**Hydrogen fuel cells**

Our new Hydrogen fuel cells are 1V at up to 1A output. Hydrogen input, easily driven from a small electrolate assembly or from a hydrogen source, our demo model uses a new high efficiency hydrogen glass of each variety to produce the hydrogen! Each cell is designed to be completely taken apart, put back together and expanded to what ever you feel like, up to 10 Watts and 12v per assembly. Cost £9.50 + VAT per unit.

We get over 10 thousand a day!...http://www.bull-electrical.com

**PHILIPS VP406 LASER DISC PLAYERS,** SCART OUTPUT, JUST PUT YOUR VIDEO DISC IN AND PRESS PLAY, STANDARD AUDIO AND VIDEO OUTPUTS, FULLY TESTED AND WORKING. £45.95 + VAT REF VP406 SMOKES ALARMS Wire-powered, made by the famous company your local newsagent or hardware store. £30.00 + VAT Ref 4553.

**10 WATT SOLAR PANEL** Amorphous silicon panel fitted in a refined aluminium frame. Panel measures 7 by 4 with terminals for easy fixing to any surface. 1.5A at 12v £25.00 + VAT Ref VP406

**12V SOLAR POWERED WATER PUMP** Perfect for many 12V DC uses, from solar hot water to fast running small water pumps. Max lift 20ft, Max flow 500lph, £25.00 + VAT Ref 4553.

**PINHOLE CAMERA MODULE WITH AUDIO** Superb quality camera with built in sound to small just 22mm square (including mounting bracket) £20.00 + VAT Ref 4553.

**SOLAR ENERGY BANK KIT** 5x 6" x 12" solar panels (amorphous silicon) 60W each and 12v 4A battery £55.00 + VAT Ref 4553.

**SOLAR MOTORS** Very motors which run quite happily on voltages from 4.5v-dc. Works on our 6v amorphous panels and you can run them from the sun 30mm x 20mm thick. £1.50 each.

**WALL TIPS ELECTRICITY AND WATER** Complete with various accessories for design, panels, controls, electronics. etc £7.00 + VAT Ref 4553.

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**STIRLING REF KIT** £50.00 + VAT. Our kit comes with a hydrogen source. our demo model will run for a 24 hour period using 1500 watts of hydrogen at 12V.

**LED DISPLAYS** 7 segments, 5 segments, 3 segments, you name it... £1.75 + VAT Ref 4553.

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**SOLAR FUEL CELLS** £4,000.00 + VAT per unit. Very very high efficiency. 100% hydrogen. £100.00 + VAT per unit.

**SOLAR BATTERIES** £40.00 + VAT each. £300.00 + VAT for 12V 100Ah Batt.

**NEW LYSIPOX** 4x 5.1 watt range hand held and two on a battery pack. £65.00 + VAT Ref 4553.

**50W INFRARED BULBS** £50.00 + VAT each.

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**SOLAR POWERED HOT WATER SYSTEM** £1,000.00 + VAT.

**TOOL FILTERS** £5.00 + VAT

**PHILIPS VP406 LASER DISC PLAYERS** £50.00 + VAT each.

**30Watts of SOLAR POWER FOR just £69.95, 4 panels each one 3.91 and producing 8v, 15v.**

**PACK OF FOUR £96.95 SOLX**

**200W WATT INVERTERS** plugs straight into your car or home electricity supply and can be used to run any of your mains operated devices from your car battery. £49.95 + VAT Ref 4553.

**THE TRUTH MACHINE** Five or ten minutes by micro transistors, micro solar, battery operated, words for conversation and the phone and the tv and we talk and talk and talk ($2 + VAT lead to a plate with an iron core 8v, 12v metal magnet "tuned to a plate in an iron core 120 ions" 15£ ref 4553.

**HYDROGEN FUEL CELL PLANS** builds your own hydrogen fuel cell (good workshop facilities required) £50.50 + VAT EPC.

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**LAPTOP COMPUTER KEYBOARDS** £49.95 + VAT Ref 4553.

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**LAPTOP BATTERIES** £95.00 + VAT Ref 4553.

**CABLES AND ADAPTEORS** £5.00 + VAT Ref 4553.

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**ELECTRONIC SPEED CONTROLLER KIT** for the above motor £16.95 + VAT. £35.00 for both motors together.

**MAIL ORDER TERMS:** CASH, PO or CHEQUE

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**240 PORTLAND ROAD, HOVE, SUSSEX. BN3 5QT (ESTABLISHED 50 YEARS).**

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**24 HOUR SERVICE:** £6.50 PLUS VAT.

**LAPTOP LCD SCREENS** 15.1" £85.00 including VAT. 200 watt £95.00 including VAT.

**SOLAR INFRA RED ALARM** £99.95 including VAT. £35.00 including VAT for 2. £20.00 including VAT for 3.

**SOLAR ARM CO - PACT SET** £99.95 including VAT, complete with 20 solar cells £45.95 including VAT Ref 4553.

**LAPTOP COMPUTER KEYBOARDS** £99.95 including VAT Ref 4553.

**ONLINE WEB CATALOGUE** bull-electrical.com

**ELECTRONIC SPEED CONTROLLER KIT** for the above motor £16.95 + VAT. £35.00 for both motors together.

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**LAPTOP COMPUTER KEYBOARDS** £99.95 including VAT Ref 4553.
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Class-D 30W Audio Amplifier; National Lottery Predictor; Tumble Dryer Alarm;
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FREE CATALOGUE - MAINLINE FLYER UK issues only between pages 900/901

TELCAN - Unfortunately this feature, advertised last month, has been held over due to lack of space
The TELEBOX MB is a high-quality VHF/UHF tuner designed for use with it own proprietary format. It offers a wide range of features and options, including:

- A sophisticated multi-standard receiver that supports a variety of broadcast services, including DVB-T, DVB-C, and DVB-S.
- A built-in ISDB-T (Japan) and ATSC (US) decoder for digital terrestrial TV reception.
- Support for H.264 video compression, allowing the reception of high-definition TV programs.
- An integrated DVB-C tuner for cable TV services.
- A user-friendly interface with a color display and menu system.
- Support for various external input/output connections, including HDMI, RJ45, and USB.

The TELEBOX MB is ideal for enthusiasts and professionals who require a reliable and versatile digital TV tuner for their home entertainment system. Its advanced features and high-quality performance makes it an excellent choice for those who value state-of-the-art technology in their TV viewing experience.
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.

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.

PLUS: EPE TEACH-IN 2000 PART 3 AND ALL THE REGULAR FEATURES

NO ONE DOES IT BETTER

Everyday Practical Electronics/ETI, December 1999

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Demand is bound to be high

JANUARY ISSUE ON SALE FRIDAY, DECEMBER 3
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No. 1 for Kits

Whether your requirement for surveillance equipment is amateur, professional or you are just fascinated by this unique area of electronics SUMA DESIGNS has a kit to fit the bill. We have been designing electronic surveillance equipment for over 20 years and you can be sure that all our kits are well tried, tested and proven and come complete with full instructions, circuit diagrams, assembly details and all high quality components including fibreglass PCB. Unless otherwise stated all transmitters are tuneable and can be received on an ordinary VHF FM radio.

Genuine SUMA kits available only direct from Suma Designs. Beware Inferior Imitations!

