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Volume 2 Issue 12
December 2000

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

VOL. 29. No. 12 DECEMBER 2000

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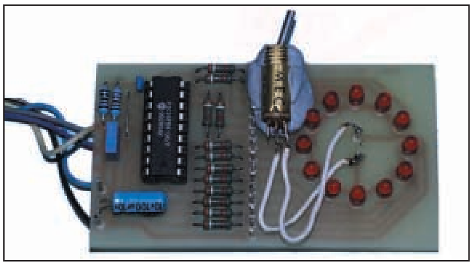

NOTE NEW PUBLISHING DATE
January issue on sale Thursday December 14

Projects and Circuits

Series and Features

Regulars and Services

Our January 2001 issue will be published on Thursday, 14 December 2000. See page 875 for details

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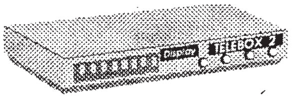
Converts your colour monitor into a QUALITY COLOUR TV!!



TV SOUND & VIDEO TUNER
*CABLE COMPATIBLE**

The **TELEBOX** is an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors or AV equipment which are fitted with a composite video or SCART input. The composite video output will also plug directly into most video recorders, allowing reception of **TV channels not normally receivable on most television receivers*** (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' UHF colour television channels. **TELEBOX MB** covers virtually all television frequencies VHF and UHF **including the HYPERBAND as used by most cable TV operators.** Ideal for **desktop computer video systems** & PIP (picture in picture) setups. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard. Brand new - fully guaranteed.

TELEBOX ST for composite video input type monitors	£36.95
TELEBOX STL as ST but fitted with integral speaker	£39.50
TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6 mHz sound specification.
*For cable / hyperband signal reception Telebox MB should be connected to a cable type service. Shipping on all Telebox's, code (B)

NEW **State of the art** PAL (UK spec) **UHF TV tuner module** with **composite** 1V pp video & **NICAM** hi fi stereo sound outputs. **Micro electronics** all on one small PCB only 73 x 160 x 52 mm enable full tuning control via a **simple 3 wire link** to an IBM pc type computer. Supplied complete with **simple working program** and documentation. Requires +12V & + 5V DC to operate.
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All units (unless stated) are ***BRAND NEW*** or removed from often brand new equipment and are fully tested, aligned and shipped to you with a full 90 day guarantee. Call or see our web site ***www.distel.co.uk*** for over 2000 unlisted drives for spares or repair.

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5¼" **Teac** FD-55GFR 1.2 Meg (for IBM pc's) RFE	£18.95(B)
5¼" **Teac** FD-55F-03-U 720K 40/80 (for BBC's etc) RFE	£29.95(B)
5¼" **BRAND NEW Mitsubishi** MF501B 360K	£22.95(B)
Table top case with integral PSU for HH 5¼" Floppy / HD	£29.95(B)
8" Shugart 800/801 8" SS refurbished & tested	£210.00(E)
8" Shugart 810 8" SS HH *Brand New*	£195.00(E)
8" Shugart 851 8" double sided refurbished & tested	£260.00(E)
8" Mitsubishi M2894-63 double sided *NEW*	£295.00(E)
8" Mitsubishi M2896-63-02U DS slimline *NEW*	£295.00(E)
Dual 8" cased drives with integral power supply 2 Mb	£499.00(E)

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2½" **TOSHIBA** MK1002MAV 1.1Gb laptop(12.5 mm H) *New*	£79.95
2½" **TOSHIBA** MK2101MAN 2.16 Gb laptop (19 mm H) *New*	£89.50
2½" **TOSHIBA** MK4309MAT 4.3Gb laptop (8.2 mm H) *New*	£105.00
2½" **TOSHIBA** MK6409MAV 6.1Gb laptop (12.7 mm H) *New*	£190.00
2½" to 3½" conversion kit for Pc's, complete with connectors	£14.95
3½" **FUJI** FK-309-26 20mb MFM I/F RFE	£59.95
3½" **CONNER** CP3024 20 mb IDE I/F (or equiv.) RFE	£59.95
3½" **CONNER** CP3044 40 mb IDE I/F (or equiv.) RFE	£69.00
3½" **QUANTUM 40S** Prodri ve 42mb SCSI I/F, New RFE	£49.00
5¼" **MINISCRIBE** 3425 20mb MFM I/F (or equiv.) RFE	£49.95
5¼" **SEAGATE** ST-238R 30 mb RLL I/F Refurb	£69.95
5¼" **CDC** 94205-51 40mb HH MFM I/F RFE tested	£69.95
5¼" **HP 97548** 850 Mb SCSI RFE tested	£99.00
5¼" **HP C3010** 2 Gbyte SCSI ***differential*** RFE tested	£195.00
8" **NEC D2246** 85 Mb SMD interface. ***New***	£199.00
8" **FUJITSU** M2322K 160Mb SMD I/F RFE tested	£195.00
8" **FUJITSU** M2392K 2 Gb SMD I/F RFE tested	£345.00

Many other drives in stock - Shipping on all drives is code (C1)

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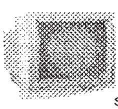
One of the highest specification monitors you will *ever* see - At this price - Don't miss it!!

