V
C2	100n ceramic
C3, C4	15p ceramic (2 off)

Semiconductors

D1, D2	1N4001 1A 50V rec. diode (2 off)
D3	red l.e.d., 3mm
D4 to D7	bi-colour (red/green) l.e.d. (4 off)
IC1	PIC16F84-10P (10MHz version), preprogrammed

Miscellaneous

X1	10MHz crystal

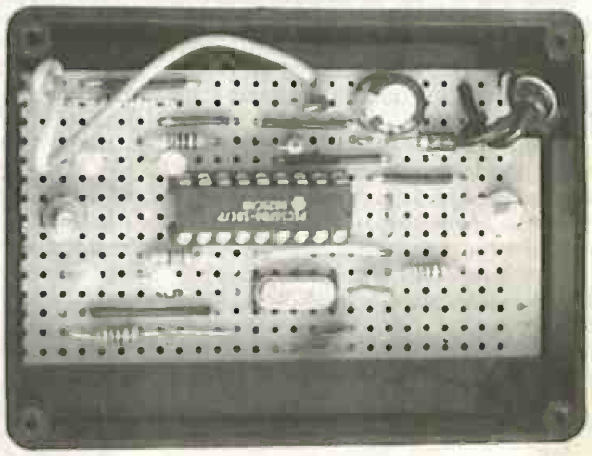
Stripboard, with central separating strip, 26 × 15 holes (see text); plastic case, 75mm × 56mm × 25mm; 18-pin d.i.l. socket; nuts and bolts, M3 × 20mm, countersunk (2 off); spacers, M3 × 6mm (2 off); probe clips, miniature, one each of red, black, yellow; extra-flexible wire for probes; connecting wire, solder etc.

Approx. Cost Guidance Only **£19** *incl. case*

Preferably use insulating sleeve on all the wire links to prevent shorts and then solder in all the components, observing polarity for the diodes and the electrolytic capacitor. The bi-colour l.e.d.s have the red anode denoted by the *longer* lead, so make sure the short lead goes to the position marked as Rk on the layout diagram.

You can't damage these l.e.d.s by getting them the wrong way round, but your colours will be reversed.

At first, only solder in one lead of each l.e.d., so that you can adjust the height to fit the box before soldering in the other one.



ENCLOSURE

Use a small plastic case for housing the Micro-Probe. Drill two holes in the bottom of the case for the stripboard's mounting screws. Use a countersink tool so that the countersunk bolts will sit flush with the surface.

Drill a 2mm hole in one end for the signal wire, and a 5mm hole in the other end for the power leads to pass through via a clamping grommet. (When you mount the stripboard, you may need to file its top end to clear the grommet.)

Solder the leads directly into the board at the positions indicated. Pass the leads through the case and tighten the grommet to clamp them.

The lid of the case is drilled with 3mm holes to line up with the l.e.d.s coming up from underneath. If you gauge the height of the l.e.d.s correctly, then with the lid on the box, they will protrude slightly above the surface. Make a paper template with the positions of the l.e.d.s on it and tape this to the lid prior to drilling.

Put both bolts through the bottom of the box and slip on the 5mm spacers, followed by the stripboard. Thread 3mm nuts onto the bolts and tighten. Put the lid on the box, guiding the l.e.d.s through the holes and fasten using the screws supplied with the box.

Solder spring loaded test clips onto the ends of the wires now protruding from the box and you have yourself a completed Micro-Probe!

TESTING

Power the unit from the target board using the power clips and attach the signal probe to the required pin. The power-on l.e.d. should be illuminated, if not check your connections and circuit.

With the Debug Include file in your default directory, put the clock and pin definitions into your code, as discussed earlier. Enter a Debug command (e.g. **DEBUG 1** into your code.

When you run the target processor, the first l.e.d. (D4) should light green on the Micro-Probe. Check operation for the other seven Debug states.

Finally, label the front panel and your Micro-Probe is ready for action!

RESOURCES

Software for the Micro-Probe is available on 3·5-inch disk from the *EPE PCB Service*, code **EPE Disk 2** (there is a nominal handling charge). It is also available *free* from the EPE FTP site. See *Shoptalk* for more details of both options. □

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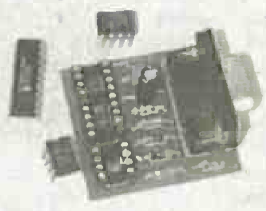

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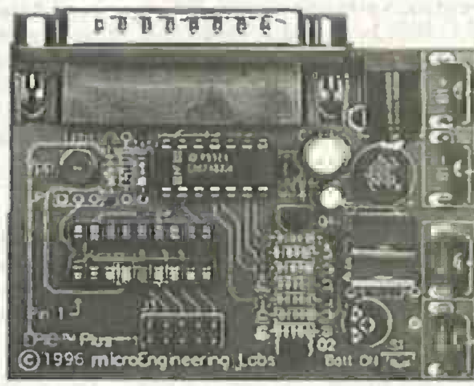

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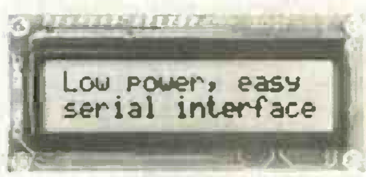

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News . . .

A roundup of the latest Everyday News from the world of electronics

PIRATE-PROOF CDs

Long hoped for by the music industry, uncopyable CDs are now a reality. Barry Fox reports.

NEW TECHNOLOGY spells bad news for people who use a PC to copy music CDs or send them over the Internet. British company C-Dilla has found a way to let a music CD play on a home hi-fi, but not on a PC's CD-ROM drive.

Computer software companies, including Microsoft and Lotus, already use C-Dilla's SafeDisc system to stop people copying ROM data discs.

SafeDisc puts the program material in an encrypted wrapper which can only be unwrapped when a digital key code on the disc matches an authorisation code entered into the PC. The key code is pressed into the disc so that a ROM drive can read it but a CD-recorder cannot copy it. So only the original disc will run the program.

UNREPEATABLE DREAMS

The record industry has been dreaming of just such an anticopy system for 30 years, since the Beatles claimed that their LP *Sergeant Pepper* could be played but not copied. Like the many systems that followed, *Pepper* was as easily copied as played.

Peter Newman, who founded C-Dilla in 1991 and invented SafeDisc, has finally found the answer. AudioLok takes advantage of the fact that the standard for music CDs, known as the Red Book, was set before the standard for CD-ROMs, known as the Yellow Book.

The ROM standard provides more powerful error correction for data than is needed for music. ROM drives are designed to handle either music or data discs. AudioLok adds false error correction code to a music disc. An ordinary music CD player simply ignores this extra code and plays the disc as normal. But a ROM drive reads the false code and rejects the disc as unplayable. This stops the owner sending the music over the Internet or copying it onto a blank disc.

A prototype AudioLok disc duly played on a CD music player but refused to play or copy on a PC. Peter Newman says he is confident that he can also stop a consumer music CD-recorder making a copy, because these devices are already designed not to copy CD-ROMs. He expects AudioLok to be ready for commercial launch in a year.

Macrovision of the US has now bought C-Dilla for around $18m. Macrovision developed the systems which film and TV companies already use to stop people copying videos. Now the company can offer the same option to the music industry.

NOTABLE PARADOX

Paradoxically C-Dilla's breakthrough and Macrovision takeover come just as the music industry's Secure Digital Music Initiative group has agreed with the electronic companies to allow owners of CDs to "rip" copies into a PC (www.sdmi.org). There had previously seemed no foolproof way to stop copying altogether.

Says Paul Jessop, Director of Technology at the music industry's world trade body the International Federation of the Phonographic Industry:

"Although in general the recording industry welcomes people listening to CDs on computers, the ability to make discs that cannot be copied on computers may be of considerable interest to some record companies."

Chinese and Chips

NEC Corporation and partner Shanghai Hua Hong (Group) Co. Ltd., have officially opened their joint-venture semiconductor plant, the largest in China. Concentrating production on Dynamic Random Access Memories (DRAM), production capacity is expected to expand to 20,000 wafers per month by the end of year 2000. Currently supplying their home market, the company proposes to eventually manufacture for world markets.

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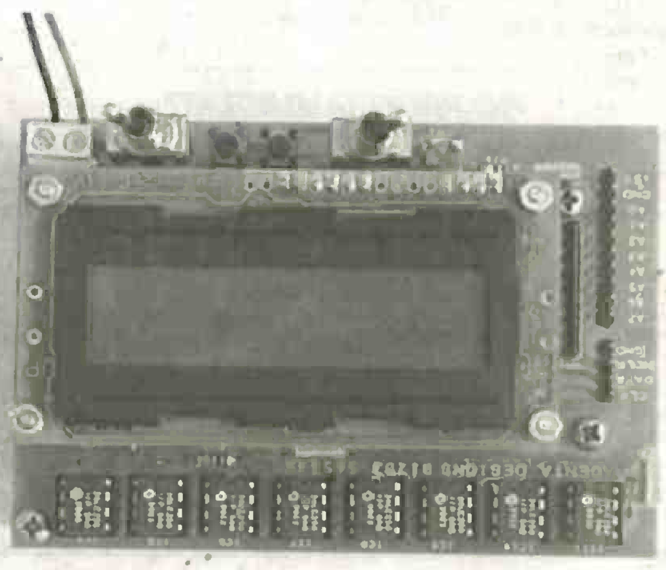
For information, browse: **http://www.nec-global.com.**

MAGENTA LOGS ON



SPECIALIST kit and component suppliers Magenta Electronics have introduced their own superb kit version of John Becker's *8-Channel Analogue Data Logger* (*EPE* Aug/Sep '99).

An enhancement welcomed by the author is the direct mounting of the liquid crystal display directly onto the main p.c.b. using rigid stand-off pillars. This makes the assembly considerably more robust than the original prototype. The inclusion of the switches on the p.c.b. is also an enhancement.

As typical of Magenta's kits, the quality of the components and of the re-designed p.c.b. is excellent.

For more information contact Magenta Electronics Ltd., Dept EPE, 135 Hunter Street, Burton-on-Trent, Staffs DE14 2ST. Tel: 01283 565435. Fax: 01283 546932. E-mail: sales@magenta2000.co.uk. Web: http://www.magenta2000.co.uk.

GET STUFFED AT CYNTHIA'S

The worldly pleasures of this planet's First Robotic Bar and Restaurant are sampled by John Becker.

NOT that we'd ever suggest you stop chatting up your favourite local bar wench, but from behind her bar Cynthia's really got what it takes to get you drooling! Ah, Earthlings, we have a tale to tell of sensuous cosmic delights and entertainment that you'll enjoy when Cynthia responds to every finger-tip's request! She's well programmed to serve you!

"And who is Cynthia?", we hear the cry from our valiant readers, thrusting hot soldering irons hard into their holders. Gather round – Cynthia's the most amazing anthrobot you're likely to meet this side of the galaxy and, together with cyber-partner Rastus, is the star feature of a new theme bar and restaurant that's just opened in London.

CYBER CHAT

Cynthia and Rastus are two 2-metre high robots, each with their own cavernous and glittering bar area from which they serve the cocktails and other drinks you've ordered through their 75-option keypads. Rastus is a bit of a DJ as well. As with any Earthly (or even Earthy!) bar tender, these two cyberoids respond to your orders with varying degrees of good or bad grace (depending on their mood, and the state of their program cycle – which in turn reflects the state of mind of their original designers and programmers!).

Accepting your order (they do obey at least one of Asimov's Laws of Robotics, paraphrased as – *Thou shalt not harm or through inactivity cause harm to occur to a human* – and it would harm you to do without your beverage, wouldn't it?), Cynthia and Rastus pivot round to the vast array of drinks on optic behind them, and fill your glass to the correct measure.

While you're at the bar, it's *you* who are likely to be chatted up by Cynthia and Rastus. We'd like to say that the tone of chat respects all Laws of Polite Conversation – but we can't lie to you, can we? You just have to accept that the occasional "questionable phraseology" might occur! But it's all in good fun and humour, and has nothing that would not be heard in a *Carry On* film.

CULINARY CALLING

After you've been cajoled by others of human persuasion to vacate your place at the bar, you have yet more delights to pursue – culinary ones. In other words, it's along the glittering corridor to Cynthia's restaurant.

The centrally-illuminated dining tables have call-buttons inset, offering choice of the service required: drinks, food, general, and bill. Hi-tech is a keyword even in the way you are attended at table. Attired in fetching Millennial black and silver togas, reassuringly human staff use handheld electronic order pads. Your order is keyed in and transmitted by short range radio through to the well-equipped kitchens. All "plastic" financial transactions are via a commercial networked EPOS system.

Described as "Multi-national", the selection, quality and competitive pricing of the food is comparable to that served in many good restaurants around the planet, and there's a special menu for "mini-droids"!

*Richard Becker (Cynthia's Conceptual Parent) requests Roger Gay (Cynthia's Behaviourist) to hand over the declaration that Cynthia will always converse in a polite and socially acceptable manner. At the time that this reviewer departed, no such undertaking had been received (but Cynthia had sweetly growled "B****r-off Human"!)*

ORBITAL SPACE-WAYS

Being in the comfort zone of a vast orbiting space station, Arthur C. Clarke *2001* style: that's the futuristic atmosphere at Cynthia's Cyberbar and Restaurant. You forget that it's all more down to Earth, set below London Bridge, in the mass of broad tunnels and brick-built caverns that pervade that area of London.

Genesis in various forms as published in PE, Nov '81. Rumour has it that the white-coated android was a working facsimile of Mike Kenward.

The walls, floors and ceilings are covered in a silvered metal skin and well interlaced with great expanses of mirrors. Any camera flash has a half-life of a thousand years (or so it seems). So does the image of the drinkers and diners – echoing down to the ends of the universe.

Myriads of light emitting diodes enhance the entire lengths of the "populated" areas. Those in the bar stools appear to be in constant twinkling and ascending orbit through the transparent stems. Cynthia's and Rastus' dominance at the end of their respective supra-spacial caverns enhances the feeling of outer-worldliness; and hints at their possible "genetic" origins. There is the profound feeling that Cynthia is a distant relative of Marvin, the robot who, reluctantly, was involved in "Hitch-Hiking Through The Galaxy".

EVOLUTIONARY RELATIVITY

As to whether Cynthia is an ancestor of Marvin, or his descendent, will probably never be ascertained, the space-time chronosynclasticparafundibulum of the polyverse is far too multi-temporal to ever establish who's whose relative and in what order from the Event Horizon, but there's a family likeness there somewhere (relatively speaking)!

To drop back out of warp-time(!), "family" is involved in this Cyber-venture in another way, this commentator's family, in the shape of his brother, Richard Becker.

Those of you who recall earlier days of electronic hobbying will probably remember that *Practical Electronics*, in November 1981, published a robotic arm, *Genesis*, designed by Richard. This was very much a "first" not only for Dick but also for *PE*, which at that time was edited by Mike Kenward (now our Owner, MD and Ed-in-Chief).

Through his company Powertran Cybernetics, Dick built up a worldwide market for his educational and light industrial robotics products, which became increasing more sophisticated at each generation. To cut short a length of history, Dick went on to found Cybernetic Instruments Ltd, of which Cynthia's Cyberbar is a division.

CHARTING SPACE-TIME

Cynthia herself (though we're not really sure of her/his gender!) became a twinkle in Dick's imaginative eye a good ten years back. Sworn to secrecy, this author has seen great wall lengths in one of Dick's large factory units increasingly covered by hundreds of mechanical drawings. Each represented a part of Cynthia Mk1, manufactured and assembled when time permitted between other commitments.

Genesis and many more of Dick's earlier robotic arms ranges were hydraulically controlled (water for blood!). Cynthia's motion, though, is generated by precision stepper motors operated under tight closed-loop control. They are operated with varying degrees of resolution, from a basic 200 steps up to around 12800 when in micro-step mode. The various limb motions are on a double axis, horizontal and vertical movement.

The sophistication of the control software ensures that movement is smooth, with different rates of acceleration and deceleration being applied depending on the position of motion. There was no need to give Cynthia third-axis (rotational) limb and wrist movement.

INNER SPACE

One might expect that the entire system would be governed by the latest in microcontrollers. Not at all – that well-proved and time-honoured favourite the 8051 is the microprocessor used (well, a modern 16-bit derivative of it anyway). "*Why change a working system?*", says Dick, having long ago optimised software-hardware interfaces for all his automation products.

In fact there are 12 slave microprocessors, one for each of the motors, all under control of a master processor. A PC-compatible computer is in overall charge of the system, including the drinks ordering keypads and Cynthia's speech generation.

Cynthia's inner organs are a sight to behold! Her body is packed with thoroughly populated printed circuit boards and stacked in awe-inspiring regimentation. The scene behind the drinks array leaves one almost dumb with admiration at how complex a system is required to select and serve the correct drink on demand. Mechanical and electronic interfaces abound, thick neural-like cable harnesses snaking their way amongst them.

PLANETARY CO-ORDINATES

Undoubtedly, all of you within sub-orbital distance of Cynthia and Rastus will by now be utterly consumed with desire to drink with them, and to dine with their human entourage.

Here's how: the address is Cynthia's Cyberbar, 4 Tooley Street, London SE1 2SY. Tel: 0171 403 6777. Fax: 0171 378 1918.

E-mail: cynthia@ cynbar.co.uk.

Web: http://www.cynbar.co.uk.

Children are welcome (there's even a dance floor, and soon there'll be an amazingly fascinating technology-orientated gift shop).

Young Amateur Awards

SIXTEEN-YEAR-OLD Mark Haynes from Harlow, Essex was recently announced as the winner of the Radio Communications Agency's *Young Amateur of the Year Award 1999*. Mark received first prize of £500, a certificate from Stephen Byers, Trade and Industry Secretary, and will be invited to a conducted tour of the RA's Monitoring Station in Baldock, Herts.

Mark gained his Novice Licence at the age of 12 and became the youngest radio amateur of his home town. In July he organised and ran a special event station commemorating the 175th anniversary of the RNLI.

If you would like to become involved in Amateur Radio, contact The Radio Society of Great Britain, Lambda House, Cranbourne Road, Potters Bar, Herts EN6 3JE. Tel: 01707 659015.

Micromouse Grand Prix

ASTONISHING – July next year will see the action of an exciting new challenge for enterprising 11 to 18 year olds. The *Micromouse Grand Prix 2000* is being organised by the UK's key engineering association Young Engineers, in collaboration with the IEE (Institution of Electrical Engineers), Europe's largest professional engineering society.

Teams of up to four are being invited to build and race their own robot, i.e. a small vehicle capable of finding its own way round a course at high speed. Entrants to this challenge will have specialised support through the Young Engineers website www.youngeng.org for chassis design, electronics, steering control, digital and programmable technology. There are several classes in which you can compete.

Preliminary race days take place around the UK in March 2000, with the Grand Prix itself in July.

For more information contact Fiona Hunt at Young Engineers' Press Office on 0171 823 3799 or Christina Dagnall of IEE Media Relations on 0171 344 5445. Mention *EPE* when phoning.

WECANFIXIT4U

RECENTLY faxed through to us is information about an interesting website, **wecanfixit4u.com**. The site offers a free directory of fixers, repairers, restorers and conservators. The company invites readers to not only use the site to search out the services they need, but also to have their own skills listed as well. They aim to provide a global directory searchable by item and hope to bring together both Fixers and those needing a Fixer.

They say: "In our proper work we build websites and publish on CD-ROM, and offer consultancy on the matching of Content to End User".

For more information contact David Hall, Chameleon HH Publishing Ltd., Dept EPE, The Quarry House, East End, Witney, Oxon OX8 6QA. Tel: 01993 880223. Fax: 01993 880236.

E-mail: data@wecanfixit4u.com.

Web: http://www.wecanfixit4u.com.

PICS AND L.C.D.S

NEW from Lascar Electronics is a 5-digit starburst liquid crystal display module with an on-board Flash PICMicro. It has been designed as the building block for thousands of display and instrumentation applications.

Using standard software routines that can be downloaded from Lascar's website, users can tailor the module's function to suit their own needs. Because of the Flash memory on board, users can re-program the module as often as they like.

Readers will know that *EPE* has so far concentrated on PIC-controlling "intelligent" alphanumeric l.c.d.s. Here now is an opportunity to make use of the more basic types of l.c.d. in conjunction with PIC devices.

Lascar's module features eight analogue inputs and up to 22 digital I/O ports, capable of driving or interfacing with other systems.

For more information contact Lascar Electronics, Dept EPE, Module House, Whiteparish, Salisbury, Wilts SP5 2SJ. Tel: 01794 884567. Fax: 01794 884616. E-mail: lascar@netcomuk.co.uk. Web: http://www.lascarelectronics.com.

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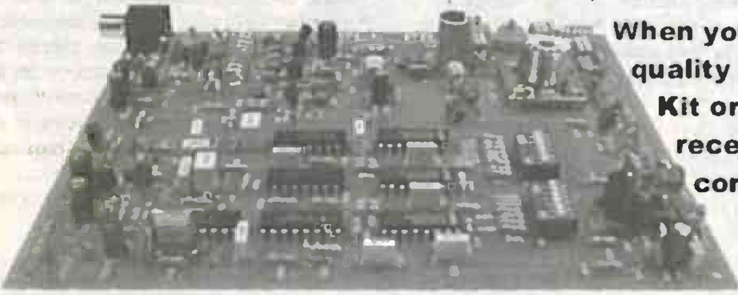

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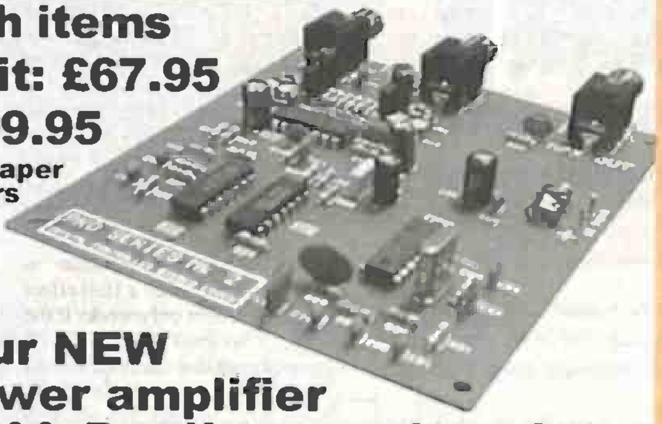

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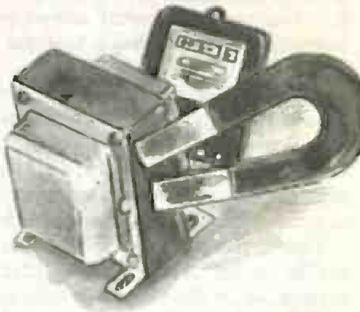
Starter Project

MAGNETIC FIELD DETECTOR



ROBERT PENFOLD

You will find the attraction with this novel, low cost, starter project.

THIS very simple project can detect fixed magnetic fields or fields that are varying at an audio frequency. Fixed or slowly changing field strengths are registered on a centre-zero meter, which indicates the polarity in addition to the relative field strength. Audio frequency fields, such as those produced around mains and audio transformers, are detected via a crystal earphone that can be used to monitor the output signal.

The unit is not intended to provide accurate measurement of magnetic field strength, and is aimed at those who like to experiment with something a bit different. Although quite simple the unit is reasonably sensitive. A small and not very powerful bar magnet can be detected by the prototype at about 100mm from the sensor, and drives the reading to full scale at a range of about 30mm.

HALL EFFECT

Detecting varying magnetic fields is quite easy, and requires nothing more than an inductor to act as the sensor. Unfortunately, static fields do not produce any output from an inductor and require a totally different approach.

The only common form of magnetic sensor that "fits the bill" is a linear Hall effect device. A Hall effect sensor is a form of semiconductor, and is actually a very simple type of component. Fig.1 helps to explain the way in which a Hall effect device works.

The sensor is just a slice of silicon having electrodes on opposite surfaces. A current is passed through the silicon, and this produces a potential gradient in the silicon. There is zero volts at the bottom of the slice, the full supply potential at the top, and a certain portion of the supply voltage at intermediate points. The two electrodes are half way up the slice, and consequently there is half the supply voltage at each one. This gives zero output voltage across the two electrodes.

Applying a suitable magnetic field to the device "skews" the current flow and the potential gradient, producing an imbalance in the output potentials. The stronger the magnetic field, the greater the difference in the output voltages.

Applying a magnetic field of the opposite polarity skews the current flow in the opposite direction, giving an output signal of the opposite polarity. The output signal therefore indicates the strength of the magnetic field and its polarity.

It is important to realise that a Hall effect sensor only works if the magnetic field is applied to one side or the other of the silicon slice. Applying the field to the front, back, top, or bottom of the sensor does not affect the current flow in a manner that will produce any imbalance at the electrodes. Consequently it will not produce any output voltage.

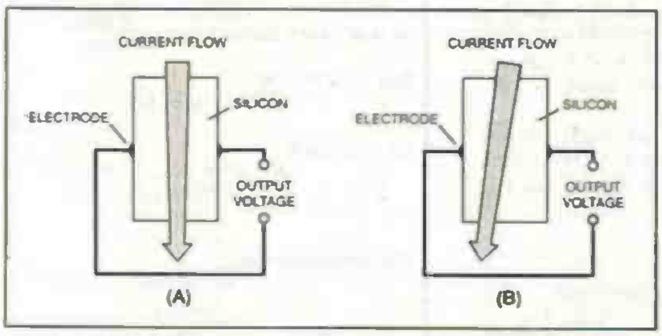


Fig.1. A Hall effect sensor is little more than a slice of silicon. (a) normal and (b) with magnetic field influence.

SENSOR

Practical Hall effect sensors are more than just the sensing element itself, and they are invariably in the form of and integrated circuit containing the sensor plus some additional circuitry. Some sensors provide a switching action, and others provide an output voltage that is proportional to the applied field strength.

In this application it is only devices in the second category that are of any use, and the device chosen for this design is the UGM3503U. This is an inexpensive device but it has a very useful level of performance and is very easy to use.

It has just three terminals, which are the supply and output terminals. An internal differential amplifier boosts the output signal from the sensing element and produces a single output that is at about half the supply potential under standby conditions.

Placing a *north* pole of a magnet close to the surface of the sensor that carries the type number produces a reduction in the output voltage, and placing a *south* pole close to this surface gives an increase in the output potential (Fig.2). The frequency response of the device is flat from d.c. to 23kHz, which means that it encompasses the full audio range.

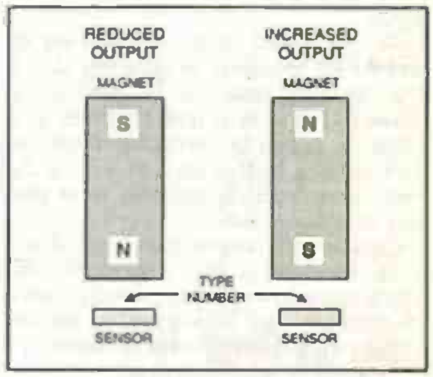


Fig.2. A Hall sensor indicates the polarity of the field as well as its strength.

CIRCUIT OPERATION

The full circuit diagram for the Magnetic Field Detector appears in Fig.3. IC1 is the Hall effect sensor and IC2, a precision op.amp, is used to provide some additional amplification. The amplifier is an operational amplifier inverting mode circuit, which has resistors R1 and R4 as the negative feedback network.

The innate voltage gain of IC2, or the "open loop" gain as it is termed, is extremely high at d.c. and low frequencies. In fact, it is over 100,000 times for a typical operational amplifier.

Using negative feedback reduces the voltage gain of the circuit as a whole to a more usable figure, and this "closed loop" gain is equal to resistor R4 divided by R1. This works out at a little over 300 in this case. Higher voltage gain would obviously give better sensitivity, but it would also give problems with noise and drift.

Op.amp IC2 amplifies the voltage difference between the input voltage to resistor R1 and the voltage at its non-inverting input (pin 3). This second voltage can be adjusted via potentiometer VR1, and in practice it is adjusted to produce a voltage that matches the normal output potential from IC1. This produces half the supply potential at the output of IC2.

The potential divider formed by resistors R5 and R6 also produces an output of half the supply potential. Meter ME1 is connected between the output of IC2 and this potential divider, and it therefore responds to the voltage *difference* between the two.

Under standby conditions both points will be at the same potential, giving zero voltage across the meter. An increase in the output voltage from IC1 produces a decrease in the output from IC2, and a negative deflection on the meter. A decrease in the output potential from IC1 has the opposite effect, producing a positive indication from the meter.

STRENGTH OF CHANGE

In both cases the greater the change in the output voltage from IC1, the higher the reading from the meter. The meter therefore indicates the relative field strength and the polarity of the magnetic field.

Applying a north pole close to the surface of the sensor that carries the type number produces a positive reading, and applying a south pole to it generates a negative reading. This may seem to be at odds with Fig.2, but bear in mind that IC2 inverts the signal.

The value used for resistors R5 and R6 controls the sensitivity of the meter circuit. The specified values permit ME1 to be driven to full scale in both directions provided the battery is reasonably fresh, but their value is high enough to prevent the meter from suffering anything more than very minor overloads.

Capacitor C2 couples the output of IC2 to earphone socket SK1. This enables the output signal to be monitored using a crystal earphone, but satisfactory results are unlikely to be obtained using any other type of earphone or with headphones.

A 6V battery supplies power to the circuit, and the current consumption is only about 9mA. Do not use a 9V battery as **this would result in the maximum supply voltage rating of IC1 being exceeded.**

GOOD PERFORMANCE

In order to produce good results in this circuit it is necessary for the operational amplifier to have good d.c. performance. Otherwise there could be major problems with drift, and d.c. offsets could make it impossible to zero the meter under standby conditions.

The op.amp also needs to be able to work properly with a supply potential of just 6V. The OP077GP is reasonably priced and gives good d.c. performance in this circuit. On the other hand, its open loop bandwidth of 600kHz equates to a closed loop bandwidth of only about 2kHz in this design.

If audio rather than d.c. performance is of most importance it would be advisable to use a TL071CP for IC2. This will give quite good d.c. performance plus a more respectable audio bandwidth of around 10kHz. To compensate for a lack of symmetry in the TL071CP's output stage resisstor R6 should be reduced from 33kilohm to 27 kilohm.

CONSTRUCTION

The stripboard layout for the Magnetic Field Detector is based on a piece that measures 19 holes by 20 copper strips. The component layout and interwiring, together with the positions of the breaks in the copper strips, are shown in Fig.4.

A board of the required size must be cut down from one of the standard sizes in which it is sold. The holes are very close together so use a hacksaw to cut along rows of holes rather than trying to cut between them. This inevitably produces quite rough edges but they are easily filed to a neat finish.

Next, drill the two 3mm diameter mounting holes and make the four breaks in the copper strips. A special tool for cutting the strips is available, but a handheld twist drill bit of about 5mm in dia. does the job just as well. Make sure that the strips are cut across their *full* width.

The circuit board is now ready for the components and link-wires to be added. With a small board such as this the order in which the components are fitted is not

Magnetic Field Detector front panel layout. The Hall effect sensor is mounted externally in a probe arrangement, such as an old pen case, and connected to the circuit board via the screened cable.

COMPONENTS

Resistors

R1	1k5	
R2,R3	10k (2 off)	See SHOP TALK page
R4	470k	
R5, R6	33k (2 off)	

All 0·25W 5% carbon film

Potentiometer

VR1	1k rotary carbon, lin

Capacitors

C1	100µ radial elect. 10V
C2	100n polyester, 5mm lead spacing

Semiconductors

IC1	UGN3503U Hall effect sensor
IC2	OP77GP precision op.amp (see text)

Miscellaneous

S1	s.p.s.t. min toggle
B1	6V battery pack (4 x AA size cells in holder)
SK1	3·5mm jack socket
ME1	100µA - 0 - 100µA moving coil panel meter

Medium size plastic or metal box; 0·1 inch matrix stripboard, size 19 holes by 20 copper strips; 8-pin d.i.l. holder; battery connector (PP3 type); control knob; crystal earphone, with lead and plug; twin-screened cable, about 0·5 metres; multistrand wire; solder pins; solder etc.

Approx. Cost Guidance Only £16 excl. earphone, case & batts.

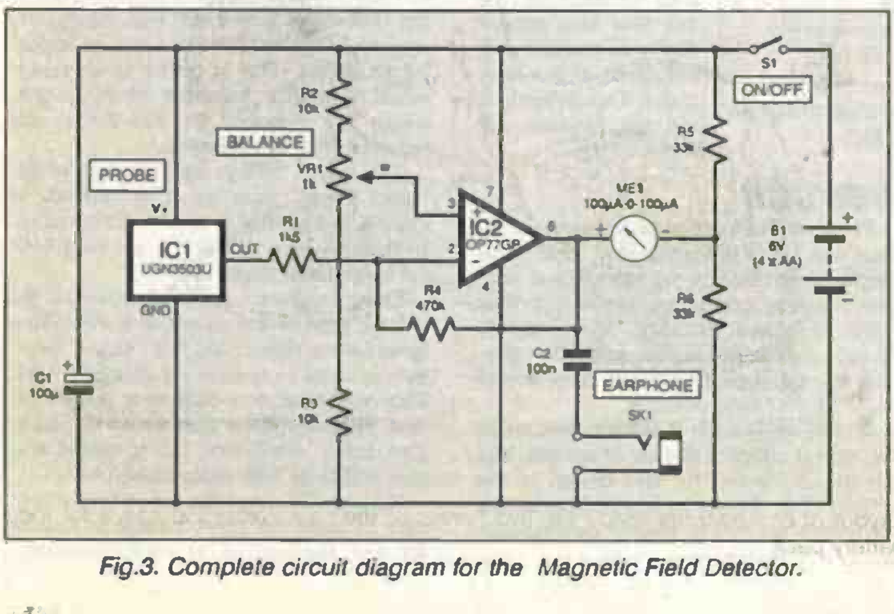


Fig.3. Complete circuit diagram for the Magnetic Field Detector.

Completed Detector showing earphone socket on one side panel.

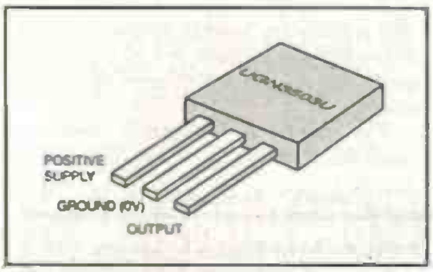


Fig.5. Connection details for the UGN3503U Hall effect sensor.

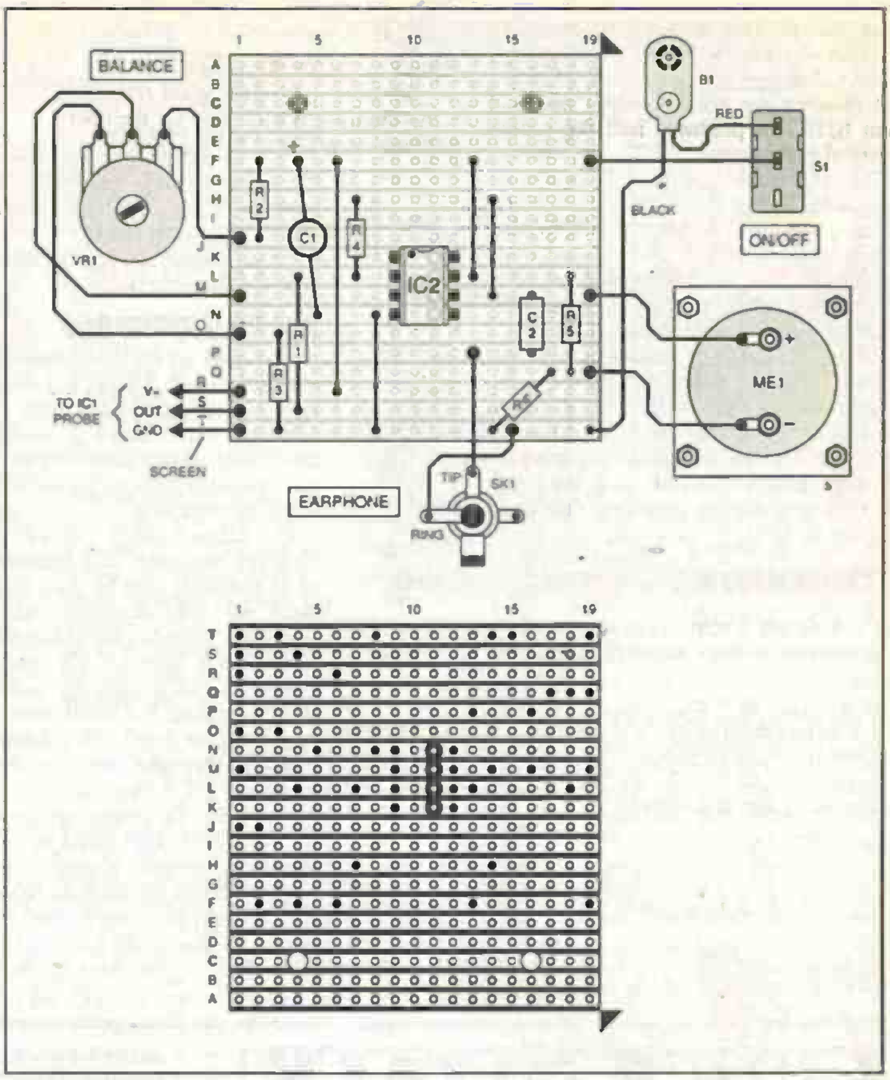


Fig.4. Stripboard component layout interwiring and details for breaks required in the underside copper tracks.

really important, but it is best to work methodically across the board so that nothing is overlooked.

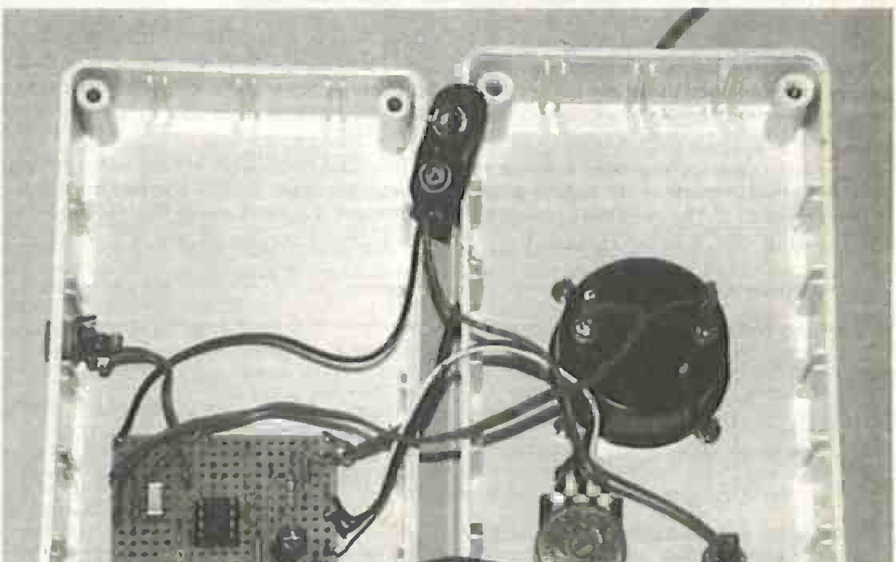
Neither the OP077GP or TL071CP is static-sensitive, but it is a good idea to use a holder for any d.i.l. integrated circuit. Be careful to fit IC2 and electrolytic capacitor C1 the right way round.

Fit single-sided solder pins at the points where connections will be made to potentiometer VR1, meter ME1, etc. It is one-millimetre diameter pins that are required for stripboard. "Tin" the pins with plenty of solder so that it is easy to make reliable connections to them.

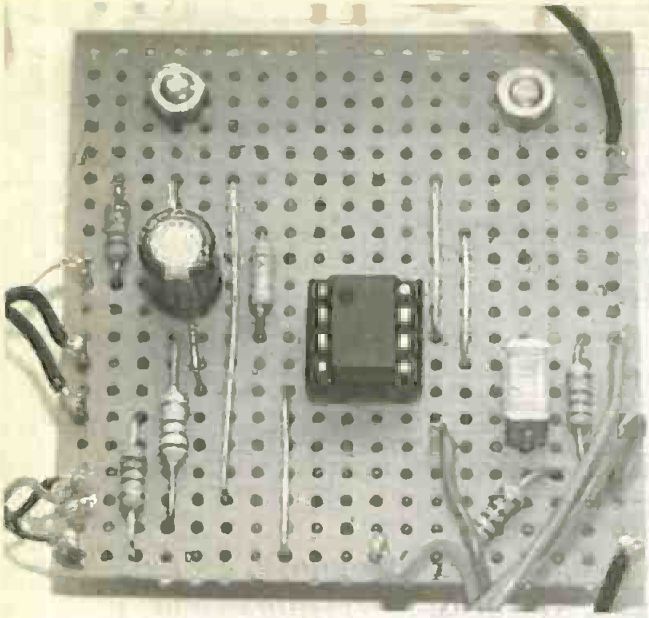
CASING-UP

Virtually any medium size plastic or metal case should be able to accommodate this project. However, be careful to choose one that has sufficient depth to take the meter and the battery pack. The latter consists of four AA size cells in a plastic holder. Connections to the holder are made using an ordinary PP3 style battery clip. Although the circuit has a fairly high voltage gain the layout is not critical, and it is just a matter of designing a layout that is easy to use.

One slightly awkward aspect of construction is fitting the meter onto the case, because this requires a large cutout to be



Layout of components inside the two halves of the case. Note the space for the battery pack.



Completed circuit board showing the four link wires and the op.amp C2 mounted in its holder.

made in the case. Most moving coil meters require a 38mm round mounting hole and the easiest way of making this is to use an adjustable hole cutter (also known as a "tank" cutter), and these are available from many DIY superstores.