<table>
<thead>
<tr>
<th>Kit Description</th>
<th>Price</th>
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<tbody>
<tr>
<td>UTX Ultra-miniature Room Transmitter</td>
<td>£16.45</td>
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<td>MTX Micro-miniature Room Transmitter</td>
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<td>STX High-performance Room Transmitter</td>
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<tr>
<td>VT500 High-power Room Transmitter</td>
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<td>VXT Voice-Activated Transmitter</td>
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<tr>
<td>SCRX Subcarrier Scrambled Room Transmitter</td>
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<td>SCLX Subcarrier Telephone Transmitter</td>
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<tr>
<td>SCDM Subcarrier Decoder Unit for SCRX</td>
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<tr>
<td>ATR Micro-Size Telephone Recording Interface</td>
<td>£31.45</td>
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<tr>
<td>CD400 Pocket Bug Detector / Locator</td>
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<tr>
<td>CD600 Professional Bug Detector / Locator</td>
<td>£40.95</td>
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<td>OX180 Crystal Controlled FM Transmitter</td>
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<tr>
<td>QLX160 Crystal Controlled Telephone Transmitter</td>
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<tr>
<td>QGSX160 Line Powered Crystal Controlled FM Transmitter</td>
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<td>ORX 180 Crystal Controlled FM Receiver</td>
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**Specials**

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<tr>
<td>DLTX/DLRX Radio Control Switch</td>
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<td>Individual Transmitter DLTX</td>
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<td>Individual Receiver DLRX</td>
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<td>MBX-1 Hi-Fi Micro Broadcaster</td>
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<td>UTX Ultra-miniature Telephone Transmitter</td>
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<td>STX High-performance Telephone Transmitter</td>
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A build-up service is available on all our kits if required.

UK customers please send cheques, POs or registered cash. Please add £2.00 per order for P&P. Goods despatched ASAP allowing for cheque clearance. Overseas customers send Sterling Bank Draft and add £5.00 per order for shipment. Credit card orders welcomed on 01827 714476.

**OUR LATEST CATALOGUE CONTAINING MANY MORE NEW SURVEILLANCE KITS NOW AVAILABLE. SEND TWO FIRST CLASS STAMPS OR OVERSEAS SEND TWO IRCs.**

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It is Yuasa made jelly type so maintenance-free and use any position. Brand new. 12 months. The regular price of these is £40 but you can buy at £15.

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GROWERS PLEASE NOTE: We now have a 12V 18AH RECHARGEABLE BATTERY. It is Yuasa made jelly type and has all the features of Yuasa batteries, but at a lower price. £15 inclusive. Order Ref: SP78.

10021A 18V 18AH RECHARGEABLE BATTERY. Yuasa made jelly type with 200% greater capacity. Make a set of these and save money.

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BUY ONE GET ONE FREE

ULTRASONIC MOVEMENT DETECTORS. Nicely boxed, free standing, with internal alarm which can be silenced by opening the door. £20. Order in pairs or can be sold singly. £10. Order Ref: 10P52.

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3-OCTAVE KEYBOARD with piano keys, brand new, previous price £39.95, now 2 for the price of one. Order Ref: 5P8.

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All with 2200VA primary winding


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500V £500 120VA, price £8. Order Ref: 10P52.

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SUPER WOOFERS

A 10m 4 ohm with power rating of 250W music and normal 150W. WARNING: The selling price for £55 is VAT, you can buy at £29 including VAT and carriage. Order Ref: 2P97. The second one is an extra speaker, 250W music. £55, including VAT and carriage, normal, again by Challenger, price £18. Order Ref: 1P95.

Deduct 10% on these prices if you order in pairs or can collect. These are all brand new in maker's packing.

TERMS

Send cash, PO, cheques or credit card number or orders under £25 and £5 service charge.

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Telephone: 01284 467500
PC BASIC Products - See our web site for details 
16C74 version (8Kbyte EEPROM) - 20 MHz £30.00, KIT £35.00 Built & Tested, Compiler Available - runs identical code.

Prices are fully inclusive. Add £3.00 for P&P and handling to each order. 
Checks/PoSs payable to Forest Electronic Developments, or phone with credit card details.
Transform your PC.... Into an oscilloscope, spectrum analyser and multimeter...

The ADC-200 range of PC based oscilloscopes offer performance only previously available on the most expensive 'benchtop' scopes. By integrating several instruments into one unit, the ADC-200 is both flexible and cost effective.

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**
- Video
- Automotive
- Electronics design
- Production line tests
- Fault finding
- Education

All units are supplied with software, cables and power supply. Prices exclude VAT.

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
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<tr>
<td>ADC-200/100</td>
<td>£499</td>
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<td>£399</td>
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<tr>
<td>ADC-200/20</td>
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**Features**
- A fraction of the cost of comparable benchtop oscilloscopes
- Up to 100 MS/s sampling
- Advanced trigger modes: capture one-off events.
- Up to 50 MHz spectrum analyser
- Large buffer memory

**A scope at your fingertips.....**

Once oscilloscopes were heavy and clumsy to handle, but over the years they have become smaller and smaller. The latest development in this field has just arrived: a digital storage oscilloscope in a handy slim housing, scarcely longer than a pencil and about as thick as your thumb. Despite its small size, its performance can match that of a service oscilloscope.

**ONLY £80**

**Applications**
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**Can use PC display**
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An affordable circuit which sweeps the incoming water supply with variable frequency electromagnetic signals. May reduce scale formation, dissolve existing scale and improve lathering ability by altering the way salts in the water behave.
Kit includes case, PCB, coupling coil and all components. High call current ensures maximum effect. L.E.D. monitor
KIT 868.............£22.95 POWER UNIT............£3.99

MICRO PEST SCARER
Our latest design - the ultimate scarer for the garden. Uses special microchip to give random delay and pulse time. Easy to build reliable circuit. Keeps pets/pets away from newly sown areas, play areas, etc. Uses power source from 9 to 34 volts.
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- HIGH POWER
- DUAL OPTION
Plug-in power supply £4.99
KIT 867 .......... £19.99
KIT + SLAVE UNIT .......................... £32.50

WINDICATOR
KIT 856............. £28.00

★ TENSI UNIT ★
DUAL OUTPUT TENSI UNIT
As featured in March '97 issue.
Magenta have prepared a FULL KIT for this excellent new project. All components, PCB, hardware and electrodes are included. Designed for simple assembly and testing and producing high level dual output drive.
KIT 866........... Full kit including four electrodes £32.90

1000V & 500V INSULATION TESTER
KIT 848........... £32.95

ULTRASONIC PEST SCARER
Keep pets/pets away from newly sown areas, fruit, vegetable and flower beds, children's play areas, patios etc. This project produces intense pulses of ultrasound which deter visiting animals.
KIT INCLUDES ALL COMPONENTS, PCB & CASE
- EFFICIENT 100V TRANSUCER OUTPUT
- UP TO 4 METRES RANGE
- COMPLETELY INAUDIBLE
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TO HUMANS
KIT 812............. £15.00
**SIMPLE PIC PROGRAMMER**

**INCREDIBLE LOW PRICE!** Kit 857 £12.99

- INCLUDES 1-PIC16F84 CHIP
- SOFTWARE DISK, LEAD
- CONNECTOR, PROFESSIONAL PC BOARD & INSTRUCTIONS

Based on February '99 EPE. Magenta designed PCB and kit. PCB with 'Reset' switch, Program switch, 5V regulator and test L.E.D.s, and connection points for access to all A and B port pins.

**PIC16C84 LCD DISPLAY DRIVER**

- INCLUDES 1-PIC16F84
- WITH DEMO PROGRAM
- SOFTWARE DISK, PCB, INSTRUCTIONS AND 16-CHARACTER 2-LINE LCD DISPLAY

Another super PIC project from Magenta. Supplied with PCB, I.C.D. with 'Reset' switch, Program switch, 5V regulator and test L.E.D.s, and connection points for access to all A and B port pins.

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- WITH PROGRAMMED 16F84 AND DISK WITH SOURCE CODE IN MPASM
- ZERO VOLT SWITCHING
- MULTIPLE CHASE PATTERNS
- OPTO ISOLATED
- 5 AMP OUTPUTS
- 12 KEYPAD CONTROL
- SPEED/ Dimming POT.
- HARD FIRED TRIACS

Now features full 4-channel chaser software on DISK and pre-programmed PIC16F84 chip. Easily re-programmed for your own applications. Software source code is fully 'commented' so that it can be followed easily.

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- PROGRAMS PIC16C84 and 16F84
- ACCEPTS TASM AND MPASM CODE

Full kit includes PIC16F84 chip, top quality p.c.b., printed with component layout, turned pin PIC socket, all components and software.