Mitsubishi FA3415ETKL 14" SVGA **Multisync** colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including **IBM PC's** in CGA, EGA, VGA & SVGA modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE.** Many features: Etched faceplate, text switching and **LOW RADIATION MPR** specification. Fully guaranteed, in EXCELLENT little used condition.



Tilt & Swivel Base £4.75
VGA cable for IBM PC included.
Only £119 (E) **Order as MITS-SVGA**
External cables for other types of computers available - CALL.

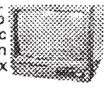
Ex demo 17" 0.28 SVGA Mitsubishi Diamond Pro monitors, Full multisync etc.
Full 90 day guarantee. Only £199.00 (E)

Just In - Microvitec 20" VGA (800 x 600 res.) colour monitors.
Good SH condition - from £299 - CALL for Info

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with <u>both</u> **RGB and standard composite 15.625 Khz video inputs** via **SCART socket** and separate phono jacks. Integral audio **power amp and speaker** for **all audio visual uses.** Will connect direct to **Amiga and Atari** BBC computers. Ideal for all **video monitoring / security** applications with **direct connection to most colour cameras.** High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested - guaranteed
Dimensions: W14" x H12¾" x 15½" D. **Only £99.00** (E)

PHILIPS HCS31 Ultra compact 9" colour video monitor with **standard composite 15.625 Khz video** input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive square black plastic case measuring W10" x H10" x 13½" D. 240 V AC mains powered. **Only £79.00** (D)

KME 10" 15M10009 high definition colour monitors with 0.28" dot pitch. Superb clarity and modern styling. Operates from any 15.625 khz sync RGB video source, with RGB analog and composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 13½" x 12" x 11". Good used condition. **Only £125** (E)



20" 22" and 26" AV SPECIALS

Superbly made UK manufacture. PIL all solid state colour monitors, complete with composite video & ***optional*** sound input. Attractive teak style case. Perfect for Schools, Shops, Disco, Clubs, etc. In EXCELLENT little used condition with full 90 day guarantee.

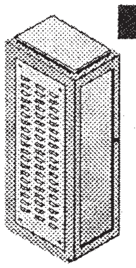
20"....£135 22"....£155 26"....£185 (F)

We probably have the largest range of video monitors in Europe, All sizes and types from 4" to 42" call for info.

DC POWER SUPPLIES

Virtually every type of power supply you can imagine. Over 10,000 Power Supplies Ex Stock Call or see our web site.

19" RACK CABINETS



Superb quality 6 foot 40U
Virtually New, Ultra Smart
Less than Half Price!

Top quality 19" rack cabinets made in UK by **Optima Enclosures Ltd.** Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and louvered removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting, plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the ***most versatile we have ever sold.*** Racks may be stacked side by side and therefore require only two side panels to stand singly or in multiple bays. Overall dimensions are: 77½" H x 32½" D x 22" W. **Order as:**

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19" 22" & 24" wide 3 to 46 U high.
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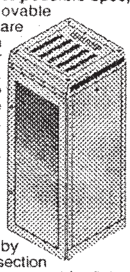

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42U version of the above only £345 - CALL

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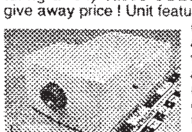

Web ref = LK33 ***ONLY £99.00 or 2 for £180.00*** (B)

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shipping charges for software is code B