Alternatively, it can be cut using a fretsaw, coping saw, or miniature round file such as an "Abrafile". Another method would be to mark out the cutout, drill a series of small holes just inside this mark and then "join-up" the holes to form the required cutout. With any of these methods it is advisable to cut just inside the perimeter of the required cutout, and then enlarge it to precisely the required size using a large round file.

Four smaller (3mm dia.) mounting holes are also required. The positions of these are easily located as they are at the corners of a 32 millimetre square having the same centre as the main cutout.

INTERWIRING

The hard wiring is reasonably straightforward. SK1 is a 3·5mm jack socket, and most sockets of this type have a built-in switch that is not required in this application. Accordingly, one tag of SK1 is left unconnected.

The Hall sensor (IC1) is mounted externally and connected to the main unit by way of a piece of twin-screened cable about 0·5 metres or so in length. An entrance hole for the cable must be drilled at a strategic point in the case, and if a metal case is used the hole should be fitted with a grommet to protect the cable. The screen is used to carry the ground (0V) connection.

Rather confusingly, the plastic encapsulation of the UGN3503U Hall effect sensor chip seems to be completely symmetrical. The only way of identifying the three leads is to use the type number on the body of the device as a reference point, see Fig.5.

Connect the sensor to the screened lead and use insulation tape or sleeving to ensure that the soldered joints cannot short-circuit together. The sensor will be neater if it is built into a probe, based on an old pen for example, but this is not essential.

TESTING

When the unit is first switched on it is likely that the meter will be driven fully positive or negative. With careful adjustment of Balance control VR1 it should be possible to zero the meter, and placing the probe near any magnetised object should then produce a suitable response from the meter.

The meter movement itself contains a permanent magnet, and placing the probe near this should produce full-scale deflection of the meter. Placing the opposite face of the probe near the meter should then produce full-scale deflection in the opposite direction.

As explained previously, applying the pole of a magnet to one of the four smaller surfaces of the sensor will not produce a significant output signal. In use the orientation of the sensor should therefore be adjusted to maximise the meter reading.

Placing the probe against the power cable of virtually any mains powered device that is switched on should produce a 50Hz "hum" from the earphone. Alternating fields will not produce an indication from the meter because the meter will register the average field strength. This will normally be zero due to the opposite poles in the signal cancelling out one another.

The circuit is reasonably stable, but occasional readjustment of VR1 will be required. □

SHOP TALK

with David Barrington

PIC Micro-Probe

The component listing for the *PIC Micro-Probe* calls for a piece of "i.c. holder" type stripboard, with a central channel, devoid of copper, running across the copper tracks. This will cost you around £5, but for just under £2 you can use a piece of standard stripboard and cut away the copper tracks as necessary. The rest of the components should be readily available.

The PIC used in this project should be the 10MHz version. For those who want a "plug-in and go" preprogrammed PIC16F84, one is available from **Magenta Electronics** (☎ *01283 565435* or *http://magenta2000.co.uk*) for the inclusive price of £5.90 (overseas readers add £1 for postage). For those who wish to program their own PICs, the software is available from the Editorial Offices on a 3·5in. PC-compatible disk, see *EPE PCB Service* page 937. If you are an Internet user, it can be downloaded *Free* from our FTP site: **ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/microprobe.**

Magnetic Field Detector – Starter Project

Just a couple of pointers regarding purchasing of components for the *Magnetic Field Detector*, this month's starter project. The first concerns the 100µA "centre zero" meter, some readers may have difficulty in locating one. The meter used in the prototype came from **Maplin** (☎ *01702 554000*), code RW98G.

If you have trouble tracking down the UGN3503U Hall effect sensor, the above company list one as order code GX09K. They also supplied the OP77G precision op.amp, code UL05F. The alternative TL071CP low-noise op.amp should be stocked by most of our component advertisers.

Ginormous Stopwatch – Giant Display

This month we complete the *Stopwatch* project with the construction of a *Giant Digital Display* module. Most of the component supply "bugs" were ironed out last month.

The high voltage 4N25 opto-coupler, code AY44, and the ULN2003 Darlington array, code AD93B, are listed by **Maplin**. The BD681 Darlington transistor may be hard to find, but the suggested alternative TIP141 and TIP142 should be readily available. Note the differing pinouts for the TIP devices (Fig.2 last month).

Ready programmed PICs are available from the author for the sum of £10 each (for either the Display module or Stopwatch) or £50 for six in any combination, with free postage to anywhere in the world. *Payments should be made out to Mr. N. Stojadinovic.* His E-mail address is: **vladimir@u030.aone.net.au** or write to: **Mr. N. Stojadinovic, PO Box 320, Woden ACT, 2606, Australia.**

A programmed PIC16C54 is also available from **Magenta Electronics** (☎ *01283 565435* or *http://magenta2000.co.uk*) for the inclusive price of £5.90 (overseas readers add £1 for postage). For those who wish to program their own PICs, the software is available from the Editorial Offices on a 3·5in., PC-compatible disk, see *EPE PCB Service* page. If you are an Internet user, it can be downloaded *Free* from our FTP site:

ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/stopwatch.

The two printed circuit boards are available from the *EPE PCB Service*, code 247 (Digit) and 248 (Port Conv.).

Loft Guard

Most of the components called-up for the *Loft Guard* project should be readily available from your usual supplier. The only problems that are likely to crop up may be finding the high value resistors.

The *single* 100 megohm resistor (R7) was only found listed under the "cermet film" range stocked by ***Electromall*** (☎ *01536 204555* or RS *http://rswww.com*), quote code 158-222. As the article points out, you could use three 33 megohm resistors (in series); the p.c.b. is also designed to accept these. This resistor (33M) came from the **Maplin** "high voltage" metal film range, order code V33M.

Note that to make up the 20 megohm resistor (R10) you will need two 10 meg types. Once again, the "series" pads have been included on the p.c.b.

The last mentioned company also supplied the miniature light-dependent resistor (l.d.r.), code AZ83E, and the high power warning buzzer, code FK84F. Although most of our components advertisers should be able to offer something similar. You could, of course, use the good old standard ORP12 l.d.r. if you wish.

Even though the semiconductors are specific versions, they should be in plentiful supply. The p.c.b. is available from the *EPE PCB Service*, code 249.

Teach-In 2000

If you have only just picked up on our new *Teach-In 2000* series with this issue, and being a newcomer to electronics, you may feel a bit apprehensive about ordering the various parts for the demonstration "exercises". Fear not, some of advertisers have put together component and hardware packs specially for the new series. A few more will be added as the series progresses, but we do not expect that to be until at least part seven.

To date, participating advertisers are as follows and readers are advised to contact them for more details:

ESR Electronic Components (☎ *0191 251 4363* or web *http://www.esr.co.uk*) Hardware/Tools and Components Pack.

Magenta Electronics (☎ *01283 565435* or *http://www.magenta2000.co.uk*) – Multimeter and Components Kit 879.

FML Electronics (☎ *01677 425840*) – Basic Components Sets.

N. R. Bardwell (☎ *0114 2552886*) – Digital Multimeter special offer.

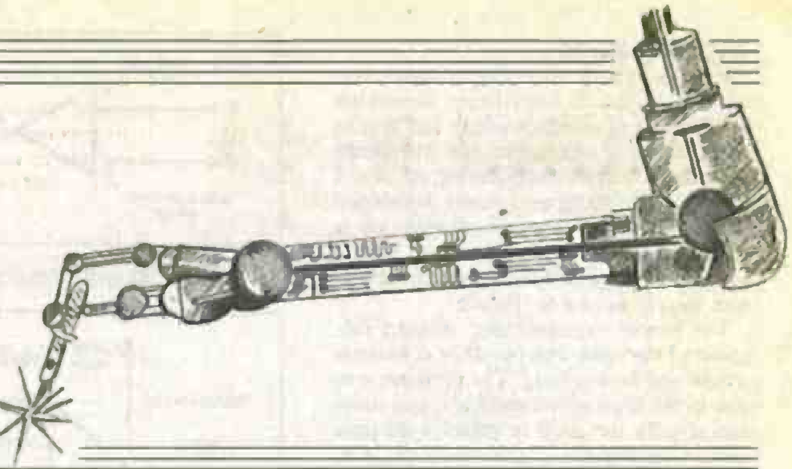
PLEASE TAKE NOTE

Demister One-Shot — **Nov '99**

Page 844 Fig.4. On the p.c.b. component layout diagram, the "body" outlines of capacitors C1 and C2 should be transposed – see photograph at top of page 845. The electrolytic, shown as a circle, should connect to the IC1 pin 8 copper track (+) and the common GND track (–). The actual annotations are correct.

Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY and IAN BELL

This month our team of surgeons commences an op.amp extravaganza, lifting the lid off these indispensable amplifying circuits. Also, fusible resistors come under their beady eyes too!

WELCOME to the very last *Circuit Surgery* column of the 1990's, and we hope there is something of interest to everybody in our monthly round-up of readers' queries and questions.

Op.Amps 101

We have had a couple of questions about op.amps and think that many readers will find a discussion of this subject useful. *Mohab Refaat* writes by E-mail: "EPE *publishes many circuits that involve audio effects or amplification. Some use "low noise" op.amps, such as the LF351 or the TL071. My first question is, how can you select an op.amp for a particular application out of a large number of candidates?*

I found the use of a "Volume" control in simple amplifier circuits to be another aspect I found a bit baffling. Sometimes it is achieved using a pot. (potentiometer) as the input resistance to the op.amp, sometimes it is used in the feedback network to control the gain. Are there any rules related to the use of either method? Thanks for opening up the world of electronic circuit design to we non-electronic engineers in a simple way!"

Also *Tony Soueid* from Lebanon writes: *"Almost every design involving analogue electronics contains an op.amp. I know how an op.amp behaves and the equations that rule its behaviour but what I don't know is what's inside that black box.*

All that we have been taught is that it is based on a differential pair of transistors, but it's far from being that simple. Can you please supply me with some information?"

It's best to start with the second part of the first question, because it deals with something very specific which follows on neatly from our recent discussion on the 22-position volume control (*Circuit Surgery*, Oct '99) and volume power outputs from amplifiers (Sept '99). We will then move on to a more general discussion on op.amps over the next month or so.

Volume Control

Both methods of volume control obviously work, in that they both provide control over the loudness of the sound produced by the amplifier. I cannot say that I have seen a formal rule for which method to use. However, we can make a distinction between the two approaches in that the input resistance approach is an *attenuator* whereas the feedback resistance is a *gain* control.

Both controls can be used together, in some applications. I therefore suggest that the "input resistance control" is suitable when the maximum input signal is at a known reasonably fixed level. The amplifier can then be designed to give *full volume* for this signal level, and the input is attenuated for lower volumes.

When the range of possible input levels is very large though, it will be necessary to be able to change the *gain* of the amplifier to a level appropriate for the input being used at any one time. Ideally, the Gain control would be set to give maximum undistorted (non-overloaded) output with the maximum input in the current situation and then left alone, with a separate control for volume.

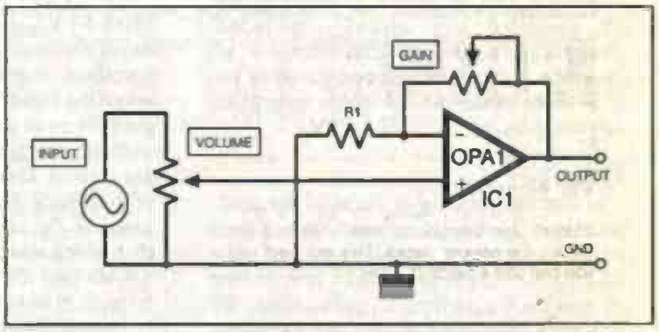


Fig.1. Circuit to illustrate the two types of volume control.

However, as gain also affects volume, the gain can be set to give the desired volume at any instance and this, of course, reduces the number of controls needed. The representative circuit in Fig.1 illustrates both types of volume control, the input signal shown on the diagram may be from an external source or an earlier stage in a larger circuit.

Making a Choice

To select an op.amp you need to know what the circuit and hence the op.amp needs to achieve, this will give you a minimum specification for the device. Then purchase the cheapest op.amp which meets all the specs!

It may not always be all that simple to calculate an op.amp spec. in great detail, but you can use a bit of common sense too. If your application is an audio amplifier it would be sensible to use a *low noise* op.amp and pay a bit more for a better spec., on the other hand if you are using it as a comparator to, say, switch on a heater when the output of a temperature sensor falls below a certain point, then an ultra low noise "audio spec" device is not really needed.

The range of circuits one can design using op.amps is so vast that we cannot give specific recommendations. The best thing you can do is understand what all the op.amp specs and ratings mean so that you can make an informed choice when necessary.

Having said this, the choice of op.amps in all the constructional projects in *EPE* probably does not necessarily follow an obvious process of selection! The projects are designed by various authors, many projects will be feasible with a wide range of general purpose op.amps and some authors will have their favourite ones that they always tend to use.

In other hobby projects, the choice of op.amp may well depend on what was available at the time! (e.g. see John Becker's comment on his choice of amplifier in the *Musical Sundial* – page 433 in the June '99 issue). For audio projects, not everyone will aim for hi-fi quality – if a very high sound quality is not really needed then why pay more for a special op.amp?

Inperfections

Having given the impression that op.amp choice is sometimes somewhat arbitrary, it is worth pointing out that in some cases it can make the difference between a circuit functioning or not. I remember working on a partly developed prototype power control system for a CO_2 laser, the existing output circuit used a general purpose op.amp which was simply not up to the job.

The power measurement worked fine some of the time, but on other occasions would not do anything. The problem was due to the high offset voltages, and more specifically the *drift* in offset with time and temperature. The circuit was replaced with one using special high precision peak measurement chips, which did a great job.

The above example illustrates a couple of points. First, it is the imperfections in "real" op.amps (as opposed to "ideal" ones) that cause problems, so understanding these and their impact will help you avoid devices that are unsuitable. Understanding op.amp imperfections will also help you understand the internal circuitry (with reference to the second reader's question) because much of the design effort arises in reducing these imperfections.

Second, there are occasions where specialist chips other than op.amps are the best option. The above case was one example, another good one would be a sample and hold circuit – you can build one using an op.amp, but you will get better performance from a ***sample and hold chip***, and, of course, some extra bits of circuitry are already included. Comparators are another case – all op.amps can be used as comparators but it is often better to use chips optimised for this purpose.

On Spec

It is worth looking at some of the specifications found on op.amp data sheets and in suppliers' catalogues and discussing how these may effect your choice of op.amp for particular applications. We will also refer to some of these specifications when we move on to look at the internal circuitry. But, before we start, we need to define some basic things about the op.amp, so let's explore them in greater detail.

The op.amp is a high-gain, direct-coupled amplifier, its symbol is shown in Fig.2. The term "direct-coupled" means that the inputs and internal stages are connected directly, not via coupling capacitors. This enables the op.amp to amplify d.c. and very low frequency signals.

The op.amp has two inputs – the ***inverting (–)*** and ***non-inverting (+)*** inputs – and an output. The inputs and outputs are usually referenced (applied or measured with respect to) ground or 0V.

Op.amps usually have two power supplies, one at a positive voltage with respect to ground and the other at the same magnitude negative with respect to ground; however many "single supply" op.amps are also available. Suppliers' catalogues usually indicate whether an op.amp is intended for single or dual

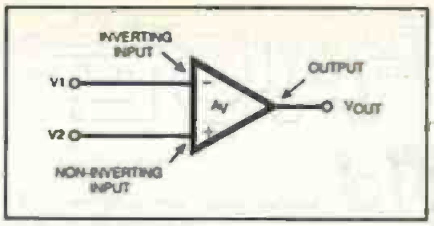


Fig.2. Op.amp circuit symbol.

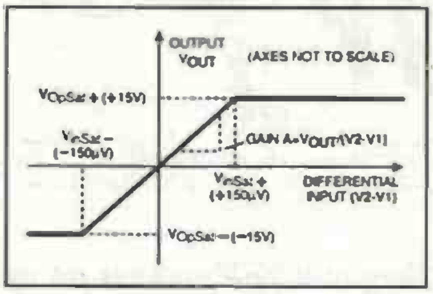


Fig.3. Graph showing the relationship between op.amp differential input voltage and its output voltage. Saturation occurs when any increases in the magnitude of the differential input do not result in further increases in output voltage. The values shown are an example for an op.amp with a gain of 100,000 and a maximum output voltage of ±15V. The gain of the op.amp is equal to the slope of the graph between the saturation points.

supply operation, otherwise check the data sheet. The power supply connections are not always shown on schematics.

The output voltage of an op.amp is given by $V_{OUT} = A_V(V_2 - V_1)$ where A_V is the *open loop* voltage gain, V_2 is the non-inverting input voltage and V_1 is the inverting input voltage. This "open loop" gain refers to the gain of the op.amp itself *without any feedback circuitry*. Op.amps are almost always used with some form of feedback though, which results in a gain for the *circuit* that is different from that of the op.amp itself.

Note that the op.amp amplifies the *difference* in voltage between its two inputs. It is a ***differential amplifier***. The equation $V_{OUT} = A_V(V_2 - V_1)$ always holds for totally ideal device, but in reality is only valid for a small range of $(V_2 - V_1)$ and there are limits on the individual values of V_2 and V_1 too. The op.amp's input-output relationship is illustrated in Fig. 3.

Some manufacturers group their op.amps into types suited to different kinds of application. Typical descriptions may include:

- ***general-purpose*** – suitable for a wide range of applications requiring moderate amplifier performance
- ***low noise*** – guaranteed very low noise for applications such as sensitive measurement and signal processing where noise from the op.amp must be within known bounds
- ***low-power/micropower*** – suitable for use in systems such as mobile equipment, where power consumption is critical
- ***wideband/high speed*** – for applications such as pulse circuits and video where accurate reproduction of complex high frequency signals is required
- ***high-power/high current*** – op.amps with high current output stages capable of driving low impedance loads
- ***low drift/high precision*** – amplifiers with minimal offset voltage, and where accuracy is preserved over a wide temperature range
- ***low bias/high impedance*** – f.e.t. input op.amps with very low input bias currents for use in buffer circuits or with large external resistors.

Some op.amps may arguably belong to more than one of these categories. The specifications given on Op.amp data sheets can be divided into: *electrical ratings* (maximum voltages etc.); *signal handling* (noise etc.) and *offsets* (which particularly effect d.c. accuracy). We'll discuss these and other practical matters in the next *Surgery. IMB.*

Fusible Resistors

Mark Lee asks: *"I would appreciate an explanation of fusible resistors and how to use them. They seem to be mainly low resistance and low power ratings. How do I use them in a circuit?"*

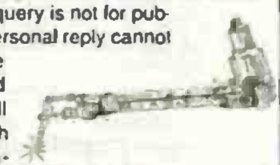
Fusible resistors are inserted into a circuit as an ordinary resistor would be, except that they have the special property that if they are overloaded for any reason (a circuit fault elsewhere downstream), then instead of burning out they are guaranteed to go open-circuit within a certain range of conditions.

This means that they will disconnect the circuit, rather than burning out or setting fire to the board. They are only produced in a limited range of values (low ohms to a few kilohms) and would be used in e.g. power supply or monitoring circuits, where a combination of resistance and overload protection is required. The main thing is that they are a fault-tolerant, fail-safe fireproof device.

Paradoxically there is even a zero ohm resistor available! These are used by manufacturers using automated p.c.b. equipment, to apply a link between two pads – it means that a machine which handles resistors is, therefore, also able to insert the equivalent of a wire link instead. *ARW.*

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. Please indicate if your query is not for publication. A personal reply cannot always be guaranteed but we will try to publish representative answers in this column.



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The EPE Chat Zone on our web site is now open as a way for readers to exchange information, views, hints and tips in virtually real time.

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INTERFACE

Robert Penfold

A SERIAL APPROACH TO PC ADD-ONS

IN THE previous *Interface* (Oct '99) article we considered the subject of serial port interfacing, and using a standard RS232C serial port to send data to a user add-on. In this month's *Interface* we will look at using a serial port to receive serial data.

Much of the background information provided in the previous article also applies to using a serial port to receive data. Refer to the earlier article if you require information on the UART registers, setting the word format and baud rate, etc.

With things reduced to the simplest level it is not difficult to read data from a serial port. Using the methods outlined in the previous *Interface* article it is possible to set the required baud rate and word format, and is then just a matter of reading data from the base address of the port. The base addresses for serial ports one and two are respectively &H3F8 (1016 decimal) and &H2F8 (760 decimal).

Mouse Experiment

If your PC has a serial port mouse it is easy to experiment with serial port reading, and the raw data from the mouse can be read from the appropriate mouse port. Using Delphi 1, this code could be applied to a timer component set with an interval of about 50 milliseconds:

```
Reading := Port[760];
Str(Reading, S);
Label1.caption := S;
```

The value of "760" in the first line is correct if the mouse is on serial port two, but must be changed to "1016" if it is on port one. The two variables must be declared in the appropriate part of the program by adding the following two lines in the section headed "var":

```
Reading : Byte;
S : String;
```

A label component must be added to the form, and its default caption should be erased. This gives the program somewhere to display the data read from the serial port. When the program is run, the data displayed on the label should change as the mouse is moved around and the buttons are operated.

Synchronisation

For many applications it is perfectly all right to take this simplistic approach, and simply read the port periodically to obtain the latest data available. For example, suppose that a Thermometer is connected to the port. By reading the port the latest temperature will always be read and displayed. The fact that each new piece of data may be read several times or the odd reading may be missed here and there will be of no practical consequence.

This is not the case in all applications though, and in some cases it may be necessary to operate on the basis of sending a trigger signal to the interface, and then reading in *x* number of bytes. It then becomes essential to properly synchronise the sending device and the program reading the data. Otherwise there is a risk of (say) reading four bytes of data twenty-five times each instead of reading 100 bytes of data once each.

There is no need for an external handshake line to control the flow of data, and a status bit of the Line Status register can be used instead. Bit 0 of this register is set to one when a complete byte has been received and transferred to the receiver Register. Writing a zero to this bit will reset it, but this is not normally necessary as it is automatically cleared when the data in the receiver register is read.

To ensure that each byte of data is read only once it is just a matter of using a software loop to monitor the received data bit, and provide a hold-off until it is set to one. This prevents the Receiver Register from being read until a new byte of data is ready.

The Delphi 1 program described previously is easily modified to provide this hold-off. In addition to the hold-off, this listing also implements a counter that shows the number of readings that have been taken. A second label component must be added to the form to accommodate the counter.

```
Port[1019] := 128;
Port[1016] := 12;
Port[1017] := 0;
Port[1019] := 3;
Port[1017] := 0;
Repeat until (Port[1021] and 1) = 1;
Reading := Port[1016];
Str(Reading, S);
Label1.caption := S;
Counter := Counter + 1;
Str(Counter, S);
Label2.caption := S;
```

The port addresses used here are for port one. For serial port two use these addresses:

760 instead of 1016
761 instead of 1017
763 instead of 1019
765 instead of 1021

In addition to applying this program to a timer component these three lines must be used to declare the variables.

```
Reading : Byte;
Counter : Byte;
S : String;
```

A further line must be added to the listing for the form, and this sets the Counter variable at an initial value of zero.

```
Counter := 0;
```

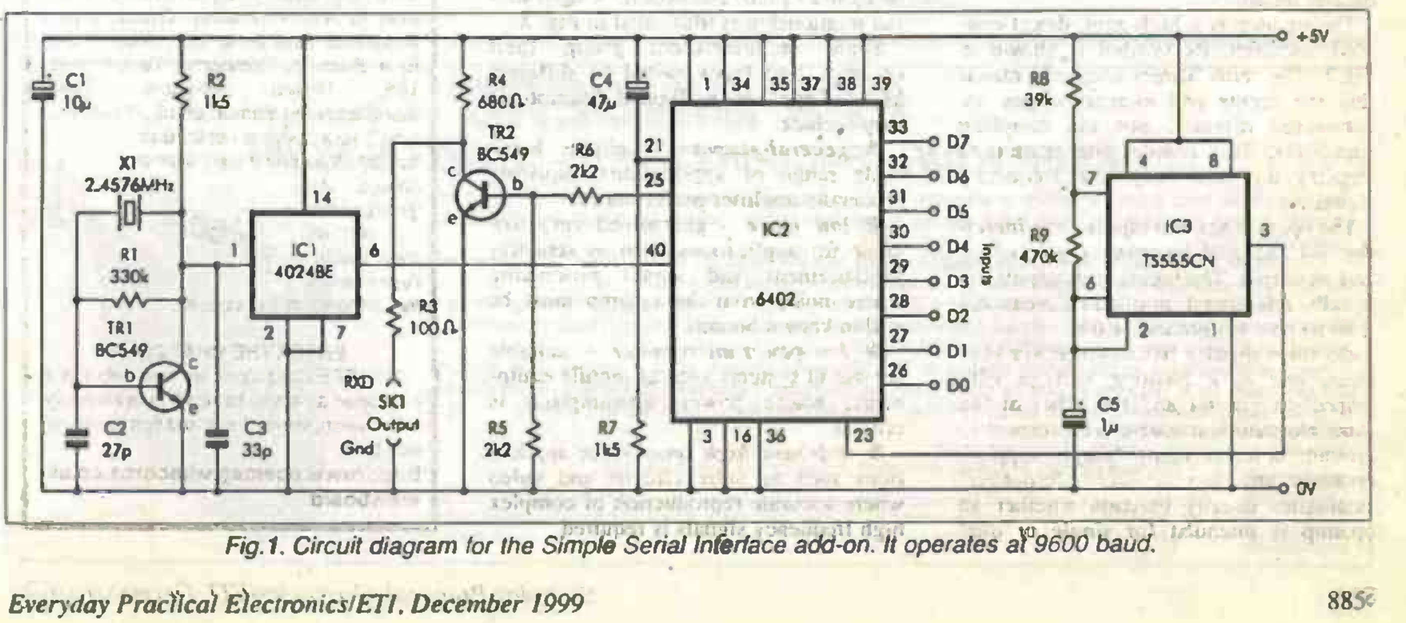


Fig.1. Circuit diagram for the Simple Serial Interface add-on. It operates at 9600 baud.

Operation

In the original test program we relied on the operating system to set up the serial port correctly, but in real world applications the program must do this. The first four lines of the listing set the port for 9600 baud operation with a word format of eight data bits, one stop bit, and no parity checking.

Using the control registers to set the baud rate and word format was covered in the previous *Interface* article, and will not be discussed again here. The fifth line switches off interrupts, and should ensure that the operating system does not upset things by reading bytes of received data.

The hold-off is provided by the Repeat...Until loop in the next line. This line repeatedly reads the Line Status register, and bitwise ANDs the result with one. This effectively strips off bits 1 to 7, and reads only bit 0.

The program loops until the returned value is one, which means that there is a fresh byte of data to be read. The port is then read and the result is displayed on Label1. Then the Counter variable is incremented by one and the new value is displayed on Label2.

Hardware

The Simple Serial Interface of Fig.1 can be used to test this program. The 6402 UART has been covered in previous articles and will not be discussed in detail here.

Transistor TR1 generates a 2·4576MHz clock signal that is divided by 16 through IC1. UART IC2 requires a clock signal at 16 times the required baud rate, and this gives an output signal at 9600 baud.

The control inputs at pins 34 to 39 of IC2 are hard-wired to produce the required word format of 8 data bits, one stop bit, with no parity checking. Transistor TR2 acts as a simple line driver and inverter, but it does not provide proper RS232C output levels.

Good results should still be obtained provided the cable used to connect the interface to the computer is no more than a few metres long. The output (SK1) connects to the Ground and Receiver Data input of the RS232C interface. These are at pins 7 and 3 respectively for a 25-pin port, or 5 and 2 for a 9-pin port (see Fig.2).

In Control

A serial interface requires some form of control logic circuit to trigger the UART at the appropriate times and send a stream of data. At its most basic the control logic can consist of nothing more than an oscillator, which is all that is used in this case.

A low power 555 timer, IC3, is used in the standard oscillator configuration. The values of timing components resistors R8, R9 and capacitor C5 set a low operating frequency of roughly 1Hz. Therefore, about once per second the output of IC3 (pin 3) goes through a high to low transition and causes IC2 to send the eight-bit value on its inputs.

Although the test program is assigned to a timer component that tries to take a reading every 50 milliseconds, which works out at 20 readings per second, it will only take about one reading per second. This is due to the software hold-off looping the program for about a second until a new byte of data has been received. If everything is working properly, the counter should therefore increment at about one and not 20 per second.

A slightly beautified version of the program after 30 seconds of taking readings is shown in Fig.3, the count has reached 31. Of course, data can be transferred at a greater rate by increasing the operating frequency of IC3 and reducing the time interval of the timer component (or simply having a routine that continuously tests the serial port).

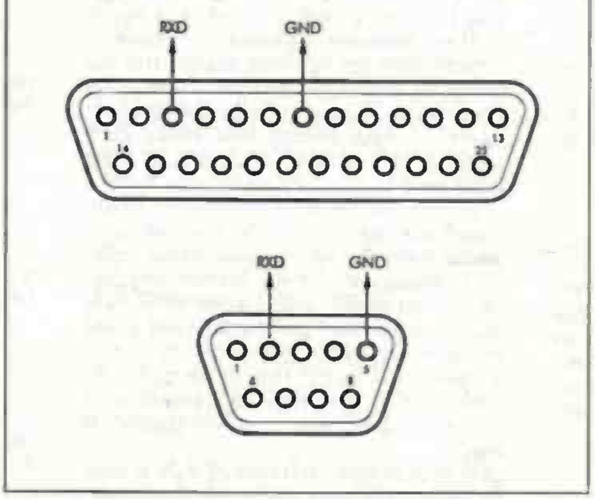


Fig.2. Interface connection details for 25-pin and 9-pin serial ports.

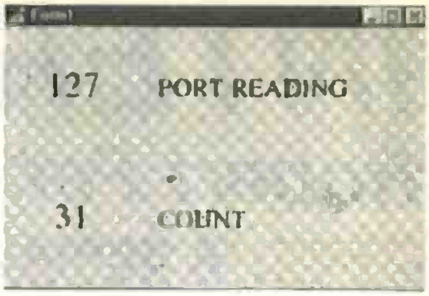


Fig.3. The counter of the test program should increment each time fresh data is received.

However, bear in mind that there are ten bits per serial byte and with a baud rate of 9600 this works out at an absolute maximum transfer rate of 960 bytes per second. In practice the maximum achievable transfer rate would probably be slightly less than this.

Although the routines provided here are written in Delphi 1, using the methods described in previous *Interface* articles it should be possible to use other versions of Delphi, Visual BASIC 6, or even GW BASIC. It is just a matter of outputting the correct values to the serial port registers, and then reading the base address. If a software hold-off is needed it might be necessary to use a different loop structure with some languages, but it should not be too difficult to apply the same bitwise ANDing and looping technique to provide the hold-off.

Extra Outputs

One or two readers have asked whether it is possible to use some of a serial port's handshake lines as general purpose outputs. The UART data sheet would seem to suggest that the Data Terminal Ready (DTR) and Request To Send (RTS) handshake outputs are respectively controlled by bits 0 and 1 of the Modem Control register. This is at address 764 for port two and 1020 for port one. It would also seem to suggest that certain handshake inputs could be read at the Modem Status register.

However, initial attempts at writing to and reading from handshake lines failed totally. Possibly these lines are implemented via some other means, but using them directly seems to be something less than straightforward.

New Technology Update

Transistor technology is poised for some major advances in the near future, reports Ian Poole.

IT IS just over fifty years since the first transistor was made at Bell Labs. Since then many advances have been made, enabling the performance to be improved beyond all recognition.

Bipolar technology has improved from the early transistors that had cut-off frequencies of only a few kilohertz and low gains to the state where r.f. transistors are available that can operate to frequencies of many Gigahertz and with much higher levels of gain than were previously possible. Not only this, but field effect transistors (f.e.t.s) are now widely available.

It is interesting to note that the development work to devise a semiconductor amplifying device was initially focussed towards the development of a field effect device. However, they were unable to make the effect work, and they changed the line of the investigations which resulted in the development of the bipolar transistor.

It took a few years before the field effect transistor was widely available. F.E.T.s also had a major impact on integrated circuit technology, enabling the degree of integration to be considerably increased.

With transistor technology now very mature it might be thought that the rate of development would slacken as fewer developments were possible. However, nothing could be further from the truth. Many new ideas are surfacing, and these will enable transistor technology to surge forward and meet the demands to tomorrow's technology, both in performance and size.

Nano-curls

The idea of nanotubes has been covered previously within this column (December 1998 *EPE*), but only in the application for producing very low resistance and high current carrying capacity conductors. The nanotubes used for the transistors that are being developed are subtly different, forming a semiconductor rather than an ordinary conductor. Although the concept has been known for several years, the technology is revolutionary and until recently it has not been possible to realise it in a physical form.

Nanotubes used for transistors have carbon walls made up from hexagonal shaped matrices. Essentially they are vaporised carbon that has been condensed into a series of hexagons. To give a better view of what they are, they can be considered as a very thin strip cut out of a graphite carbon plane which has been rolled up and sealed at either end. The dimensions are naturally very small, and the dimensions are measured in atomic proportions.

The carbon hexagons that are used to make the tubes have a natural tendency to curl. The way in which they curl determines their electrical characteristics.

Fortunately, it is possible to control the way in which this curling takes place. By rolling it in a way that gives a straight molecular alignment the nanotube behaves like an ordinary conductor. However if the curl is arranged so that molecular structure is twisted then the nanotube behaves like a semiconductor.

A considerable amount of experimentation was required to enable the right properties to be obtained. It was necessary to have the right amount of curl. In fact, the early nanotubes consisted of multiple concentric layers. However, the nanotubes that are used now consist of just a single wall comprising of a single atomic thickness.

Transistors

Having developed the basic semiconductor the next major hurdle was to develop a useful device. Surprisingly, two organisations announced they had succeeded. In 1998 the IBM Thomas Watson Research Laboratories and the Delft University in Holland both claimed they had managed to fabricate a transistor using this revolutionary new technology.

The device consisted of a single nanotube having a thickness of one atom. Once rolled the tube was about one nanometre in diameter. This was connected between two electrodes that were about 400 nanometres apart, and the whole structure was mounted on a silicon substrate onto which a layer of silicon dioxide had been set down to act as insulation. The nanotube then acted as the channel whose conductivity could be controlled in the normal way.

Although the channel length of the early development model was relatively large it could be made very much smaller. In fact, some working lab models have been made with lengths of around 40nm and it is estimated that in future channel lengths of only 20nm should be achievable.

As the speed of operation is primarily controlled by the length of the channel this will result in a considerable increase in the speed of operation. This means that considerable improvements will be possible over the latest production f.e.t.s fabricated using the latest 0·18 micron process which have channel lengths of around 120nm.

Future

This technology is very new and still very much in its experimental stages and much basic work is being undertaken to ensure that the process can be reliably introduced into production apart from developing the basic technology. As a result it is likely to be several years before nanotube transistors are available. Nevertheless, work is progressing apace.

One of the problems results from the minute dimensions used in these devices. It makes them less robust and more open to problems arising from impurities. The gate insulation area is one where this is particularly apparent. The very thin gate insulation has to be completely free from impurities as a result of its extremely small dimensions.

Atom leakage is also a problem and interconnection resistances also have to be investigated. The experimental devices produced so far have had problems arising from the very high resistance between the nanotube used for the channel and the contacts.

In current experimental devices the resistance has been of the order of one megohm. Clearly there will be many advantages to be gained from reducing this value. By comparison the discreet f.e.t.s that are widely used in today's circuits have channel resistances of only a few hundred ohms. The higher values currently being obtained in the new devices will reduce the high frequency performance of the whole circuit in which they are used.

Wafer Thin

Another area that is being investigated is that of producing suitable wafers. Those that can be produced at the moment, on an industrial scale, do not have a sufficiently fine surface to enable the minute nanometre sizes required for the new transistors to be fabricated sufficiently accurately. A rapid thermal oxidation process is being developed but even when this has been perfected it is not expected that it will support the sizes below about 50nm for commercial production, and this will mean that the full capability of the new technology will not be realised.

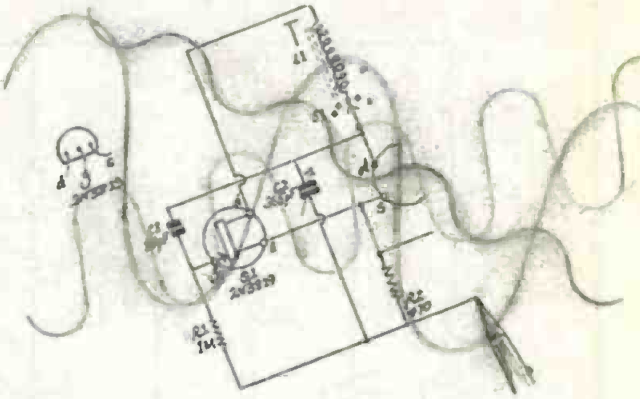
Whilst no obvious solution is even on the horizon, development work is still progressing. It is quite possible that developments in other areas of semiconductor technology may enable the requirement to be met by the time the development of the nanotube transistor technology has reached a sufficiently advanced stage.

In order to introduce this new technology onto the market new fabrication techniques are required. This results from the fact that the extremely small sizes mean that "quantum well effects" become an issue.

To overcome this, new materials are needed and in turn this leads to the fact that new processes and lines will be required. However with other technologies nearing the end of their roadmaps, the need for new technologies like these nanotube transistors will be required to ensure that semiconductor technology can keep up with developments in other areas and possibly stay one step ahead.

Special Series

PRACTICAL OSCILLATOR DESIGNS



RAYMOND HAIGH

Most text books deal with oscillators in a theoretical way. This series, prepared with the electronics enthusiast and experimenter very much in mind, is intensely practical. Tried and tested circuits are fleshed out with component values, and their vices and virtues are exposed.

PART SIX– RESISTOR/CAPACITOR OSCILLATORS

SO FAR we have covered oscillators which rely on quartz crystals or inductors and capacitors to determine the operating frequency. In this final part of the series, circuits in which resistors and capacitors perform this function will be considered.

Resistor/capacitor (*R/C*) oscillators are widely used for the generation of specific waveforms (e.g., sine, square, sawtooth) over the 5Hz to 50KHz range. Circuits of this kind will oscillate from well below 1Hz to above 2MHz, but a high degree of frequency stability and waveform purity becomes increasingly difficult to achieve above 100kHz or so.

Resistors and capacitors fix the frequency of oscillation by controlling the phase of feedback, or by timing the action of switching circuits.

PHASE SHIFTING

The signal at the base (input) of a common emitter transistor stage is 180 degrees out of phase with the amplified signal at the collector (output). For oscillation to take place, feedback from collector to base must be in phase, and the output signal must, therefore, be shifted through 180 degrees.

This can be achieved by inserting a network of resistors and capacitors in the feedback path, the component values determining the frequency at which the desired phase shift takes place. In this way, the R/C network fixes the frequency of oscillation.

If care is taken with the associated circuitry, phase shifting R/C oscillators can generate sinewaves of high purity. The Wien bridge oscillator is the classic example of circuits of this kind. Here, the R/C network is configured to give zero phase shift at the frequency of oscillation.

RELAXATION OSCILLATORS

Capacitors take time to become charged when a d.c. voltage is applied across them via a resistor. The larger the values of resistance and capacitance in the series circuit, the longer the charging time.

The rising voltage across the capacitor, as it is being charged, can be used to trigger a change of state in a transistor switching stage. If this also results in the capacitor being discharged, the cycle will start again, and we have a circuit which oscillates at a frequency determined by the amount of resistance and capacitance.

> **PHASE SHIFTERS**
>
> A simple phase shifting oscillator suitable for generating spot frequencies is given in Fig.1. The usual formula relating frequency to resistance and capacitance in circuits of this kind is:
>
> $$f = \frac{65000}{RC}$$
>
> when f is in Hertz, R is in ohms, and C is in μF.
>
> With this particular arrangement, the frequency of oscillation is usually about 20 per cent lower than the figure derived by calculation.

Arrangements of this kind are known as *relaxation oscillators*. They produce saw tooth or square waveforms which are rich in harmonics. Unijunction transistor and multivibrator oscillators operate in this way.

PHASE SHIFT OSCILLATOR

A simple oscillator in which a network of resistors and capacitors are used to shift the phase of the feedback is shown in Fig.1. Here, transistor TR1 is configured as a common emitter amplifier with the output developed across the collector (c) load resistor R2. Bias is applied via resistor R1.

In theory, a single resistor and capacitor combination can shift the phase of a signal through 90 degrees. This capability cannot be utilised in practice, however, because the signal is excessively attenuated.

Accordingly, three R/C elements, each shifting the phase by 60 degrees, are cascaded to produce the required 180 degrees phase inversion. Signal attenuation is reduced to acceptable limits, but the amplifier must still provide a gain of at least 29 times for oscillation to be maintained.

In Fig.1, the combinations of R3/C1, R4/C2, and the input resistance of TR1 (in parallel with R1) combined with capacitor C3, form the three stage phase shifting network. It should be noted that the capacitors and resistors in the network have the same value. Increasing the amount of resistance and/or capacitance will lower the frequency of oscillation: a reduction will raise it.

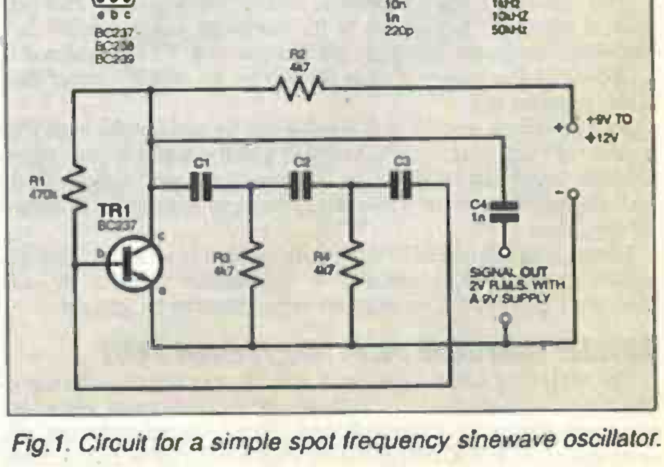


Fig.1. Circuit for a simple spot frequency sinewave oscillator.