*Needs QBASIC or QUICKBASIC*

Kit 871 ... £13.99. Built and tested £21.99

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**ALL PARTS FOR SERIES INCLUDING PCBs.**

- PROGRAMMED CHIP, CD-ROM AND DISPLAYS

Main Board - Full Kit £131.95

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- NEW PCB DESIGN
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- MANUAL AND SOFTWARE
- 2 SERIAL PORTS
- PIC AND I/O PORT OPTIONS
- I2C PORT OPTIONS

**Mini-Lab & Micro Lab Electronics Teach-In 7**

As featured in EPE and now published as Teach-In 7. All parts are supplied by Magenta. Teach-In 7 is £9.95 from us or EPE

Full Mini Lab Kit - £119.95 - Power Supply extra - £22.95

Full Micro Lab Kit - £155.95

Built Micro Lab - £89.95

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- Learn Programming from scratch using PIC16F84
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Includes: PIC16F84 Chip, TOP Quality PCB printed with Component Layout and all components (*not ZIF Socket or Displays*). Included with the Magenta Kit is a disk with Test and Demonstration routines.

Kit 870 .... £27.95. Built & Tested .... £42.95


LCD Display .... £7.99 LED Display .........£6.99

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- READ, WRITE, ASSEMBLE & DISASSEMBLE PICS
- SIMPLE POWER SUPPLY OPTIONS 5-30V
- ALL SWITCHING UNDER SOFTWARE CONTROL
- MAGENTA DESIGNED PCB HAS TERMINAL PINS AND OSCILLATOR CONNECTIONS FOR ALL CHIPS
- INCLUDES SOFTWARE AND PIC CHIP

Kit 878 .... £22.99 with 16F84 .... £29.99 with 16F877

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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 some fascinating magazine published, photos of the computer on our www.epemag.com. This is so that readers can “chat” to each other. This series should start in the Feb ’00 issue (on sale Jan. 7).

As man) readers will know, we have a Chat Zone on our UK www.epemag.com. As with the above, this is via our web site at www.epemag.com. 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 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: editoriax@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.

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: editoriax@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.

AVAILABILITY
Copies of EPE/ETI are available on subscription anywhere in the world (see left), from all UK newsagents (distributed by COMAG and from the following electronic component retailers: Omn Electronics and Maplin in S. Africa. EPE can also be purchased from retail magazine outlets around the world. An Internet on-line version can be purchased from www.epemag.com
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 I.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 I.E.D.s attached to a spare port is an excellent idea, and the author always tries to incorporate a bank of them on a printed circuit board wherever possible. This gives you an on-board debugger straightaway—but only if you have the port pins to spare. This is chip-dependent, 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 I.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.

The Micro-Probe itself, and the Target code you have assembled to add to the target application to output the debug words.

**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 included instruction embodied in the Target

---

**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 105MHz, 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 I.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 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 I.E.D.s are connected to Port B via ballast resistors R3 to R6. These I.E.D.s are actually two I.E.D.s in one package, connected back-to-back across each other. Depending on the direction of the current, the I.E.D. illuminates either red or green, so with four I.E.D.s, eight signal indications can be displayed.

If you prefer, you can replace the bi-colour I.E.D.s with eight individual I.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 I.E.D.s will light.
**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 timer 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 (MPSAM 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 i.e.d. green
DEBUG 2 lights the first i.e.d. red
DEBUG 7 lights the fourth i.e.d. green
```

If your target application makes use of interrupting, 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 i.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\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 unchanged, then a sample loop occurs every ten instruction cycles (1 cycle = 0.4us at 10MHz), or every 4us. 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 "1011" (the Syncword). The pin is sampled six cycles later (2-4us) to make sure that the sample point is not too near the leading edge of the first pulse. Thereafter, the pin is sampled every 4us 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...
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.

The Power Unit from the target board using the power clips and attach the signal probe to the required pin. The power-on

ENCLOSE
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 counterbore 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 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 i.e.d.s coming up through the case and fit flush on the underside. Make sure the short lead goes to the position marked as Rk on the layout diagram.

You can't damage these i.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 i.e.d., so that you can adjust the height to fit the box before soldering in the other one.

Resources
Software for the Micro-Probe is available on 3.5-inch disk from the EPE PCB Service, code EPE D1. Enter a Debug command (e.g. DEBUG 1) into your code.

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

When you run the target processor, the first I.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!
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The PicBasic Pro Compiler runs on PC compatibles. It can create programs for the PIC12C67x, PIC12CE67x, PIC14Cxxx, PIC16C55x, 6xx, 7xx, 84, 9xx, PIC16C66xx and PIC16F8x and 16F8xx microcontrollers. The PicBasic Pro Compiler Instruction set is upward compatible with the BASIC Stamp II and Pro uses BS2 syntax. Programs can be compiled and programmed directly into a PICmicro microcontroller. The easy-to-use BASIC language makes PICmicro programming available to everyone with its English-like instruction set. No more scary assembly language!

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- Runs on two 9-volt batteries or optional AC adapter
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- Available assembled and tested or as bare board with diskette

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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.

NEC pioneered the concept of C&C, the integration of Computers and Communications. They employ in excess of 150,000 people around the globe.

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, Staffordshire 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 anthropoid 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 own 75-option keypads. Rastus is a bit of a DJ as well. As with any Earthly (or even Earthly!) 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 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 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 “mindroids”!

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’trim-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.

The walls, floors and ceilings are covered in a silvered metal skin and well interspersed 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.

Myriad small 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 chronosynclastic parafundibulum of the polyverse is far too multi-temporal for it 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 robotic cybernetics 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's 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-proven 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@cybar.co.uk.

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

Children are welcome (there's even a dance floor, and soon there'll be an amazingly fascinating technology-orientated gift shop).
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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 30nm.

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 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.

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 UGM13503U. This is an inexpensive device but it has a very useful level of performance and is very easy to use.

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 terminal.
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 satisfactory results are obtained using 9mA. Do not use a 9V battery as the output signal to be monitored using a crystal earphone socket SK1. This enables the meter 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 60kHz 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 resistor R6 should be reduced from 33kiloohm to 27kiloohm.

**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 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.

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 critical.

**COMPONENTS**

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>1k5, 10k (2 off), 470k, 33k (2 off)</td>
</tr>
<tr>
<td>Capacitors</td>
<td>100µF radial electrolytic, 10V, 5mm lead spacing</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>UGN3503U Hall effect sensor, OP77GP precision op.amp (see text)</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>s.p.s.l min igloge, 6V battery pack (4 x AA size cells in holder), 3-5mm jack socket, 100µA - 0 - 100µA moving coil panel meter</td>
</tr>
</tbody>
</table>

**Approx. Cost**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium size plastic or metal box</td>
<td>£16</td>
</tr>
<tr>
<td>0.1 inch matrix stripboard, size 19 holes by 20 copper strips</td>
<td>excl. earphone, case &amp; batts.</td>
</tr>
</tbody>
</table>
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.

Everyday Practical Electronics/ET1, December 1999
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.

Reluctantly confessing that the 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.

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

The circuit board now needs ready access to the power supply. For this reason, the power supply terminal are fitted to the rear panel of the case so that the case may be mounted on a panel in a 'through' fitting. This will be necessary to allow the circuit board to be mounted directly in a case that will fit within the available space in the consumer's case.

A magnetic field detector for the new series A few more will be added as the series progresses. The prototype unit measured 100 megohm resistor (R7) was only found listed under the "cermet film" range stocked by Maplin (0121 204 6535 or RS http://www.wwwn.com; code 158-222. As the article points out, you can use three 33 megohm resistors in series; the p.b.s is also designed to accept these. This resistor (33M) came from the Maplin "high voltage" metal film range, order code V33M.

The high voltage 4N25 coax-coax, code AV44, and the ULN2003 Darlington transistor maybe used 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.

The magnetic field detector is Starter Project

A magnetic field detector is Starter Project

If you are an Internet user, it can be downloaded for free from our FTP site: ftp://ftp.esperim.wimburne.co.uk/pub/SIC/microprobe.

Loft Guard

Most of the components called-up for the Loft Guard project should be readily available from your usual suppliers. 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 Maplin (0121 204 6535 or RS http://www.wwwn.com; code 158-222. As the article points out, you can use three 33 megohm resistors in series; the p.b.s is also designed to accept these. This resistor (33M) came from the Maplin "high voltage" metal film range, order code V33M.

The low Impedance 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.esperim.wimburne.co.uk/pub/SIC/microprobe.

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, seasoned advertisers have put some of these parts and what's needed for their projects online 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:

Magnetic Field Detector - Starter Project

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PIC Micro-Probe

The component listing for the PIC Micro-Probe calls for a piece of "lc holder" type stripboard, with a central channel, devoid of copper, 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 108Hz version. For those who want a "play-in" and got some programmed PIC16F84, one is available from Maplen (0123 550435 or http://www.magentia2000.co.uk请教 code AV44. Check 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.esperim.wimburne.co.uk/pub/SIC/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 100A "centre zero" meter, some readers may have difficulty in locating one. The meter used in the prototype came from Maplin (01782 556000, code RV95C). 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 GA05. The alternative TL071C low-noise op.amp should be stocked by most of our component advertisers.

Gnomonic StopWatch - Giant Display

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

The high voltage 4N25 opto-coupler, code AV44, and the ULN2003 Darlington array, code AV9B3, are listed by Maplin. The BD681 Darlington transistor may be hard to find, but the suggested alternative TIP111 and TIP142 should be readily available. Note the wiring pinouts for the TIP devices (Fig 2 last month).

When the unit is first switched on it may be that the display module or StopWatch) or C56 for six in any combination, with free postage to anywhere in the world. Payments should be made to Mr. N. Stojadinovic, His E-mail address is: vladimir@x030.aone.net.au or write to Mr. N. Stojadinovic, PO Box 320, Woden ACT, 2606, Australia.

A programmed PIC16C54 is also available from Magnetic Electronics (0123 550435 or http://www.magentia2000.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.esperim.wimburne.co.uk/pub/SIC/microprobe.

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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.b.c. The last mentioned company also supplied the miniature light-dependent resistor (ldr.), code AZ83E, and the high power warning buzzer, code FK94E. Although most of our components advertisers should be able to offer something similar. You could, of course, use the old good standard ORP12 ldr. if you wish. Even though the semiconductors are specific versions, they should be in plentiful supply. The p.b.s is available from the EPE PCB Service, code 249.

Teach-In 2000

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PIL Applications (01677 425840) - Basic Component Sets.

N. R. Bardwell (0114 2525286). Digital Multi-meter special offer.

Please NOTE TAKEN

demister one-shot

page 844 Fig 4.4. on the p.b.c. component layout diagram, the "boxed" outlines of the components C1 and C2 show they should be situated in the top left corner of the component layout diagram.

£5.90. This electrolytic shown as a circle, should connect to the IC1 pin 6 copper track (+) and the common GND track (-). The actual annotations are correct.
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!

Welcometo 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 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 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 output of 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.

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?
Imperfections

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 CO₂ 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 operating 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 (the second reader’s question) because quite 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 CO₂ laser, and, of course, some extra bits of circuitry (with reference to the second reader’s question) because quite much of the design effort arises in reducing these imperfections.

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 look at 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 OV.

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 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 \( V_{1} \). 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 instrumentation 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/low precision** - amplifiers with minimum offset voltage, and where accuracy is preserved over a wide temperature range
- **low bias/low 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 ARV.

**CIRCUIT THERAPY**

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Everyday Practical Electronics/ETI, December 1999
INTER
FACE
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 $\text{&H88}$ (1016 decimal) and $\text{&H28}$ (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 port. Using Delphi 1, this code could be applied to a timer component set with an interval of about 50 milliseconds:

```delphi
Labell.caption := S;
Label2.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":
```

```
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 hand-shake 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.

```
Port1 := 128;
Port1016 := 12;
Port1017 := 0;
Port1019 := 3;
Port1017 := 0;
```

Repeat until (Port1021) and 1) = 1;

Reading := Port1016;

Str(Reading, S);
Labell.caption := S;
Label2.caption := S;
Counter := Counter + 1;
Str(Counter, 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 355 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). However, 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, 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 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 other means, but using them directly seems to be something less than straightforward.
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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 m.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-curts

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 vapourised 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 ligands 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 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 that 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 discrete 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.

Waffer 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.
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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. Tired 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 sinusewaves 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 value 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 $\mu$F.

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.
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 47 kilohms, 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 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 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 a preset VR2 enables the frequency of oscillation to be adjusted slightly. (At 10kHz it can be shifted by plus or minus 15kHz).

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 this circuit 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 a frequency.

Wien bridge oscillators vary in complexity, and a simple, inexpensive, yet very effective version of the circuit is shown 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.e. (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 R5 type thermistor (temperature dependent 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 preset 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 dependent 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 \( \mu F \).

The frequency of oscillation is very dependent 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, 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 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 CS 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 \( \mu F \). 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.
ADJUSTING THE FREQUENCY

The operating frequency of simple astable multivibrators is very dependent 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 C5 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. Do they, 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.3, 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 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.

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 $\mu$F.

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 IC, 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:

\[ f = \frac{2800000}{(R_1 + 2000)C} \]

where \( f \) is in Hertz, \( R \) is the total value of VR1 and R2 in ohms, and \( C \) is in \( \mu F \).

The formula is reasonably accurate up to 5 kHz 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.

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 1 kHz.

Provided the supply voltage is held between 8 V and 12 V, 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.

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" wave) at the emitter. The impedance of any accepting circuit presented to the emitter must be high or the unijunction action will be impaired.

**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 \( \mu F \). 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 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 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" wave) at the emitter. The impedance of any accepting circuit presented to the emitter must be high or the unijunction action will be impaired.

**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.c.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.
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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 (Y0 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, Tx is connected to Rx2, Rx to Tx2 and Rx1 is held at logic 1 so the PC communicates with device Y. 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 Tx1 and Rx2 is held at 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.
**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 or bathroom) 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.

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**Rechargeable PP9 Battery – Energy Saver**

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

If you discard a recharged PP9 layer-type battery 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.

The power for the charging circuit is provided by an external 12V to 15V d.c. power supply capable of providing a 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 (no voltage) regulator, and the current flowing is limited by the series resistor R1. The current I is 1.25R1, 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.

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**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 control 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 IC3 is used to disable the voltage drop between +7.5V and -7.5V provided by the open emitter input of the comparator (pin 1 of IC6).

With 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 sink causing the voltage drop across R17 to increase sufficiently to turn TR4 off. Essentially, MOSFET's 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 IC3, 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 heat sinks may be 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.

Everyday Practical Electronics/ET1, December 1999
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.

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 hack 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 eel-ewinks found it useful!

Glyn Shaw, Staines, Middx.

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

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

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.

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/norma) 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 i.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.
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 LED 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 LED 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 LED illuminates. Back off VR1 until the LED just extinguishes. Any increase in the audio level will now be limited to the level selected.

Duncan Boyd,
Blackburn, Scotland.

Everyday Practical Electronics/ETI, December 1999
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 AC. The potentiometer VR1 can be used for varying the output voltage in the range of 50V to 220V AC, 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. (If was unable to trace the power MOSFETs used by the writer and a substitute may be needed, e.g. the IRFP50 or similar, offered as a suggestion only - ARW). M.T. Iqbal, Rawalpindi, Pakistan

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**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** - recesses 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.

Res. 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. Kaparlik - 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.
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 5 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
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, and 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.e. timer configured as a monostable. It may be actuated 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 product of capacitor(s) C3 and resistor R7. The higher the value of either or both of these components, the greater the time the output 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, 2x4.7μF or even one or two 1μF 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 time period 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, W1, 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.