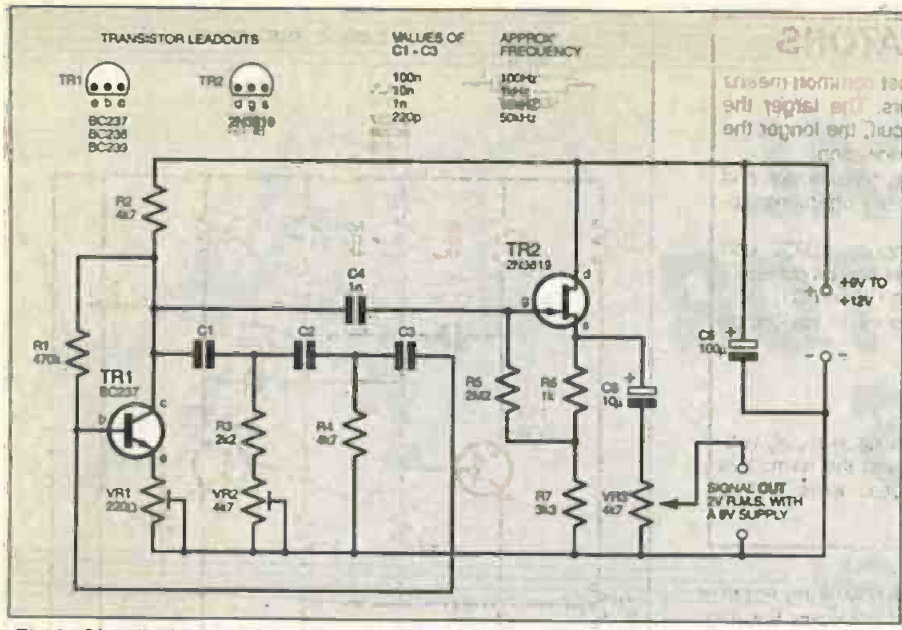


Fig.2. Circuit diagram for an adjustable spot frequency sinewave oscillator with an output buffer stage.

R/C OSCILLATORS

Combinations of resistors and capacitors can be used to fix the frequency of an oscillator. They do this in two ways:

(1) By determining the phase of signals in a positive feedback loop. Circuits of this kind can generate high quality sinewaves.

(2) By timing the switching of the maintaining devices between *on* and *off* states. Arrangements of this kind are known as *relaxation oscillators.* They generate square, sawtooth or pulse waveforms.

COMPONENTS

Capacitors used for phase shifting or timing should be polystyrene, polyester, or Mylar film types. When identical capacitors are required (see Figs.1, 2 and 3) they should be of 10 per cent tolerance or better.

Note that this only applies to the circuits given here. Some phase shift oscillators require 1 per cent tolerance components before they will operate reliably.

The circuit is essentially a spot frequency signal generator which can operate from below 50Hz up to more than 50kHz. Its output waveform is of tolerable quality, but the impedance of the accepting circuit must be high or oscillation may be inhibited. An impedance of 47kilohms, which halves the signal output, should be regarded as the acceptable lower limit for reliable oscillation.

IMPROVED PHASE SHIFT OSCILLATOR

With the addition of two pre-set resistors (potentiometers) and an output buffer stage, TR2, the performance of the circuit is considerably improved. The modified version of the circuit becomes an adjustable spot frequency oscillator and is shown in Fig.2. The upper frequency limit is around 60kHz, and the amplifier must have a gain of at least 29 times in order to maintain oscillation.

Negative feedback developed across the unbypassed emitter "resistor", preset VR1, reduces the gain of transistor TR1. Setting this resistor so that the circuit will only just oscillate results in the generation of a sinewave of high quality.

Replacing part of one of the resistors (R3) in the phase shifting network with pre-set VR2 enables the frequency of oscillation to be adjusted slightly. (At 10kHz it can be shifted by plus or minus 1·5kHz).

The f.e.t. (field effect transistor) source follower stage TR2 presents a very high impedance to the oscillator and a suitably low impedance to the accepting circuit. Gate resistor R5 is connected to a tapping on the source resistor formed by R6 and R7, rather than to the negative rail.

By this means, correct gate biasing can be maintained with TR2 source (s) held at about 4V, and this greatly improves the signal handling capability of the stage. Moreover, the gate resistor R5 is partially bootstrapped and this increases input impedance to almost 10 megohms.

Decoupling capacitor C5 will not be needed in all cases. Variable potentiometer VR3, connected to the source of TR2 by d.c. blocking capacitor C6, enables the output level to be adjusted.

WIDE RANGE A.F. GENERATOR

The frequency selective network at the heart of most audio signal generators was devised by Wilhelm Wien, a German physicist, about a century ago. Originally used as a measuring bridge, the combination of series and parallel R/C elements produces a network which imparts zero phase shift at one frequency.

Because there is no phase shifting within the R/C network at the frequency of oscillation, maintaining amplifiers for Wien bridge oscillators must have two stages. (Each stage imparts a shift of 180 degrees and this results in the output being back in phase with the input). Provided the gain of the amplifier is three times or greater, oscillation will be maintained. With such a modest gain requirement it is not difficult to apply heavy negative feedback in order to stabilise signal amplitude and improve waveform quality.

Wien bridge oscillators vary in complexity, and a simple, inexpensive, yet very effective version of the classic circuit is given in Fig.3; a low distortion A.F. Signal Generator. Here, the Wien network is placed in a positive feedback loop around a 741 operational amplifier i.c. (The feedback must be in phase, so the non-inverting input at pin 3 is used.)

A low current filament lamp LP1 shunts a negative feedback path (between output pin 6, and inverting input pin 2) in order to stabilise the amplitude of oscillation. Bridge capacitors, C1 to C8, are selected by ganged rotary switch S1a and S1b. The specified values more than cover the entire audio frequency spectrum.

Ganged potentiometers, VR1a and VR1b, form the resistive arms of the bridge and set the frequency. Range limiter resistors R1 and R2 ensure consistent operation over the full sweep of the potentiometers.

AMPLITUDE CONTROL

In order to obtain a high quality sinewave, signal amplitude must be kept below the level at which the maintaining amplifier begins to overload. (Overload causes clipping or flattening of the waveform peaks).

Automatic control of signal amplitude in Wien bridge oscillators is usually effected by an R51 type thermistor (temperature dependant resistor). These devices are sensitive but expensive, and here an ordinary low-current filament lamp is used in its place.

The resistance of a lamp filament rises dramatically when current flows through it and raises its temperature. If the output at pin 6 increases, more current flows and its resistance rises. Lamp LP1 is connected as the lower arm of a potential divider, VR2/R3 forming the upper section. An increase in the resistance of the lamp will, therefore, increase the amount of gain-reducing negative feedback and hold the signal amplitude constant.

In practice, preset VR2 is adjusted to give the highest possible output consistent with a perfect sinusoidal waveform. If an oscilloscope is not available to display a trace, good results can be ensured by setting VR2 so that oscillation is only just maintained. A 47 ohm pre-set should be substituted for VR2 and R3 if a supplier can be found.

There is some amplitude "bounce" when the frequency is changed rapidly, and this is a feature of all Wien oscillators which incorporate a temperature dependant resistor as a control element (the resistance heats and cools comparatively slowly). Circuits using f.e.t.s as voltage-variable control resistors, or diodes as amplitude limiters, have been devised to overcome this "bouncing". However, unless the design is complex, they usually exhibit higher distortion.

OUTPUT LEVELS

The simple control circuitry places a rather low resistance across the amplifier output, and the signal voltage available before the onset of distortion is limited to around 1V r.m.s. A larger output is often desirable, and the buffer stage transistor TR1, in Fig.3, provides a modest amount of signal amplification.

RELAXATION OSCILLATORS

Charging a capacitor, via a resistor, is the most common means of fixing the frequency of relaxation oscillators. The larger the capacitance and/or resistance in the series circuit, the longer the charging time and the lower the frequency of oscillation.

A widely used circuit of this kind is the astable multivibrator, and a version which permits some adjustment of the operating frequency is given in Fig.4.

The frequency determining networks comprise R3/C2 and R5/C1. For an equal mark/space ratio (*off* pulses and *on* pulses of equal duration), R3 and C2 must be identical to R5 and C1.

A very approximate formula relating frequency to resistance and capacitance is:

$$f = \frac{700000}{RC}$$

when *f* is in Hertz, *R* is in ohms, and *C* is in μF.

The frequency of oscillation is very dependant upon supply voltage and, to a lesser extent, transistor types, and the formula is inevitably approximate. The output is a square wave with a rounded leading edge.

Emitter (e) resistor R5 is unbypassed, and the resulting negative feedback reduces gain to the required level and improves linearity. In theory, the gain of this stage is approximately VR3 divided by R5 (i.e., four times), but, in practice, it is rather less than this. Base bias is provided by resistor R4. C10 is a decoupling capacitor, and C11 blocks the flow of d.c. into the accepting circuit.

PERFORMANCE

Although simple and inexpensive, the A.F. Signal Generator circuit performs well when preset VR2 has been correctly adjusted. Distortion figures as low as 0·1 per cent are claimed for circuits of this kind, and a check with an oscilloscope will reveal that the sinewave is of high quality.

Output level remains constant over fairly wide shifts in supply voltage, and across the switched ranges. Oscillation is maintained up to 70kHz, but performance begins to fall off a little after 30kHz or so.

Constructors would have to commit themselves to considerably more expense and effort in order to realise any significant improvement on this circuit. Note that the oscillator will not function correctly if a lamp with a higher wattage rating, or a lower working voltage than 6V, is fitted.

RELAXATION OSCILLATORS

The most common form of relaxation oscillator is the astable (i.e. non-stable) variant of H. Abraham and E. Bloch's multivibrator. Conceived by the two Frenchmen in 1918, the name "multivibrator" was given to this type of circuit because the output is rich in harmonics (they can extend

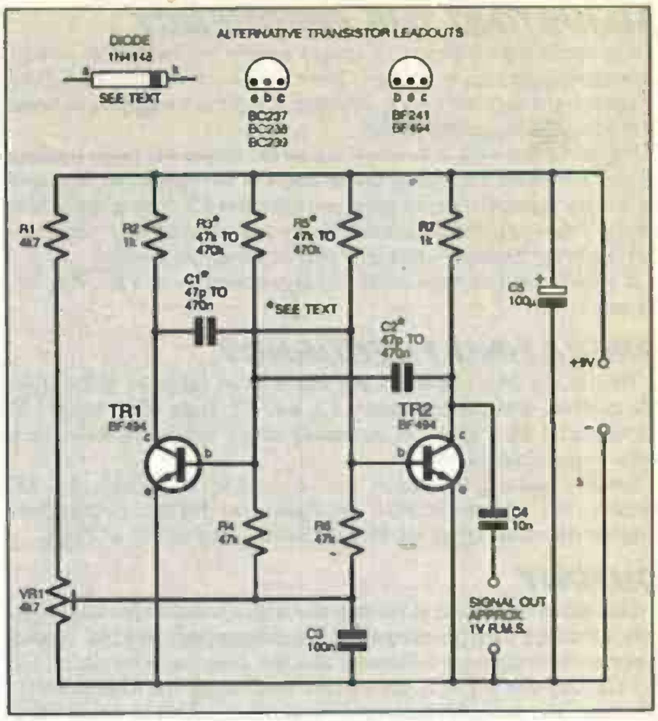


Fig.4. Circuit for an astable multivibrator, with frequency shifting arrangement.

beyond the thousandth). A typical circuit arrangement, with the addition of frequency adjusting refinements, is given in Fig.4.

Two common emitter transistor stages, TR1 and TR2, act as switches, and their bases and collectors are cross coupled by capacitors C1 and C2. Base biasing is supplied by R3 and R5. These resistor and capacitor combinations, R3/C2 and R5/C1, act as the timing networks which determine the frequency of oscillation.

The coupling capacitors alternately charge, via the bias resistors, and discharge, via the transistors, and the rising and falling voltages on the capacitors switch the transistors on and off, thereby maintaining the circuit action. The frequency at which the switching, or oscillation, takes place is, of course, determined by the time constants of the R/C combinations.

Collector loads are formed by resistors R2 and R7. Capacitor C5 decouples the circuit from the supply line and C4 blocks the flow of d.c. into the accepting circuit.

WIEN BRIDGE

A network of resistors and capacitors, known as a Wien bridge, is used to determine frequency in most professional audio oscillators. With this network, phase shift is zero at one particular frequency. A typical circuit is given in Fig.3.

The resistors and capacitors in each arm of the bridge (VR1a/VR1b and C1/C5, C2/C6, etc.,) are of equal value, and the standard formula relating frequency to resistance and capacitance is:

$$f = \frac{160000}{RC}$$

when *f* is in Hertz, *R* is in ohms, and *C* is in μF. The actual frequency of oscillation is around 10 per cent lower than the figure indicated by calculation, and the ranges quoted in Fig.3 are based on actual measurements.

The amplifier need only have a gain of three times for oscillation to be maintained. This modest requirement permits the use of heavy, amplitude controlling negative feedback, and the quality of the generated sinewave can be extremely high.

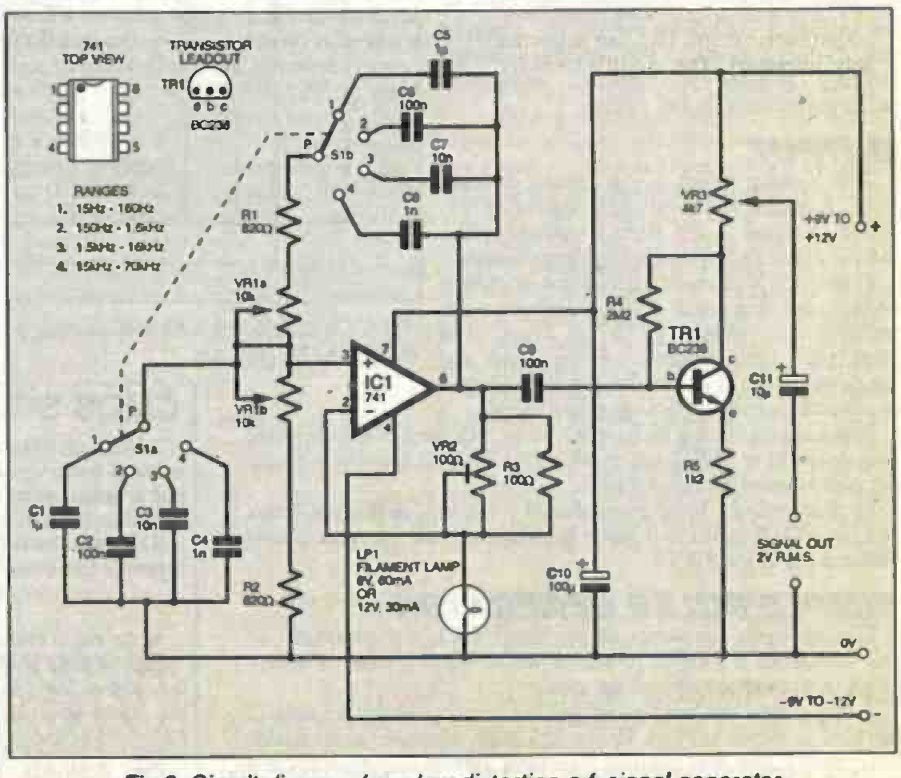


Fig.3. Circuit diagram for a low distortion a.f. signal generator.

ADJUSTING THE FREQUENCY

The operating frequency of simple astable multivibrators is very dependant upon supply voltage. Their frequency can also be shifted by applying a variable bias to the base (b) of the transistors in order to modify the triggering action.

Potentiometer VR1, connected across the supply via range limiting resistor R1, varies the voltage on the bases of the transistors. Resistors R4 and R6 isolate the signal paths and capacitor C3 decouples the bias supply. This arrangement permits a fairly wide adjustment of the nominal operating frequency, typically plus or minus 20 per cent.

If a basic multivibrator is all that is required, omit VR1, R1, R4, R6 and C3.

OPERATING FREQUENCY

The timing (bias) resistors R3 and R5 can range in value from 47k to 470k, and the capacitors, C1 and C2, from 47pF to several microfarads. This gives an operating range extending from sub-audio frequencies to 2MHz.

Small signal a.f. transistors can be used up to 100kHz, but r.f. devices will ensure reliable oscillation at higher frequencies. Suitable transistor types are also included in the circuit of Fig.4.

OUTPUT

The output waveform is rectangular with a rounded leading edge. This rounding can be eliminated by connecting 1N4148 diodes between the transistor collectors and the coupling capacitors, C1 and C2 (cathode (k) to collector (c)). Additional one kilohm resistors must be connected between the diode anodes and the positive supply rail to maintain the circuit action.

If the timing networks, R3/C2 and R5/C1, are identical, the mark/space ratio of the output waveform will be equal. They do not, of course, have to be the same, and by tailoring the component values, pulses of short duration separated by comparatively long time intervals can be generated.

CMOS SQUARE WAVE GENERATOR

A CMOS (complimentary metal oxide semiconductor) digital i.c. can be used as an excellent square wave generator. A typical circuit is given in Fig.5, where the inputs to three of the NOR gates in a 4001B i.c. are wired together to form inverting amplifiers. A resistor/capacitor timing network is connected in the feedback path between gates IC1a and IC1b. The third gate, IC1c, is used as a buffer stage.

Capacitors C1 to C6, selected by rotary switch S1, enable the unit to cover from 10Hz to above 250kHz. Potentiometer, VR1, acts as the frequency control by varying the charging and discharging time of the capacitors. Range limiting resistor R2 ensures consistent performance over its full sweep.

OUTPUT

The loading effect of the output control VR2 reduces the available signal level, which is equal to the supply voltage when the oscillator is fed into a high impedance.

Frequency is affected by changes in supply voltage, but to a much lesser extent than the multivibrator circuit given in Fig.4. The mark/space ratio is almost exactly equal, and the square wave is of excellent quality. Output is constant over the entire operating range.

Reducing the timing resistor R2 below 10k pushes the operating frequency up to 2MHz and more on the highest frequency range, but performance becomes erratic.

Most inverting CMOS gates should work well in this oscillator, and the 4011B (quad two-input NAND gate) has the same pinout connections as the 4001B.

SIMPLE PULSE GENERATOR

In many cases the nature of the waveform is not important: all that is required is a signal to test or trouble-shoot a piece of equipment, or to generate an audible tone.

A very simple and inexpensive oscillator circuit, suitable for tasks of this kind, is shown in Fig.6. Here a 555 timer, connected as an astable multivibrator, generates a pulsed waveform. Various ranges are selected by switch S1 and potentiometer VR1 sets the frequency of oscillation.

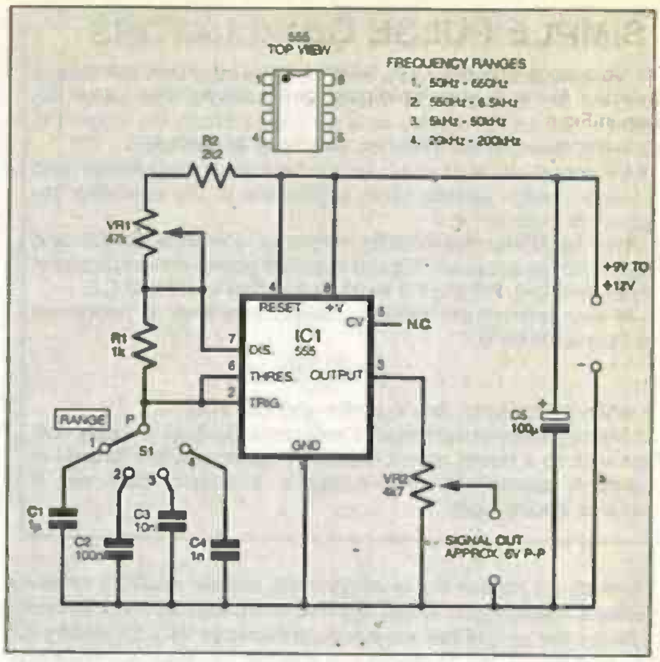


Fig.6. Using the renowned 555 timer i.c. to produce a 50Hz to 200kHz pulse generator.

The timing capacitors, C1 to C4, are charged via R1, VR1 and R2, but they discharge more rapidly through resistor R1. The output at IC1 pin 3 is, therefore, a chain of pulses, and adjustment of VR1 will alter both the frequency and the mark/space ratio of the output. Increasing the value of VR1 to one megohm will maximise the frequency sweep with a single capacitor. A sawtooth waveform is available, at high impedance, across the timing capacitor.

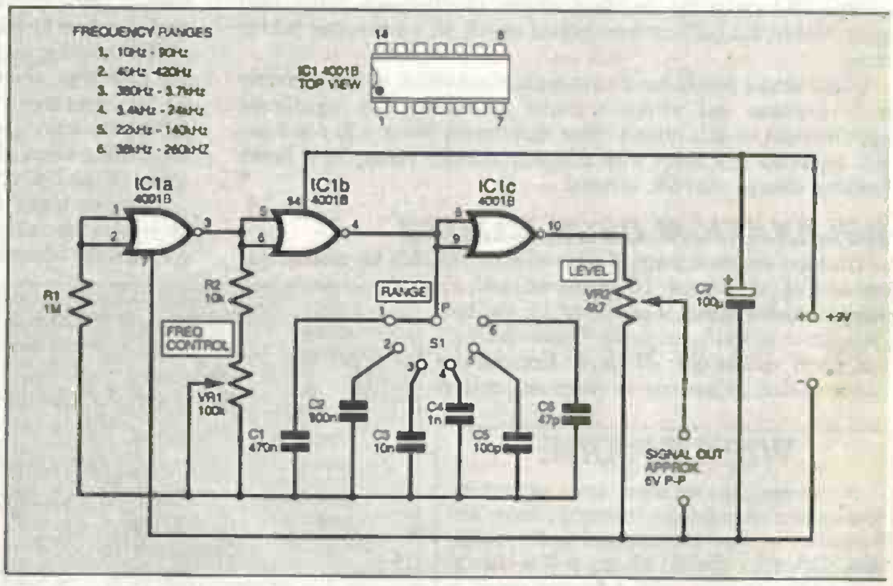


Fig.5. Circuit diagram for a wide range, square wave generator using a 4001B quad 2-input NOR gate i.c.

CMOS SQUARE WAVE GENERATOR

CMOS digital i.c.s can be configured as relaxation oscillators in order to generate square waves of excellent quality. A typical circuit is given in Fig.5, where R2 and VR1, together with a capacitor, C1 to C6, determine the frequency of oscillation.

The usual formula relating frequency to resistance and capacitance for this circuit is:

$$f = \frac{450000}{RC}$$

when f is in Hertz, R is in ohms, and C is in μF.

The formula gives tolerably accurate results at low frequencies but, above 1kHz or so, the frequency of oscillation is lower than the figure given by calculation. The ranges quoted in Fig.5 are based on actual measurements.

The circuit delivers a square wave of excellent quality with an equal mark/space ratio.

SIMPLE PULSE GENERATOR

The ubiquitous 555 timer i.c., when connected as an astable multivibrator, forms a very simple pulse generator. A typical circuit is given in Fig.6.

An approximate formula for the calculation of frequency, with this particular circuit, is:

$$f = \frac{2800000}{(R + 2000)C}$$

where f is in Hertz, R is the total value of VR1 and R2 in ohms, and C is in μF.

The formula is reasonably accurate up to 5kHz or so, then the frequency of oscillation is lower than the figure indicated by calculation. Again, the ranges quoted in Fig.6 are based on measurement, not calculation.

When a very simple and inexpensive means of trouble shooting audio equipment is required, this circuit is hard to beat. The upper frequency limit extends a little beyond 200kHz.

The device acts as a voltage triggered switch. A typical sawtooth generator circuit is given in Fig.7, where resistor R1 and capacitor C1 determine the frequency of oscillation and R2 and R3 stabilise the transistor against temperature variations.

Emitter (e) impedance is high when the device is off (not conducting) and low when it is on. When the supply is first connected, capacitor C1 is discharged, the emitter is at zero potential and presents a high impedance to the capacitor, enabling it to be charged via resistor R1.

When a critical voltage (known as the "peak" point) has been developed across the capacitor, the unijunction triggers to the on state and the capacitor discharges through the now low impedance emitter circuit. The voltage falls to zero, the process is repeated, and oscillation is maintained.

A positive going pulse is available at base 1, a negative going pulse at base 2, and a sawtooth (strictly speaking a "shark's fin") waveform at the emitter. The impedance of any accepting circuit presented to the emitter must be high or the unijunction action will be impaired.

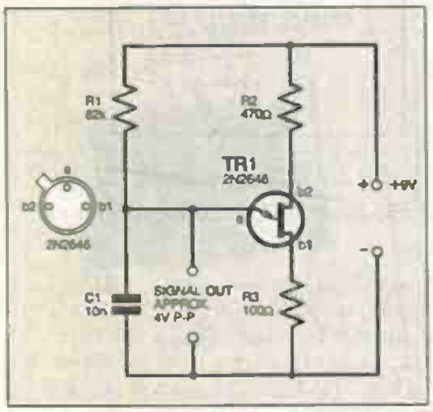


Fig.7. Simple sawtooth generator. With the values specified for R1 and C1 the circuit wil oscillate at 1kHz approx.

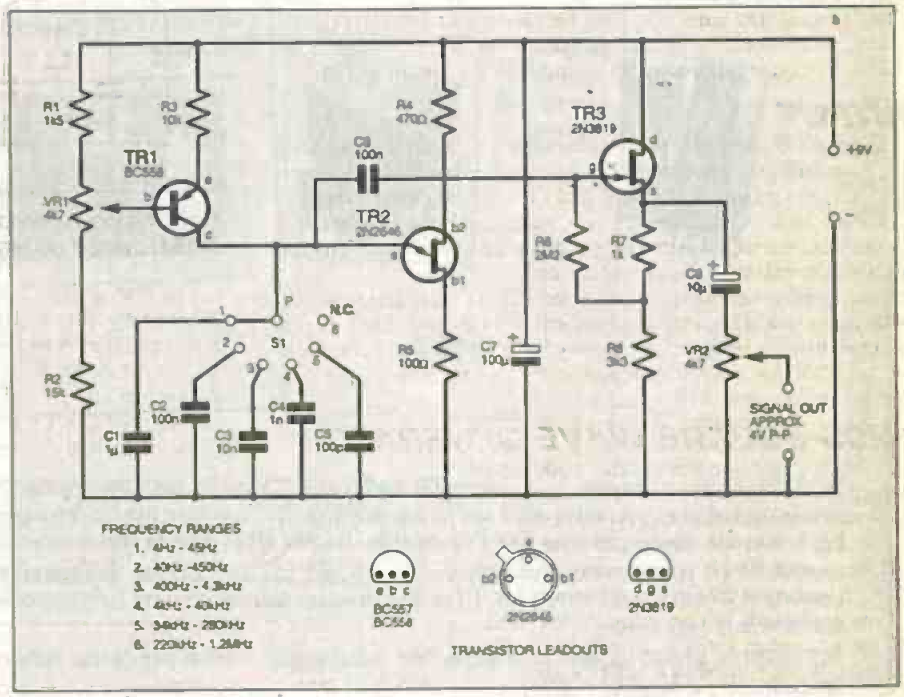


Fig.8. Circuit for a linear sawtooth generator.

If the simplest possible spot-frequency signal generator is required, VR1 and R2 can be replaced by a single fixed value resistor. A capacitor can be permanently wired between IC1 pin 2 and the negative supply rail, and VR2 can be deleted. A 100k resistor and a 100nF capacitor in the timing network should make the circuit oscillate at around 1kHz.

Provided the supply voltage is held between 8V and 12V, variations have a minimal effect on the frequency of oscillation. Wider excursions cause significant shifts.

SIMPLE SAWTOOTH GENERATOR

A device known as a unijunction transistor can form the basis of a simple sawtooth generator. Used almost exclusively in relaxation oscillator circuits, it comprises a tiny strip of *n*-type silicon material with non-rectifying junctions (base 1 and base 2) located at either end. A rectifying junction (emitter) is formed in a region of *p*-type material along its length.

SAWTOOTH GENERATORS

A unijunction transistor can form the basis of a very simple relaxation oscillator, and a typical circuit is given in Fig.7.

The following formula, which relates frequency to resistance and capacitance in the timing circuit (R1 and C1), produces tolerably accurate results:

$$f = \frac{800000}{RC}$$

when f is in Hertz, R is in ohms, and C is in μF. A sawtooth waveform with a peak-to-peak value equal to half the supply volts is developed across the timing capacitor.

The output of this simple, single transistor oscillator is non-linear and at a high impedance, and an improved version is given in Fig.8. This more complicated circuit generates an extremely linear sawtooth wave and has a low impedance output.

Because of the way the timing capacitor is charged, it is not possible to quote a simple formula for the calculation of frequency. The measured ranges quoted in Fig.8 should, however, form a useful guide to component values for spot-frequency versions of the circuit.

The value of resistor R1 can range from 10 kilohm to one megohm (1M), and capacitor C1 from 1μF or more down to 100pF. Connecting a one megohm potentiometer in the R1 position will provide a wide frequency coverage with a single capacitor. The peak-to-peak signal output at the emitter is approximately equal to half the supply voltage.

LINEAR SAWTOOTH GENERATOR

Whilst the sheer simplicity of the circuit arrangement shown in Fig.7 makes it attractive for some applications, the high output impedance and non-linear waveform limit its usefulness.

In the circuit diagram shown in Fig.8, the timing capacitor (C1 to C5) is charged via a constant current generator stage, transistor TR1. A f.e.t. source follower buffer stage, TR3, presents a high impedance to the unijunction's emitter and a suitably low impedance to the accepting circuit. By these means, the limitations of the basic circuit are overcome.

When a capacitor is charged via a resistor, the initial voltage rise is rapid, gradually tailing off as it approaches a fully charged state. Because of this, the waveform developed across the capacitor is not linear.

In Fig.8, current flow through transistor TR1 to capacitors C1 to C5 (via switch S1) is controlled solely by the setting of VR1, and the charging rate of the timing capacitor is, therefore, constant. This results in a linear voltage rise and a more perfect sawtooth waveform.

The buffer stage, TR3, is identical to the one adopted for the sine wave generator shown in Fig.2, and its operation has already been described. Frequency of oscillation is particularly dependant upon supply voltage, and a well regulated power supply is essential for the correct operation of this circuit. Stray capacitance acts as the timing capacitor on the highest frequency range. □

INGENUITY UNLIMITED

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Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BS21 1PF. (We do not accept *IU* submission via E-mail.)
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Serial Port Splitter – Line Sharing

When you run out of spare serial ports on your PC, the circuit shown in Fig. 1 may be used to effectively add another port. The idea is to share the PC serial port between two external RS232 devices (device X and device Y in Fig. 1) and the PC communicates with them one at a time.

In the circuit diagram shown in Fig.1, IC1 and IC2 are the familiar MAX232 voltage level translators which convert the RS232 signal levels from the serial port of the PC (and also from devices X and Y) to TTL/CMOS levels for manipulating by IC3, a data selector/multiplexer. Signals on the two sets of inputs (A0 to A3 and B0 to B3) are selected and routed to the output (YO to Y3) by the Select input (pin 1 of IC3).

When Select is at logic 0, signals on IC3 port A are routed to the output port (Y0-Y3). In this case, the Tx of the PC serial port is connected to Rx1; Rx to Tx1 and Rx2 is held logic 1 (idle condition). The PC therefore communicates with device X, and device Y is effectively disconnected from the PC.

When Select is at logic 1, signals on port B are routed to the output port instead. In this case, Tx is connected to Rx2, Rx to Tx2 and Rx1 is held at logic 1 so the PC communicates with device Y.

Switching between device X and device Y is controlled by the RTS signal from the PC serial port. RTS can be toggled by a piece of simple software which configures the control registers of the UART chip in the PC.

W. Ip, Belfast.

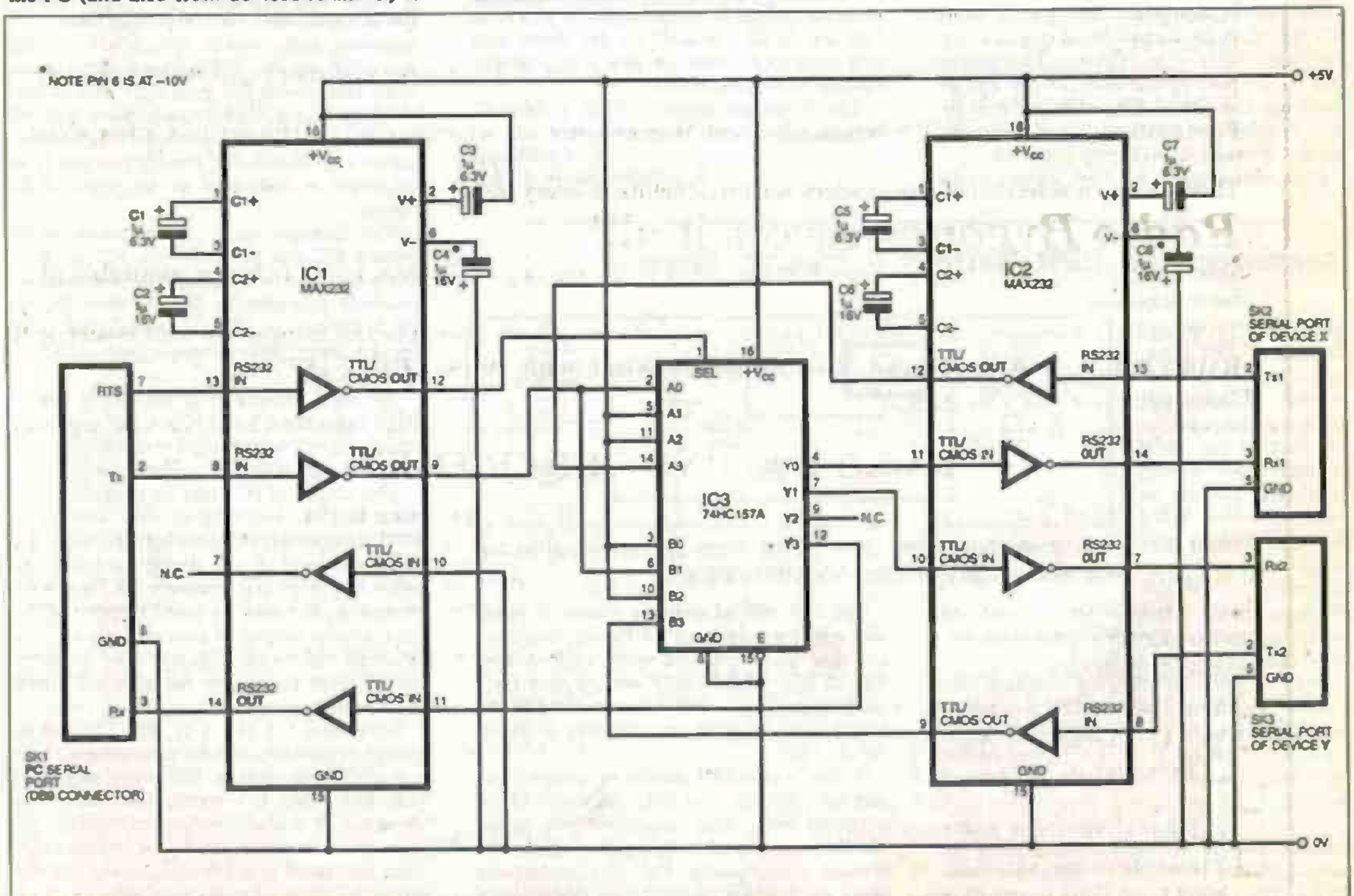


Fig.1. Circuit diagram for the Serial Port Splitter. Note that pin 6 of IC1 and IC2 is at –10V with respect to the 0V line.

Elderly Person Monitor – Take Care

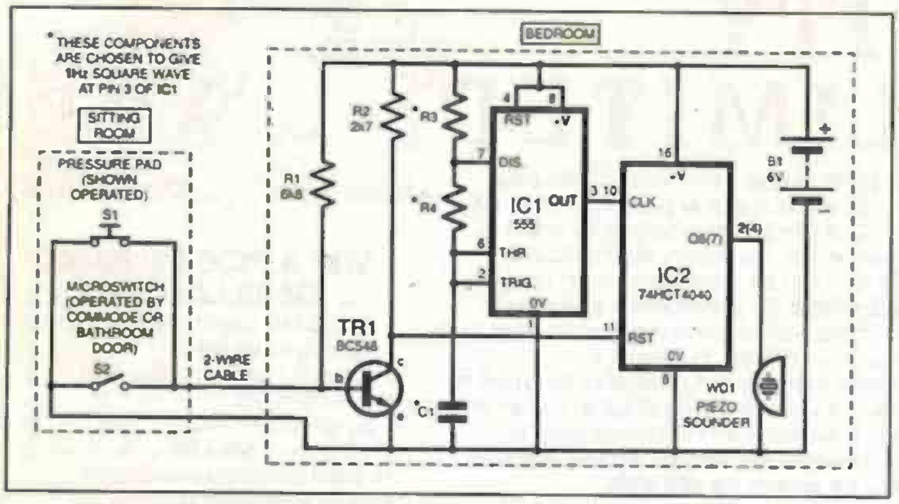


Fig.2. Circuit diagram for an Elderly Person Monitor.

An elderly relative who resides with us occasionally falls accidentally, and has laid there for some time in a distressed state without being able to summon help. Consequently, a simple independent alarm was designed and the resulting circuit is shown in Fig.2.

Unless a "reset" operation is applied before a certain time period has elapsed the alarm will automatically sound. The principle of operation can be adapted as required and may inspire other ideas.

While the person is in bed a pressure pad (S1) under the mattress is held in the closed circuit condition. This maintains the 4040 12-Stage Ripple Counter IC2 in its reset state via transistor TR1 and so the piezo sounder WD1 is disabled.

Clock pulses of approximately 1Hz frequency are fed continually from the 555 timer IC1 (pin 3) to the counter input of IC2 at pin 10 (CLK), but have no effect until the person gets out of bed (in our case, to use a commode but it could be adapted to be reset by, say, a bathroom door) at which point the counter is enabled and begins counting.

If the time taken to get from the bed to the commode or bathroom (where a seat or door-activated microswitch, S2, automatically resets the counter again) is long enough for counter output Q6 (or Q7 perhaps) to go high, the alarm WD1 sounds in a neighbouring room so that one can investigate and check that the person is all right.

A delay of between one and two minutes was selected to allow the elderly person sufficient time and also because in practice the microswitch S2 wasn't always operated. In our case the switch opens when the person leaves the commode, and so IC2 begins counting.

If the time taken for the person returning to bed (which resets the counter) is again long enough for the alarm to sound, then that person is standing up, or returning to bed or has fallen. Since an elderly person is unlikely to remain standing for more than (say) two minutes and is also unlikely to take more than two minutes to return to bed, it is probable that the person has fallen.

The prototype operated from a safe 6V battery, which could be rechargeable.

C. Embleton,
Northallerton, N. Yorks.

Rechargeable PP9 Battery – Energy Saver

If you discard exhausted PP9 layer-type batteries this can become an expensive process as these batteries cost about three pounds each. It was decided to provide an alternative using Nickel Cadmium cells together with an extremely simple charging circuit which is built within the housing of an exhausted PP9 battery. The circuit diagram is shown in Fig. 3.

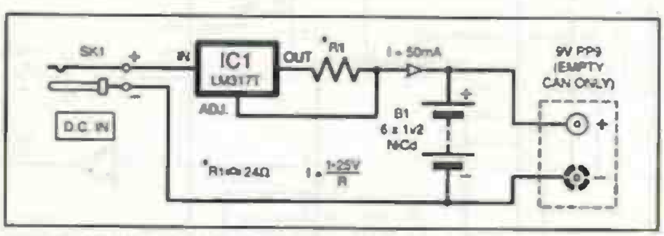


Fig.3. Rechargeable PP9 circuit. Note all components are housed inside the discarded PP9 casing.

The power for the charging circuit is provided by an external 12V to 15V d.c. power supply capable of providing 50mA or so. This is hooked up via a d.c. power socket SK1 which is also fitted into the battery housing.

In this circuit IC1 is configured as a constant-current (not voltage) regulator, and the current flowing is limited by the series resistor R1. The current I is 1·25/R1, hence for a 50mA current R1 is about 24 ohms (220 ohms in parallel with 27 ohms will do).

Six 1·2V NiCad cells are placed in series and wired across the PP9 battery terminals and they will be charged by the constant current of IC1. The on-load voltage of a fully charged set of six cells was measured at just under 10V with an average current of 25mA being drawn.

A steel-cased PP9 should be prised apart and its contents carefully disposed of as chemical waste, then the circuit built inside and the case folded back together again. My present rechargeable PP9 has undergone about 40 charging cycles during its existence and anticipate many more – what a saving!

D. Allen, Cheltenham.

Class-D 30W Audio Amplifier – Power Play

Audio amplifiers are typically class-AB in operation, and whilst these produce good quality amplification they are also quite inefficient at 50 to 60 per cent or so. A class-D amplifier is much more efficient, with efficiencies of between 90 per cent to almost 100 per cent being possible as it is essentially a switching circuit.

A suggested circuit diagram for a 30W Class-D Audio Amplifier is shown in Fig.4. The incoming audio signal is amplified by the inverting operational amplifier IC1, with adjustable volume controlled by potentiometer VR1. A PWM (pulse width modulation) signal is produced by comparing the audio signal with a 100kHz triangle wave.

This is achieved using the comparator IC6. Resistor R13 is used to provide positive feedback and C6 is a speed-up capacitor which improves comparator response time. The comparator output swings between ±7·5V. The pull-up resistor R12 provides +7·5V whilst –7·5V is provided by the open emitter input of the comparator (pin 1 of IC6).