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**COMPONENTS**

<table>
<thead>
<tr>
<th>Components</th>
<th>Value/Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R1, R2: 10MΩ, R3, R8, R9: 470kΩ (3 off)</td>
</tr>
<tr>
<td></td>
<td>R4: miniature light-dependent resistor, 5MΩ dark resistance (5mm dia. - see text)</td>
</tr>
<tr>
<td></td>
<td>R5, R6: 1MΩ (2 off)</td>
</tr>
<tr>
<td></td>
<td>R7: 100kΩ ceramic film (or 3 off 33MΩ - see text)</td>
</tr>
<tr>
<td></td>
<td>R10: 10MΩ (2 off - see text)</td>
</tr>
</tbody>
</table>

All 0.25W 5% carbon film, except R4 and R7

**Potentiometer**

| VR1: 1M sub-min preset, vert. |

**SEE SHOP TALK page**

**Capacitors**

| C1, C2: 47nF min. metallised polyester, 5mm pin spacing (2 off) |
| C3: 2x2mF min. metallised polyester, 5mm pin spacing (2 off or as required - see text) |

**Test capacitor**

| 100nF min. metallised polyester, 5mm pin spacing (see text) |

**Semiconductors**

| D1, D2: 1N4148 signal diode (2 off) |
| TR1: MPSA65 npn Darlington transistor |
| IC1: ICL7611 micropower op.amp |
| IC2: 7555IHPA 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 248, plastic box, size 138mm x 76mm x 38mm internal; 8-pin d.i.l. i.e. socket (2 off); plastic stand-off insulators (3 off); FPP-type battery connector; small fixings; multistrand connecting wire; solder, etc.

**Approx. Cost**

£19 excl. batteries

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**Guidance Only**

906 Everyday Practical Electronics/ETI, December 1999
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 I.d.r. in position using the full length of its end leads for the moment. If the specified miniature type of I.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.

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 I.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 bare 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 I.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 I.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 I.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 I.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.

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. Shorten 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.

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.

**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 outside 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.

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**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 Telecution 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 set I had ever seen. When he 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 Esn), 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 before). “Anyway, they will never replace us as good as we are.”

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 57) 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, cleaning the rotating channel switch, replacing the input valves (I think these were ECC81 and ECC84).

AC power was rectified with a valve. This was replaced by a half-wave rectifier, using two diodes, then a transformer and display stabilizing 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 overheated, we had to gently ease the CRT forward in order to do so. Part of the HT was killed off by the oil. The Studios were covered with oil containers, if the HT axed over, user then had to inject more oil. Never try to align anything one small turn – this caused the 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 put the set up there 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 were given a good tap with the thick end of a screwdriver (Is this where the term bornie bashers came from?). This was to see if the valve was on the verge of death, or noisy! There were many more such nonsensical acts of violence.

We were on piecework as well. We did have a much higher rate to work on, namely the KD, I don’t know the model number, but this was a hard wired set, i.e. no p.c.b. The KD had a frame output transformer at the left hand side looking from behind. The quality controller thought this was the best place to file the label, to tell the world that this set had passed his inspection. All was well until the team responsible for re-creating 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 of its 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.

**LEAPING CALENDARS (AGAIN)**

In several recent Readout columns, we have discussed calendars in relation to the Millennium. We want to say a reality Big Thank You to Mr W.F. Ritchie, of Fraserburgh, Aberdeenshire, who went to so much 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 79 years I make do with my Hewlett Packard 48G calculator, which... has a built-in clock and calendar covering a period from the start of the Gregorian calendar to 31st December 1999.” 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 a 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 could happen.

However, readers who have downloaded the program from our FTP site may inadvertently find that their unzipped files are in the wrong directories. 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 test file on the PIC Toolkit Mk2 path that explains this (pic_toolkit_install.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 ASM/NCV directory (folder) referred to must be created as C: \ASM/NCV. (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 program writing area of these programs and typing in the command, for example, ERROR 76. Then run this one-line program, upon which the program will read and display a test 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 Z80 bus 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 your PIC-LOGIC tool. I have used the dissease function to recover a program from a PIC16C64 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 proving 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 in the early thirties. Although I was keen to read engineers, money was scarce, and I could only afford to spend on their construction. Then came WWII and I tried to get into Signals, but it was not to be. I served in 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 valle to solid state. What a fascinating subject it is! I find my main interests are in Digital electronics and test instruments. I have recently built a number of them, including some from EPE. I now have subscriptions to five electronic 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 down to earth schematics. The articles give you 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, could provide a method and a circuit, for the testing and evaluation of toroids. I have recently obtained a vast array of sizes and materials, and they can be bought cheaply. But not knowing its composition, i.e. iron dust or ferrite, and what frequency it was manufactured for, I thought I could provide a method and a circuit for the testing and evaluation of toroids. I also have another request, and perhaps some of your columnists or readers, better versed in electronics, could provide a method and a circuit, for the testing and evaluation of toroids. I have recently obtained a vast array of sizes and materials, and they can be bought cheaply. But not knowing its composition, i.e. iron dust or ferrite, and what frequency it was manufactured for, I thought I could provide a method and a circuit for the testing and evaluation of toroids. I also have another request, and perhaps some of your columnists or readers, better versed in electronics, could provide a method and a circuit, for the testing and evaluation of toroids.

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 actuate 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 iron and doggish 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, Alberta, Canada

We know that many readers have responded favourably to Raymond's oscillator discussions. Today I would like to ask whether any articles relating to them would be too esoteric to appeal to most readers. However, perhaps readers might care to tell us what they think.

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.

TRANSPORTER PROBLEM

Dear EPE,

I am 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 DA3 is high, the voltage on PIC pin 4 (MCLR) should be 0V, but I still get 4.5V. When DA3 is high, I get 4.5V on TR1. Now when both OCL power converters I used is only rated to supply 100mA and the L.e.d. I chose draws 20mA. Could there be not enough current going to the MCLR pin? I should check it supply 12V? Should I replace both the power converters 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. So far, so good. I am using 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. The transistor I used is rated with a maximum collector current of 600mA.

I have just started working with PIC micros and I really enjoy your magazine because of your in-depth and gives down to earth schematics. I have also used 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 I.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 I.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 on one of the pins).

One alternative to the BC549 (a device which is part of my regular design stock) is the BC109. Another is the 2N7004, but note that this device has a pinout which is a mirror image of the BC549 and BC109 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 "I suspect 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 definitely are interested in PICs as 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 dissected 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 PICutor CD-ROM and associated hardware (see page 912).

But as to actually indulging in "endless discussions of code", we're not going to do so as a regular part of PIC projects. By-and-large, the only discussion of code is when it is pertinent to explain how a particular design should be operated. Otherwise, any discussion 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 a main component 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 the equivalent in "machine-code" can be 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 design 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 and accompanied by a relative reduction in processing speed.

For my purposes, I need the compactness and operation speed of sub-assembler. In this context, I am 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, otherwise IC5 is left floating. Is this a mistake, or is the diagram correct?

Tom Web.

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 stand 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, most light must on average arrive from 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 approach in the extended discussion.

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

George Short, Brighton, East Sussex

Good to hear from you again George. Yes, I've thought about Sundials for Dull Days and I think that it is feasible, although precautions would need to be taken to ensure that only the sun's light (absorbed or clear) would be responded to and not other light sources. Several approaches come to mind 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 appreciated at the moment ... Still, where's the fun without the challenge?? Radio Bygones will, of course, continue to be published in its own right.
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*by Mike Tooley*

Electronic Circuits and 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, electronic 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.

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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. A selection of electrolytic capacitors (radial construction).

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 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.

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.

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.
Everyday Practical Electronics/ETV. December 1999

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.).

**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 waves. In normal use, you won’t notice any temperature changes 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.**
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 grid, similar to that in Photo 2.3. This particular graph is for a 1 μF capacitor and 1 MΩ resistor. One axis shows the varings of a combination whose timings would be far too 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 1 μF. Press the <> key (multiply) twice. On each press the graph will redraw to suit the changed value. You should see C = 100 μF after the second <> press.