When this signal swings positive transistor TR1 acts as a current sink, which increases the voltage drop across resistor R16; this voltage drop is enough to turn MOSFET TR3 on. When the signal swings negative, TR2 acts as a current source causing the voltage drop across R17 to increase sufficiently to turn TR4 on. Essentially, MOSFETs TR3 and TR4 are activated alternately, producing a PWM signal which swings between plus and minus 15V.

It is now necessary to restore this amplified PWM signal back into a reproduction of the incoming audio signal. This is achieved by averaging out the PWM signal using a 3rd order Butterworth low-pass filter with its cut-off frequency (25kHz) much lower than the triangle wave frequency, ensuring large attenuation at 100kHz. The resulting output is an amplified reproduction of the input audio signal.

The triangle wave generator is based around IC2 and IC5, whereby IC2 is effectively a square wave generator with positive feedback provided by R7 and R11. Diodes D1 to D5 acts as a bi-directional clamp (D3 being a Zener diode), clamping the voltage to about ±6V.

An ideal integrator is formed by preset VR2, capacitor C5 and IC5 which converts a square wave into a triangle wave. Preset control VR2 allows the frequency to be altered.

The output of IC5 (pin 6) provides feedback to IC2, and resistor R14 and preset VR3 form an adjustable attenuator allowing the magnitude of the triangle wave to be adjusted. After construction, VR2 and VR3 should be adjusted in order to provide the best quality output. A pair of ordinary 741 op.amps (IC4 and IC3) are used as unity gain buffers to provide the plus and minus 7·5V supplies.

Capacitors C3, C4, C11, and C12 act as charge reservoirs, and the remaining capacitors are for decoupling. The circuit requires a plus and minus 15V supply rail, and it will drive a 30W 8 ohm loudspeaker from the *LC* network at capacitor C13 and inductor L2. Note that small heatsinks maybe required for MOSFET transistors TR3 and TR4.

Lee Matthews,
Kirkby-in-Ashfield, Notts.

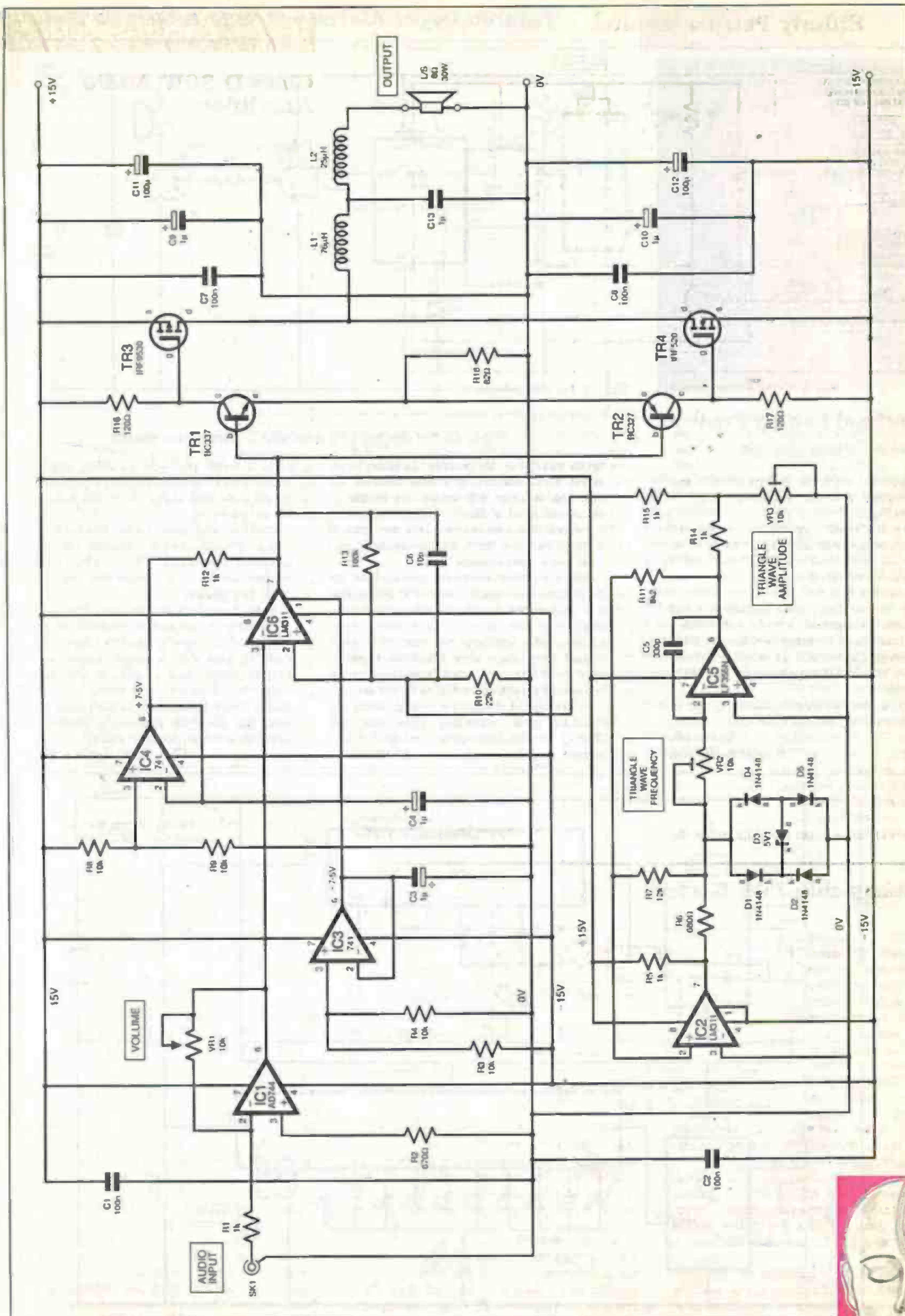
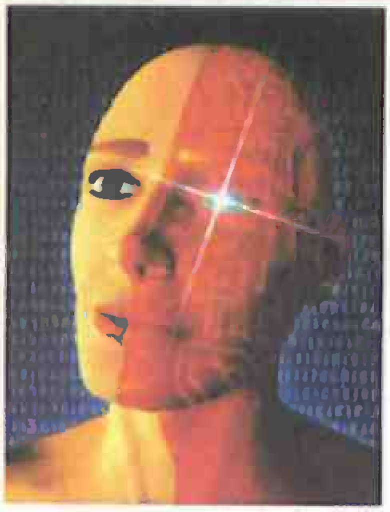


Fig.4. Complete circuit diagram for the Class-D 30W Audio Amplifier.



National Lottery Predictor – It Could Be Us

A simple form of random counter is illustrated in Fig.5 which may help with the mentally-exhausting process of selecting six entirely random numbers for the weekly National Lottery. The circuit consists of two CMOS 4017 decade counters each driven by a 555-based clock.

Counter IC2 will display tens (0-4) whilst IC4 will display units. Therefore, a number between 0 and 49 will be displayed on a series of light-emitting diodes upon the operation of pushswitch S2 which enables both counters. Separate switches for tens and units could be used instead.

Note that sometimes, numbers may repeat and zero may also be displayed.

Edward Bibby,
Woolston, Warrington.

Tumble Dryer Alarm – It Won't Crease You

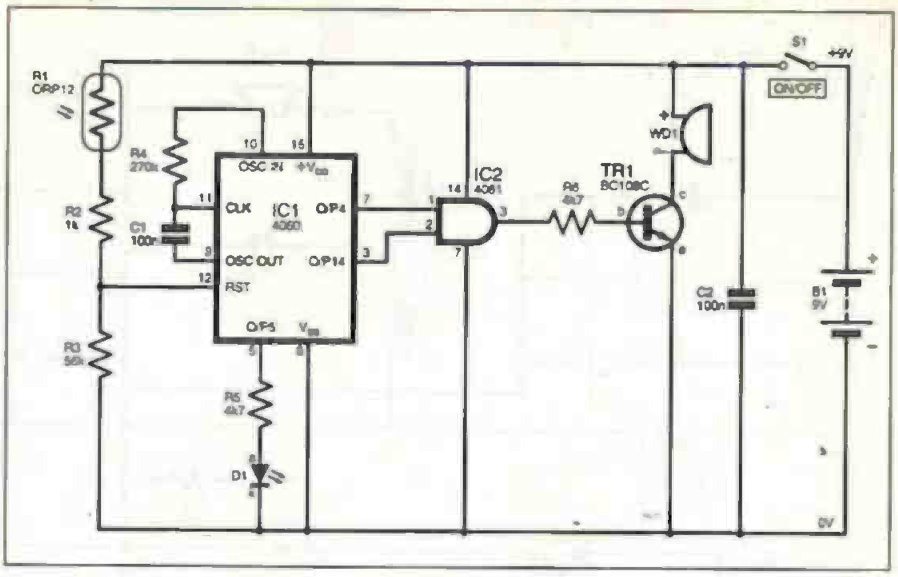


Fig.6. Circuit diagram for a simple Tumble Dryer Alarm.

The need for the simple Tumble Dryer Alarm circuit of Fig.6 arose because our new tumble drier did not have a buzzer to indicate that it had finished. My wife needed a solution but vetoed absolutely any idea of digging into the back of the machine and "fiddling with the mains"!

As the machine works by sensing how dry the clothes are, the only way of knowing that it is nearing the end of its cycle is when one of the neon indicators on the machine extinguishes. This indicates the start of a short "crease care" cycle after which the machine stops. Some kind of optically-isolated switch followed by a delay seemed to be the answer.

In the circuit diagram of Fig.6, when the machine neon indicator goes out, the ORP12 light-dependent resistor, R1, ensures that the voltage on pin 12 (Reset) of IC1, a 4060 oscillator/counter, goes low which starts the counter. Output 14 at pin 3, which goes high at the end of the delay period, is fed along with the output of pin 7 into one of the AND gates of the 4081. This provides a pulsed input to transistor TR1 which activates the sounder WD1. Pin 5 of IC1 flashes the l.e.d. D1 when the crease care cycle has started.

With the values shown, the delay is about six minutes which can be varied by adjusting the values of capacitor and/or resistor R4. A suitably powerful sounder would be the Maplin, order code FK84F, or the Squires, code 80-015 (takes more current – 35mA), which can be heard in all parts of the house to warn that the cycle has nearly finished. My wife has certainly found it useful!

Glyn Shaw, Staines, Middx.

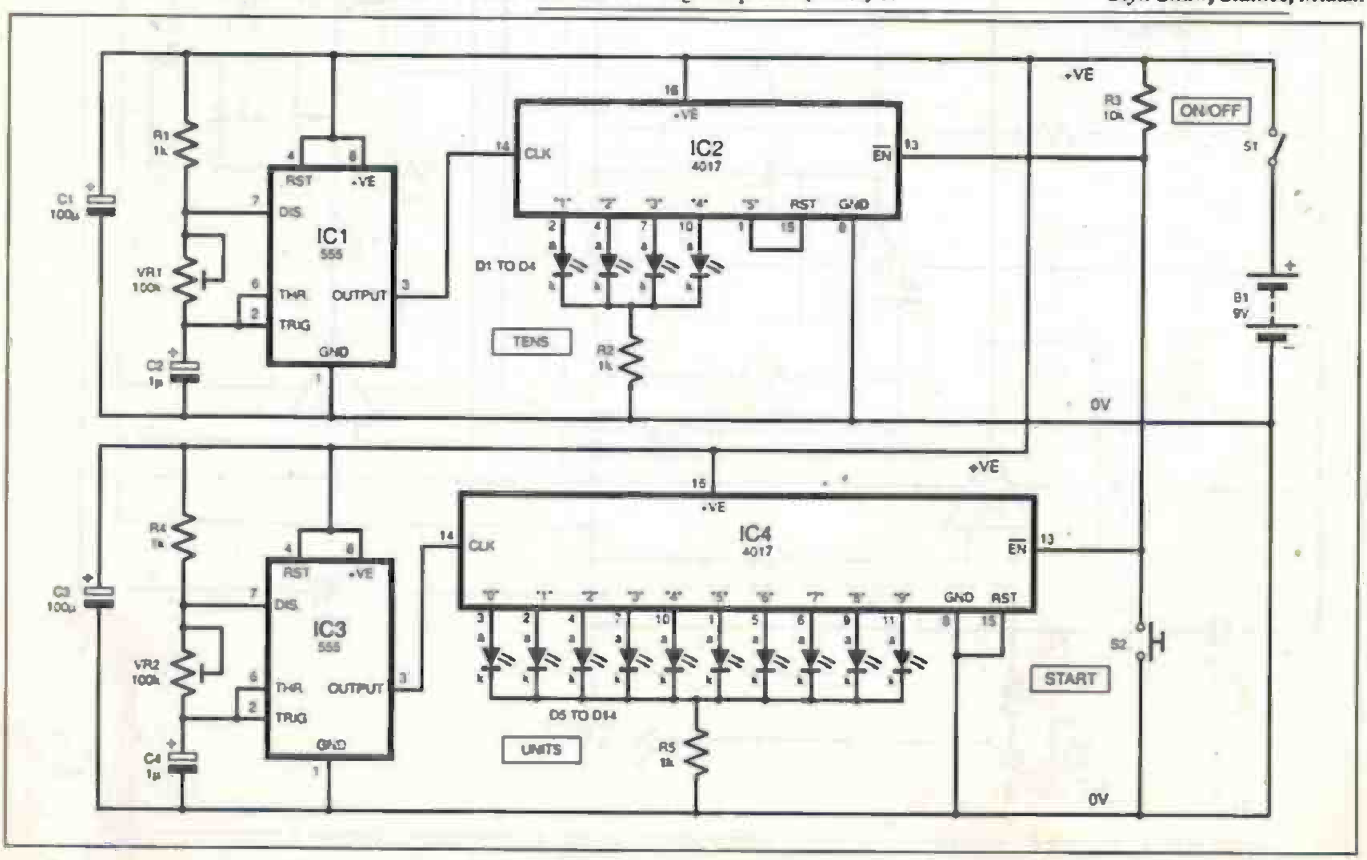


Fig.5. National Lottery Predictor "random number" generator circuit diagram.

Narrow Band Vision – Nipkow Disc-overy

THE SYSTEM shown in Fig.7 illustrates a simple but fascinating electromechanical technique for transmitting a small video image over amateur radio bands. It consists of a simple modulator based on a Nipkow disc, a mechanical scanning device used in early television systems. The Nipkow disc has a single-revolution spiral of small holes (25 in this case) which if rotated can be used to provide raster scanning of an object.

With the circuit shown, a basic 25-line monochrome video image may be sent using amateur radio equipment over a good quality clear voice channel. This resolution is high enough for facial recognition of a person in close-up. It should not be compared to a slow-scan system which can only send still images. Readers may also wish to experiment with other transmission media (e.g. wire-based audio, intercoms etc.).

The transmitter section, which also shows the relative placement of the mechanical parts, is shown in Fig.7a. A Nipkow disc may be made from stiff card, using a plate to draw a circle 180mm diameter or so.

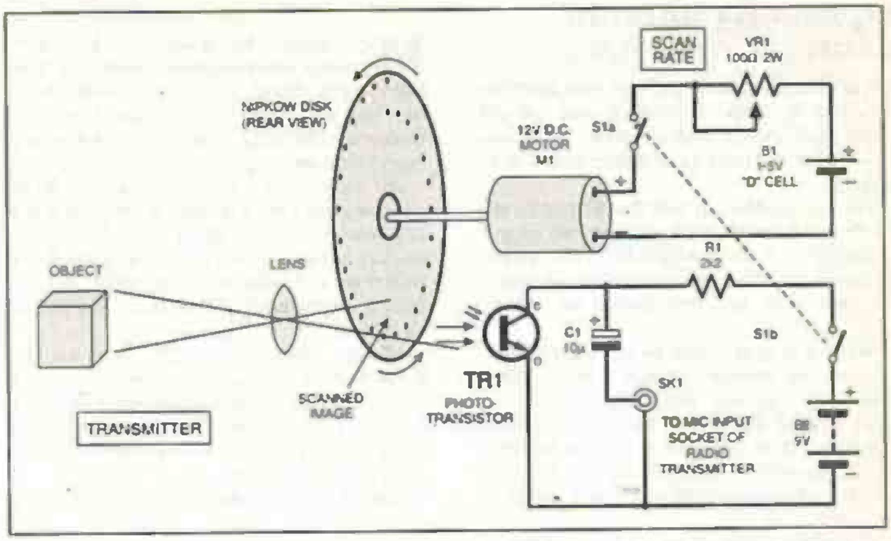


Fig.7a. Circuit/mechanical arrangement of the Nipkow 25-line Transmitter section.

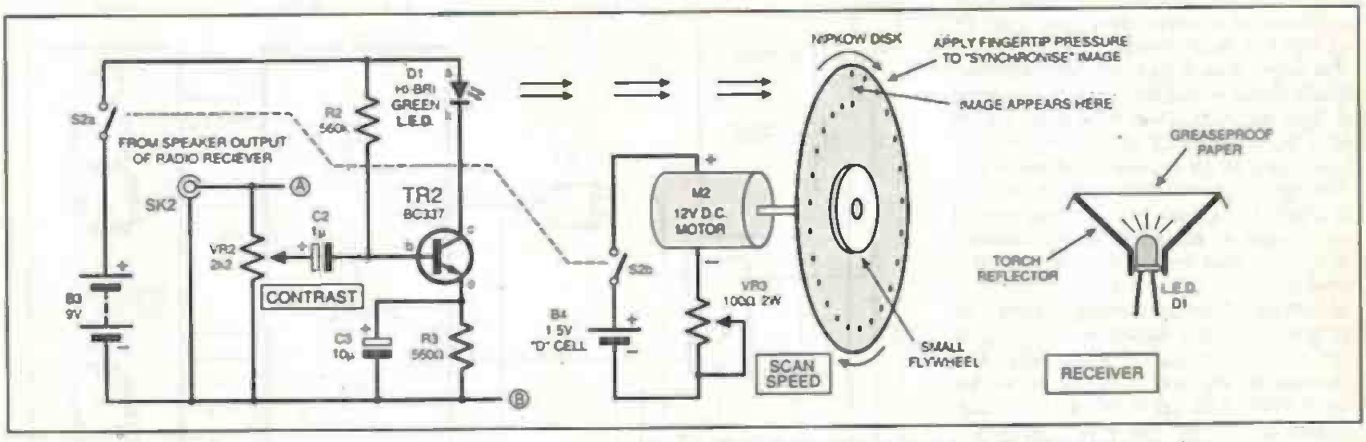


Fig.7b. Circuit/mechanical set-up for Receiver section.

The object to be pictured must be brightly lit, and it is captured through a lens and converted into a narrow-band vision waveform by TR1, a phototransistor placed in a plastic box *behind* the scanning disc. The phototransistor (e.g. a PN202, but other types may work equally well) requires a 9V supply. A good-quality d.c. motor (say, 12V d.c.) is powered from a single D-cell and potentiometer VR1 (rated at 2W) controls its speed. The signal is decoupled by capacitor C1 and applied to the microphone input socket SK1 of the radio transmitter.

Receiver

In Fig.7b, the loudspeaker/ headphone output is fed to a single transistor stage consisting of TR2 and surrounding components. The l.e.d. D1 is a high-brightness green device placed in a flashlight reflector, and a piece of greaseproof or tracing paper is placed over it to obtain a more uniform spread of light.

With this placed underneath the "receiver" disc, a reasonably uniform raster is obtained. Note that the picture requires the room to be in near darkness if it is to be discernible by looking through the spinning disc.

The Receiver disc is rotated slightly faster than the Transmitter disc and the image will then be visible, although it may be "rolling" or swirling. By applying very light pressure to the receiver disc, it can be synchronised to the point where you can get a reasonably stable image.

A flywheel, formed from an old loudspeaker magnet, was placed on top of the prototype receiver disc to add some momentum and help with synchronisation. None of the parts are critical and substitutes may be made.

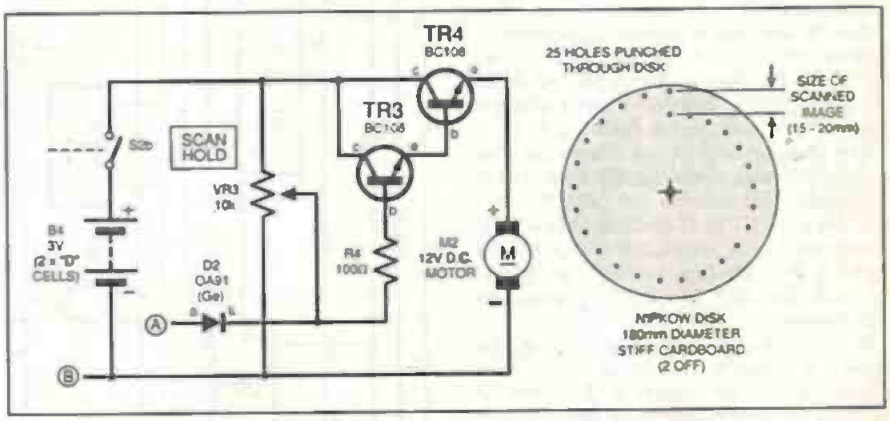
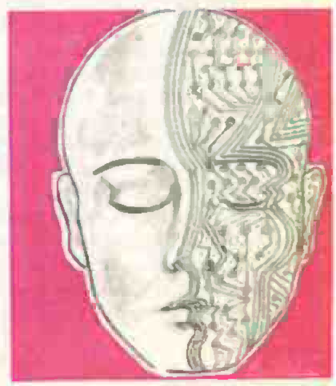


Fig.7c. Improved Receiver add-on with Scan/Sync control (VR3).

An experimental but worthwhile modification to the receiver is shown in Fig.7c, which offers a form of sync. control. This provides some pulse advancement on the receiver disc's rotation which is now controlled by a transistor Darlington pair (TR3, TR4).

It is important that a good quality smooth d.c. motor is used, and the two motors should have reasonably matched characteristics. Although the circuit is not perfect, it is well worth the extra effort.

Michael Robertson, Chasetown, Staffs.



Squash/Badminton Scorer – Final Call

THE circuit diagram in Fig.8 will keep the score in both badminton and squash games and should end all those arguments about what the score is or whose turn it is to serve!

The two pushbutton switches S1 and S2 are for Player A and Player B. The umpire simply presses the button corresponding to the player who won the rally. The circuit then calculates the new score and who should be serving next.

When a typical switch button is pressed or released, its contacts do not make a clean connection, instead they might open and close (*switch bounce*) several times before stabilising. A typical period of time before a switch becomes steady (bounce time) is 5ms, which in this case might add 2 or 3 points to a player's score!

One solution to get around this problem is to check the state of the switches say every 50ms. Hence the 555 timer IC1 is an astable multivibrator which produces a square wave of approximately 20Hz. This clocks the D-type flip-flops IC2a and IC2b.

The output from IC2a is the debounced output from button A, and the output from IC2b is that from button B. These debounced signals feed a JK flip-flop IC3 as well as the clock inputs to two decade counters (IC4 and IC6).

The counters keep track of the points that each player has scored, and their outputs will drive 7-segment common cathode displays directly. The other two counters IC5 and IC7 are for the tens of points for each player.

In both squash and badminton a player may only gain a point if he/she was serving. If they were not serving but win a rally, they then serve for the next point. In this circuit when a player's button is pressed the corresponding counter for that player receives a clock pulse: the counter will only increment if the clock inhibit input is low (i.e. the player was serving).

The JK flip-flops will latch to "remember" who was serving. In this circuit one can imagine a JK flip-flop as a simple Set-Reset bistable which is updated when a positive clock pulse appears on the clock input.

The first flip-flop (IC3a) is updated with every clock pulse from the 555 timer and it remembers who won the last rally. The second flip-flop (IC3b) is updated once all the buttons have been released. It copies what is stored in the preceding flip-flop, and its output feeds the clock inhibit inputs (pin 2) of the counters.

For example, if player B is serving, the clock inhibit input (pin 2) for counter B (IC6) will be low and for counter A (IC5) high. If player A wins the rally a clock pulse goes to counter A, but, because its clock inhibit is high the counter does not increment. The first flip-flop now "remembers" that player A should be serving next.

Once button A is released the second flip-flop is updated. The circuit is then ready – if player A wins the next point his/her score will increase. If player B wins the next shot however, the scores will not change but the serve will go back to player B.

The scores for both players are displayed on dual 7-segment displays. Note that the person who is serving is indicated by the decimal point of their display being illuminated. Pressing both buttons at the same time resets the unit.

David Liddament, Caversham, Reading.

Time-lapse Unit for Camcorder – In The Frame

MANY camcorder owners would like to produce more creative videos, such as time lapse films which condense slow-moving sequences into a short period. Unfortunately, time-lapse facilities are only found on more expensive video cameras.

All camcorders, however, have a REM (remote) socket, for use with a manual stop/start lead. The REM socket on camcorders however is not the same as the REM socket on a cassette recorder, which is basically a simple n.o./n.c. (normal open/normal closed) switch.

Manual control of a camcorder via the REM socket requires "pulse operation", i.e. a short pulse to start and a second short pulse to stop. This overrides the "pause control", and places the camera in its pause mode during a break in filming.

The circuit diagram shown in Fig.9 uses a 556 timer, (twin 555 timers in a 14-pin package), whereby each timer is configured as a one-shot monostable. The output from each timer is used to trigger the input of the other timer via an *RC* network.

This arrangement is commonly known as a cascade timer. The result is a dual timer with varying on/off times and a brief negative-going pulse at either one of the trigger inputs (pins 6 and 8) every time each monostable times out.

During each cycle, pin 6 and pin 8 are held at logic 1 by pull-up resistors R2 and R3. A pair of back-to-back l.e.d.s. D1 and D2 indicate whether the circuit is paused or filming. When the output from one timer is high, the other will be low.

The trigger inputs A and B are connected to pin 1 and pin 2 of a dual NAND peripheral driver 40107 (IC3). The output is then taken

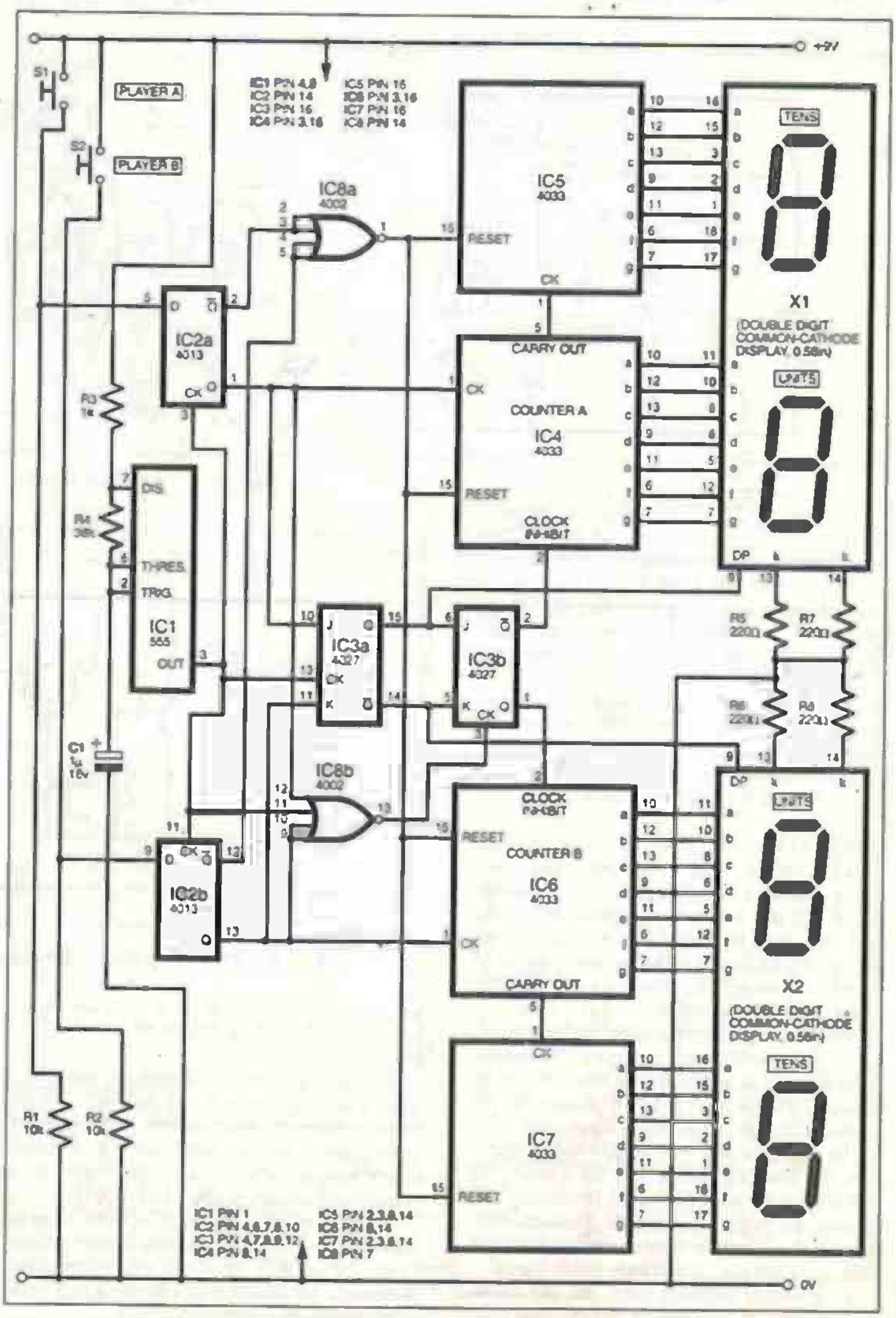


Fig.8. Circuit diagram for the Squash/Badminton Scorer.

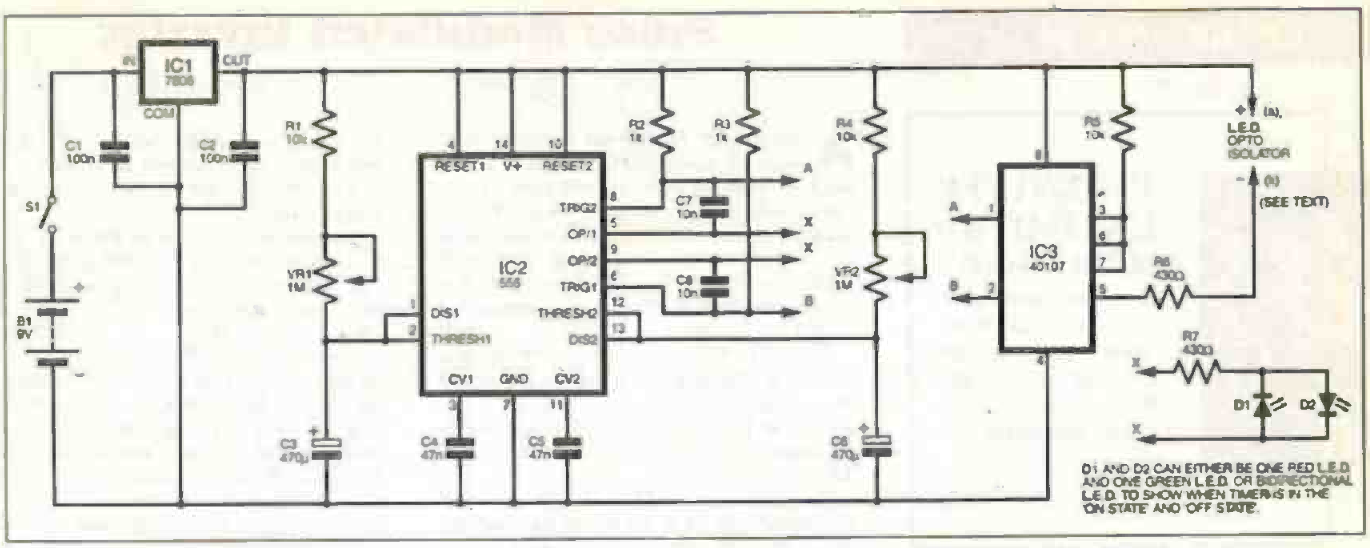


Fig.9. Circuit diagram for the Time-lapse Unit for Camcorder.

from pin 3 and connected to pins 6 and 7 of the second driver. This produces a strong negative pulse whenever either of the monostables changes state.

The resulting pulse can be used to power the l.e.d. emitter in a preferred opto-isolator (not shown) or a solid-state relay. The use of an opto-isolator ensures that no voltage or current from the timer unit can interfere with the camcorder circuitry.

The whole circuit can be powered from a 9V battery. A 6V regulator IC1 ensures that set times do not drift due to decreasing battery voltage.

Timing components VR1 with C3, and VR2 with C6 should give a maximum time of 270 seconds. There is no point in increasing this time period, as camcorders automatically shut down if left in pause mode for more than 5 minutes. The on-time can be very short, i.e., enough to capture two or three frames.

Philip Male,
Drake's Broughton, Pershore.

Audio Limiter – Just The Limit

An audio limiter circuit was required which would accept a wide input voltage range without introducing too much distortion when limiting. The circuit of Fig. 10 achieves this as well as allowing a variable limit level and output level. The circuit could be used in many areas, particularly in limiting the signal applied to an audio power amplifier, protecting those valuable tweeters!

The design uses the MC3340P electronic attenuator chip (IC1). Resistors R1 and R2 attenuate the input signal to a level suitable for the MC3340. The maximum level applied to the device should be 500mV r.m.s.

The input signal is also applied to IC2a via capacitor C2, which together with diode D1 acts as a precision rectifier. The voltage across capacitor C4 sits at the wiper level of Limit control VR1 until the audio level exceeds this value.

At this point diode D1 begins to conduct so the voltage across C4 rises. The voltage on the output of IC2b (pin 7) then falls. This voltage is inverted and attenuated by IC2c and its associated resistors. Audio Level control VR2 adds an offset to the output of IC2c which configures the attenuator in its linear region. The output of IC2c is then applied to the attenuation control pin of the MC3340. The op.amp IC2d forms a simple comparator which drives an l.e.d. D2 during limiting.

To set up the Audio Limiter, adjust VR2 so that the output of IC2c is at least 4V to set the attenuator in its linear region. A higher level can be applied to vary the relative output level. Next, apply the maximum level of audio and adjust VR1 until the l.e.d. illuminates. Back off VR1 until the l.e.d. just extinguishes. Any increase in the audio level will now be limited to the level selected.

Duncan Boyd,
Blackburn, Scotland.

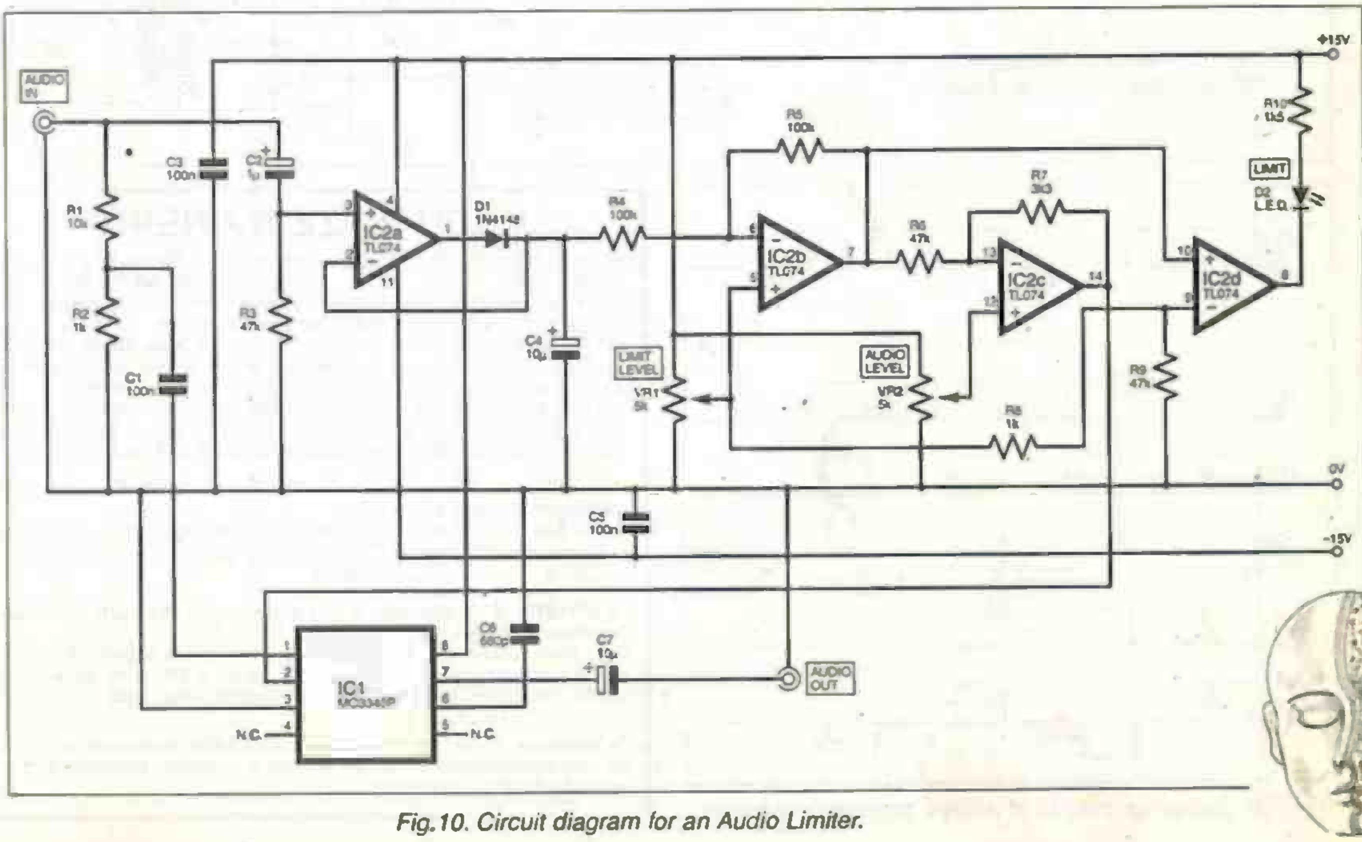


Fig.10. Circuit diagram for an Audio Limiter.

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IU is *your* forum where you can offer other readers the benefit of your Ingenuity. Share those ideas, earn some cash and possibly a prize!

Pulse Modulated Inverter – Mains Motor Controller

A SINGLE-PULSE Modulated Inverter circuit diagram is shown in Fig.11a which can be used to operate a series-wound motor up to 1hp in variable speed mode, from a 12V lead-acid car battery. The series motor may be an electric drill or the drive motor of a small electric vehicle or buggy for example. The circuit waveforms of various outputs are shown in Fig.11b.

In Fig.11a IC1 (a 4047B) is working as a 100Hz astable which triggers an adjustable monostable (IC2). The period of the monostable can be varied using VR1 *(the timing capacitor C2 should be 1nF minimum – ARW)*.

The NAND gates of IC3 (4011B) are used to separate positive cycle signals for the power MOS transistor TR1 and the negative cycle signal for TR2. The two Zener diodes D1 and D2 provide protection for the transistors whilst diode D3 and capacitor C3 help provide isolation between the driver and the output stage.

Transformer T1 steps up the input voltage to a maximum 200V a.c. The potentiometer VR1 can be used for varying the output voltage in the range of 50V to 220V a.c., suitable for many applications.

Both power MOSFETs must be mounted on heatsinks and the main On/Off switch S1 should also be capable of carrying the full load current. The winding details of the transformer are also given. *(I was unable to trace the power MOSFETs used by the writer and a substitute may be needed, e.g. the IRFPG50 or similar, offered as a suggestion only. ARW)*

M.T. Iqbal, Rawalpindi, Pakistan

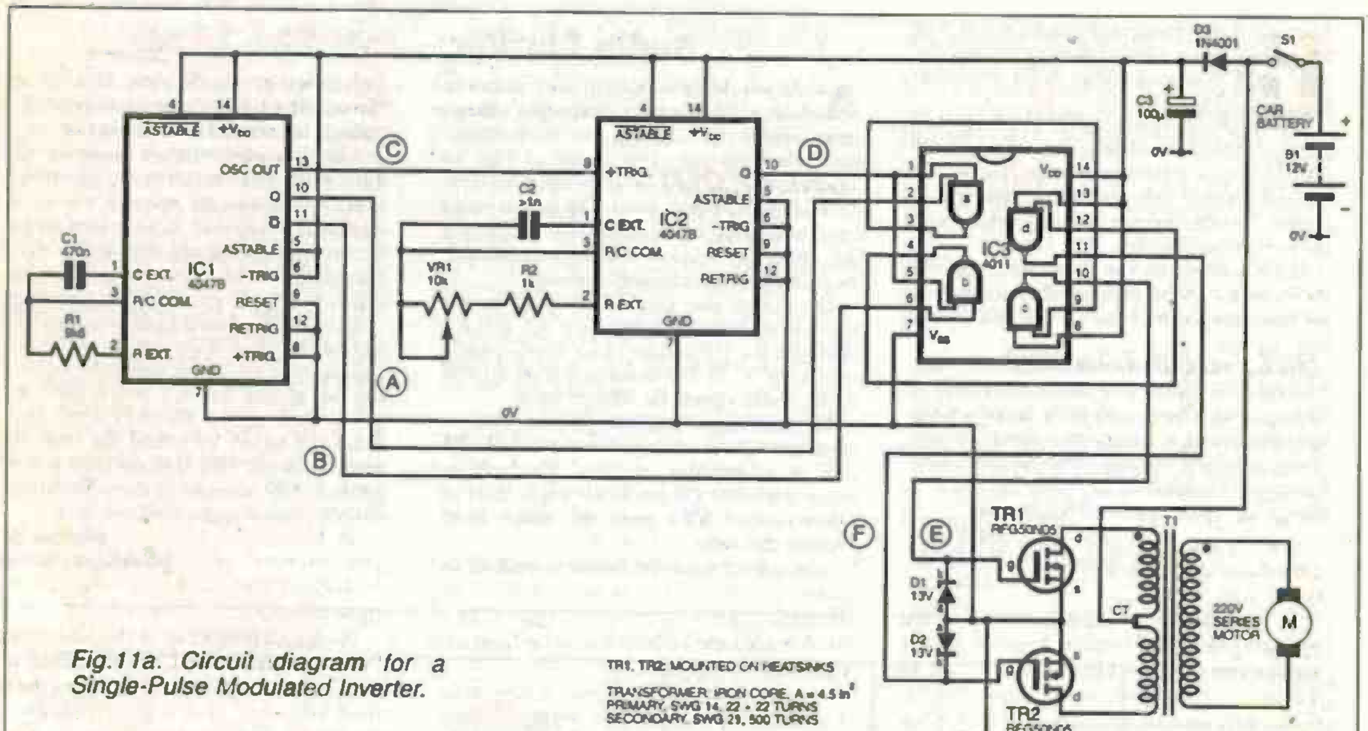


Fig.11a. Circuit diagram for a Single-Pulse Modulated Inverter.

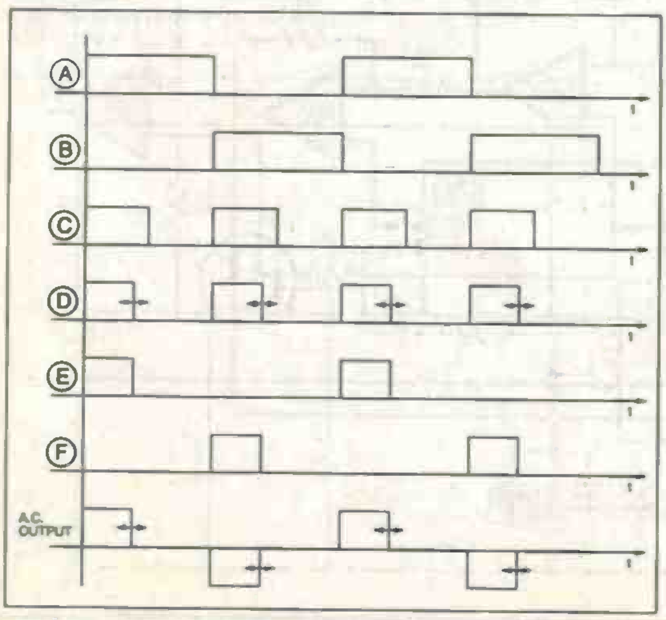


Fig.11b. Output waveforms at various stages of the circuit.

PICO PRIZE WINNERS

It's time to decide the winners of superb PICO Technology PC-based oscilloscopes, once again generously donated by PICO (www.picotech.com) for three lucky entrants whom in our judgment submitted the best ideas published in the past six months. As always, every entry was judged on a number of criteria including the extent of "lateral thinking" or novelty, technical merit, resourcefulness, appropriateness, and overall completeness. Presentation was used as a tie-breaker.

The final-choice was difficult and, after careful consideration, *EPE* Editor Mike Kenward and *Ingenuity Unlimited* host Alan Winstanley jointly selected the following winners from the June-November issues:

WINNER – receives an impressive PICO ADC200-50 Digital Storage Oscilloscope, ***worth over £450!***

Lee Archer – **TV Test Pattern Generator (September 1999)** – illustrating the adaptation of a teletext timing chip, this circuit was considered to be thoroughly developed and complete.

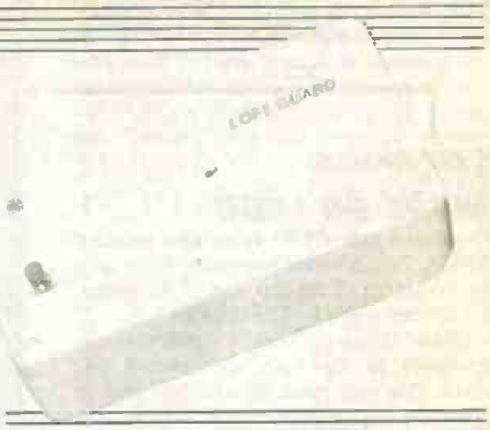
RUNNERS-UP – both are lucky recipients of **PICO ADC-40 Single Channel PC-based Oscilloscopes.**

Rev. Thos Scarborough – **Loop Aerial MW Radio (August 1999).** This was a novel radio receiver design using some traditional techniques, and we are also happy to acknowledge the contributions made by our most Ingenious Reverend.

Z. Kaparnik – **One Volt L.E.D. (November 1999).** A number of intriguing and professionally presented micropower circuits optimised to operate an l.e.d. from a single cell.

Constructional Project

LOFT GUARD



TERRY de VAUX-BALBIRNIE

Has the light been left switched on?

HAVING a permanently-wired mains light in the roof space is handy, especially if you keep a lot of useful material up there. Unfortunately, it is all too easy to leave it switched on as any user will testify.

Once the hatch is closed, there is no external sign that the light is on. It could then remain like that until the next visit – possibly several weeks or even months later. In the meantime, a significant amount of electricity would have been wasted.

SELF-CONTAINED

The Loft Guard is built as a small, battery-powered unit which is left in some suitable position inside the loft. It protects against leaving the light switched on by sounding a loud warning after 8 minutes or other preset time. This can be heard through the ceiling even with the loft hatch closed and alerts the next person passing by underneath it.

In the prototype model, the specified operating time was found to be sufficient. If you happen to be working for a long time in the loft, a Reset pushbutton switch on top of the unit may be operated every so often to reset the circuit and hold the sounder off for a further set time interval. This switch may also be used after it has begun to sound to stop it.

If you habitually spend long periods up there, it would be possible to increase the operating time and details for doing this are given later. Similarly, you could shorten it if required.

CHECKOUT

Before beginning construction work, check that the loft space is reasonably dark when the light is switched off. Make sure you will be able to site the unit where light from the lamp will reach it and, at the same time, above some place where the sound will readily attract attention – for example, near the top of the stairs.

Of course, the unit could be used in other similar situations. For example, to guard against a cupboard light being left switched on inadvertently. You could even site the buzzer remotely if required.

The standby current requirement of the prototype unit is less than 100µA. Using the specified 9V battery pack, consisting of six AA alkaline cells, a life of at least one year may be expected.

However, this will depend on how many times and for how long the buzzer sounds. While actually operating, the current rises to some 10mA. You could use a PP3 battery but the life would be correspondingly shorter.

CIRCUIT DESCRIPTION

The Loft Guard circuit works by sensing the change in illumination as the loft light is operated. Switching it on triggers a timer which holds the sounder off for the preset delay period. If the light is switched off during that time, the circuit will automatically reset ready for the next time.

The complete circuit diagram for the Loft Guard is shown in Fig.1. It will be seen that operation depends on the action of two integrated circuits. The first of these, IC1, is an operational amplifier (op.amp) responsible for the light-sensing aspect while the other, IC2, carries out the timing.

Looking at IC1 first, the inverting input (pin 2) is maintained at one-half of supply voltage (nominally 4·5V) due to the potential divider action of equal-value resistors R1 and R2. The non-inverting input (pin 3) has a voltage applied to it dependent on the values of the resistors in another potential divider.

In this case, its top arm consists of preset potentiometer, VR1, connected in series with fixed resistor R3 and the lower one, light-dependent resistor (l.d.r.) R4.

As the illumination of the l.d.r. sensitive "window" is reduced, the resistance of the device increases. In total darkness the specified l.d.r. will have a resistance in excess of 5MΩ. Even when there is a small amount of light, it will exceed 1MΩ.

In tests on the prototype in the author's loft, the "light" resistance was found to be

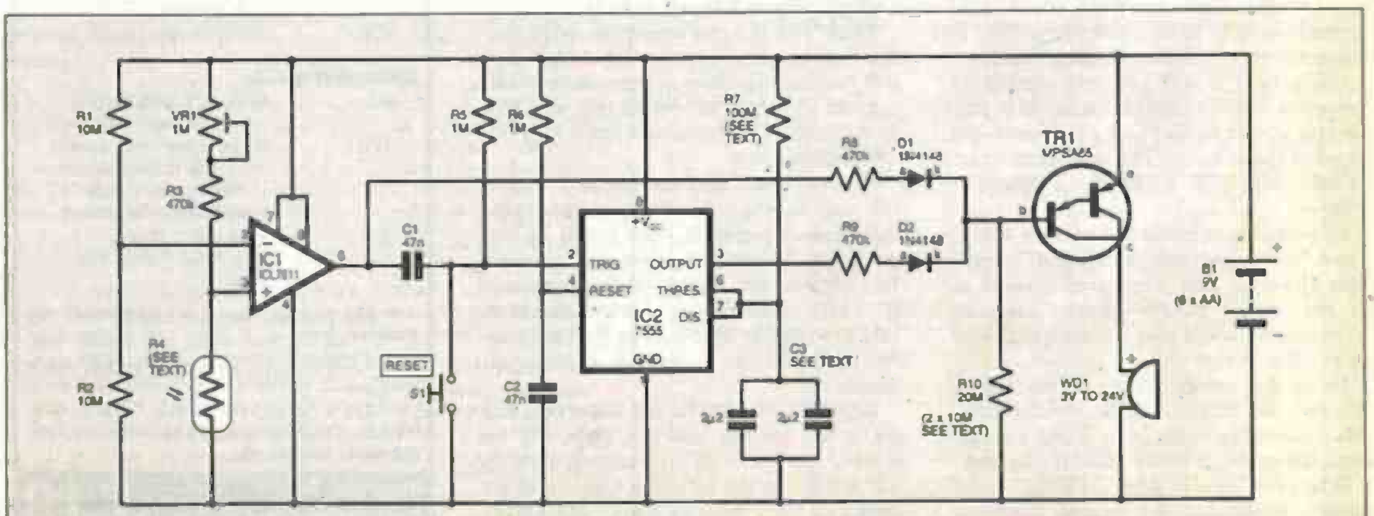


Fig.1. Complete circuit diagram for the Loft Guard.

some 100kΩ. Of course, in any particular situation this value will depend on the relative positions of the unit and loft light, plus also the power rating of the bulb and other factors. The point is that there is a wide difference between the l.d.r. "dark" and "light" resistance.

MORE OR LESS

Suppose preset VR1 is set to a value of 300kΩ. This is added to resistor R3 to give the resistance of the top arm of the potential divider – that is, 770 kilohms.

Under standby ("dark") conditions the resistance of the l.d.r. will exceed this value. This will result in a voltage greater than 4·5V appearing across it and hence at IC1 pin 3. When the loft light is on, the resistance of the l.d.r. will be less than 770 kilohms and the voltage at pin 3 will fall below 4·5V.

When the voltage at the op.amp non-inverting input (IC1 pin 3) exceeds that at the inverting one (that is, under "dark" conditions), the op.amp output, pin 6, will be high. When it is less ("light" conditions), it will be low. At the end of construction, preset VR1 will be adjusted so that this happens under the actual conditions prevailing in the loft.

Note that both op.amp inverting and non-inverting voltages are derived from potential dividers connected across the power supply. As the battery ages and the available voltage falls, the relative state of the inputs will remain unchanged. The circuit will therefore still work correctly. Of course, the battery pack will eventually develop insufficient terminal voltage to operate the buzzer satisfactorily and it will then need to be replaced.

Now look at IC2. This is an i.c. timer configured as a monostable. It may be activated by a *low* pulse applied to the trigger input (pin 2) – while high there is no effect.

Once triggered, the output (pin 3) goes high and remains like that until the circuit times out. The operating period depends on the value of capacitor(s) C3 and resistor, R7. The higher the value of either or both of these components, the greater the timing will be in proportion.

HIGH VALUES

Resistor R7 has a very high resistance (100 meg.) and the specified component may not be available to all readers. It could be made up from lower values connected in series and more will be said about this later.

Capacitor C3 will probably consist of two separate components connected in parallel (as shown in the Fig.1.) to provide the required capacitance. The suggested value (2·2μF) will give a combined effect of 4·4μF.

Of course, you could use a single 4·7μF, two 4·7μF or even one or two 10μF capacitors providing they were small enough to fit the circuit board layout. Such an arrangement would give a correspondingly longer time period.

Using the values shown in the circuit diagram, the timing will be about 8 minutes. It could be reduced by using a single capacitor having a lower value if required.

When the l.d.r. is dark – that is, under standby conditions, the op.amp output at pin 6 will be high and there will be no effect on IC2. However, when the output goes low (i.e. when the light is switched on), a low pulse is transferred, via capacitor C1, to IC2 trigger input (pin 2). The monostable then begins a timing cycle.

The purpose of capacitor C1 is to allow only a short pulse to pass. This is because if IC2 pin 2 was maintained in a low state continuously, the monostable would never time out since it would remain triggered. While on standby, resistor R5 maintains the trigger input in a high condition and this prevents possible false operation.

KEEP IT UP

The reset pin of IC2 (pin 4) needs to be kept high to enable operation of the monostable and this is the purpose of resistor R6. However, to allow the circuit to settle down when switched on and to prevent possible false triggering, it is held low for a short time using capacitor C2.

During this time the monostable is disabled and nothing can happen. The capacitor soon charges through resistor R6 and allows pin 4 to go high.

Pushbutton (Reset) switch S1 may be operated momentarily at any time to begin a new timing cycle and so hold the warning buzzer off. This works by taking the trigger input low for an instant.

While IC2 output is high (that is, during the course of timing), the base (b) of Darlington transistor TR1 will also be made high (close to positive supply voltage) via resistor R9 and diode D2. Under standby conditions, the l.d.r. R4 will be in near-darkness and IC1 pin 6 will be high. This also provides a high state at TR1 base through resistor R8 and diode D1.

Since TR1 is a *pnp* transistor rather than the more usual *npn* type, such a high state will maintain the base at near emitter voltage and so hold it off. No current will flow in the collector circuit and buzzer, WD1, will remain silent.

Suppose some light reaches the l.d.r. R4, IC2 will be triggered and a timing cycle will begin. Op.amp IC1 pin 6 will go low but this will have no effect on transistor TR1 because this state is blocked by diode D1 which is now reverse-biased. However, TR1 base will be kept high by the high condition of IC2 pin 3 and the buzzer will remain off.

When the monostable has timed out, IC2 pin 3 will go low and this state will be blocked by diode D2. Assuming light is still falling on the l.d.r., TR1 base will no longer be made high by either path R8/D1 or R9/D2. This allows it to go low via resistor R10 and the device is turned on

COMPONENTS

Resistors

R1, R2	10M	
R3, R8, R9	470k (3 off)	
R4	miniature light-dependent resistor, 5MΩ dark resistance. (5mm dia. – see text)	
R5, R6	1M (2 off)	
R7	100M cermet film (or 3 off 33M – see text)	
R10	10M (2 off – see text)	

All 0·25W 5% carbon film, except R4 and R7

See SHOP TALK page

Potentiometer

VR1	1M sub-min preset, vert.

Capacitors

C1, C2	47n min. metallised polyester, 5mm pin spacing (2 off).
C3	2μ2 min. metallised polyester, 5mm pin spacing (2 off or as required – see text)
Test capacitor (see text)	100n min. metallised polyester, 5mm pin spacing

Semiconductors

D1, D2	1N4148 signal diode (2 off).
TR1	MPSA65 *pnp* Darlington transistor
IC1	ICL7611 micropower op.amp.
IC2	7555IPA low-power timer

Miscellaneous

S1	miniature pushbutton switch, push-to-make
WD1	Audible warning device 103dB output at 1m minimum. 10mA d.c. operation maximum
B1	9V battery pack (6 x AA cells), with holder

Printed circuit board available from the *EPE PCB Service*, code 249; plastic box, size 138mm x 76mm x 38mm internal; 8-pin d.i.l. i.c. socket (2 off); plastic stand-off insulators (3 off); PP3-type battery connector; small fixings; multistrand connecting wire; solder, etc.

Approx. Cost Guidance Only **£19** *excl. batteries* (remember, it is *pnp* transistor!). Collector current then flows and the buzzer operates.

The fact that TR1 is a *Darlington* transistor results in it having an exceptionally high current gain. Only a very small base current (a fraction of a microamp) is therefore sufficient to operate the buzzer hence the very high value of resistor R10. Remember, the flow of current is in the opposite sense for a *pnp* transistor compared with *npn*.

KEEPING IT DOWN

It is essential that the continuous current requirement of the circuit is kept very low to minimise battery drain. This is achieved by choosing very low power integrated circuits.

Also, the resistors in the potential divider chains are made very high. If the loft is reasonably dark under standby conditions, the resistance of the l.d.r. will also be high and this reduces still further the current flowing through the series arrangement of VR1, R3 and R4.

To be effective, the buzzer must be of a very loud type yet have a current requirement of 10mA maximum. The specified unit (103db at 1m) was found to work very well.

CONSTRUCTION

The Loft Guard circuit is constructed on a small printed circuit board (p.c.b.) and the topside component layout and underside track master details are shown in Fig. 2. This board is available from the *EPE PCB Service*, code 249. All components are mounted on this except the battery holder, buzzer and pushbutton reset switch.

Commence board construction by drilling the three mounting holes in the positions indicated. Follow by soldering the i.c. sockets in position (do not insert the i.c.s at this stage) then all other components except capacitor(s) C3, light-dependent resistor R4, the diodes and transistor. *On no account solder the i.c.s direct to the board – it would be very easy to damage them.*

Note, resistor R10 (20MΩ) consists of two individual 10MΩ units connected in *series* using the pads indicated (both positions are labelled R10). If the 100MΩ cermet film type resistor specified for R7 is not available, connect three 33MΩ resistors in series instead using the pads provided on the p.c.b. – the three positions are labelled R7.

The photographs show the single specified resistor being used. This is soldered directly between the pads connecting IC2 pins 6, 7 and 8 – they are labelled "x" in Fig.2. If you can find no other way of doing it, you can connect ten 10MΩ resistors in series, zig-zag fashion, and connect the ends of the "chain" to the "x" pads.

Connect a 100nF "test" capacitor to either C3 position. This will provide an operating period of around ten seconds which will be more convenient for testing purposes than the full operating time.

Solder the l.d.r. in position using the full length of its end leads for the moment. If the specified *miniature* type of l.d.r. is not available the larger ORP12 type could be used. However, it would take up more space and would need a certain amount of adjustment to its position.

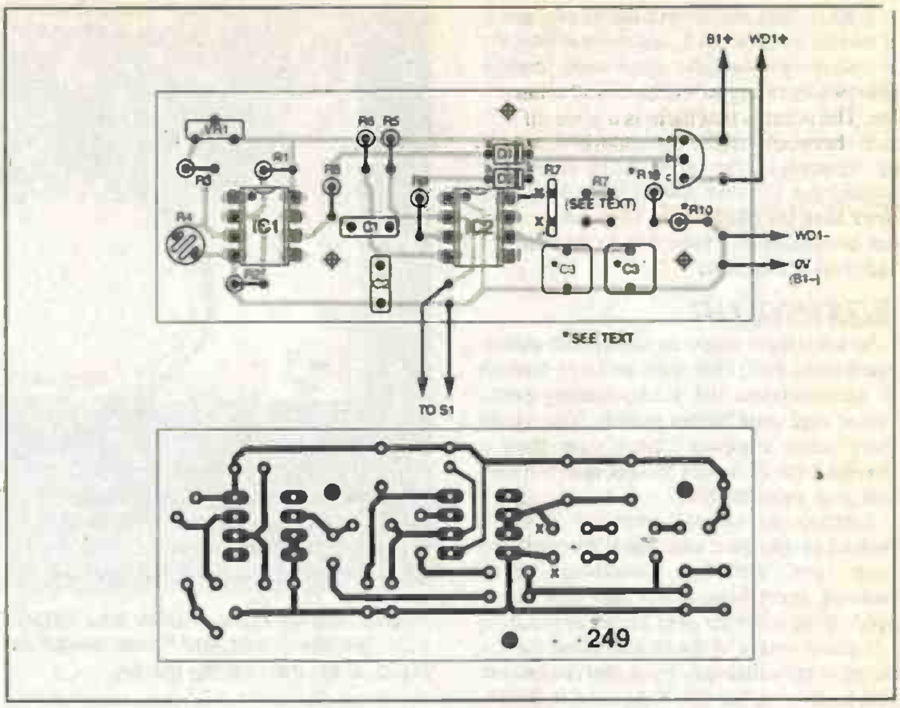
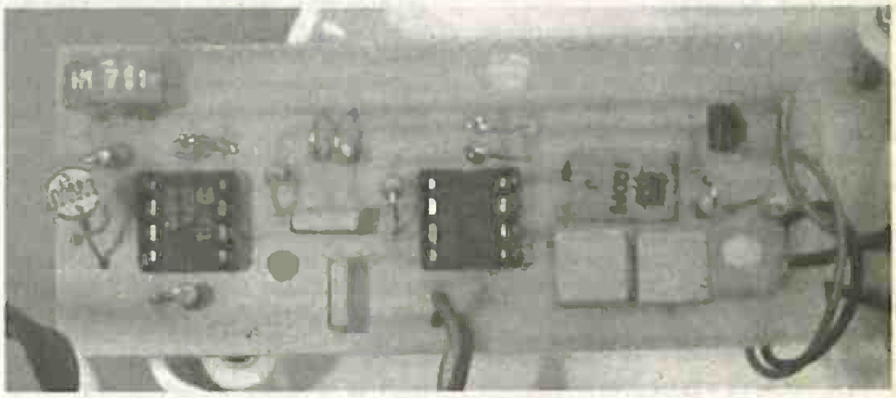


Fig.2. Printed circuit board component layout and full size copper foil master pattern.



Components mounted on the completed circuit board. Note that a single cermet film resistor has been used for R7 (see text).

POLARITIES

Now solder the polarity-sensitive components in place. These are the two diodes and Darlington transistor TR1. When soldering the diodes note that the cathode (k) end has a black band. When mounting the transistor, take care to place it as shown in the photographs with the flat face to the *left*.

Solder the battery connector wires to the p.c.b. If the battery holder has tag connections instead of being the more usual PP3 type, use short pieces of stranded wire instead. Connect pieces of light-duty stranded connecting wire for the Reset switch S1 and solder the buzzer leads to the WD1 pads – the red one is the *positive* lead.

Insert the i.c.s in their holders, with the correct orientation. These are both CMOS devices and could possibly be damaged by static charge which may exist on the body. To avoid possible problems, touch something which is earthed (such as a metal water tap) before unpacking them and handling their pins.

TESTING

Most readers will wish to carry out a basic test before mounting the circuit board in its box. This will allow any errors to be corrected more easily. It would be a good idea to tape over the hole in the buzzer for the moment to reduce the sound output because it is very loud!

Cover the l.d.r. with a piece of black p.v.c. tape to simulate placing it in darkness (or be ready to work in darkness). Adjust preset VR1 to approximately mid-track position and connect the batteries. Keep the switch wires separated so that the bared ends cannot touch.

Working on an insulating surface (such as wood or plastic) to prevent short circuits at the p.c.b. tracks, place the AA cells in the holder and connect it up. Peel back some of the p.v.c. tape to allow some light to reach the l.d.r. – the buzzer may give a momentary "chirp" which may be ignored.

After about ten seconds or thereabouts (remember, the timing has been reduced) the buzzer should sound. If you re-cover the l.d.r., it should stop immediately. Similarly, if you touch together the switch wires, it should stop.

If you have problems making it work, make sure the l.d.r. window really is covered to exclude *almost all* light – some types of black tape are far from opaque. If necessary, carry out the test in a dark cupboard. It is not satisfactory to cover the l.d.r. window with a finger!

If all is well, disconnect the battery holder and remove the i.c.s, again observing the anti-static precautions mentioned earlier. De-solder the buzzer wires and test capacitor C3.

With the required timing in mind, decide on the value of the capacitor, or capacitors needed for C3 and solder them in place. Note that an *electrolytic* capacitor would not be satisfactory here due to its inherent high leakage current.

BOXING UP

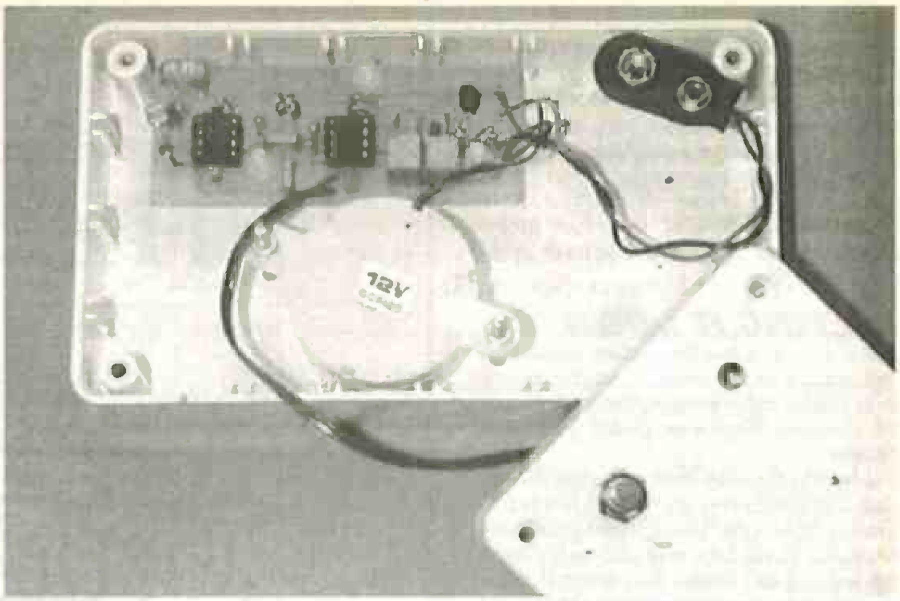
You are now ready to mount the circuit board in its box. This must be large enough to accommodate the p.c.b., battery pack, buzzer and pushbutton switch. You could use a more compact case if you used a smaller type of battery but, remember, this will give a shorter life.

Arrange the internal components on the bottom of the box and mark through the p.c.b. and sounder mounting holes. Remove everything again and drill these holes. Drill a further hole rather larger than that in the centre of the buzzer itself for the sound to pass through. Note that the buzzer will be mounted so that the sound is directed *downwards* (see photograph). This will allow the maximum amount of sound to pass through the ceiling.

Mount the p.c.b. temporarily on plastic stand-off insulators. You may wish to mark the position of preset VR1 on the side of the box so that a hole may be drilled to allow it to be adjusted more easily.

Measure the position of the l.d.r. "window" (top surface) and mark this on the lid of the box. Drill a clearance hole for it. With the lid in place, and the l.d.r. protruding, measure how much the end leads need to be shortened so that the window will be level with the face of the box.

Remove the p.c.b. and adjust the l.d.r. soldered joints to give the correct clearance. It would be a good idea to leave the leads a little on the long side because they can be bent slightly at the end to make small adjustments to the height.



Positioning of components and circuit board inside the prototype case. Note the l.d.r. "window" hole and Reset switch position in the lid. The space to the right of the p.c.b. is for the battery holder.

Drill a hole in the lid for the Reset switch and attach it. Solder the switch wires leading from the p.c.b. to its terminals. Drill the hole for VR1 adjustment if this is needed. Shortening the buzzer wires as necessary, solder them back to the p.c.b. pads. Insert the i.c.s again taking precautions against static charge build-up.

Mount the p.c.b. and attach the buzzer using a pair of long, thin bolts. Do not forget to remove any tape which was used to reduce the sound output, during testing, before attaching it. Insert the AA cells and secure the battery holder to the base of the box using a small bracket if necessary.

Place the lid temporarily in position but do not secure it yet. Adjust the l.d.r. end leads as necessary so that the window is level with the top face of the box (see photograph). Take care that they cannot touch one another and cause a short-circuit.

FINAL CHECKS

Test the circuit under real conditions. Try the unit in different positions in the loft to find the best one. Leave preset VR1 adjusted as far clockwise as you can (as viewed from the top edge of the p.c.b.) consistent with correct operation. When satisfied with the performance, secure the lid.

Check that the sound can be heard below the unit when the loft hatch is closed. You could remove a small amount of roof insulation from around the case to allow the sound to pass through more efficiently but this was not found necessary with the prototype.

It is suggested that the unit be allowed to sound every now and again to check the efficiency. When the buzzer can no longer be heard as it should, the batteries should be replaced. □

READOUT

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

WIN A DIGITAL MULTIMETER

A $3^1/_2$ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

Every month we will give a Digital Multimeter to the author of the best *Readout* letter.

★ LETTER OF THE MONTH ★

TELE BYGONES

Dear EPE,

Whilst looking for a computer magazine, I came across *EPE*, glanced through, then decided to purchase it. It brought back a lot of memories. Many moons ago (mid 1960s), I did a Government training course, to become a Television and Radio Engineer, with the promise of a job at the end.

About half way through, our instructor had to go on a three-day course. He returned, with the biggest TV receiver imaginable, the first colour TV any of us had seen. When it was switched on it worked for just a short time, when all at once, a bang, then smoke. The cause was something to do with HT.

I remember seeing what seemed to be three or four very large wirewound resistors burnt out. These were the days when the transistor was first brought about (*actually invented in 1948. Ed*); we had little if any training on these. We were told "Not to bother checking these they don't go faulty!" (I've heard that one before). "Anyhow, they will never replace the good old valve."

I did manage to finish the course and get a job working for Granada Television, not to be mistaken with Granada Broadcasting station. I was literally working on a conveyor belt. We had to pick up the sets (Murphy model 5?) from one end and refurbish them. This meant changing the on/off switch (the one being replaced was operated by lifting the lid), replacing the frame output valve and frame bias, clean the rotating channel switch, replacing the two valves (I think these were EC80 and ECC81).

A.C. power was rectified with a valve. This we replaced by a half-wave rectifier, using two diodes, and then replaced the smoothing capacitors. If any other valves had to be replaced, we had to gently ease the CRT forward in order to do so. Part of the HT was enclosed in an oil container, if the HT arced over then you had to inject more oil! Never try to align anything one small turn – this could lead to replacing of i.f. can, or whatever it was you were turning. This happened due to the age of the set.

When you had done all the work that needed to be done, it was time to ask the quality controllers to inspect the set. The first thing they did was to lift the set up three to four inches off the bench then drop it back on, apparently to see the effect, if any, on the screen! Then each of the valves was given a good tap with the thick end of a screwdriver (is this where the term *bottle bashers* came from?). This was to see if the valve was on the verge of death, or noisy! There were many more such nonsense acts of violence . . .

We were on piecework as well. We did have a much better set to work on, namely the KB, I don't know the model number, but this was a hard-wired set, i.e. no p.c.b. The KB had a frame output transformer at the top left-hand side looking from behind. The quality controller thought this was the best place to tie his label, to tell the world that this set had passed *his* inspection. All was well until the team responsible for re-casing got their hands on it and, yes you've guessed it, pulled the tag off along with the transformer wires. Oh the good old days!

I left this type of electronics to work with hearing aids. This was sub-sub-miniature work, and very rewarding. A resistor was just bigger than a pinhead. Now I believe they use i.c.s.

I have now ordered a two-year subscription to *EPE*, and also twelve months back issues. I shall also be sending for three CDs to help me. I have a lot of catching up to do!

Keith Barlow, Bury, Lancs

Isn't history fascinating! Welcome to the modern world of electronics, Keith. Good luck with your "catching up". It's good to hear from you.

TOOLKIT MK2 AND WIN 98

Dear EPE,

I would like to comment on the parallel port interface software for the *PIC Toolkit Mk2* (May-Jun '99). SETUP showed that the ACK bit was not working. However, inspection with DEBUG and direct manipulation of the port registers showed that the bit reflected the correct value.

Single stepping past the INP instruction in TKSET06.BAS worked too, so I suspected a timing issue. I duplicated the INP instruction to add a small delay and it worked OK.

This was using a 233MHz Pentium running Win 98 (although the same problem occurred in DOS mode).

Pete Shew, via the Net

Very useful comment Pete, thanks. All my software is tested on four machines of varying ages and abilities, using Win 3.1 and Win 95, at speeds up to 120MHz. I do not have a Win 98 machine and so any info on that system's operation is useful in this context.

LEAPING CALENDARS (AGAIN)

In several recent Readout *columns, we have discussed calendars in relation to the Millennium. We want to say a really* Big Thank You *to Mr W.F. Ritchie, of Fraserburgh, Aberdeenshire, who went to a lot of trouble to send us a great deal of information on the subject, including tables of data. Sadly, it is too lengthy to reproduce here.*

One of the many interesting points made is that, whereas the changeover to a Gregorian calendar (in honour of Pope Gregory XIII) began in 1582, Britain did not adopt it until 1752, which caused considerable controversy because, in that year, 11 days had to vanish ("Give us back our 11 days!"). Greece was even later – it was the last modern nation to make the change, in 1923.

Mr Ritchie also says that "At the age of 78 years I make do with my Hewlett Packard 48GX calculator, which . . . has a built-in clock and calendar covering a period from the start of the Gregorian calendar to 31st December 9999". Astonishing!

DOS ERROR 76

Dear EPE,

I have built *PIC Toolkit Mk2* (May-Jun '99) and the first part of the Setup, where the voltages and parallel port are checked is OK. However, when I press enter to carry on with the Setup, I get the message: "Setup program unforeseen MS DOS ERROR 76". Can you please help me?

Anthony Marshall, via the Net

The ERROR 76 message ("path not found") is that generated by MS DOS when it cannot find a particular file or directory named by the user. In Toolkit's *Setup this could occur if an attempt is made to install the program with its zipped files being in the wrong directory. When the program is installed from our 3·5-inch disk as available from the Editorial Office, it seems unlikely that this can happen.*

However, readers who have downloaded the program from our FTP site may inadvertently find that their unzipped files are in the wrong directory. The files need to be installed in directory **C:\PIC**, *as expected by various file accessing commands within the suite of programs.*

There is normally a text file on the FTP Toolkit Mk2 path that explains this **(pic_toolkit_instal.txt)**, *although there was a brief period during which the file "went missing". It should be there now – follow its instructions (if it's not, advise the Webmaster for that site).*

The ASMCNV directory (folder) referred to must be created as **C:\ASMCNV**. *(It should not be created in the PIC directory, where it will not be found.)*

Incidentally, readers with QBasic or QuickBASIC can find out what a particular DOS Error number means by entering the programwriting area of these programs and typing in the command, for example, ERROR 76. *Then run this one-line program, upon which the program will halt and display a text box containing the relevant error message.*

LOGGING EXCELS

Dear EPE,

I've just read Part 2 of the *8-Channel Analogue Data Logger* (Aug-Sep '99) and have to say I like it. I have always wanted to build one using a good old Z80 CPU and a ZNxxx but even when I had the chips I never got around to it! Your design is made so easy with the PIC16F877.

Being able to upload the data to a PC is really essential, and your comments on using Excel to view the data are very good.

I have also downloaded version V2.3 of *Toolkit Mk2* – I have used the dissemble function to recover a program from a PIC16C84 that I had lost the .ASM text for, it will make rewriting a lot easier!

Mel Saunders, via the Net

It's good to know that a design which took me so much time to research and implement is providing you and many other readers with a useful tool. There were four "learning curves" involved – getting to know the PIC16F877, the serial memories, serial communication between PIC and PC, plus Excel (to which I had previously only had brief exposure when we produced the CD-ROM for PICtutor).

A WAVE FOR OSCILLATORS

Dear EPE,

This is the first letter I have ever written to an electronics magazine. To establish, very briefly, my background, I was brought up with the vacuum tube starting in the early thirties. Although I was keen to build receivers, money was scarce, and I could only read about their construction. Then came WWII and I tried to get into Signals, but it was not to be. I served in the infantry. Then came family responsibilities, and the necessity to earn a living, and a move to Canada in 1954.

Only now, in retirement, have I the time to "convert" myself from the valve to solid state. What a fascinating subject it is! I find my main interests are receivers and test instruments and have recently built a number of them, including some from *EPE*. Now I have subscriptions to five electronics magazines from the USA, and two from England, and of the seven your magazine stands head and shoulders above them all. I can only say it is simply the BEST!

The series of articles on oscillators by Raymond Haigh is excellent, the subject is dealt with in depth and gives down to earth schematics. The articles give one confidence to go ahead and build each type of oscillator, and indeed I have already built some of them, and I intend to construct many more.

I also have another request, and perhaps some of your columnists or readers, better versed in electronics than I, could provide a method and a circuit, for the testing and evaluation of toroids. This component, as is well known, exists on the surplus market in a vast array of sizes and material composition, and they can be bought very cheaply. But not knowing its composition, i.e. iron dust or ferrite, and what frequency it was designed for, one would hesitate to incorporate it in any project.

Perhaps the circuit would take the form of a BH curve tracer, where, instead of a 50Hz or 60Hz input, a standard signal generator could activate the circuit, and the output displayed on the scope.

I realize that a full and complete evaluation of any magnetic material is a complex subject, full of mind boggling maths! But it seems to me that if we know its composition and designed frequency, this would give confidence to incorporate the item in a project with reasonable chance of success.

I look forward to perhaps seeing an article on the above! Please keep the practical projects and informational articles coming.

B.J. Maloney, Alberton, Canada

We know that many readers have responded favourably to Raymond's oscillator discussions. Toroids-wise, though, we suspect that an article relating to them would be too esoteric to appeal to most readers. However, perhaps readers might care to tell us we're wrong!

We appreciate your praising words. With our international readership continuing to grow, in a large part due to our EPE Online *editions on the Internet, it's good to learn what readers worldwide think of us.*

TRANSISTOR PROBLEM

Dear EPE,

I'm having some trouble getting my *PIC Toolkit Mk2* (May-Jun '99) to work and hope you can be of some help.

I am not getting the correct voltage measurements and I believe it has to do with two of the components: the power supply and TR1.

First, when the parallel port bit DA4 is high, the voltage on PIC pin 4 (MCLR) should be 12V, but I am only getting 8·2V. Now the 78LC05 power converter I used is only rated to supply 100mA and the l.e.d. I chose draws 20mA. Could there not be enough current going to the MAX665 Flash memory programmer for it to supply 12V? Should I replace both the power converter to get more juice and the l.e.d. to consume less?

Second, when the parallel port bits DA3 and DA4 are high, the voltage on MCLR should be 0V, but I still get 8·6V. When DA3 is high alone, I get 4·5V on MCLR, so something is working. I used a different *npn* transistor for the reset instead of the BC549 specified because I could not find that listed in any of my catalogues here in the USA. Instead I used a generic *npn* with a maximum collector current of 600mA.

I have just started working with PIC micros and I really enjoy your magazine because of your concentration on them. I purchased your *PIC Toolkit* p.c.b. and put together this programmer to see what I could learn and save a few bucks. I appreciate your work. Thanks very much.

Fred Ramsing,
University of Nevada, Reno, USA

The l.e.d. is unlikely to be the cause of the problem since its current is limited by resistor R13 and does not depend on the l.e.d.'s actual rating (which states the maximum current at which the device can be safely operated, not the current at which it always works).

It seems probable that the transistor is to blame, perhaps because its pins are not orientated correctly. Check the data sheet (or supplier) for the pinout of the device and ensure that the pin designations correspond with those shown in Fig.4 of the published article (you may need to "twist" the device if they are in a different order).

One alternative to the BC549 (a device which is part of my regular design stock) is the BC109. Another is the 2N3704, but note that this device has a pinout of ECB *whereas the BC549 and BC109 have* CBE. *In reality, practically any general purpose* npn *transistor should work if correctly orientated, it's only being asked to switch a very small current on and off.*

Having sent the above info direct to Fred, he subsequently E-mailed back: "Thanks a ton, it works fine!!"

PICKING UP ON ED

Dear EPE,

In your *Editorial* of Nov '99, you say "It seems that some of our readers are definitely not interested in PICs". It's not the PICs they're not interested in it's the endless discussions on code that put them off!. I feel the same.

Why not steer clear of code and talk in terms of Basic programming with which a vast number of your readers must be familiar? I notice that some companies offer PIC Basic compilers. Why bother with the grief of learning code? Please enlighten me.

Murray Cameron, via the Net

Ah, Murray, you've misunderstood Editor Mike's statement! By "some" is meant that "a few" – a minority in fact – of our readers are not interested. The vast majority most definitely are interested in PICs at the programming as well as the applications levels.

A couple of years (or so) back, I ran an experiment with one of my published PIC projects. I discussed at length one aspect of the program that controlled the project, in order to see what reader response would be to that extended discussion.

The result was astonishing – many readers expressed their gratitude for the discussion. So much so, that I felt justified in suggesting to Mike the PIC Tutorial *series, which we subsequently ran from March to May '98. It was one of the most successful series that* EPE *has ever run. Demand for back issues (photocopies only now) of the series still continues. The success of the series also prompted us to further develop the concept and produce the* PICtutor *CD-ROM and associated hardware (see page 912).*

But as to actually indulging in "endless discussions of code", we don't do so as a regular part of PIC projects. By-and-large, the only discussion of code is when it is pertinent to explaining how a particular design should be operated. Otherwise, extended discussions about code from a programmer's point of view have been confined to such educational features as the PIC Tutorial *and* PIC16F877 Mini Tutorial *(and* Readout!*). Even my* 8-Channel Analogue Data Logger *of Aug/Sep '99 (which for the first time introduced the PIC16F877 as part of a project) did not significantly discuss code, that being left to the* Mini Tutorial.

Regarding PIC Basic compilers, I am sure that for short lengths of code writing they are probably an excellent asset for some readers who do not have the inclination to delve into writing PIC code directly. For myself, though, the type of designs I create are not suited to compilation from one language to another in this context. There is usually a large overhead of extra code that is generated when such transformations take place, accompanied by a relative reduction in processing speed.

For my purposes, I need the compactness and optimum speed of sub-routine processing that writing in "machine-code" can achieve. Writing in PIC is as second-nature to me as writing in any of the other several computer-type languages that I know and use. There are a lot of readers who are similarly adept and who delight in PICs in particular. Projects based on PICs have turned out to be amongst the most successful projects we have published in our 28 (nearly 29) years of existence!