Press the down arrow key once to select factor R. Press <> (divide) once to set R = 100 kΩ. 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) 100 μF capacitor charges via a 100 kΩ resistor when a voltage of 6 V 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 = 10 secs 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 sec (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

### 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 "μF" or "mF", since many keyboards do not have the Greek symbol readily available. The use of "mF" is to be deprecated because it is pronounced as "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 "new" or "muff".

- **Nano farads**, being 1000 millionths 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 "enf" or just "en", i.e. a value of 10 nF might be pronounced as "ten-en". The use of the term "nuff" is unlikely.

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

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 <>. 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:

\[ V_c = V_s \times (1 - EXP(-4 / CR)) \]

for the charging rate, and:

\[ V_c = V_s \times (EXP(-4 / CR)) \]

for the discharging rate

where:

- \( V_c \) = voltage across the capacitors

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 (100 μF) is expressed in microfarads (100) and R (100 kΩ) is expressed in megohms (10). Resulting in a CR value of 10 seconds (10 × 0.1), as shown to the right of the display.

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 formule 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-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
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 used for an electrolytic when high values of capacitance are used.

We suggest you experiment with different voltage ratings for 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.e.) 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 the system 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!) 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 “VC”, 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 CANNOT 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 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)**
- **Polypropylene (polarised)**
- **Polyester (non-polarised)**
- **Polyester (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.

---

**Table 2.1: Capacitor varieties and their typical characteristics**

<table>
<thead>
<tr>
<th>Capacitor Type</th>
<th>Ceramic</th>
<th>Electrolytic</th>
<th>Metal film</th>
<th>Mica</th>
<th>Polyester</th>
<th>Polycarbonate</th>
<th>Polystyrene</th>
<th>Tantalum</th>
<th>Polypolypropylene</th>
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<tbody>
<tr>
<td>Capacitance (µF)</td>
<td>2-20µF</td>
<td>100µF</td>
<td>1µF</td>
<td>10µF</td>
<td>100µF</td>
<td>1µF</td>
<td>10µF</td>
<td>100µF</td>
<td>100µF</td>
</tr>
<tr>
<td>Voltage Rating (V)</td>
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<td>250V</td>
<td>350V</td>
<td>630V</td>
<td>630V</td>
<td>100V</td>
<td>35V</td>
<td>150V</td>
<td>220V</td>
</tr>
<tr>
<td>Temperature Coefficient (ppm/°C)</td>
<td>+20</td>
<td>+100</td>
<td>0</td>
<td>+20</td>
<td>+40</td>
<td>+70</td>
<td>+40</td>
<td>+100</td>
<td>+20</td>
</tr>
<tr>
<td>Stability</td>
<td>Fair</td>
<td>Excellent</td>
<td>Fair</td>
<td>Good</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Ambient Temperature (°C)</td>
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<td>-40 to 85</td>
<td>-25 to 85</td>
<td>-40 to 85</td>
<td>-55 to 85</td>
<td>-50 to 100</td>
<td>-60 to 100</td>
<td>-100 to 100</td>
<td>-120 to 120</td>
</tr>
<tr>
<td>Voltage Tolerance (%)</td>
<td>±10</td>
<td>±20</td>
<td>±5</td>
<td>±20</td>
<td>±20</td>
<td>±5</td>
<td>±20</td>
<td>±20</td>
<td>±20</td>
</tr>
<tr>
<td>Typical Physical Shapes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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*Everyday Practical Electronics/ETI, December 1999*
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 (≈ 1.414), thus the chosen capacitor's voltage rating must take this into account.

**RIFFLE 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.

**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 obvious - the positive 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 used in other applications. There are two common types of connection: 1st and 2nd. Each method has its own advantages and disadvantages. Which type you choose depends on the circuit and its requirements.

**Figure 2.7. Tantalum capacitor colour coding.**

---

Table 2.2. Tantalum capacitor colour coding.

<table>
<thead>
<tr>
<th>Colour</th>
<th>Figure</th>
<th>Multiplier</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>1 $\mu F$</td>
<td>10V</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>10 $\mu F$</td>
<td>-</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>100 $\mu F$</td>
<td>-</td>
</tr>
<tr>
<td>Orange</td>
<td>4</td>
<td>-</td>
<td>6.3V</td>
</tr>
<tr>
<td>Yellow</td>
<td>5</td>
<td>-</td>
<td>16V</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>-</td>
<td>20V</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gold</td>
<td>8</td>
<td>0.01 $\mu F$</td>
<td>25V</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>0.1 $\mu F$</td>
<td>30V</td>
</tr>
<tr>
<td>Pink</td>
<td>-</td>
<td>-</td>
<td>35V</td>
</tr>
</tbody>
</table>

---

Table 2.3. Ceramic capacitor letter coding.

<table>
<thead>
<tr>
<th>1st Suffix</th>
<th>Tolerance C ≤ 10pF</th>
<th>2nd Suffix</th>
<th>Rated Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>±5 $\mu F$</td>
<td>B</td>
<td>50V d.c.</td>
</tr>
<tr>
<td>B</td>
<td>±2.5 $\mu F$</td>
<td>C</td>
<td>125V d.c.</td>
</tr>
<tr>
<td>C</td>
<td>±1 $\mu F$</td>
<td>D</td>
<td>160V d.c.</td>
</tr>
<tr>
<td>D</td>
<td>±0.5 $\mu F$</td>
<td>E</td>
<td>250V d.c.</td>
</tr>
<tr>
<td>E</td>
<td>±0.25 $\mu F$</td>
<td>F</td>
<td>350V d.c.</td>
</tr>
<tr>
<td>F</td>
<td>±0.1 $\mu F$</td>
<td>G</td>
<td>700V d.c.</td>
</tr>
<tr>
<td>G</td>
<td>±0.05 $\mu F$</td>
<td>H</td>
<td>1000V d.c.</td>
</tr>
<tr>
<td>H</td>
<td>±0.025 $\mu F$</td>
<td>I</td>
<td>250V a.c.</td>
</tr>
<tr>
<td>I</td>
<td>±0.01 $\mu F$</td>
<td>J</td>
<td>500V a.c.</td>
</tr>
<tr>
<td>J</td>
<td>±0.005 $\mu F$</td>
<td>K</td>
<td>1000V a.c.</td>
</tr>
<tr>
<td>K</td>
<td>±0.0025 $\mu F$</td>
<td>L</td>
<td>±0.01%</td>
</tr>
<tr>
<td>L</td>
<td>±0.001 $\mu F$</td>
<td>M</td>
<td>±30% - 20%</td>
</tr>
<tr>
<td>M</td>
<td>±0.0005 $\mu F$</td>
<td>N</td>
<td>±50% - 20%</td>
</tr>
<tr>
<td>N</td>
<td>±0.00025 $\mu F$</td>
<td>O</td>
<td>±80% - 20%</td>
</tr>
<tr>
<td>O</td>
<td>±0.0001 $\mu F$</td>
<td>P</td>
<td>±100%</td>
</tr>
<tr>
<td>P</td>
<td>±0.00005 $\mu F$</td>
<td>Q</td>
<td>±120% - 10%</td>
</tr>
<tr>
<td>Q</td>
<td>±0.000025 $\mu F$</td>
<td>R</td>
<td>±140% - 7%</td>
</tr>
<tr>
<td>R</td>
<td>±0.00001 $\mu F$</td>
<td>S</td>
<td>±160% - 3%</td>
</tr>
<tr>
<td>S</td>
<td>±0.000005 $\mu F$</td>
<td>T</td>
<td>±180% - 1%</td>
</tr>
<tr>
<td>T</td>
<td>±0.0000025 $\mu F$</td>
<td>U</td>
<td>±200%</td>
</tr>
<tr>
<td>U</td>
<td>±0.000001 $\mu F$</td>
<td>V</td>
<td>-</td>
</tr>
<tr>
<td>V</td>
<td>±0.0000005 $\mu F$</td>
<td>W</td>
<td>-</td>
</tr>
<tr>
<td>W</td>
<td>±0.00000025 $\mu F$</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>X</td>
<td>±0.0000001 $\mu F$</td>
<td>Y</td>
<td>-</td>
</tr>
<tr>
<td>Y</td>
<td>±0.00000005 $\mu F$</td>
<td>Z</td>
<td>-</td>
</tr>
</tbody>
</table>

---

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. 102 = 10000pF = 10μF.