CHILD GUARD QUERY

Dear EPE,

In *Child Guard* (Sep '99), IC5 and IC6 both have their address pins connected the same way. However, pin 10 on IC6 is connected to ground, whilst on IC5 it is left floating. Is this a mistake, or is the diagram correct?

Martin Male, via the Net

We referred Martin's question to the author, Tom Web, who replied:

There is no problem with pin 10 on IC6 being connected to ground. This is required to make IC6 continuously transmit a signal. On IC5 the same pin should be left floating as shown in the diagrams, since the pin is carrying information which is not required in this design. In other words the diagrams in the article are correct.

Tom Web and Max Horsey, via the Net

OVERCAST SUNDIALS

Dear EPE,

John Becker's *Musical Sundial* (R.A. Evans, *Readout* Nov '99) could well have its uses. Sun time differs from clock time by up to a quarter of an hour. It may be of interest to know the difference. Human beings can't read a sundial when the sky is overcast (hence the well known sundial motto "I count only the sunny hours"), but electronics might. Even when the sun is hidden, more light must on average arrive from its direction than from other parts of the sky. An integrating light detector might show where it is.

An electronic sundial could be remote-indicating, allowing lazy people like me to monitor it without going out. If it measures light intensity it might warn you to use sun lotion. Naturally, any such device should be solar powered! Perhaps readers could suggest an appropriate high tech motto.

P.S. Interested to see that *Radio Bygones* now emanates from Wimborne Publishing. If you go on absorbing other mags, your abbreviated title will be as long as the original name!

George Short, Brighton, East Sussex

Good to hear from you again George. Yes, I've thought about Sundials for Dull Days and think that it is feasible, although precautions would need to be taken to ensure that only the sun's light (obscured or clear) would be responded to and not other, brighter, sources. Should I get the craving to do Sundial Mk2, *I might try this approach, and attempt the use of just three sensors and a bit (?) of triangulation through the PIC software – probably more of a problem than I appreciate at the moment . . . Still, where's the fun without the challenge?!* Radio Bygones *will, of course, continue to be published in its own right.*

Everyday Practical Electronics are pleased to be able to offer all readers these

ELECTRONICS CD-ROMS

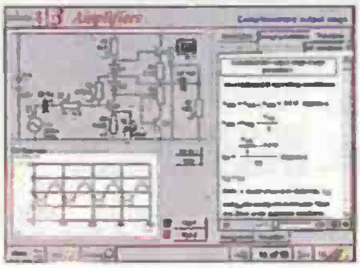
ANALOGUE ELECTRONICS

by Mike Tooley

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

FUNCTIONS

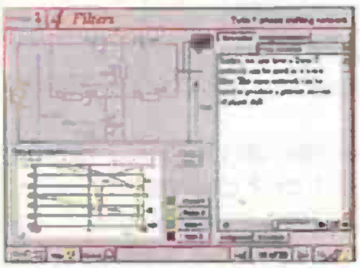
The component values on all circuits can be edited and the user can use the simulation engine to see how the value of each component affects circuit performance. You can, for instance, alter frequency and [illegible] and plot outputs on a [illegible] oscilloscope or show [illegible] graphs etc.



Complimentary output stage.

COVERAGE

Sections on the CD-ROM include **Fundamentals** – Analogue Signals (5 sections), Transistors (4 sections), Waveshaping Circuits (6 sections); **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators; **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections); **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections); **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators; **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.



Twin-T phase shifting network

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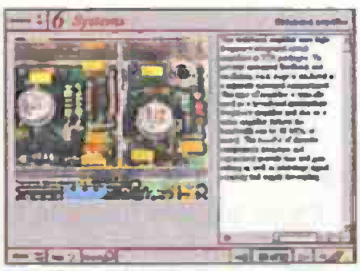
- **Complete hi-fi amplifier case study**

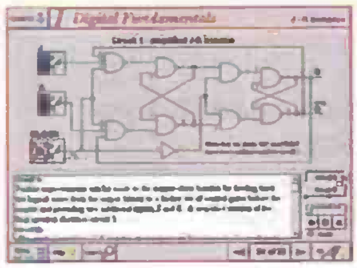


Gallery – Wideband Amplifier

DIGITAL ELECTRONICS

by Mike Tooley

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (below), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.



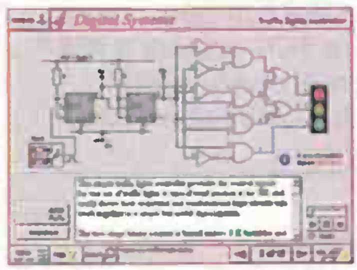
Virtual laboratory – Flip-Flops

FUNDAMENTALS

Fundamentals introduces the basics of digital electronics including binary and hexadecimal numbering systems, ASCII, basic logic gates and their operation, monostable action and circuits, and bistables – including JK and D-type flip-flops.

COMBINATIONAL LOGIC

Multiple gate circuits, equivalent logic functions and specialised logic functions such as majority vote, parity checker, scrambler, half and full adders. Includes fully interactive virtual laboratories for all circuits.



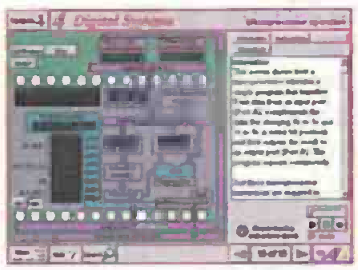
Virtual laboratory – Traffic Lights

SEQUENTIAL LOGIC

Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers.

DIGITAL SYSTEMS

A/D and D/A converters and their parameters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units.



Microprocessor

GALLERY

A catalogue of commonly used IC schematics taken from the 74xx and 40xx series. Also includes photographs of common digital integrated circuits and circuit technology.

Prices for each of the two CD-ROMs above are:

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Institutional (Schools/HE/FE/Industry)	**£99 *plus* VAT**
Institutional 10 user (Network Licence)	**£199 *plus* VAT**

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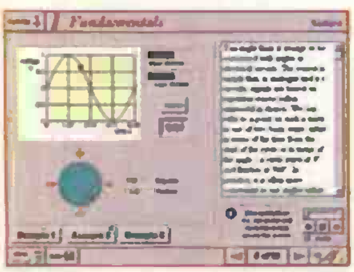
TWO APPLICATIONS ON ONE CD-ROM

ELECTRONIC CIRCUITS & COMPONENTS + THE PARTS GALLERY *by Mike Tooley*

Electronic Circuits & Components provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding as they proceed through the sections on the CD-ROM. Sections on the disk include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits . Active Circuits***

The Parts Gallery – many students have a good understanding of electronic theory but still have difficulty in recognising the vast number of different types of electronic components and symbols. *The Parts Gallery* helps overcome this problem; it will help students to recognise common electronic components and their corresponding symbols in circuit diagrams. Selections on the disk include: ***Components ,Components Quiz, Symbols, Symbols Quiz, Circuit Technology***



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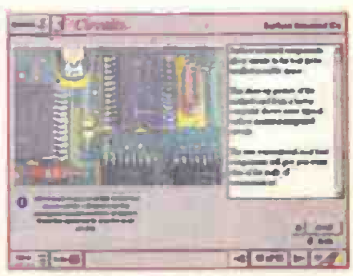
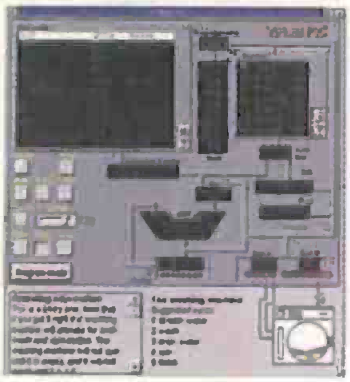
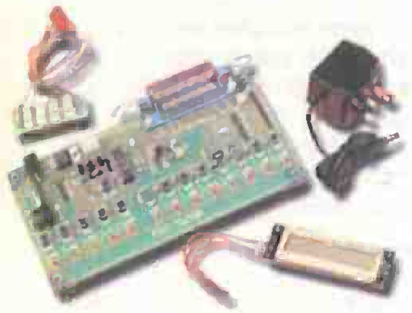


Circuit technology screen

Interested in programming PIC microcontrollers? Learn with **PICtutor** *by John Becker*



The Virtual PIC



Deluxe PICtutor Hardware

This highly acclaimed CD-ROM, together with the PICtutor experimental and development board, will teach you how to use PIC microcontrollers with special emphasis on the PIC16x84 devices. The board will also act as a development test bed and programmer for future projects as your programming skills develop. This interactive presentation uses the specially developed **Virtual PIC Simulator** to show exactly what is happening as you run, or step through, a program. In this way the CD provides the easiest and best ever introduction to the subject.
Nearly 40 Tutorials cover virtually every aspect of PIC programming in an easy to follow logical sequence.

HARDWARE
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Two levels of PICtutor hardware are available – Standard and Deluxe. The **Standard** unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials.
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designing your circuit
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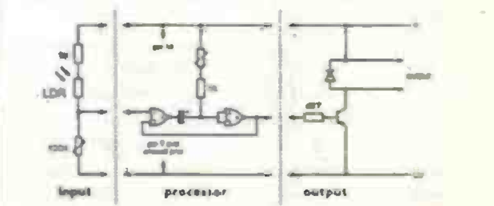

"I found that I could design a circuit without my teacher's help. And it worked! Everything was to hand – which chips to use – and which pins did what." Andrew Preston (GCSE student)

A Web Browser is required for Modular Circuit Design – one is provided on the *EPE CD-ROM No. 1* (see below) but most modern computers are supplied with one.

Minimum system requirements for these CD-ROMs: PC with 486/33MHz, VGA+256 colours, CD-ROM drive, 8MB RAM, 8MB hard disk space. Windows 3.1/95/98/NT, mouse, sound card (not required for *PICtutor* or *Modular Circuit Design*).

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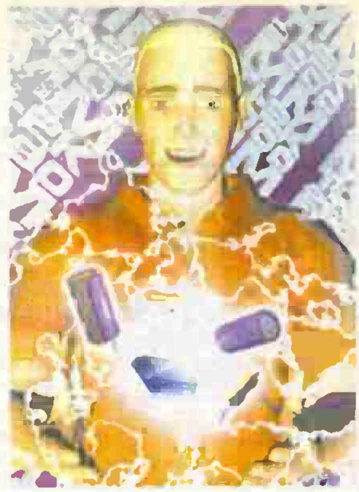
EPE/ETI Tutorial Series

TEACH-IN 2000

Part Two – Capacitors



JOHN BECKER

What we are doing during this 10-part *Teach-In 2000* series is to lead you through the fascinating maze of what electronics is all about! We are assuming that you know nothing about the subject, and are taking individual components and concepts in simple steps and showing you, with lots of examples, what you can achieve, and without it taxing your brain too much!

Through these simple steps we hope to prove to you that using electronic components need not be a complex task and that, providing you think about each stage of what you are trying to create, you can actually design and build something that works!

Last month we introduced colour codes and resistors. We now look at capacitors and show you some of the things they can achieve when used with resistors.

In that fascinating bag of parts that you bought, you will see a number of blue (or black) tube-like components with two wires sticking out of one end (see Photo 2.1). They are some rather remarkable components called electrolytic capacitors. Find the one whose value says 100µF. For this experiment consider the capacitor to be called C1.

One wire of C1 is usually longer than the other and has a large arrow pointing at it from the case. This wire is called the negative (–ve) wire, often shown with a "–" (minus) symbol. The other is called the positive (+ve) wire, for which a "+" (plus) symbol may be used. This is illustrated schematically in Fig.2.1a. This type of construction is called *radial*.

A variant of electrolytic capacitor case style is also manufactured, as in Fig.2.1b, which is called *axial* construction and whose +ve and –ve connections are at either end as illustrated.

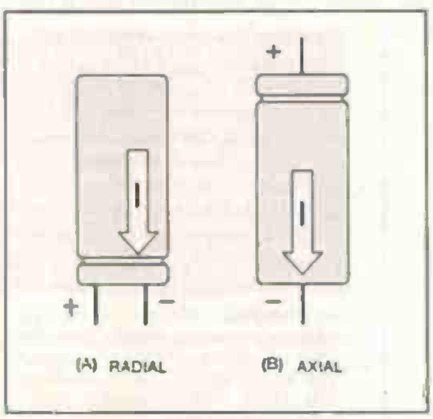


Fig.2.1. Typical case styles for electrolytic capacitors.

Photo 2.1. A selection of electrolytic capacitors (radial construction).

A CURVATURE IN TIME

Referring to Fig.2.2, plug C1 into the breadboard with its leads orientated as indicated by the + symbol in the diagram (the – symbol, although marked on the capacitor, is often not shown in layout diagrams). Now fit a 100kΩ resistor (call it R1) as shown. Insert terminal pins for the power supply connections (see Photo 2.2).

Clip one power supply lead to the battery's negative (–) terminal and to the board as shown in Fig.2.2. Clip the other power supply lead to the board as well, but don't connect the other end to the battery's positive (+) terminal yet.

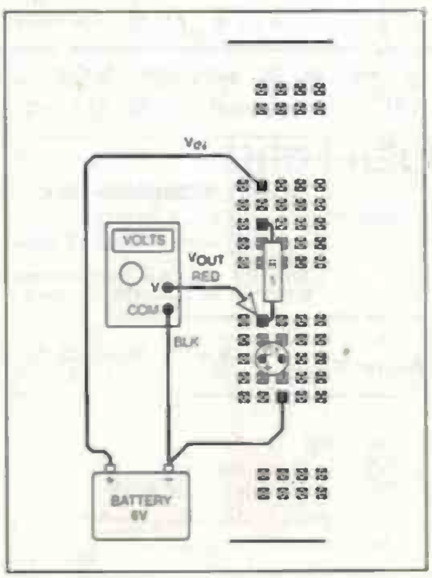


Fig.2.2 and Photo 2.2, breadboard layout for the first resistor/capacitor timing experiment.

It is conventional to use a red lead for the positive power supply connection. For the negative power supply connection it is the author's preference to use a green lead, although the use of black is also common.

Note that in many circuits (including those discussed in this *Teach-In*), the battery's negative connection is taken as the common reference point against which voltage readings are taken. As such, it is regarded as being at zero volts (0V).

Consequently, throughout this series (unless you are told specifically otherwise) the meter's COM lead should always be connected to the battery negative connection when taking voltage readings.

Clip your multimeter's leads as shown and set the meter to the first volts d.c. range above 6V. Note the reading, 0V at this moment. While you watch the meter, get a friend to clip the red wire to the battery's positive (+) terminal, noting the position of the seconds hand on his watch as he does so.

(Girls, ladies, forgive the use of "he" and "his" forms of reference – it would be tedious to this author's typing finger to keep giving the feminine form as well the masculine, he/she, his/hers and so on. We know that females of the species are also interested in electronics!)

Watch your meter and yell "NOW" as soon as it shows a reading of 2V. At which point your friend should tell you the number of seconds that have passed since clipping the red lead to the battery.

Continue watching and timing and yell again when the meter reaches 4V and again at 6V (assuming you haven't run down your battery since last month's *Teach-In* – if you have, get a new one!). Leave the battery fully connected while you consider your results.

What timings have you got for the 2V, 4V and 6V marks? Hopefully, about 4 seconds for the 2V, 10 secs for 4V, and, oh – about 40 to 50 seconds? And what do you make of these timings? The voltage steps have been at 2V intervals, yet the timings have become progressively slower for each step.

Let's now do things backwards. Watch the meter and tell your friend to note the seconds hand again as he *unclips* the red lead from battery positive and clips it (do it quickly) to the battery negative. You now yell out when the meter shows readings of 4V, 2V and 0V.

This time you should have found that 4V is reached after about 4 secs, 2V at 10 secs and (almost) 0V at about 40 to 50 secs. You will see, too, that timings have again become progressively slower for each 2V step.

Don't worry if the actual timings you get are somewhat different to ours, for a start you are not using an accurate timer, secondly, the actual values of a capacitor compared to its stated value can differ by even as much as 50% (more about this in due course).

Additionally, your battery is probably not supplying exactly 6V. Furthermore, the resistance of your meter (which you established last month) is forming a potential divider with resistor R1, so fractionally "pulling down" the voltage at the junction of C1 and R1.

What you have just demonstrated is that when a voltage is applied to a capacitor via a resistor, the capacitor starts to charge up with the voltage, commencing at quite a fast rate, but then more slowly as its charge increases, until near the end of when the voltage on the capacitor is close to that of the battery, the charging rate becomes almost imperceptible. You have also shown that the opposite is true as well (i.e. during discharge).

The charge/discharge property of a capacitance-resistance combination has the most profound effect upon the whole realm of electronics technology.

But, before we examine the results of your timed yelling, let's first have a look at the basic nature of a capacitor.

PANEL 2.1 – A.C. AND D.C. VOLTAGES

Alternating (a.c.) voltages are those that repeatedly change their magnitude above and below a midway reference voltage level (often taken as 0V, as in mains electricity supplies, but may be other voltages). *Direct* (d.c.) voltages are those that remain at any fixed voltage level, either above 0V or below it.

Strictly speaking, ***a.c.*** and ***d.c.*** actually mean ***alternating current*** and ***direct current*** and, as such, to use the terms ***a.c. voltage*** and ***d.c. voltage*** is incorrect. However, for some unknown reason, the terms a.v. and d.v. (which would be more appropriate when referring to alternating and direct voltages) do not seem to exist.

It can be argued, however, that it is not the ***voltage*** that flows, but the ***current***. Indeed the term ***voltage*** merely represents a concept rather than something that actually flows. As an ancient (1962) copy of the ***Penguin Dictionary of Electronics*** puts it: "Voltage. Strictly, a ***difference*** of ***electric potential*** expressed in volts. However, the term is used more generally as a synonym for electrical potential".

Voltage is certainly a more convenient term and ties in with the fact that the unit of measurement for potential difference (p.d.) is the *volt*, for which the symbol is V.

Note that you may encounter another term instead of voltage or potential difference, ***electromotive force*** (e.m.f.).

WHAT IS A CAPACITOR?

A capacitor is a component which has the capacity to store electrical energy (hence its name). In this sense, capacitors can be thought of as a type of battery, but, unlike a battery, they do not depend on a chemical reaction for this function to occur. Rather, they take advantage of a convenient fact of nature that prevails when two metal plates are placed close to each other, but not touching, and a voltage source is connected across them (see Fig.2.3).

At the moment that the voltage is applied, an electrical charge is transferred to the plates at a rate depending on the voltage level applied, the material from which the plates are made, their total area, distance apart, the substance which lies between them (called the *dielectric*), and the amount of resistance existing in the connection path (including the capacitor's internal resistance). If the voltage is applied for sufficient length of time, eventually there will be *virtually* the same voltage across the plates as available from the source.

When the voltage source is removed, the plates will retain their charge until a conductor of some sort is connected across them. As soon as there is a conducting path between the two plates, the charge begins to flow from one to the other, trying to return to the previously uncharged state. The discharging rate is governed by the same factors as controlled the charging rate.

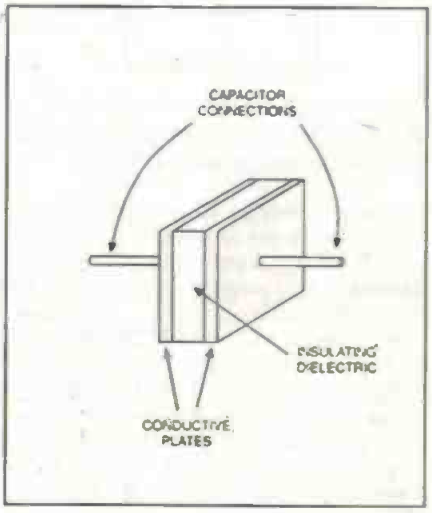


Fig.2.3. Basic construction of a simple capacitor.

Given enough time, all of the electrical charge stored across the plates will reduce to zero. But, you may ask, what happens to the electrical charge itself? Principally, it is converted into heat in the discharging conductor and capacitor's internal resistance, although in extreme circumstances some could be converted into light or radio energy. In normal use, you won't notice any temperature change in the capacitor or the conductor.

A capacitor's ability to be charged by a voltage and to hold the charge (almost) indefinitely allows it to be used in electrical and electronic circuits in a variety of ways:

- To simply store a voltage until it is needed
- To smooth out fluctuations in voltage levels
- In conjunction with other components, such as resistors for example, to determine the rate at which voltage changes occur at a particular point in a circuit
- To shorten or extend pulse lengths
- To transfer changing differences in voltage levels between one side of the capacitor and the other, in other words, to allow alternating (a.c.) voltages to be transferred whilst preventing direct (d.c.) voltages from flowing from one part of a circuit to another (see also Panel 2.1)

CAPACITANCE VALUE

The amount of electrical charge that a capacitor can hold is known as its *capacitance value* (surprise, surprise!), and the unit which is used to define it is the ***Farad***. It is named after another electrical pioneer in the nineteenth century, Michael Faraday. He was a Londoner, born 22-9-1791, died 25-8-1867.

More intimate information about Farad values is given in Panel 2.2.

There are several symbols that can be used to represent a capacitor, as shown in Fig.2.4. Some represent the type of capacitor, but there are also differences of international standard used in some cases. Those used in *EPE* are the ones to the left of each pair.

The circuit diagram for what you have just been doing on your breadboard is shown in Fig.2.5. (We didn't comment on the battery symbol in Part 1, make a mental note of it now!)

We'll say more about capacitors later, so back to your timing results . . .

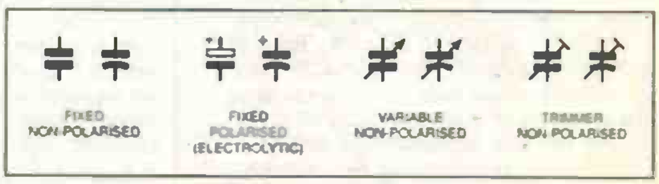


Fig.2.4. Commonly used symbols for capacitors.

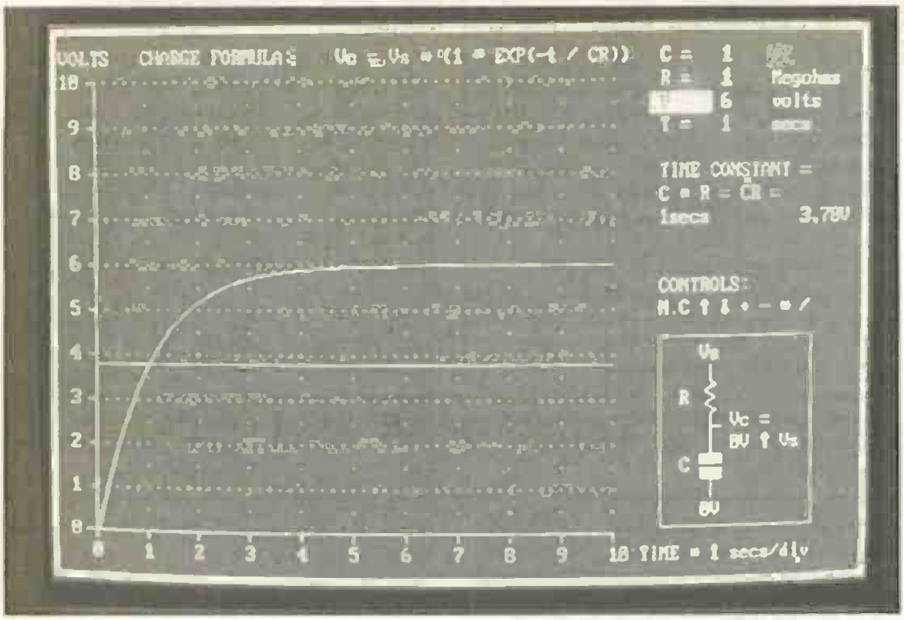


Photo 2.3. Capacitor charging graph displayed on the interactive computer screen.

DISPLAY GRAPH

We can illustrate a capacitor's rate of charge and discharge using another of our software demos. From the main menu select Resistor-Capacitor Charging Graph.

On entry to this display you will see a rising graph on a grid, similar to that in Photo 2.3. This particular graph is that for a 1µF capacitor and 1MΩ resistor, a combination whose timings would be far to fast for you and friend to keep pace with!

As with the resistor display examples last month, you can change the values associated with this demo. At the top right you should see C highlighted and its value as 1µF. Press the <*> key (multiply) twice. On each press the graph will redraw to suit the changed value. You should see C = 100µF after the second <*> press.

Press the down arrow key once to select factor R. Press </> (divide) once to set R = 100 kilohms. Press the down arrow once to select V, then press <-> (minus) four times to set V = 6 volts. Again press the down arrow to select T, and press <*> once to set T = 10 secs.

TIME CONSTANT

In front of you now is the graph that illustrates how an ideal (and "empty" – uncharged) 100µF capacitor charges via a 100kΩ resistor when a voltage of 6V is instantaneously applied to it. The vertical axis of the graph represents volts, and the horizontal axis shows elapsed time in seconds. The time between each horizontal step is the value shown times 10, because T has been set to 10 seconds per division.

Look closely at the graph. Where it reaches the 2V grid line, you can just about estimate that the time taken so far is about 4 secs. It's clear to see that 4V is reached at about 10 secs, and that it has just about reached 6V at around 50 secs. You can select a "magnified" view of the 2V mark by pressing <-> to make T = 1 secs (excuse the mismatch of singular and plural!).

Why the blue horizontal line just below 4V?, you must be wondering. By convention, the line represents the 63% level of the power supply voltage across the resistor/capacitor series. The rate at which the capacitor charges

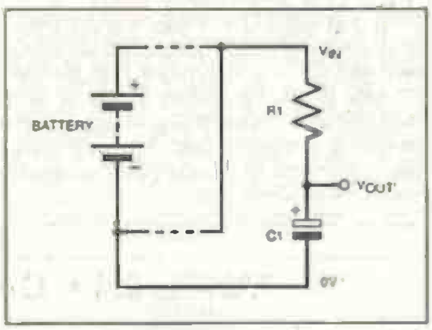


Fig.2.5. Circuit diagram for the capacitor charge/discharge experiment.

to that 63% voltage is termed its *time-constant*, which is the value obtained when the capacitance (C) and resistance (R) values are multiplied. It is generally referred to as the *CR* (or *RC*) value.

It is important to note that the units for C and R must be expressed with the correct orders of magnitude. In the example shown, C (100µF) is expressed in microfarads (100) and R (100kΩ) is expressed in megohms (0·1), resulting in a CR value of 10 seconds (100 × 0·1), as shown to the right of the display.

With a 6V supply, the 63% voltage is 3·78V (6 × 0·63), shown alongside the CR value.

DISCHARGE GRAPH

So, we have illustrated the charging up of your R-C combination. The discharge illustration is similar, but in reverse. Return the time scale value to T = 10 secs, then Press <C>.

The curve now starts high, at 6V and smoothly descends to 0V. It crosses 4V at about 4 secs, 2V at close to 10 secs, and reaches 0V round about 50 secs – just as we predicted earlier, and you were probably close to it with your experiment.

The blue line has changed its position though. The reason is simple, again by convention, it now represents the 63% level *below* the starting voltage or 37% *above* the termination voltage, in this case 6V and 0V respectively.

The rate of change is said to be *exponential*, and in its calculation you ideally need a scientific calculator (and the knowledge of how to use it), because the formula is a bit complex:

Vc = Vs × (1 – EXP(–t / CR))
for the charging rate, and:

Vc = Vs × (EXP(–t / CR))
for the discharging rate

where:

Vc = voltage across the capacitor
Vs = voltage across the capacitor/resistor series
t = elapsed time
CR = time constant
EXP = exponent

You will see these formulae shown, as appropriate, at the top of the graph display.

We are not going to ask you to memorise the formulae or test your knowledge of how to use them. Since you now have a computer program that does it for you, let it do the brain-teasers! The answers for any values not included in the C-R-V-T ranges provided can be estimated from the nearest selected values.

(What you can do more simply, however, is calculate the RC time constant, by multiplying the values of C and R. Do

PANEL 2.2 – CAPACITANCE UNITS

A capacitance value of one Farad is a unit of charge which, in practical terms, is far too large to be useful in everyday electrical and electronic circuits. For convenience, the unit is usually divided and expressed in sub-units, such as:

● ***Microfarads***, being one millionth of one Farad, and usually written as µF (Greek "mu" followed by a capital F), although it is common for it to be written as "uF" or "mF", since many keyboards do not have the Greek symbol readily available. (The use of "mF" is to be deplored because it really means *millifarad* rather than *microfarad*.) It is also common, where the meaning of the term is implied, for it to be written simply as "µ", in component lists for instance. Verbally, these abbreviations are often pronounced as "mew" or "muff". For example, a 10µF capacitor might be referred to as having a value of "ten-mew" or "ten-muff".

● ***Nanofarads***, being 1000-millionth of a Farad and usually written as "nF", although the "F" may be dropped where it is implied in the context. Verbally, the abbreviation might be pronounced "en-eff" or just "en", i.e. a value of 10nF might be pronounced as "ten-en". The use of the term "nuff" is unlikely.

● ***Picofarads***, being one million-millionth of a Farad and usually written as "pF", though again the "F" might be dropped when it is implied. Pronunciation is usually "puff" (as in "stairs puff him out!"), although it might sometimes be heard as "pee", i.e. "ten-pee" for 10pF.

Table 2.1: Capacitor varieties and their typical characteristics

Capacitor	Ceramic	Electrolytic	Metal film	Mica	Polyester	Polycarbonate	Polystyrene	Tantalum	Polypropylene
Capacitance range (F)	2·2p to 100n	100n to 47000μ	1μ to 16μ	2·2p to 10n	1n to 10μ	10n to 10μ	10p to 10n	100n to 100μ	100p to 470n
Typical tolerance (%)	±2 to ±80	−10 to +50	±20	±1	±5 ±20	±20	±1, ±2·5 and ±5	±20	±5 to ±20
Typical voltage rating (d.c.)	50V to 15kV	6·3V to 450V	250V to 600V	350V typical	63V to 400V	63V to 630V	50V to 630V	6·3V to 35V	100V to 1·5kV
Temperature coefficient (ppm/°C)	+100 to −4700	+1000 (typical)	+100 to +200	+35 to +70	−200	+60	−150 to +80	+100 to +1000	−200 (typical)
Stability	Fair	Poor	Fair	Excellent	Fair	Good	Good	Fair	Fair/Good
Ambient Temperature range (°C)	−35 to +85	−40 to +85	−25 to +85	−40 to +80	−40 to +100	−55 to +100	−40 to +70	−40 to +85	−55 to +100

note that the values must be expressed in units of the correct magnitude to achieve a valid answer, as we said a few paragraphs earlier.)

Just for a bit of idle illustration, the circuit diagram for the R-C series is shown at bottom right of the screen. Note how the arrow changes direction and value depending on the charge/discharge mode. The capacitor symbol shown is that for a non-polarised type (see later, plus Fig.2.4), but in reality the symbol should more reasonably be that for an electrolytic when high values of capacitance are used.

We suggest you experiment with different range values on the screen, and if you think you can actually time some of the graphs using your breadboard assembly, set R1 and C1 to the same values as displayed. (Be sure to read Panel 2.3, however!)

In the accompanying Experimental article, we shall tell you about how to combine two or more capacitors to achieve different values. In this Tutorial section, though, it's time to discuss some more facts about capacitors – first have a read of Panels 2.4 and 2.5, and then read on from here.

CAPACITOR SELECTION

Some concepts referred to in this section are likely to be alien to you. Where they are not further discussed here, they will be covered in later parts of *Teach-In*. We have to mention them now as they are relevant to this section – you should re-read it once you have read the future parts. Should we not cover something that you are puzzled by, you can always ask us to clarify it through *Circuit Surgery* or *Readout* pages.

There are several factors to be considered when selecting a capacitor for a particular application, which include:

- Capacitance value
- Working voltage
- Tolerance
- Leakage current
- Temperature coefficient
- Stability

Unless you are involved with a particularly demanding design, it is principally the first two which will concern you, but you should be aware of the following:

When substituting capacitors, either because they have failed in an existing circuit, or because the precise type specified in the components list of a constructional project is not readily available from your normal supplier, it is important to ensure that the replacement performs to a specification which is at least as good as that of the specified component.

PANEL 2.3 – BEWARE THE FORCE!

Do be warned that you should NEVER insert or remove components from a circuit board when the power is switched on.

Whilst this (arguably) is not so necessary to observe with passive components such as resistors and capacitors in a low voltage circuit, active components (to be met later) such as integrated circuits (i.c.s) and transistors can die in such circumstances.

It also important to note that capacitors can hold their charge for a while even after the power is switched off. Ideally, you should allow a few seconds for them to discharge before handling them. With a low voltage supply, such as 6V, this is perhaps not critical. However, with higher voltages, of greater than 30V for example, it is ESSENTIAL that you should allow for the discharge time. To really ensure that a capacitor is fully discharged, CAREFULLY touch a 10kΩ resistor across its +ve and −ve connections for a few seconds – taking great care that YOU do not touch the wires.

We also have to caution you (not as the "Old Bill" but as friendly voices across the page!) – DO NOT use a metal tool (e.g. screwdriver) to short out capacitor terminals for instantaneous discharge. It can be damaging to both the capacitor and the screwdriver (although it does make a nice spark and mini-thunder crack!).

PANEL 2.4 – CAPACITOR TYPES

Capacitors are manufactured as having two very basic characteristics, they are either:

- Polarised, or
- Non-polarised

the latter being manufactured as fixed and variable capacitance types.

In circuit diagrams and constructional charts, a fixed capacitor's numerical identity is usually prefixed by "C", e.g. C21. A variable capacitor may have its number also prefixed by "C", although it is more likely to be prefixed by "VC" (Variable Capacitor), or perhaps "CV" (Capacitor Variable).

Polarised capacitors, as their name implies, are very particular about which side of them is connected to a (relatively) positive voltage. Connecting them the wrong way round can have dire results, a matter which is discussed in the main text. It is polarised capacitors that you have been using so far, sub-type "electrolytic" – this is why we stressed earlier that you should only connect their +ve and −ve leads as shown.

Non-polarised capacitors can *normally* be connected into a circuit either way round, although there are *some* circumstances where the relative position of the output electrode foil is placed in relation to other parts of a circuit. The coloured ends of some polystyrene capacitors, for example, can indicate this type of polarity, although it is not a *true* polarity as referred to with regard to polarised electrolytic or tantalum capacitors. (The author has never had occasion be concerned about this detail, over several decades of doing electronics.)

Capacitors are also manufactured in a seemingly-bewildering array of sub-types, basically named in respect of the nature of the dielectric material used between the plates:

- Electrolytic (polarised)
- Tantalum (polarised)
- Polypropylene (non-polarised)
- Polycarbonate (non-polarised)
- Polyester (non-polarised)
- Polystyrene (non-polarised)
- Metallised film (non-polarised)
- Ceramic (non-polarised)
- Mica (non-polarised) – sometimes called silver-mica
- Trimmers – variable capacitors (non-polarised)
- Air-spaced – variable capacitors (non-polarised)
- Paper – now rare (non-polarised)
- Oil-filled – now rare (non-polarised)

There are also sub-types of the sub-types! Have a look at a major component supplier's catalogue and prepare to be astonished . . . Fortunately, until you are much more into the depths of serious electronics design, the subtle differences between some types need be of little concern.

Typical physical shapes for six capacitor types are shown in Fig.2.6. A summary of the characteristics for the most commonly available types of fixed capacitor is given in Table 2.1.

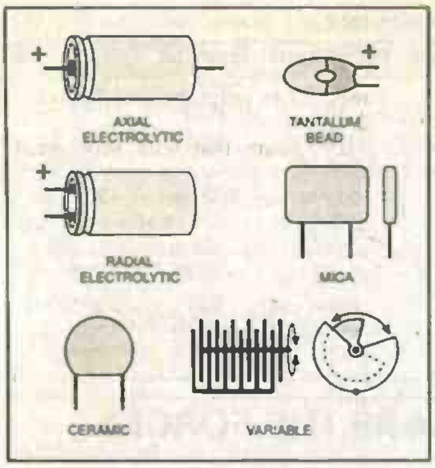


Fig.2.6. Examples of capacitor body styles. Other styles exist.

However, it is quite permissible to replace a capacitor which has a working voltage rating of 15V by one rated at 25V, for instance. The *working voltage* rating simply states the *maximum* voltage at which a component should be operated in normal service. Generally speaking, a higher working voltage rating is nearly always acceptable electronically (physical size permitting, of course). Similarly, a capacitor with a tolerance of 20% can always be replaced by a similar one having a tolerance of 10%. A better tolerance rating is always acceptable electrically.

WORKING TO RULE

It is also important to note that working voltages are related to operating temperatures and at high temperatures (well above "normal" room temperatures) all capacitors should be significantly derated (assumed to have a lower working voltage than that stated). In normal everyday applications, however, this factor is usually irrelevant.

Capacitors should always be operated at well below their nominal maximum working voltages. If a circuit is designed for operation at 9V, for example, a capacitor rated at a working voltage of 9V or 10V should not be used, rather, one rated at 16V or greater should be chosen. Even one rated at 63V, for instance, would be acceptable, provided that its size (which is likely to be greater with increased voltage ratings) is suitable for the circuit board on which it may need to be mounted.

As a rule of thumb, the quoted working voltage rating should be at least 50% greater than the voltage at which the component is required to work in the circuit, although there are occasions, such as in power supply circuits, where a much greater margin should be allowed, possibly even as much as four times the nominal supply voltage.

Where an a.c. voltage rating is specified, this is normally for sinusoidal operation (sine waves) at either 50Hz or 60Hz (Hz, or *Hertz*, is a unit of frequency in cycles per second). Performance will not usually be significantly affected at low frequencies (up to 100kHz, or so), but above this, or when non-sinusoidal (e.g. pulsed) waveforms are involved, the capacitor must be derated in order to minimise losses in its dielectric material which can produce internal heating and lack of stability.

You should also be aware that a sinusoidal waveform normally has its voltage quoted as an r.m.s. (root of the mean square) value, whereas in fact its *peak* value is nearly 50% higher (× 1·41), thus the chosen capacitor's voltage rating must take this into account.

RIPPLE FACTOR

Capacitors used for smoothing and reservoir (substantial storage) applications in d.c. power supplies must have an adequate *ripple current* rating. This rating refers to the a.c. characteristic of the current (at the ripple frequency, e.g. 50Hz for UK mains operated power supplies) which remains after the principal alternating (a.c.) voltage has been rectified to a d.c. voltage.

Without a capacitor following the rectifier, the ripple voltage will be approximately half that of the original a.c. peak-to-peak voltage. It is the job of the following capacitor to smooth out that ripple, a task which is complicated when large currents are demanded by the ensuing circuit. Component data sheets and catalogues will usually quote the typical ripple current rating for the large value capacitors required for power supply use. The chosen ripple current rating should always be greater than the ripple current expected.

Table 2.3. Ceramic capacitor letter coding.

1st Suffix	Tolerance C = <10pF	Tolerance C >= 10pF	2nd Suffix	Rated Voltage
B	±0·1pF	–	A	50V d.c.
C	±0·25pF	–	B	125V d.c.
D	±0·5pF	±0·5%	C	160V d.c.
F	±1·0pF	±1·0%	D	250V d.c.
G	±2·0pF	±2·0%	E	350V d.c.
H	–	±2·5%	G	700V d.c.
J	–	±5·0%	H	1000V d.c.
K	–	±10%	U	250V a.c.
M	–	±20%	V	350V a.c.
P	–	+100%	W	500V a.c.
R	–	+30/–20%		–
S	–	+50/–20%		–
Z	–	+80/–20%		–

e.g. *n 47 KD* = 0·47nF ±10% 250V d.c. (n = nanofarads)

WHICH WAY ROUND?

A most important consideration when using polarised capacitors (e.g. electrolytic and Tantalum), is that they should be connected the correct way round. The positive side of the capacitor must always be connected to the side of the circuit which has, or is likely to have, the highest voltage.

Across power supply lines, this orientation of polarity will always be obvious – the positive side of the capacitor goes to the positive supply line. It is not always so instinctively obvious when the capacitor is

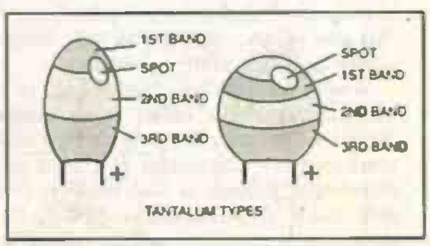


Fig.2.7. Tantalum capacitor colour coding.

PANEL 2.5 – IDENTITY CODING

The majority of capacitors now have their values printed on them, although colour-coded varieties are still to be found. Examples of the colour codes which might be encountered are shown in Table 2.2 plus Fig.2.7. As with resistors, the colours allocated to each numeral from 0 to 9 conform to the standard colour code system.

Where capacitors have their values printed on them, the information may well be abbreviated or allocated a letter coding. Ceramic capacitors, for example, may have their tolerance and voltage ratings coded as in Table 2.3.

A 3-digit coding is commonly used to mark some ceramic capacitors. The first two digits correspond to the first two digits of the value, whilst the third digit is a multiplier which gives the number of zeroes to be added to give the value in pF, e.g. *103* = 10000pF = 0·01μF.

Which brings us to the sometimes misunderstood use of pF, nF and μF. An nF value is 1000 times greater than pF, and 1000 times less than μF. Therefore, the following typical conversions apply to values seen on some capacitors:

1nF (or 1n) = 1000pF
10nF (or 10n) = 10000pF = 0·01μF
100nF (or 100n) = 100000pF = 0·1μF

However, despite all this *possible* coding, with many modern capacitors, their values are normally obvious from the uncoded information printed on them (although you may need a magnifying glass in order to read them).

Table 2.2. Tantalum capacitor colour coding.

Reading from the top, Bands 1 and 2 = Capacity, Spot = Multiplier, Band 3 = Voltage

Colour	*Figure*	*Multiplier*		*Voltage*
Black	0	1	μF	10V
Brown	1	10	μF	–
Red	2	100	μF	–
Orange	3	–	–	–
Yellow	4	–	–	6·3V
Green	5	–	–	16V
Blue	6	–	–	20V
Violet	7	–	–	–
Grey	8	0·01	μF	25V
White	9	0·1	μF	30V
Pink	–	–	–	35V

being used to couple a.c. signals between different parts of a circuit. If in doubt, think about what d.c. levels are likely to exist if the a.c. signal ceases, and face the capacitor accordingly.

There are instances, though, when the polarity of the voltage across an electrolytic might keep reversing (as in some types of oscillator, for example), adversely affecting both the capacitor and the correct operation of the circuit. In this case, two equal value electrolytic capacitors can be used in series, both negative ends connected together, both positive ends facing outwards. The value for each capacitor should be twice the total capacitance required.

If a polarised capacitor is connected the wrong way round, in *extreme* circumstances it can over-heat, causing damage to itself and other components, and in a *really severe* case the capacitor may even explode. At the very least, the circuit may not operate as intended.

POLARITY MARKINGS

Polarity is usually clearly marked, but there are several ways in which it might be done. The ends from which the connecting wires come out may be marked with "+" or "–" signs, or there might be a large arrow pointing to the negative end or to a particular wire (as we discussed at the beginning of this Tutorial). With electrolytic capacitors having a wire at each end (axial construction), the positive end is likely to have a crimp around the casing and the circular face at that end is likely to be a plastic material, often black.

Also, where the lead connections to the capacitor are obvious, the negative lead will be seen to be attached to the outer metal casing of the body. (The "opposite" term to *axial* construction is *radial*, in which both capacitor wires come out from the same end – shown earlier in Fig.2.1.)

Non-polarised capacitors can generally be connected either way round, although there are specialised situations where the orientation in relation to the capacitor's outer foil may be significant (as we comment about polystyrene capacitors in Panel 2.4).

Be aware that with very small polystyrene capacitors, an occasional fault can be experienced in that the leads can become detached internally. It is very unusual, but it can cause the capacitor to develop an open circuit, or a short circuit.

LIGHTLY CHARGED

We suggest you now move on to the Experimental article and just generally play around as suggested there. You can even "lighten" up the experience as well.

Next month we look at components whose values are not rigidly fixed – variable resistors (variable capacitors will be discussed in a later part), and sensor resistors. Herr Georg Ohm and his famous Law also come under scrutiny.

TEACH-IN 2000 – Experimental 2

MEASURING AND CALCULATING CAPACITANCE

In the Tutorial of Part 2, while using different R1 and C1 values on your breadboard to mimic the screen display, you might have come up against a bit of a snag! The screen has specified a C-R combination for which you don't have the component values. Well, actually, you know you can make up the resistor value using serial or parallel combinations, as discussed in Part 1. It's the capacitor values that are the problem.

Fret not! Capacitors too can be combined in series or parallel to achieve other capacitance values. The rules are as simple as those for resistors, except that they are the opposite way round.

CAPACITOR COMBINATIONS

When capacitors are in *series*, as are the three shown in Fig.2.8a, the total capacitance value (C_T) is calculated as:

$$C_T = 1 / ((1 / C1) + (1 / C2) + (1 / C3) + (etc))$$

which is, of course, identical to the resistors in *parallel* formula, except for the letter change.

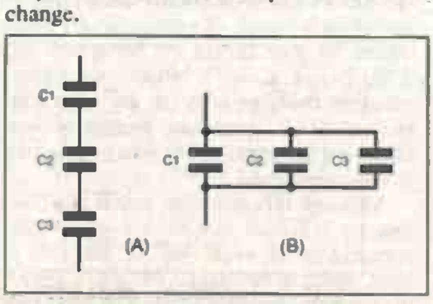


Fig.2.8. Capacitor in series (A), and parallel (B).

For capacitors in *parallel* (as for the three in Fig.2.8b) the formula is simply:

$$C1 + C2 + C3 + (etc).$$

Computer program Capacitors in Series and Parallel, accessible from the main menu, allows you to set the values for two and three capacitors and have the computer calculate the resulting total series and parallel values (see Photo 2.4). There is also a Self-test option allowing you to check your understanding of the two formulae involved.

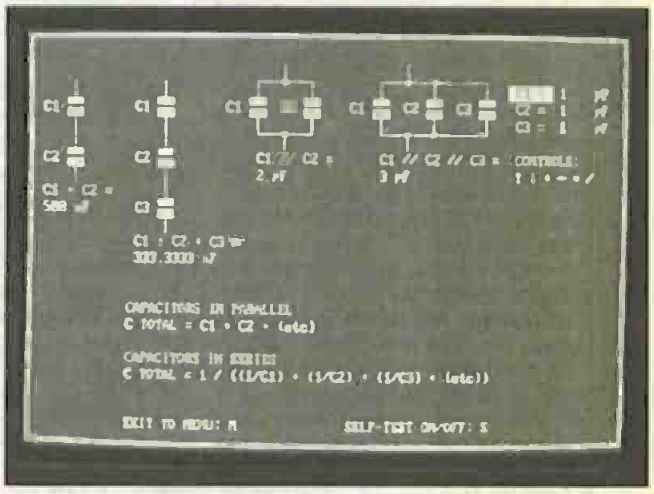


Photo 2.4. Interactive computer screen for calculating serial and parallel capacitor combinations.

PARALLEL TEST

Set up your breadboard as shown in Fig.2.9 (and Photo 2.5), in which three capacitors are shown in parallel (as in Fig.2.8b), where C1 = 100μF, C2 = 47μF and C3 = 2·2μF. This combination is being used in place of the single capacitor (C1) in your Tutorial Part 2 charge/discharge experiment (Fig.2.2 and Fig.2.5). Resistor R1 is given a value of 100kΩ.

Do the charge/discharge experiment, noting the time at the 63% and 37% voltage levels, i.e. 4V and 2V respectively. (You will find it easier to do this experiment if you make up and use another short lead with two crocodile clips on it.)

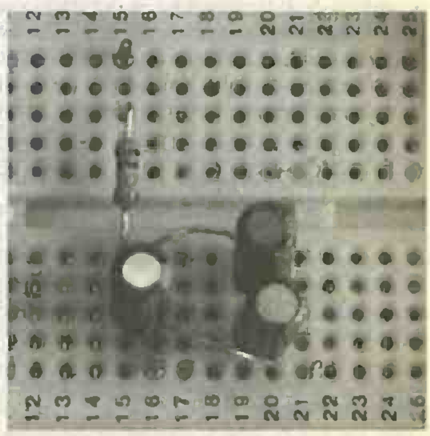


Photo 2.5. Breadboard layout for examining capacitors in parallel.

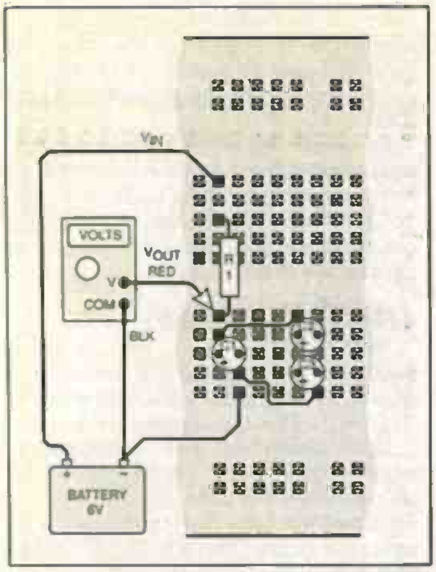


Fig.2.9. Breadboard layout for capacitors in parallel experiment.

Did you achieve timings of about 15 secs at the voltage points? That's the time constant associated with R1 = 100kΩ and C1 = 150µF, the latter being very close to the answer of 149·2µF for C1, C2 and C3 in parallel.

SERIES TEST

Return to your screen graph and set C and R to 150µF and 100kΩ, where you can see the 15 seconds timing when the graph slope crosses the percentage line.

Now calculate the total capacitance if the same three capacitors are connected in series, as shown in Fig.2.8a. If you don't get an answer of approximately 2·06µF, try again.

You won't be able to do the breadboard check with this value, the time-constant is too fast in this instance, but you can use the display to show the graph for the nearest available value of 2·2µF, i.e. 0·22 secs with R1 at 100kΩ. (Later on, you could set up your own experiment using three capacitors in series for which a time constant significantly longer than 0·22 seconds is expected.)

The time constant for 2·06µF (call it 2µF) and R = 100kΩ is actually 0·2 secs. Use your graph display to find out what value of R is needed to achieve that value when C = 2·2µF. We trust you'll find it to be 91kΩ.

SLOWER TEST

On your breadboard, now use just one capacitor, with a value of 220µF (100 times the value of the above 2·2µF), and with the breadboard assembly of Fig.2.2 modified to suit. Testing your knowledge of resistor combinations, replace R1 with a made up value of 91kΩ. Two resistors will do it (within 100 ohms) – what are they and how are they connected? (Refer back to Part 1 if in doubt.)

Now do your time check routine – the time constant should be (ideally) 100 times the above 0·2 secs, i.e. 20 secs.

This now brings us to an interesting point: how do you set an exact time constant without using multiple values of capacitors and resistors? The answer's simple, and there are two ready-made components that help in this, the *variable capacitor*, and the *variable resistor* (more commonly known as the *potentiometer*). The latter we shall investigate next month.

LIGHTING UP TIME

We are again going ask you to use a light emitting diode (l.e.d.), as we did in Part 1. We are also asking you to use an *inverting logic gate* (also known as a *NOT* gate). You'll be told more about both devices on another occasion, but you don't need to fully understand them if you use them as we now tell you.

The l.e.d., as you discovered in Part 1, is a neat little device that glows when a voltage is connected across it in a specific direction via a suitable resistor.

It is important that the resistor should be used since the l.e.d. cannot survive if more than about 2V is connected across it. You are about to use it with a 6V supply, and the resistor has to drop the voltage to an acceptable level. In this instance we want you to use a 470Ω resistor, as we did previously.

What we want to do is use the l.e.d. (call it D1) to indicate when a certain voltage has been reached on a charging or discharging capacitor. The problem is, though, that the time constant when a 470Ω resistor is used is too short for the capacitance values you can realistically select.

We need, therefore, to use a technique which allows a reasonably long time constant to be set, and still to provide enough power to drive the l.e.d. via a 470Ω resistor (call it R2).

This is where the logic gate (call it IC1a) is used – as a type of amplifier. Amongst your bag of parts you'll find some black "caterpillars" with 14 legs, seven-a-side. Find one marked 74HC04. There are likely to be lots of other forms of marking as well, but somewhere you should be able to discern the 74HC04 identity.

The 74HC04 and the l.e.d. are examples of components that belong to the general class known as *active* devices (as opposed to the general class called *passives*, of which resistors and capacitors are examples). Like the l.e.d., the 74HC04 is another member of that enormous family of components referred to as *semiconductors*. It also belongs to a sub-group of that family, generally known as *integrated circuits* (often abbreviated to *i.c.s*). More particularly, it is a *digital logic* i.c.

SEMICONDUCTOR HANDLING

As with electrolytic capacitors, by far the vast majority of semiconductors can only be connected to a power supply in one direction. Many can die if connected the wrong way round. Even if they don't die, they will not work correctly. This is equally true for a 74HC04.

Always connect semiconductors and other active devices into a circuit in the manner specified in circuit diagrams, constructional layouts or data sheets. Always ensure that the circuit's power supply is switched off before inserting or removing them.

One further cautionary note: You will be aware that you can sometimes generate sparks when combing your hair or taking off a sweater. This is caused by the discharge of static electricity which can build up on some substances, including your body and that of animals, frequently by the action of friction in a dry atmosphere. Such discharges, if they occur when you touch some semiconductors can kill the devices – the level of voltage discharge being greater than the device is designed to handle.

To avoid this happening, it is advisable to *touch an earthed bare metal object immediately prior to handling integrated circuits*. A water pipe is a suitable object, as is the exposed bare metal work of an item of *earthed* mains powered equipment. When i.c.s have been supplied in a black plastic foam, or bag marked as being "static sensitive", leave devices where they are until needed. Then keep the handling of their legs to a minimum.

The author reassures you, however, that for all the years he has been handling i.c.s, he cannot remember killing one with static electricity. They are very robust, especially those manufactured over the last decade or so.

We shall discuss static electricity further in a future part of *Teach-In*.

INVERTER GATE

The 74HC04 device is known as a *hex* (six) inverter gate – in other words it has six inverter gates within it, all usable separately. It's pinouts are shown in Fig.2.10, where the symbols within the outline are those for inverter gates.

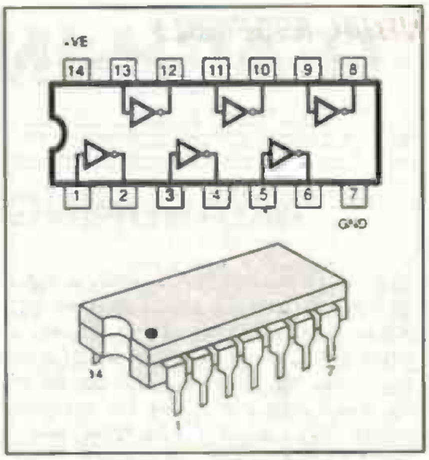


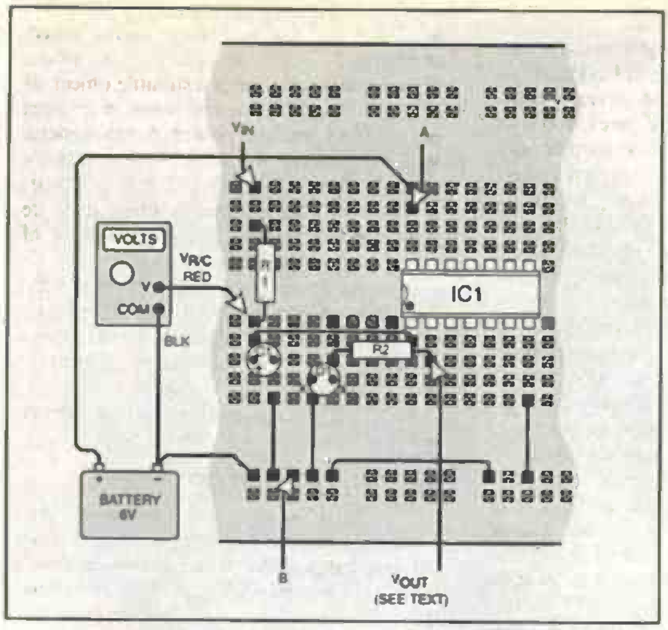
Fig.2.10. Pinouts and typical case style for 74HC04 hex inverter gate. Note the inversion gate symbols within the pinout drawing.

An inverter gate, as you will be told when we discuss digital electronics in a later part, has an output that is at a level called *Logic High* when its input is at a level called *Logic Low*, and vice versa.

So what's Logic High and Logic Low? Well, in this instance, *High* refers to +6V (the power supply voltage level) and *Low* is simply 0V. The two terms are respectively also known as *Logic 1* and *Logic 0*.

The logic gate, though, does not have to have exactly 0V or +6V on its input for the output to respond. There is a range of voltage levels below which the gate thinks it's being provided with Logic 0, and there's range of voltage levels above which the gate thinks it's being provided with Logic 1. In a region somewhere between those two levels, the gate tends to get a bit confused and may keep changing its mind about what logic level it's being offered.

Although this dithering would be a problem in a digital circuit, it's of no great importance for what we are going to do here, which is to connect the gate's input to the resistor-capacitor series you have been charging and discharging.



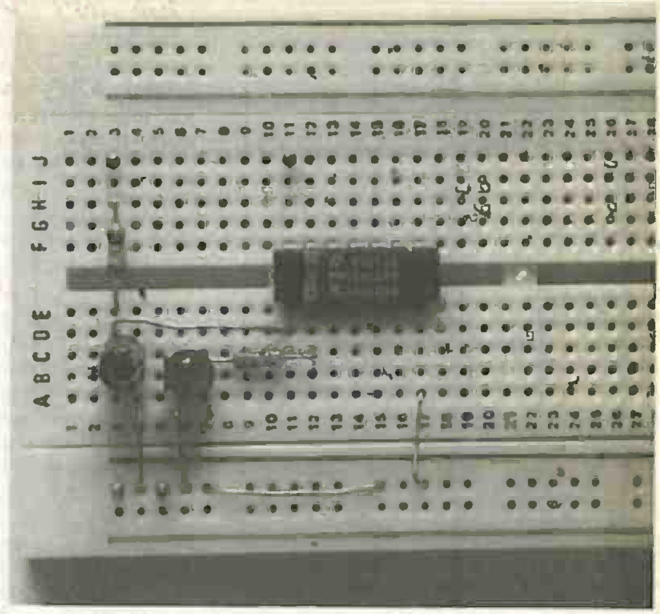


Fig.2.11 and Photo 2.6, breadboard layout for the first timing experiment using an inverter gate.

INITIAL ASSEMBLY

Connect up your breadboard as shown in Fig.2.11 (see also Photo 2.6). Note two things in particular: the position of the flat side on the l.e.d., and the position of the "notch" (or dot/dimple, on some devices) of the 74HC04. (See also *Practically Speaking* on page 834 last month – Nov '99.) The circuit diagram for this component configuration is shown in Fig.2.12.

Now perform some more capacitor charge/discharge experiments. You will see that the l.e.d. is on when the capacitor voltage is fairly low, and off when the voltage is fairly high. You may find that the l.e.d. blinks a bit between the two levels – this is due to IC1 not being sure of its input logic level. The effect is more likely to be seen when the time constant is really slow.

See if you can establish what the capacitor voltage is when the l.e.d. on-offness fully changes from one state to the other.

MORE L.E.D.S

Just for fun, connect up another inverter gate (IC1b) and five more l.e.d.s (D2 to D6)

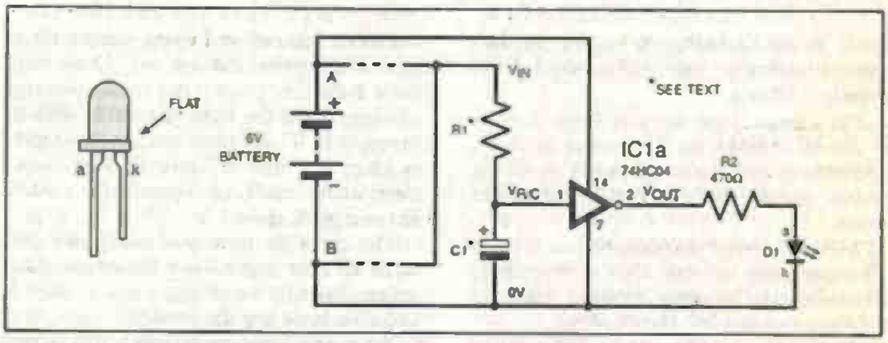


Fig.2.12. Circuit diagram for the experiment in Fig.2.11, plus (left) pinouts for a typical l.e.d (light emitting diode).

plus the extra resistors (R3 to R7 – also of 470Ω) as shown in Fig.2.13.

Now you will find that D1 and D2 alternate in their on-off states. This is due to D2 being connected to the +6V power supply, whereas D1 is connected to the 0V line.

The action of D3 and D4 will be seen to be the opposite of D1 and D2 (as will D5 and D6). Which brings us to an interesting point about inverter gates. When two are used in series, as done here, a double inversion occurs and so the final output logic level is the same as seen by the input to the first gate.

What we'd also like you to do is to make a note of the voltage that actually occurs at the junctions of the l.e.d.s and their respective resistors. Also note the voltages at the outputs of the two gates – do they actually reach 0V and +6V?

What affect do two l.e.d.s have on the output voltages of the gates? Compare with the voltages produced without l.e.d.s connected. We shall discuss this in another Tutorial. Also see if you can draw the circuit diagram for Fig.2.13.

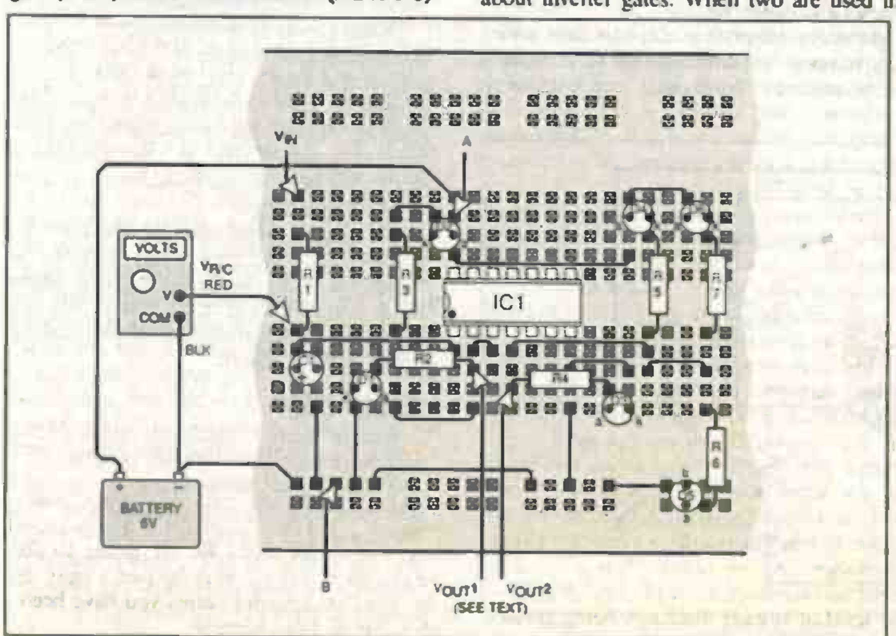


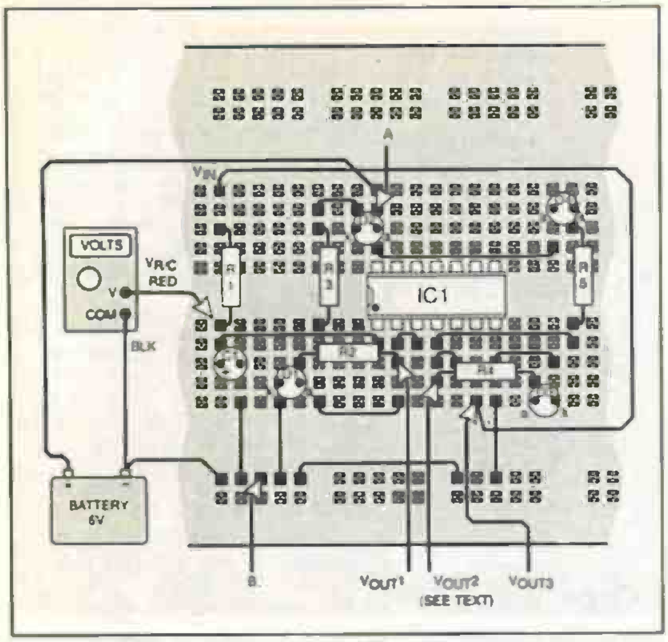
Fig.2.13. Breadboard assembly of Fig.2.11 modified to include five more l.e.d.s.

FLASHY

We wonder if you realise how easy it is now to put the capacitor charging/discharging under automatic control for perpetual repetition of the cycles? One way to do it, using an additional inverter gate, IC1c, is shown in the circuit diagram of Fig.2.15 (we'll discuss the change of i.c. type number from 74HC04 to 74HC14 in a moment).

Using the values shown, reconstruct your breadboard assembly as illustrated in Fig.2.14 (deleting D5, D6, R6, R7), and still using the 74HC04 device. Note that a crocodile-clipped link is made between point Vout3 and Vin. See also Photo 2.7.

Connect up the power. What you should see now is that all four l.e.d.s appear to be glowing, but at a reduced brilliance level. In fact, they are all rapidly switching on and off, but too fast to differentiate between



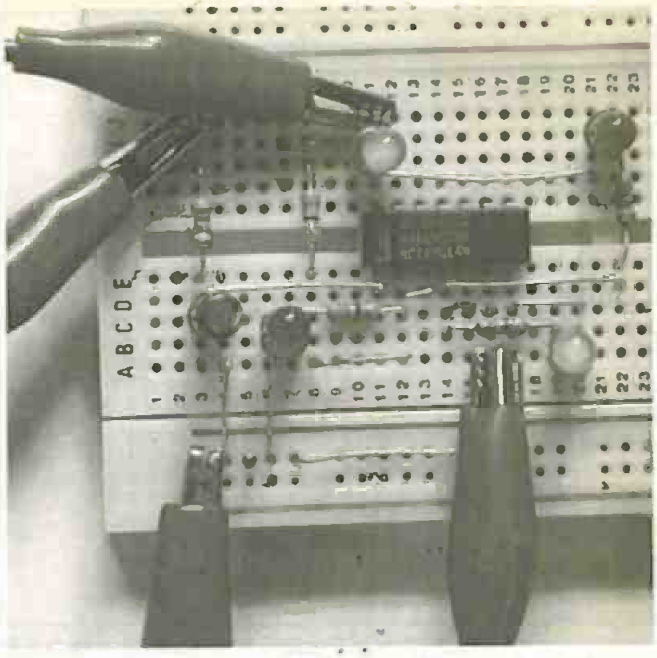


Fig.2.14 and Photo 2.7, layout for the oscillator experiment, (Fig.2.15). Note the new link between IC1 pins 4 and 5.

them. In the author's test model, the rate was in excess of one million cycles per second (1MHz)!

The clever thing we/you have done is to use IC1c to invert the output of IC1b, and then to use the output of IC1c as the power supply for the resistor-capacitor chain.

With the correct combination of R1 and C1 values, this has the effect of repeatedly switching the voltage feeding into R1 between +ve and 0V. Here's why:

When power is first switched on, the voltage at the input to IC1a and the output of IC1b will be low (double inversion), and the output of IC1c will be high (another inversion). This output is now supplying +ve to R1, and C1 starts to charge up (as it did when you connected it directly to the +ve voltage line).

We said earlier that inverter gates have a threshold voltage above which an input level of Logic 0 is assumed. Eventually, as C1 continues to charge, the voltage at the input of IC1a will rise above the threshold, and IC1a's output will fall to Logic 0. As a result, the output at IC1b will immediately go high, and the output of IC1c go low.

This action, in an instant, causes C1 to start *discharging* through R1. Eventually, there comes the point when the discharging voltage falls to the Logic 0 level as seen by the input to IC1a. It now once more switches its output back to Logic 1, IC1b output switches back to Logic 0, and IC1c switches to Logic 1 again.

The cycle has now been completed, and starts all over again. Thus it continues, ad-infinitum, until something stops it, such as you disconnecting the power!

What you have created with this simple component arrangement, is an *oscillator*.

For interest, try to take a voltage reading at IC1c pin 6. You will find that is probably extremely erratic, although it may indicate a voltage at around the 3V mark (half-way between the 6V battery supply and 0V).

SCHMITT TRIGGER

As the circuit stands, its frequency of oscillation is somewhat unpredictable. We said earlier that the 74HC04 has a midway input voltage level range in which the inverter is not too sure which logic level is being applied to it. It is at this midway level that the circuit is rapidly switching over from one state to another. What we ideally need is for the circuit to switch over only at the input levels which are *guaranteed* to be Logic 1 and Logic 0.

To achieve this exactitude with an ordinary inverter gate such as the 74HC04 would require the use of additional circuitry. However, there is a similar inverter type which automatically responds only to those input voltages which are at the *guaranteed* logic levels, ignoring those input voltages which lie between the two thresholds. Such an inverter is known as a *Schmitt trigger* inverter.

One type of Schmitt trigger inverter is the 74HC14 which, like the 74HC04, has six inverters within it and its pins are arranged in the same order. Note the symbol within each of the inverter outlines in Fig.2.15 that indicate its Schmitt trigger status.

With power disconnected, find a 74HC14 device from your bag of components and substitute it into the 74HC04 position on your breadboard.

When power is re-applied, you will see a considerable difference in the rate at which the l.e.d.s now flash. Indeed, you should be able to count the flashes quite readily. This dramatic change in the flash rate is entirely due to the switchover occurring only at the guaranteed Schmitt trigger logic levels.

Using your meter you can now track the voltage level at the R1/C1 junction at which the logic changes occur. Also meter the output of IC1c (pin 6 – Vout3). You will see that it is repeatedly switching between Logic 1 and Logic 0.

TIME OUT

Before Part 3, think up some timing and capacitor value situations and see if you can solve them using the various software options and a calculator. Also see if you can get the oscillator to run so that its output at IC1c changes at exact intervals of your choosing, say once per second or once per 10 seconds. Until next month, 'bye for now.

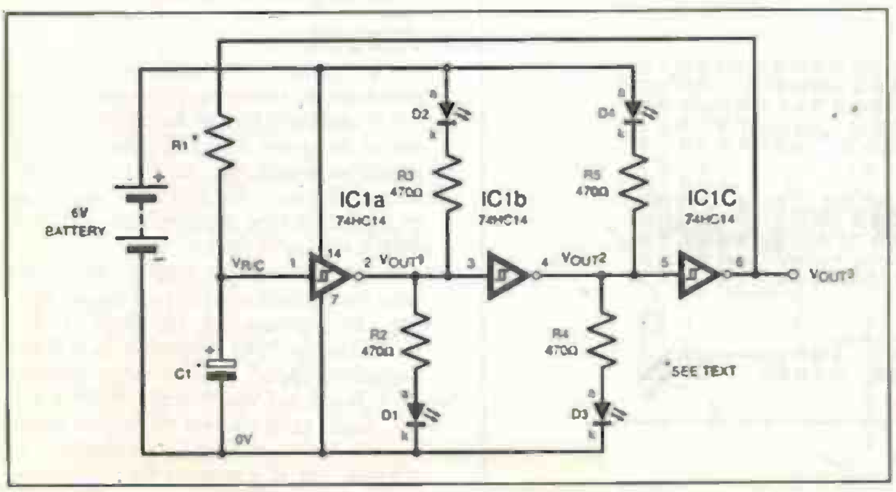
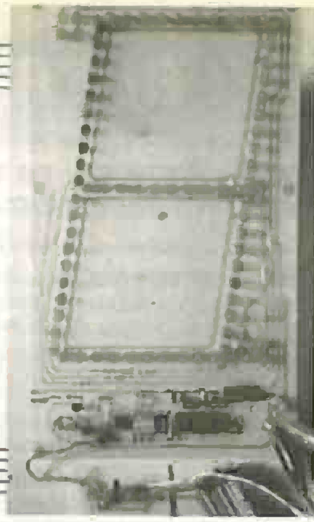


Fig.2.15. Circuit diagram for the oscillator experiment.

GINORMOUS STOPWATCH

NED STOJADINOVIC Part 2



Now you're "up and running", why not add some Giant Displays to your events Stopwatch.

This Large Digit Display unit was originally designed for use with the *Ginormous Stopwatch* module presented last month. It has 178mm (7-inch) characters and can use high brightness l.e.d.s for dazzling daylight performance.

It can also be driven from a standard computer *serial* port with the optional adapter, allowing it to be used as a scoreboard, bingo number display, clock, etc.

CIRCUIT OVERVIEW

The heart of the circuit is a PIC16C54 microcontroller and this has two relatively simple tasks. The first is to receive serial data from the *Stopwatch* module or computer serial port. The data reaches the micro via an optoisolator (IC4), as discussed in Part 1, and the individual digit modules can be daisy chained together up to a maximum of 16 modules.

The software responds to all 16 addresses but the *Stopwatch* module only uses seven of them. However, when driven from a computer using the Serial Port Converter, the Large Digit Display units will respond to all 16 addresses.

The second task is to switch on the various segments on the display to form the digits 0 to 9.

SOFTWARE

In keeping with the author's stated objective of designing without designing, he used two pieces of software from the Parallax web site at www.parallaxinc.com. These were from application notes concerning receiving serial data and utilising a jump table to display digits on a 7-segment display. Readers are referred to these notes.

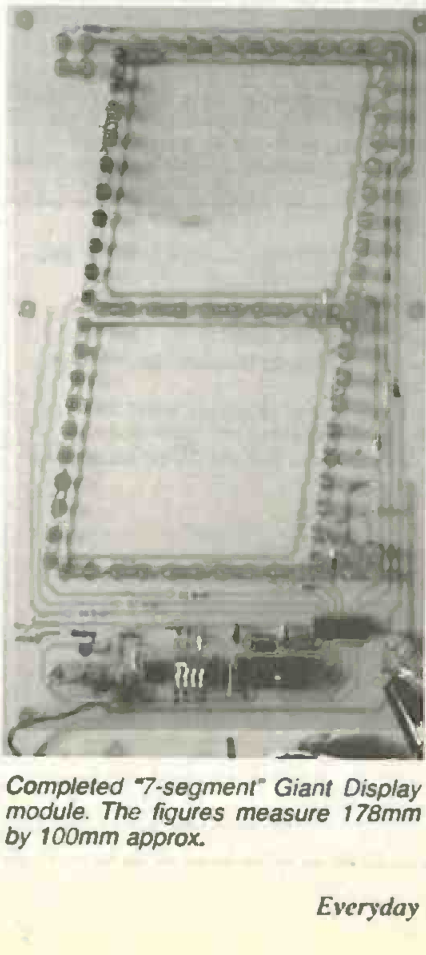
It is interesting to note that it was easiest to choose the same crystal frequency as the *Stopwatch* module (3·2768MHz). This allowed the author to play with the software's "bit_k" constant without worrying about serial link compatibility between the *Stopwatch* and Large Digit modules.

Of course, large display modules that are to be driven by a computer must comply with the standard computer baud rates and everything has been standardised at 9600 bits/sec.

It was necessary, though, to come up with a protocol to address the correct module and tell that module what number to display. This turned out to be quite easy, and it can be done in one byte.

First, consider the number to be displayed. In binary you need four bits to display the digits 0 to 9, like this:

Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001



Completed "7-segment" Giant Display module. The figures measure 178mm by 100mm approx.

Actually, four bits will allow you to count from 0 to 15 (binary 1111), but we only need to count up to 9. Let's call these bits "n", as in "nnnn". Similarly, four bits will allow us to have modules numbered from 0 to 15, call these bits "d".

Computers and PIC micros like to deal in bytes, which are eight bits, so the software makes the "nnnn" and "dddd" bits into artificial bytes:

dddd becomes dddd0000, which is one byte

nnnn becomes 0000nnnn, which is another byte

The two bytes are ORed together (inclusive-OR) bit by bit to form a single byte which looks like ddddnnnn. This single byte contains both the module number and the digit to be displayed.

For example, to make module 1 display the number 1, the output byte would be 00010001. To make module 2 display the number 1 it would be 00100001.

CIRCUIT DIAGRAM

Referring to the circuit diagram in Fig.1, data is received via the optocoupler IC4. The driving device (e.g. the *Stopwatch*) switches an l.e.d. inside the optocoupler on and off and the light from its l.e.d. shines onto an optotransistor, switching it on and off in unison.

Resistor R1 holds the output of IC4, pin 5, at 5V until the transistor switches on and shorts pin 5 to ground. Pin 5 is connected directly to the PIC microcontroller IC2 at its pin RB7, which is set up as an input pin.

When output pin 5 of IC4 is at 0V, it switches on transistor TR1 and, via current limiting resistor R3, causes current to flow through optocoupler IC4 of the *next* digit module. In this way the modules are daisy-chained one to the next.

Dual-in-line switch S1 to S4 is used to set the digit's module address number by placing the relevant code on the PIC's RA0 to RA3 data pins. Pins RA0 and RA1 are normally held at 0V via resistors R4 and R5; pins RA2 and RA3 are normally held at 5V via resistors R6 and R7. This method of biasing was done simply to make the board design easier and the software takes it into account. When the appropriate switch is closed, the logic level seen by pins RA0 to RA3 is inverted

The status of the switches is read whenever a serial data byte is received by the

PIC via its RB7 input. The 4-bit status code forms the "dddd" bits referred to earlier.

DISPLAY

Pins RB0 to RB6 of the PIC are used as the 7-bit output to the seven sets of 10 l.e.d.s that make up the seven segments of the display. The PIC16C54 cannot by itself handle the current required by the l.e.d.s and so IC3 acts as an intermediary buffer.

This device is a rugged little chip intended as a solenoid driver and can handle almost 50V and 500mA, and is nice and cheap as well. It is essentially seven open-collector Darlington transistors that can be turned on and off by the 5V and 0V logic level voltages from the PIC.

The l.e.d.s are arranged in pairs in a series/parallel arrangement, meaning that one pair is connected in series with the next pair. There is a voltage drop of nearly 2V across each l.e.d. or pair of l.e.d.s in a parallel arrangement and the five pairs are arranged in series.

Thus the five pairs will drop the 12V supply by 5 × 2V, or about 10V, leaving the ballast resistor with 2V (12V – 10V) to reduce to zero. The l.e.d.s run well at about 20mA and so a simple application of E = IR gives a value of 100 ohms for the ballast resistors.

The value of the ballast resistor is not critical and the l.e.d.s will put out good light from about 10mA to some 30mA, which is the maximum for most l.e.d.s. If you need to save power, try putting in 220 ohms ballast resistors and see how the light output looks.

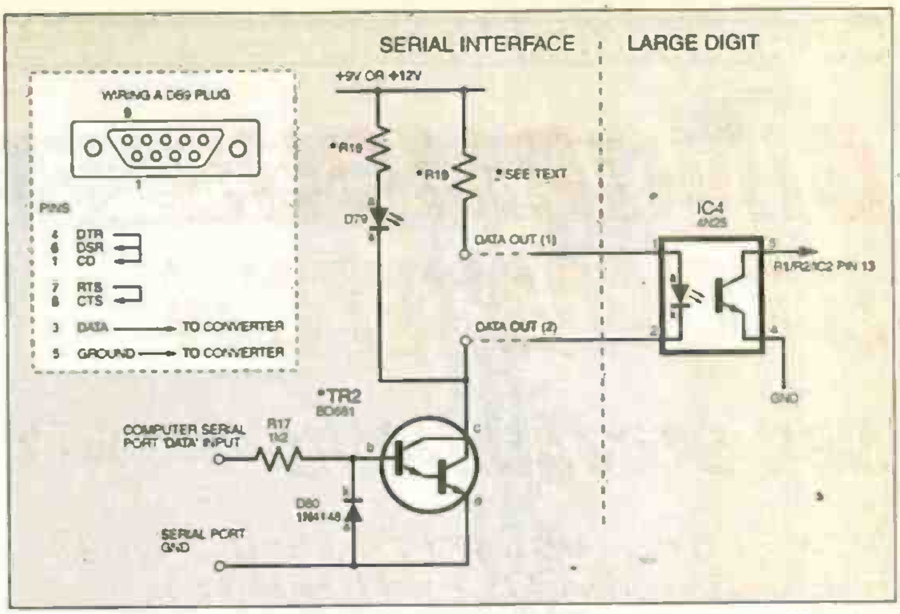


Fig.2. Circuit diagram for a simple Serial Port Converter Interface add-on. The values of resistors R18 and R19 should be 330 ohms for 9V and 560 ohms for 12V.

The decimal point and colon l.e.d.s are done the same way except that the l.e.d.s are all in series as there are not as many of them. These l.e.d.s are not controlled in any way and are simply connected across the 12V power supply, via limit resistors R15 and R16, constantly remaining on while the power is on.

SERIAL PORT CONVERTER

The digit modules can also be driven from a computer serial port with the aid of a converter module interface (see Fig.2). This is simply a Darlington transistor switch (TR2) which converts the ±15V signals from the serial port to voltages of the correct polarity to drive the optocouplers.

The transistor also provides the reasonably heavy current required by optocouplers connected in "star" configuration (see the last section of this article).

The converter has its own power supply because it has to provide power to the internal l.e.d.s of the optocouplers. The battery used can be 9V or 12V merely by changing resistors R18 and R19. The values should be 330Ω for 9V and 560Ω for 12V.

The converter also has an l.e.d. on board (D79) to indicate serial port activity and is a great help for trouble shooting.

CONSTRUCTION

The printed circuit boards for the Large Digit Display and optional computer Serial Port Converter Interface board are available from the *EPE PCB Service* page, codes 247 and 248, respectively. The component assembly and track layout details for the boards are shown in Fig.3 and Fig.4.

There is nothing difficult about the construction but the l.e.d.s are, as may be expected, rather tedious. It is suggested that you test each segment as it is finished.