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 = 1μF
- 10nF (or 10n) = 10000pF = 0.1μF
- 100nF (or 10μm) = 10000pF = 0.1μF
- 1μF (or 1μ) = 1000000pF = 1000μF

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).
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:

\[
C_T = \frac{1}{(1/C_1) + (1/C_2) + (1/C_3) + \text{(etc)}}
\]

which is, of course, identical to the resistors in parallel formula, except for the letter change.

For capacitors in parallel (as for the three in Fig.2.8b) the formula is simply:

\[
C_1 + C_2 + C_3 + \text{(etc)}.
\]

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.

**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 \( C_1 = 100\mu F, C_2 = 47\mu F \) and \( C_3 = 2.2\mu F \). 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.)
LITRITING UP TIME

We are again going ask you to use a light emitting diode (i.e., 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 i.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 i.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 i.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 i.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 i.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 i.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.e.s). More particularly, it is a digital logic i.e.

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 objects, 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 waxed pipe is a suitable object, as is the exposed bare metal work of an i.e.d. earthed mains powered equipment. When i.e.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.e.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...

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 its 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 differing 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.
**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 I.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 I.E.D. is on when the capacitor voltage is fairly low, and off when the voltage is fairly high. You may find that the I.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 I.E.D. on-offness fully changes from one state to the other.

**MORE I.E.D.S**

Just for fun, connect up another inverter gate (IC1b) and five more I.E.D.s (D2 to D6) 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 I.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 I.E.D.s have on the output voltages of the gates? Compare with the voltages produced without I.E.D.s connected. We shall discuss this in another Tutorial. Also see if you can draw the circuit diagram for Fig.2.13.

**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.E. 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 I.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...
them. In the author's test model, the rate was in excess of one million cycles per second (1MHz).

The clever thing we 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, it reaches 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 it is probably extremely erratic, although it may indicate a voltage at around 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. This is at the 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 exactly 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 the circuit diagram for the oscillator experiment. (Fig.2.15). Note the new link between IC1 pins 4 and 5.

**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.
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TEST EQUIPMENT: How to Choose and Use Test Equipment. Assemble a Toolkit, Set Up a Workshop, and Get the Most from Your Multimeter and Oscilloscope, etc.

SERVICING TECHNIQUES: The regular Supplements include vital guidelines on how to Service Audio Amplifiers, Radio Receivers, TV Receivers, Cassette Recorders, Video Recorders, Personal Computers, etc.

TECHNICAL NOTES: Commencing with the IBM PC, PC-XT, PC-AT, this section and the regular Supplements deal with a very wide range of specific types of equipment.

REFERENCE DATA: Detailing vital parameters for Diodes, Small-Signal Transistors, Power Transistors, Thyristors, Triacs and Field Effect Transistors. Supplements include Operational Amplifiers, Logic Circuits, Optoelectronic Devices, etc.

SAFETY: Be knowledgeable about Safety Regulations, Electrical Safety and First Aid.
Constructional Project

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 I.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 utilizing 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:

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0000</td>
</tr>
<tr>
<td>1</td>
<td>0001</td>
</tr>
<tr>
<td>2</td>
<td>0010</td>
</tr>
<tr>
<td>3</td>
<td>0011</td>
</tr>
<tr>
<td>4</td>
<td>0100</td>
</tr>
<tr>
<td>5</td>
<td>0101</td>
</tr>
<tr>
<td>6</td>
<td>0110</td>
</tr>
<tr>
<td>7</td>
<td>0111</td>
</tr>
<tr>
<td>8</td>
<td>1000</td>
</tr>
<tr>
<td>9</td>
<td>1001</td>
</tr>
</tbody>
</table>

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 you 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 00110001. 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 I.e.d. inside the optocoupler on and off and the light from its I.e.d. shines onto an optotransistor, switching it on or 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 8B7, 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 I.e.d.s that make up the seven segments of the display. The PIC16C54 cannot by itself handle the current required by the I.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 I.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 I.e.d.s in a parallel arrangement and the five pairs arc arranged in series.

Thus the five pairs will drop the 12V supply by 5 x 2V, or about 10V, leaving the last resistor with 2V (12V - 10V) to to. The I.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 I.e.d.s will put out good light from about 10mA to some 30mA, which is the maximum for most I.e.d.s. If you need to save power, try putting in 220 ohms ballast resistors and see how the light output looks.

The decimal point and colon I.e.d.s are done the same way except that the I.e.d.s are all in series as there are not as many of them. These I.e.d.s are not controlled in any way and arc 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 I.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 I.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 I.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 I.e.d.s and make sure that they are all the correct way around, noting that some high brightness I.e.d.s have different orientations to those of ordinary I.e.d.s. If
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.
in doubt, you can check by temporarily connecting the I.e.d. in series with a 1kΩ resistor across a 12V power supply.

Flip the board over and solder only one lead of each I.e.d. When you have done that, go back and grasp both leads of each I.e.d. and re-melt the solder while gently pulling upwards on the leads. This will seat each I.e.d. onto the circuit board and generally make sure it is pointing straight out from the board. This is important as high brightness I.e.d.s only appear bright when you look directly onto them. If they are tilted, they will 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 the ballast resistors (R8 to R16) and some power leads for the 12V supply.

### Table 1: Module Selection Switches

<table>
<thead>
<tr>
<th>Module</th>
<th>Switch Settings</th>
<th>Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>off</td>
<td>off</td>
</tr>
<tr>
<td>1</td>
<td>off</td>
<td>off</td>
</tr>
<tr>
<td>2</td>
<td>off</td>
<td>off</td>
</tr>
<tr>
<td>3</td>
<td>off</td>
<td>on</td>
</tr>
<tr>
<td>4</td>
<td>on</td>
<td>off</td>
</tr>
<tr>
<td>5</td>
<td>on</td>
<td>on</td>
</tr>
<tr>
<td>6</td>
<td>on</td>
<td>on</td>
</tr>
<tr>
<td>7</td>
<td>on</td>
<td>on</td>
</tr>
<tr>
<td>8</td>
<td>on</td>
<td>off</td>
</tr>
<tr>
<td>9</td>
<td>on</td>
<td>on</td>
</tr>
<tr>
<td>10</td>
<td>on</td>
<td>off</td>
</tr>
<tr>
<td>11</td>
<td>on</td>
<td>off</td>
</tr>
<tr>
<td>12</td>
<td>on</td>
<td>off</td>
</tr>
<tr>
<td>13</td>
<td>on</td>
<td>off</td>
</tr>
<tr>
<td>14</td>
<td>on</td>
<td>off</td>
</tr>
<tr>
<td>15</td>
<td>on</td>
<td>on</td>
</tr>
</tbody>
</table>

* 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 (G). 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 I.e.d.s the wrong way around, broken tracks, or the wrong ballast resistor value, in that order.

If all is well, continue inserting I.e.d.s, testing, inserting, testing...

If any I.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.

Because the colon and decimal point I.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.

**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 also show up any solder-splashes or broken tracks to these pins.

Switch off the power and insert IC3, the I.e.d. driver device. To 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 I.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.

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 publication of Part 1 the software has been revised by the author. The new version is on the EPE disk and website.
We can supply back issues of EPE and ETI (see panel) by post; most EPE issues from the past five years are available. An EPE index for the last five years is also available – see order form. Alternatively, indexes are published in the December issue for the same price.

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If you or an soon will be, involved in the use of microprocessors, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors: assuming no previous knowledge of the subject, with technical/mathematical back-ground. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern microprocessors.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved to be a problem in the past are clearly explained. John Crisp covers the complete range of microprocessors from the Intel 8085 to the 68020, and the book is designed for today's fast 32-bit and 64-bit versions that power PCs and engine cars of the future.

Contents: The world changed in 1971; Microprocessors don't have to be frightening; Hardware and software; The heart of the system; The microprocessor; The microcomputer; In the future; A typology of microprocessors; Basic computer design; Using and programming the microcomputer; Other microprocessors; Further study on microprocessors; Logic gates; Modern microprocessor applications.

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ALL CIRCUITS, ALL DESIGN

Everyday Practical Electronics/ETI. December 1999
Specially imported by EPE – Excellent value
An Unconventional Guide to Electronics Fundamentals, Components and Processes
This book gives an overview of 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 IC's 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 the professional, 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  
DIGITAL ELECTRONICS – A PRACTICAL APPROACH
With FREE Software: Number One Systems – EASY-PC Professional XM and Pulsor (Limited Functionality)
Richard Monk
Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic, 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 included in 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 circuits 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 NVQ. 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  
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. No background knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to logic design.
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AN INTRODUCTION TO LOUDSPEAKERS AND ENCLOSURE DESIGN
K. Corbett
This book explores the various features, good points and snags of speaker design. It examines the whys and wherefores so that the reader can understand the principles involved and so make an informed choice of design, or even undertake simple enclosures for him- or herself. Crossover units are also explained, the various types, how they work, the distortions they produce and how to avoid them. Finally there is a step-by-step description of the construction of the K. Corbett loudspeaker kit.
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Hans-Günther Stadler

This book is indispensable for anyone who needs information about the package shapes, pin connections and basic electrical characteristics for each of the many thousands of transistors listed. The data includes the circuit diagram, forward and reverse characteristics, and power dissipation, current gain and forward transfer characteristic. A special section is devoted to the performance of a range of compact transistors, which are just a multimetal (plus a few in a few cases) in the same package. Some useful check methods are also included.

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Eric Johnston

The principles of operation of the various types of test instrument are explained in simple terms with a minimum of mathematical analysis. The book covers analogue and digital meters, bolometer, oscilloscopes, signal generators, counters, timers and frequency measurement. The practical uses of the instruments are also examined.

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This book is primarily aimed at beginners and those of limited experience who want to understand the basic principles of analogue and digital multipliers, discussing the relationship between the basic types of multiplier and the use of the multiplier in circuits. Chapter 2 covers the principles of operation of multipliers. Capacitors and diodes. Circuit testing is covered in Chapter 2. It is an essential tool for any electronics engineer or technician.

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Geoff Mips

The author has used his 30 years experience in industry to draw together the basic information that is considered to be essential. Facts, formulae, data and charts are presented to help the engineer when designing, developing, evaluating, fault finding and repairing electronic circuits. The result is a handy voluminous volume: a memory aid, tutor and reference source which is recommended to all electronics engineers, students and technicians.

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PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING

Robin Pain

This book is not a theory book, it is a book of practical tips, hints and alternatives 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 the subject too mathematical or specialist.

The book covers Basics - Voltage, current and resistance; Capacitance, inductance and impedance; Diodes and transistors; DC and negative feedback; Fault finding - Analogue fault finding; Digital fault finding - Memory: Binary and hexadecimal; Addressing: Direct logic; Microprocessor action; I /O control; CRT control; Dynamic RAM; Fault finding digital systems: Dual trace oscilloscopes; IC replacement.

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An Introduction to Light in Electronics

F. A. Wilson

This book is not for the expert but neither is it for the complete novice. It is assumed that the reader has some basic knowledge of electronics. After dealing with subjects like fundamentals, waves and particles and the nature of light such things as Emitters, Detectors and Diodes are covered. Chapter 7 details four different types of Lasers before concluding with a chapter on Fibre Optics.

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Understanding Digital Technology

F. A. Wilson

This book examines what digital technology has to offer and then considers its arithmetic and how it can be arranged for making decisions in so many possibilities. It also looks at the part digital has to play in the ever-expanding information technology, especially in modern microsystem systems and television. It avoids getting deeply involved in mathematics.

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R. A. Penfold

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R. A. Penfold

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Everyday Practical Electronics/ETI, December 1999
**PCB SERVICE**

Printed circuit boards for certain EPE constructional projects are available from the PCB Service. These are fabricated in glass fibre, and are fully drilled and router tinned. All prices include VAT and postage and packing. Add £1 per board for overseas orders or queries by Fax); E-mail: orders@epemag.wimborne.co.uk. Please check price and availability in the latest issue. Back issues page for details.

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**EPE SOFTWARE**

Software programs for EPE projects marked with an asterisk * are available on 3.5 inch PC-compatible disk or free from our Internet site. Five disks are available: PIC Tutorial (Mar-May '98 issues); PIC Toolkit Mk2 (May-Jun '99 issues); PIC Disk 1 (Apr '95 -Dec '98 issues); EPE Disk 2 (Jan '99 issue to current cover date); EPE Teach-In 2000. The disks are available: PIC Tutorial (for the UK) to cover our admin costs (the software itself is free). Overseas (each): £23.35 surface mail, £4.35 each airmail. All files can be downloaded free from our Internet FTP site: ftp://ftp.epemag.wimborne.co.uk.

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**Everyday Practical Electronics**

Everyday Practical Electronics/S:, December 1999

937
Transfer Protocol.

users having apparently been foiled by the process of File

more than one unfavourable comment about the FTP site, some

tronc. thermistor or halogen lamp. they say. Using an ohmmeter

devoted to Call Service Error 50! The problem could be a fuser.

California (www.all-laser.com) and - bingo

"laserjet" into Deja News (www.deja.com) to see what other folks


problem is usu-

it is always more encouraging to know that users have tried to help

them by E-mail instead, and I will of course try to oblige. although

in the USA.

repair scanners, and the site also had a map feature which displayed

suddenly broke down at quite a critical time, so my first pon of call

with his HP LaserJet. an old but very sturdy LaserJet 3 which was

I printed that off, threw everything in the car and went off in

search of a 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 usu-

ally where to start. Have a look at the brand new Help web site


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 contribu-
tions therein. The reader wondered if my mood could be gauged
from the way I signed off my messages: perhaps a curt “ARW” sig-
nature 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 cus-
tomer anyway, your scribe bides 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 elec-
tronics, 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 dis-
posal. 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 com-
plaints 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 mes-
sages 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
or 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 con-
firm. 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 flaky, or if a beginner is frustrated with the com-
plex 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 regular-
ly included in computer magazine cover-mouted 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.
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Everyday Practical Electronics/ETI, December 1999
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A range of videos selected by EPE and designed to provide instruction on electronics theory. Each video gives a sound introduction and grounding in a specialised area of the subject. The tapes make learning both easier and more enjoyable than pure textbook or magazine study. They have proved particularly useful in schools, colleges, training departments and electronics clubs as well as to general hobbyists and those following distance learning courses etc.

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Each video uses a mixture of animated current flow in circuits plus text, plus cartoon instruction etc., and a very full commentary to get the points across. The tapes are imported by us and originate from VCR Educational Products Co., an American supplier. We are the worldwide distributors of the PAL and SECAM versions of these tapes. (All videos are to the UK PAL standard on VHS tapes unless you specifically request SECAM versions.)
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Published on approximately the first Friday of each month by Wimborne Publishing Ltd., Allen House, East Bourough, Wimborne, Dorset BH21 1PB. Printed in England by Wimborne (Printers) Ltd., Blandford, B320 9NP. Distributed by COMAG Magazine Marketing, Tavistock Rd., West Drayton, UB7 7OE. Subscriptions INLAND £26.50 and OVERSEAS £32.50 standard air service (£50 express airmail) payable to "Everyday Practical Electronics", John Post, Allen House, East Bourough, Wimborne, Dorset BH21 1PB. Email: sales@openag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS (U.K.) is sold subject to the following conditions, namely that it shall not, without the written consent of the Publisher be sold, lent, rented, hired out or otherwise disposed of by way of Trade at more than the recommended selling prices shown on the covers and that it shall not be lent, hired out or otherwise disposed of to a multisubscription or in any unauthorized cover or in any unauthorized format or by way of Trade or offered to or as part of any publication or advertising, literary or pictorial material whatsoever.

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