Start assembly of the Large Display board (Fig.3) with the top right segment. Insert all the l.e.d.s and make sure that they are all the correct way around, noting that some high brightness l.e.d.s have different orientations to those of ordinary l.e.d.s. If

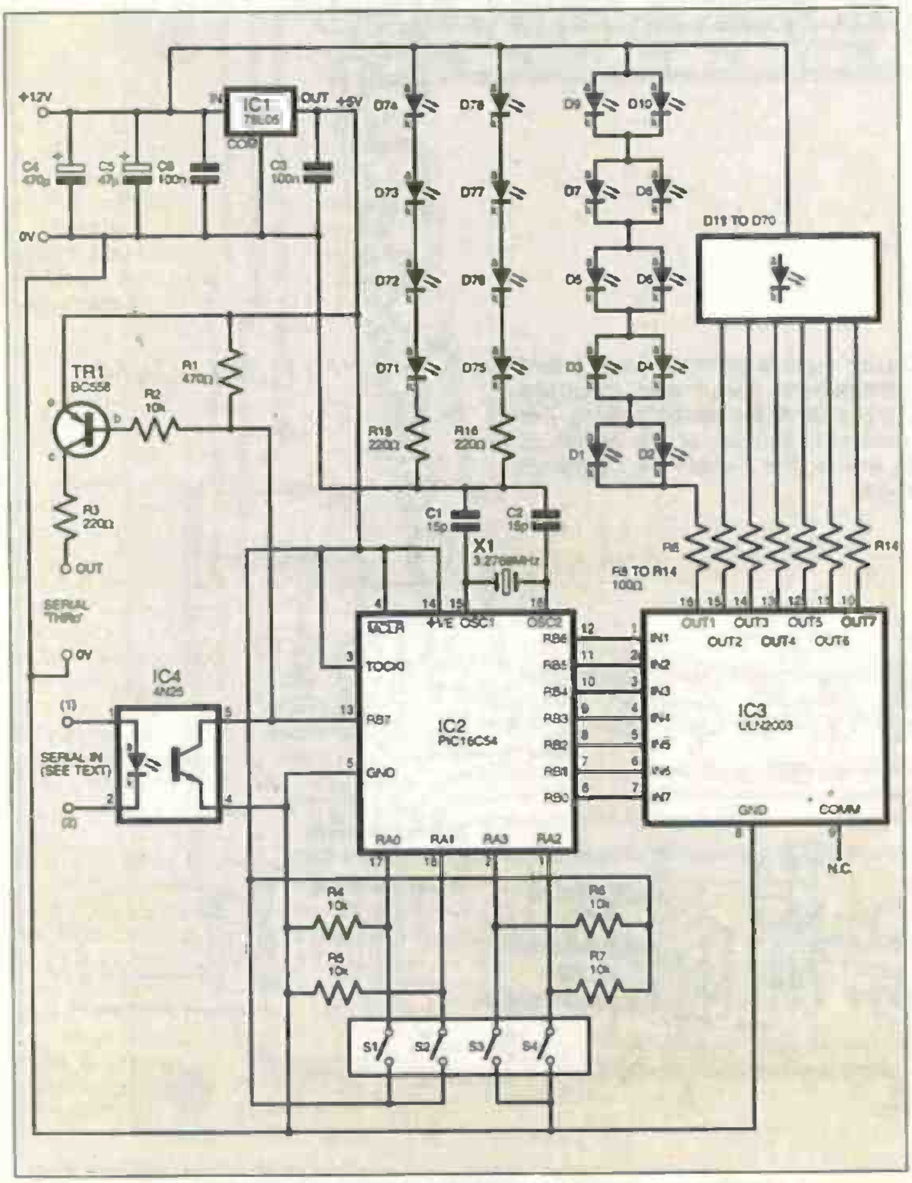


Fig.1. Circuit diagram for the Giant Digital Display module.

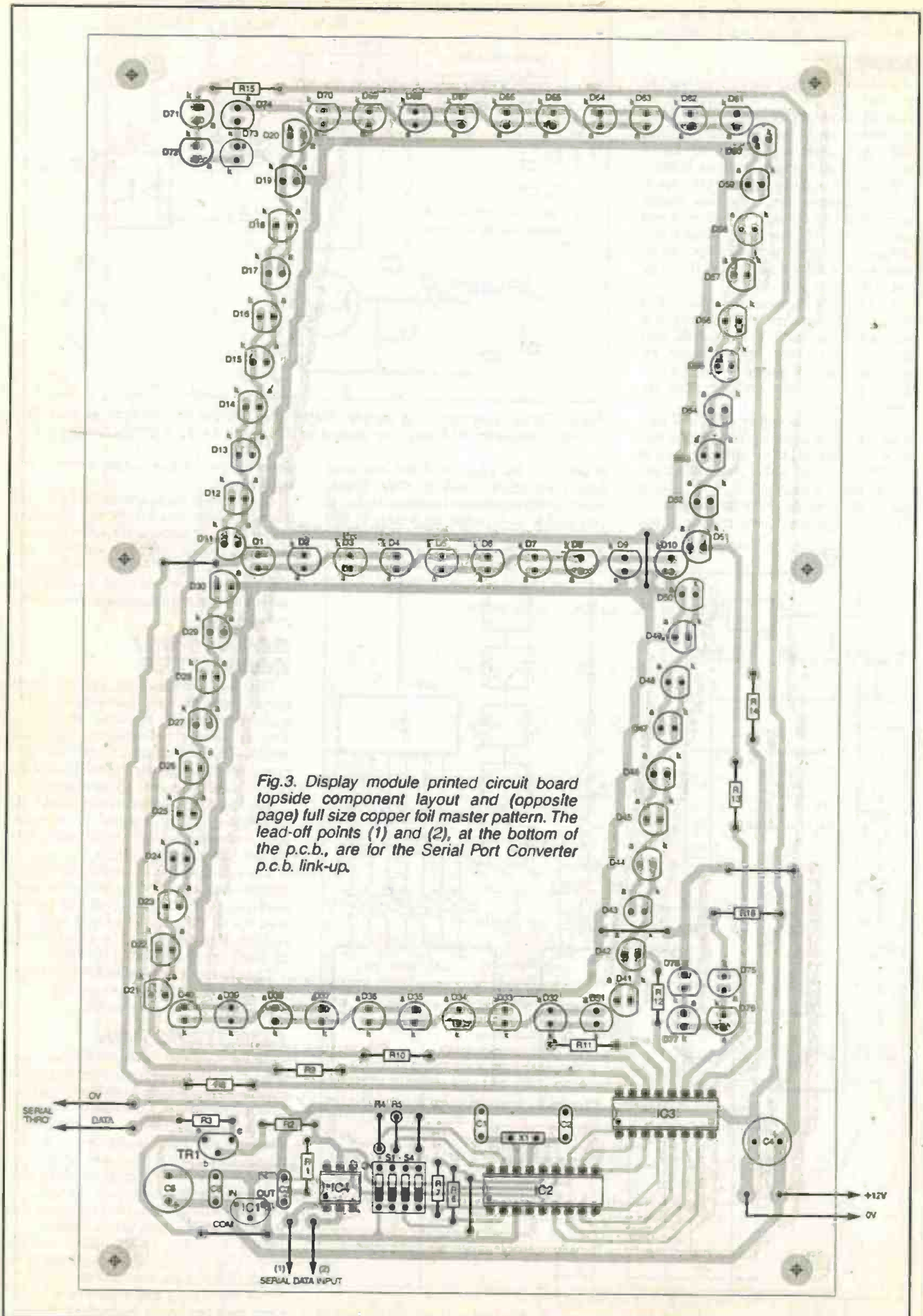
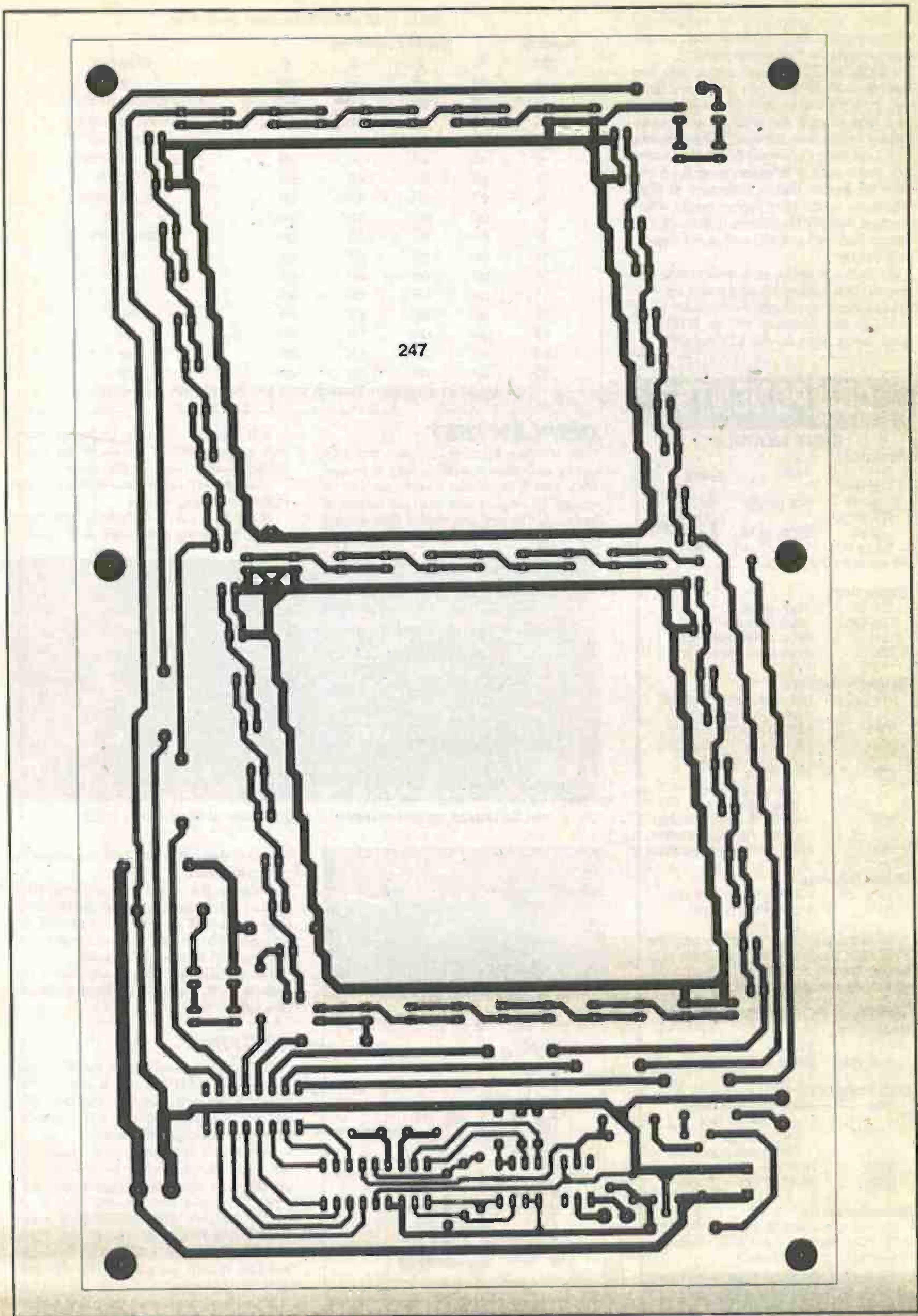


Fig.3. Display module printed circuit board topside component layout and (opposite page) full size copper foil master pattern. The lead-off points (1) and (2), at the bottom of the p.c.b., are for the Serial Port Converter p.c.b. link-up.


247

in doubt, you can check by temporarily connecting the l.e.d. in series with a 1kΩ resistor across a 12V power supply.

Flip the board over and solder only one lead of each l.e.d. When you have done that, go back and grasp both leads of each l.e.d. and re-melt the solder while gently pulling upwards on the leads. This will seat each l.e.d. onto the circuit board and generally make sure it is pointing straight out from the board. This is important as high brightness l.e.d.s only appear bright when you look directly onto them, if they are tilted they look dull and this makes the display look patchy.

Go back and solder each second lead and give the first soldered lead a touch up with fresh solder if necessary. Now solder in all of the ballast resistors (R8 to R16) and some power leads for the 12V supply.

COMPONENTS

DIGIT MODULE

Resistors
R1 470Ω
R2, R4 to R7 10k (5 off)
R3, R15, R16 220Ω (3 off)
R8 to R14 100Ω (7 off)
All resistors 0·25W 5%.

See SHOP TALK page

Capacitors
C1, C2 15pF ceramic
C3, C6 100n ceramic
C4 470µ radial elect. 16V
C5 47µ radial elect. 10V

Semiconductors
D1 to D78 red l.e.d., 5mm, normal or high brightness
TR1 BC558 *pnp* transistor
IC1 78L05 +5V 100mA voltage regulator
IC2 PIC16C54 microcontroller, preprogrammed
IC3 ULN2003 7 x Darlington driver, common emitter
IC4 4N25 or 4N28 optoisolator

Miscellaneous
S1 to S4 4-way d.i.l. on/off switch
X1 3·2768MHz crystal (see text)

Printed circuit board, available from the *EPE PCB Service*, code 247; 6-pin d.i.l. socket; 16-pin d.i.l. socket; 18-pin d.i.l. socket; connecting wire; solder, etc.

SERIAL PORT CONVERTER

Resistors
R17 1k2
R18, R19 330Ω for 9V, 560Ω for 12V

Semiconductors
TR2 BD681 (or equivalent, e.g. TIP141 or TIP142) *npn* Darlington transistor
D79 red l.e.d., 5mm
D80 1N4148 signal diode

Miscellaneous
Printed circuit board, available from the *EPE PCB Service*, code 248; connector to suit serial port lead used.

Approx. Cost Guidance Only **£35** *(Standard l.e.d.s)*

Table 1: Module Selection Switches

Module No.	Switch Settings 1	2	3	4	Display
0	off	off	off	off	★
1	off	off	off	on	hundredth seconds
2	off	off	on	off	tenth seconds
3	off	off	on	on	seconds
4	off	on	off	off	ten seconds
5	off	on	off	on	minutes
6	off	on	on	off	ten minutes
7	off	on	on	on	hours
8	on	off	off	off	ten hours
9	on	off	off	on	★
10	on	off	on	off	★
11	on	off	on	on	★
12	on	off	off	off	★
13	on	on	off	off	★
14	on	on	on	off	★
15	on	on	on	on	★

★ Used in computer version with the Serial Port Converter.

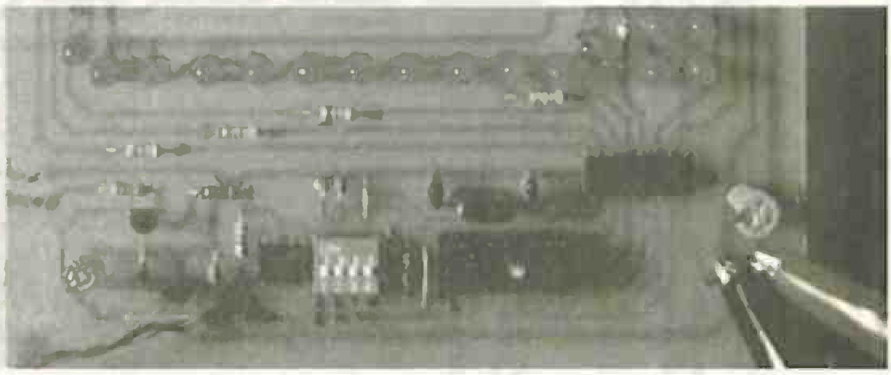
DISPLAY TEST

To test the segment, connect the 12V supply and connect a flying lead to ground (0V). Touch the flying lead to the end of resistor R13 that is nearest to the bottom of the board. The segment should light up nice and bright.

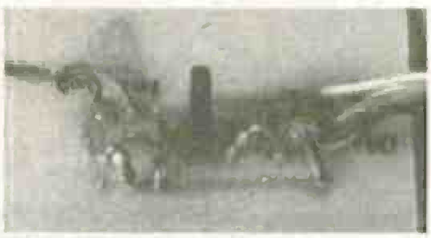
If it does not, look for l.e.d.s the wrong way around, broken tracks, or the wrong ballast resistor value, in that order.

If all is well, continue inserting l.e.d.s, testing, inserting, testing...

If any l.e.d.s are a tight fit at their skirts, gently file down their sides until there is room for them to sit without colliding with their neighbours.



Completed control and power supply area of the Display p.c.b.



Because the colon and decimal point l.e.d.s are intended to be permanently turned on, they (and/or their ballast resistor) should be omitted if those functions are not required on any of the boards.

Put in all the other components and sockets for IC2 to IC4, but do not install the i.c.s yet.

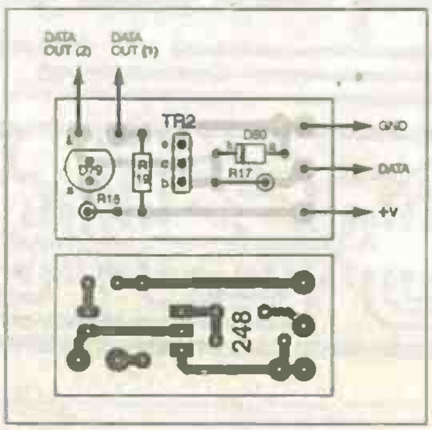


Fig.4. Printed circuit board details for the Serial Port converter.

TESTING

Power up the board and at the IC2 socket test for 5V and 0V at pins 5 and 14. This will test the power supply regulator IC1, and will also show up any solder splashes or broken tracks to these pins.

Switch off the power and insert IC3, the l.e.d. driver device. To now test the operation of the various segments, take a flying lead and connect one end to 5V, say to the link wire immediately below IC1. Touch the other end of the flying lead in turn to pins 1 to 7 of IC3's socket and you should see each of the segments light accordingly.

If you have connected the colon or decimal point l.e.d.s, they should have turned on when you applied the power.

Now power down and carefully put the PIC (preprogrammed, of course) into its socket, being very careful about orientation. Remember that it is a CMOS chip and so be sure to briefly ground yourself to discharge static electricity before handling it. Also insert IC4.

Turning on the power should now give you a nice big figure "0" and if not, immediately power down and start looking for causes. The *Stopwatch* article last month has some tips on troubleshooting this type of circuit.

If you are using the *Stopwatch* module, connect it to one digit board via a handy length pair of leads, being careful to connect signal and ground wires the correct way around. Select the module address number via the d.i.l. switch (S1 to S4) as per Table 1. Note that the software "knows" that switches S3 and S4 are connected in order of RA3 and RA2 (instead of RA2 and RA3 as might be expected).

Power up both boards and start the Stopwatch. This should immediately start the digit board displaying the selected time unit. If it just sits on "0", use a logic probe or similar to test for a fast changing signal on pin 5 of the optocoupler, IC4.

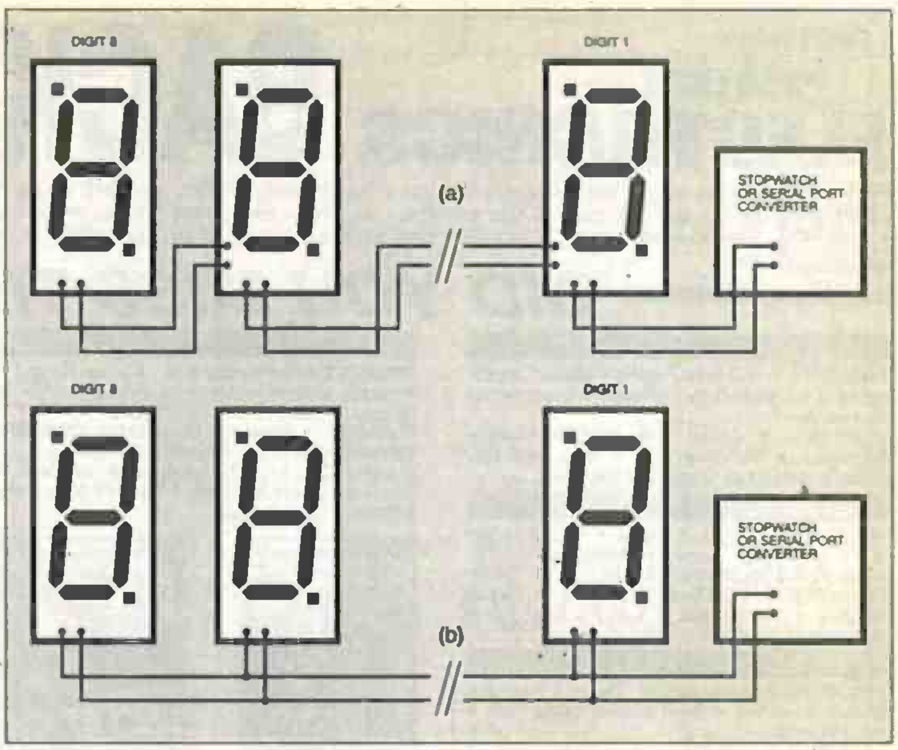


Fig.5. Suggested method of connecting the Giant Display modules to the Stopwatch (Part 1) or Serial Port Converter. (a) In "daisy chain" fashion or (b) "star" configuration.

PORT INTERFACE

If using the Serial Port Converter, connect up the digit board and power as above. Now run the QBASIC demo program, making sure that the module d.i.l. switches are all off. Put in a different switch setting from the list each time you run the program and the module should immediately display the correct number.

You will know if the converter is working by observing its l.e.d. Whenever serial data is being transmitted it will flash quite noticeably.

STAR CONNECTION

The digit modules are designed to be hooked up in "daisy chain" configuration, see Fig.5a, and this should work well in most cases. It is possible, especially when many modules are used for the signal to get a bit lost in its trip down the chain; remember the design allows up to 16 digit modules to be used.

In this case, use the "star" configuration in Fig.5b where the driver transistor in the Stopwatch or Serial Port Converter switches all of the optocouplers directly. Note that this will put quite a strain on the battery of the Serial Port Converter or *Stopwatch* module as it now has to power all of the optocouplers at the same time.

To select a battery size, assume that each module uses about 15mA when running and plan accordingly. For example, 10 modules times 15mA is 150mA and so a battery of 1·2Ah (amp hour) capacity will drive the display for eight hours.

COMPUTER SERIAL PORTS

While developing this project the author came across a strange fact: not all computer serial ports operate at quite the same speed and the modules will consequently malfunction on some computers.

For those programming their own PIC and wanting to drive the modules from a computer port, try varying the value of "bit_k" in the software for the PIC. The comments section in the source code tells you how to do it.

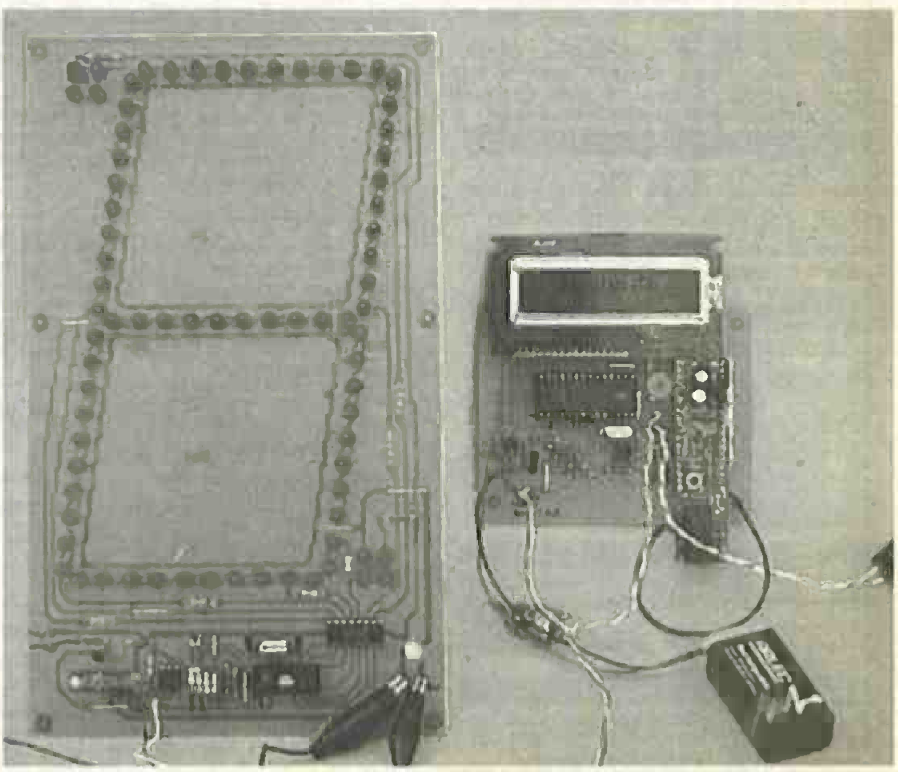
If you only want to drive the modules from a computer, a slightly different source code for the PIC has been included (called **serin4.src**) which requires the use of a 4MHz crystal instead of the 3·2768MHz one, and operates at 2400 baud. The slower baud rate is unnoticeable to our slow human senses and results in a design which is forgiving of long serial cables and bit rate errors in the computer or micro.

SOFTWARE

The software for the Large Digit module, including the QBASIC demo program, is available on a 3·5-inch disk from the Editorial office (see *EPE PCB/Software Service* page for details and cost), and free via the *EPE* web site.

Preprogrammed PICs for this module are available as discussed in *Shoptalk*.

Note that since publicaton of Part 1 the software has been revised by the author. The new version is on the *EPE* disk and website ☐



One Display module being driven by last month's Stopwatch.

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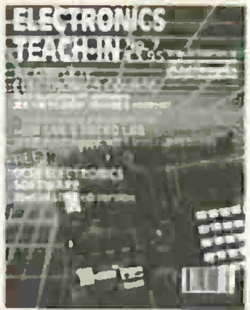

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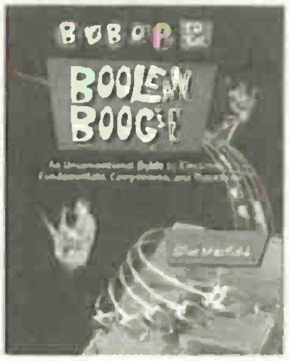
An Unconventional Guide to Electronics Fundamentals, Components and Processes



This book gives the "big picture" of digital electronics. This in-depth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean algebra and Karnaugh maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!). Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day....

470 pages – large format **Order code BEB1** **£24.95**

DIGITAL ELECTRONICS – A PRACTICAL APPROACH

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Richard Monk

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchronous and synchronous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer-aided design including the FREE software.

There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

Those who prefer the 'Teach-In' approach or would rather experiment with some simple circuits should find the book's final chapters on printed circuit board production and project ideas especially useful.

250 pages **Order code NE28** **£16.99**

DIGITAL GATES AND FLIP-FLOPS

Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.

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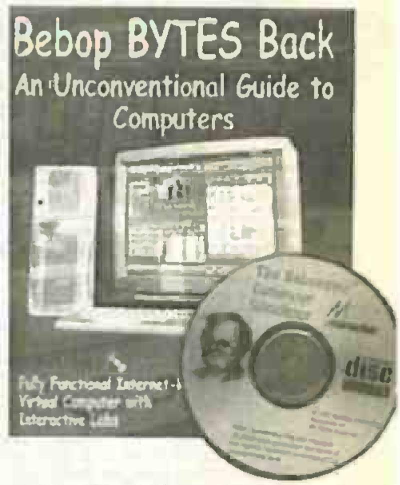

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This follow-on to *Bebop To The Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the accompanying CD-ROM (for Windows 95 machines only) contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the book contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this one!

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Edited by Owen Bishop

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System Requirements: PC running Windows 3.x, 95 or NT on a 386 or better processor. 4MB RAM, 8MB disk space.

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Audio and Music

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V. Capel

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148 pages **Order code BP256** **£3.99**

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R. A. Penfold

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Other circuits include: Audio limiter to prevent overloading of power amplifiers. Passive tone controls. Active tone controls. PA filters (highpass and lowpass). Scratch and rumble filters. Loudness filter. Audio mixers. Volume and balance controls.

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V. Capel

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Much of the trouble is often the hall itself, not the equipment, but there is a simple and practical way of greatly improving acoustics. Some microphones are prone to feedback while others are not. Certain loudspeaker systems are much better than others, and the way the units are positioned can produce a reduced feedback. All these matters are fully explored as well as electronic aids such as equalizers, frequency-shifters and notch filters.

The special requirements of live group concerts are considered, and also the related problem of instability that is sometimes encountered with large set-ups. We even take a look at some unsuccessful attempts to cure feedback so as to save readers wasted time and effort duplicating them.

Also included is the circuit and layout of an inexpensive but highly successful twin-notch filter, and details on how to operate it.

92 pages **Temporarily out of print**

Testing, Theory, Data and Reference

SCROGGIE'S FOUNDATIONS OF WIRELESS AND ELECTRONICS – ELEVENTH EDITION
S. W. Amos and Roger Amos

Scroggie's Foundations is a classic text for anyone working with electronics, who needs to know the art and craft of the subject. It covers both the theory and practical aspects of a huge range of topics from valve and tube technology, and the application of cathode ray tubes to radar, to digital tape systems and optical recording techniques.

Since *Foundations of Wireless* was first published over 60 years ago, it has helped many thousands of readers to become familiar with the principles of radio and electronics. The original author Sowerby was succeeded by Scroggie in the 1940s, whose name became synonymous with this classic primer for practitioners and students alike. Stan Amos, one of the fathers of modern electronics and the author of many well-known books in the area, took over the revision of this book in the 1980s and it is he, with his son, who have produced this latest version.

400 pages **Order code NE27** **£19.99**

ELECTRONICS MADE SIMPLE
Ian Sinclair

Assuming no prior knowledge, *Electronics Made Simple* presents an outline of modern electronics with an emphasis on understanding how systems work rather than on details of circuit diagrams and calculations. It is ideal for students on a range of courses in electronics, including GCSE, C&G and GNVQ, and for students of other subjects who will be using electronic instruments and methods.

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.

Page 199 (large format) **Order code NE23** **£12.99**

TRANSISTOR DATA TABLES
Hans-Günther Steidle

The tables in this book contain information about the package shape, pin connections and basic electrical data for each of the many thousands of transistors listed. The data includes maximum reverse voltage, forward current and power dissipation, current gain and forward transadmittance and resistance, cut-off frequency and details of applications.

A book of this size is of necessity restricted in its scope, and the individual transistor types cannot therefore be described in the sort of detail that maybe found in some larger and considerably more expensive data books. However, the list of manufacturers' addresses will make it easier for the prospective user to obtain further information, if necessary.

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R. A. Penfold

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Everything from Oscillators, through R, C & L measurements (and much more) to Waveform Generators and testing Zeners.

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R. A. Penfold

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In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** **£2.95**

NEWNES ELECTRONICS TOOLKIT – SECOND EDITION
Geoff Phillips

The author has used his 30 years experience in industry to draw together the basic information that is constantly demanded. Facts, formulae, data and charts are presented to help the engineer when designing, developing, evaluating, fault finding and repairing electronic circuits. The result is this handy workmate volume: a memory aid, tutor and reference source which is recommended to all electronics engineers, students and technicians.

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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Robin Pain

This is not a book of theory. It is a book of practical tips, hints, and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialized.

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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F. A. Wilson

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F. A. Wilson C.G.I.A., C.Eng., F.I.E.E., F.I. Mgt.

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Various chapters cover: Digital Arithmetic, Electronic Logic, Conversions between Analogue and Digital Structures, Transmission Systems. Several Appendices explain some of the concepts more fully and a glossary of terms is included.

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R. A. Penfold

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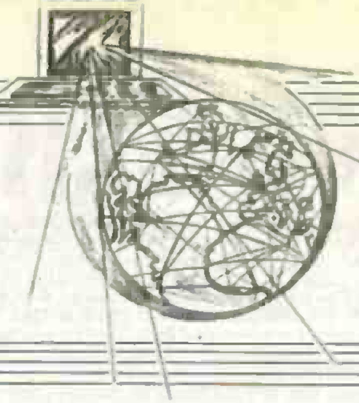
SURFING THE INTERNET



NET WORK

ALAN WINSTANLEY

JET SCREAM

SEVERAL examples have arisen recently which illustrate how useful the Internet can be, as well as how it can also be the bane of my life. Recently a friend asked me if I could help with a problem with his HP LaserJet, an old but very sturdy LaserJet 3 which was displaying the dreaded message on its l.c.d. *Call Service Error 50.*

I own an LJ 3P as well, but my own experiences of out-of-warranty service had left a distinctly bad taste. My ScanJet 4C scanner suddenly broke down at quite a critical time, so my first port of call was the HP web site. It had a list of dealers who could (reportedly) repair scanners, and the site also had a map feature which displayed a zoomable road map of the UK showing my nearest dealer.

I printed that off, threw everything in the car and went off in search of a scanner saviour. Two weeks later the HP dealer charged the equivalent of nearly £100 *not* to mend it, because after putting in about a day's work it transpired that they can't be fixed anyway. ("There is no repair path," the official jargon explained.)

The replacement scanner, an HP 6250, has had more than its fair share of installation difficulties, and again the Internet proved vital in finding the patches and fixes from the HP web site. Their slow but moderately useful scanner forum also helped explain why, when I tried to share the scanner on my network, the host PC would try to dial the Internet instead (it still does, by the way).

Remember readers, that if you ever have hardware or software problems, there's a chance you're not alone, and often all you need to do is search for the answer on the Internet. The problem is usually where to start. Have a look at the brand new Help web site operated by CNET at **www.help.com**.

So to help my friend with his LaserJet 3, I started by typing "laserjet" into Deja News (www.deja.com) to see what other folks have said in the past. After reading through many of the newsgroup messages archived there, several web sites caught my eye.

It was not that long before I turned up Parts Now Inc. (**www.partsnowinc.com**) and also All Laser Service in California (www.all-laser.com) and – bingo – there was a page devoted to Call Service Error 50! The problem could be a fuser, triac, thermistor or halogen lamp, they say. Using an ohmmeter we can now hopefully pinpoint the fault and fix this one ourselves, if we can get the spares.

HELP US TO HELP YOU

I was once quite amused by a quip made by a reader in relation to our *Chat Zone* service, or more specifically, my own contributions therein. The reader wondered if my mood could be gauged from the way I signed off my messages: perhaps a curt "ARW" signature signified a certain amount of grumpiness (never) whilst the full moniker – usually bashed out in some haste I must say – meant that I was feeling a tad more affable that day. Who, me?

One thing that does admittedly test my patience at times is when I'm on the receiving end of some intemperate E-mails from users of our web or FTP site. However, acknowledging the principle that customers are always right, even when they are completely wrong, and no-one ever won an argument with a customer anyway, your scribe bites his tongue and sallies forth with an ever-helpful reply.

Following the launch of *Teach-In 2000*, my E-mail has been alive with requests for help from readers who are new to electronics, new to computing, or new to the Internet (or new to all three). Although I'm happy to oblige, surprisingly there has been more than one unfavourable comment about the FTP site, some users having apparently been foiled by the process of File Transfer Protocol.

As one reader put it, "ours is the one web site in the world which has defeated me," actually referring to the FTP file server, which I must say is extremely reliable and has tons of bandwidth at its disposal. The problem is that Internet users, especially newcomers, are progressively being spoiled by world wide web sites, to the total exclusion of the other ways of making information readily available over the Internet.

So when *Teach-In 2000* is launched and I receive several complaints about the hopelessness of our FTP site, the weary writer starts to feel rather exasperated. I have described the processes of FTP several times in the past. The first problem is that FTP is FTP, not the hypertext transfer protocol associated with web servers.

BROW-BEATEN

Web browsers have varying degrees of success or tolerance when accessing FTP sites, and in my own experience, Microsoft Internet Explorer 5 is far more obliging with the process of anonymous FTP than version 4.0 ever was. Furthermore, every instance of "extended response" server error messages (generated for whatever reason) arose, in my experience, due to the use of MSIE 4.0, never anyone's favourite browser. As I state on the *EPE* web site, such error messages are browser issues, not related to our server.

All such problems seem to have gone after adopting MSIE 5.0, which deals with anonymous FTP in an orderly fashion. If some readers are nervous about upgrading their Microsoft browser they have every reason to be so. Sometimes it goes smoothly, at other times a wheel might fall off in the process, causing major headaches for the user who has usually done nothing wrong at all.

For evidence of this, one only has to read the Microsoft or W95/98 newsgroups. Never-the-less, it should be accepted that a browser upgrade will be required sooner or later – maybe every 12 to 18 months or so.

Presently the ideal answer is really to use proper FTP software, which will be second nature to seasoned users. I regret it when users take umbrage at the suggestion that an upgrade is required, or that we are trying to bar MSIE 4.0 users from the FTP site. Try to upgrade from the obsolete browser if possible. Internet Explorer 5 has the honour of being the first Microsoft browser I could actually recommend.

HELP-LINE

Here at *EPE* HQ we want all readers to enjoy such splendid series as *Teach-In 2000* so we try to lend a hand where we can, often going well beyond the call of normal duty as many readers will confirm. When things don't seem to go right, it is very easy to dash off an urgent or intolerant E-mail on the spur of the moment, just because a user has experienced some frustration or other.

It's also very easy now to send an impatient "chaser" the next day, which merely adds to our volume of work. It isn't our fault if a user's browser is flakey, or if a beginner is frustrated with the complex techniques of operating a personal computer, or has never heard of FTP before now.

You don't need to fetch a hefty browser upgrade from the Internet either (another reader complaint), as browser upgrades are regularly included in computer magazine cover-mounted CD ROMs, and furthermore, the upgrade is there on an indestructible CD for future backup. You could alternatively have a look at *EPE Online*'s web site (**www.epemag.com**) and fetch files from our web server hosted in the USA.

Occasionally, readers are so stuck that they ask that I send files to them by E-mail instead, and I will of course try to oblige, although it is always more encouraging to know that users have tried to help themselves to begin with.

If you have any queries, comments or (whisper) complaints, please feel free to share them with other readers in the *EPE Chat Zone*, or E-mail them to **alan@epemag.demon.co.uk**.

EVERYDAY PRACTICAL ELECTRONICS

The No 1 Magazine for Electronics & Computer Projects

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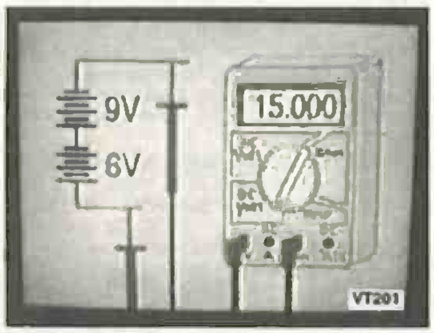

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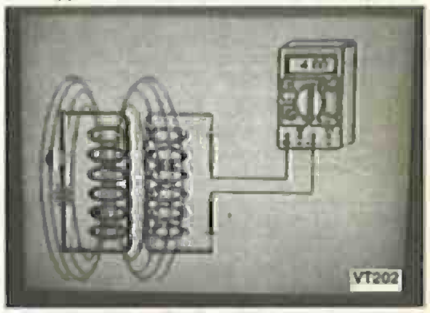

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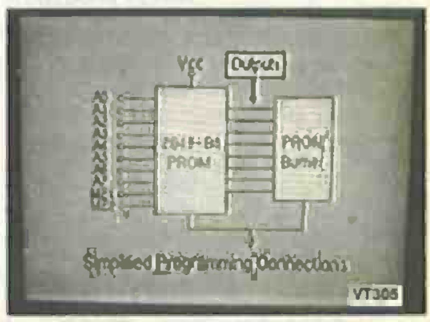

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For rates and information on display and classified advertising please contact our Advertisement Manager, Peter Mew as above.

Miscellaneous

PRINTED CIRCUIT BOARDS – QUICK SERVICE. Prototype and Production. Artwork raised from magazines or draft designs at low cost. PCBs also designed from schematics. Production assembly also undertaken. For details send to P. Agar, Unit 5, East Belfast Enterprise Park, 308 Albertbridge Road, Belfast, BT5 4GX, or phone/fax 01232 738897.

VALVE ENTHUSIASTS: Capacitors and other parts in stock. For free advice/lists please ring. Geoff Davies (Radio), Tel. 01788 574774.

PROTOTYPE PRINTED CIRCUIT BOARDS one offs and quantities, for details send s.a.e. to B. M. Ansbro, 38 Poynings Drive, Hove, Sussex BN3 8GR, or phone Brighton 883871, fax 01273 706670.

WANTED: A copy of Stripboard Magic by Ambyr. Tel/Fax Dave Larner, 01493 721879.

GOLDEN GOOSE SERIAL EEPROM COPIERS, copies to/from 24C16, 24LC16B, 25C166, 24C32, 24LC32A, etc. Call (01245) 358209 after 6 pm, or visit www.golden-goose.co.uk for details.

PIC16F877-04, £6.00 each, s.a.e. plus cheque to R. Boardman, 4 Chapel Close, Ellesmere Port, South Wirral, CH65 2HP. Tel. 0151 356 4588.

SECOND USER TEST EQUIPMENT for sale: Scopes, generators, dmms, etc. H.P., Tektronix, Datron, Hameg, Marconi, Fluke, etc. Low prices. Also some non-working equipment for parts, experiments, etc. Ring or E-mail for list. 07930 144803 or bford@mitectelcom.com.

PROTOTYPE P.C.B. PRODUCTION from CAD designs. Send printout of copper track layout and NC drill file on disk to: Mr Belt, 5 Velden Way, Mill Road, Market Rasen, Lincs LN8 3HD. For prices and information send s.a.e.

FLAT C.R.T., only ½in. thick. For handheld oscilloscope probe? £38 with socket. 01455 613588.

AMPLIFIER BARGAINS: 50 watt, rugged module plus heatsink, £8; 30 watt, stereo and controls, £9. K.I.A., 1 Regent Road, Ilkley LS29 9EA. Leaflet s.a.e.

G.C.S.E. ELECTRONIC KITS, at pocket money prices. S.A.E. for FREE catalogue. SIR-KIT Electronics, 52 Severn Road, Clacton, CO15 3RB.

EPE NET ADDRESSES

EPE FTP site: **ftp://ftp.epemag.wimborne.co.uk**

Access the FTP site by typing the above into your web browser, or by setting up an FTP session using appropriate FTP software, then go into quoted sub-directories:

PIC-project source code files: **/pub/PICS**

PIC projects each have their own folder; navigate to the correct folder and open it, then fetch all the files contained within. *Do not try to download the folder itself!*

EPE text files: **/pub/docs**

Basic Soldering Guide: **solder.txt**

EPE TENS Unit user advice: **tens.doc** and **tens.txt**

Ingenuity Unlimited submission guidance: **ing_unit.txt**

New readers and subscribers info: **epe_info.txt**

Newsgroups or Usenet users advice: **usenet.txt**

Ni-Cad discussion: **nicadfaq.zip** and **nicad2.zip**

UK Sources FAQ: **uksource.zip**

Writing for *EPE* advice: **write4us.txt**

Ensure you set your FTP software to ASCII transfer when fetching text files, or they may be unreadable.

Note that any file which ends in .zip needs unzipping before use. Unzip utilities can be downloaded from:

http://www.winzip.com or **http://www.pkware.com**

On-line readers! Try the new EPE *Chat Zone* – a virtually real-time Internet "discussion board" in a simple to use web-based forum! http://www.epemag.wimborne.co.uk/wwwboard

Or buy *EPE Online*: www.epemag.com

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For Editorial address and phone numbers see page 869

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