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Wayne Kerr RA200 Audio frequency response analyser	£2500
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ALLGON 8360.11805-1880 MHz hybrid power combiners	£250
Trend DSA 274 Data Analyser with G703(2M) 64 i/o	£POA
Marconi 6310 Programmable 2 to 22 GHz sweep generator	£6500
Marconi 2022C 10KHz-1GHz RF signal generator	£1550
Marconi 2030 opt 03 10KHz-1.3 GHz signal generator,New	£4995
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Emerson AP130 2.5KVA industrial spec.UPS	£2100
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Siemens K4400 64Kb to 140Mb demux analyser	£2950
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Motorola VME Bus Boards & Components List. SAE / CALL	£POA
Trio 0-18 vdc linear, metered 30 amp bench PSU. **New**	£550
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ANRITSU 9654A Optical DC-2.5G/b waveform monitor	£5650
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ANRITSU ML93A optical power meter	£990
ANRITSU Fibre optic characteristic test set	£POA
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TEK TDS380 400Mhz digital realtime + disk drive, FFT etc	£2900
TEK TDS524A 500Mhz digital realtime + colour display etc	£5100
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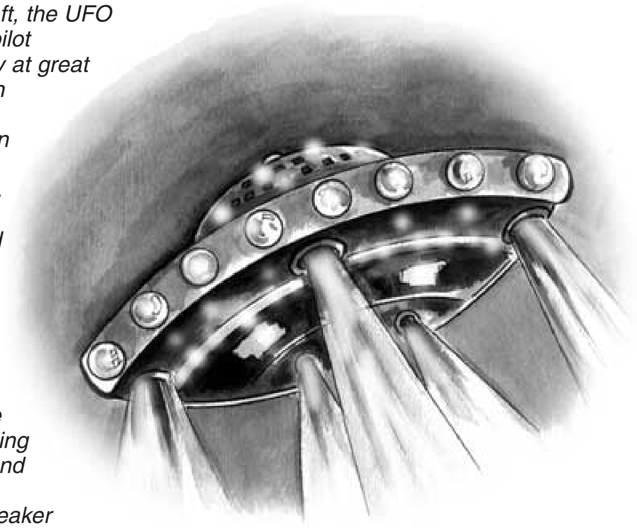
NEXT MONTH

UFO DETECTOR AND EVENT RECORDER



Although some ancient texts are said to contain references to spacecraft, the UFO enigma really began on the afternoon of 24 June, 1947, when aircraft pilot Kenneth Arnold reported nine crescent-shaped objects crossing the sky at great speed near Mount Rainier in the State of Washington, USA. Since then there have been countless sightings, world-wide, and private and government organisations have been set up to investigate and report on the phenomena.

And there's been no shortage of encounters to fill the researchers' files. Whilst many incidents have been shown to have a terrestrial origin, there remains a solid core of cases where inexplicable phenomena and reliable witnesses combine to challenge our disbelief.

One thing running like a thread through many of the reports is the powerful magnetic disturbance which accompanies the craft. Car and aircraft ignition systems falter or fail (presumably the ignition coil core becomes saturated), and dashboard and navigation instruments behave erratically.

As recently as 30 March this year, a family travelling along the Klondike Highway in Canada claim to have observed a saucer-shaped UFO closing in on their car. Headlights dimmed, the tape recorder stopped playing and battery operated watches malfunctioned.

The equipment to be described next month will detect and record far weaker magnetic perturbations than these. Stand-by current is extremely low, and the battery powered units can be operated economically in remote locations. Go out and find your alien!

A TWO-WAY INTERCOM

Intercom projects used to be part of the staple diet of electronic construction enthusiasts with at least one appearing somewhere every year. Over time they seem to have become less common, perhaps because they can be bought quite cheaply nowadays, so when a reader asked if EPE *had recently published one, editorial eyebrows rose at the discovery that some eight years had passed since the last appeared. It seemed timely, therefore, to present a new intercom design.*

It might be asked why anyone would build an intercom when they can be bought quite cheaply. In fact there are several reasons. A home-built design can be customised, built into other projects, modified and used in ways its original design never intended. Parts of the circuit might be adapted for use in other projects. The constructor can easily repair it if it goes wrong and an intercom is a good starter project for those seeking electronic experience. Last, but by no means least, constructors with children will probably find that an intercom's entertainment potential will earn them lots of brownie points with the kids! Given all this, a new design seems well worthwhile.

VERSATILE OPTICAL TRIGGER

This is a circuit that is flexible enough to cater for many different applications. In its basic form, the Versatile Optical Trigger switches a load on or off, depending on the amount of light falling on its sensor. It can be set to respond in reasonably bright conditions or in dim light. It can be adapted to work either way round, switching on when the light gets brighter, or when it becomes dimmer.

Applications for the basic circuit include switching on a porch lamp at dusk, briefly sounding a buzzer when someone's shadow falls on the sensor (or when the cat leaves the house by the cat door), or to switch on a lamp in a cupboard when the door is opened. We leave it to the imagination of the reader to find other interesting things to do with this circuit.

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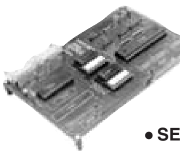

KIT 621 £99.95

- ON BOARD 5V REGULATOR
- PSU £6.99
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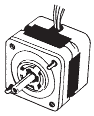
Stepping Motors



MD38...Mini 48 step...£8.65
MD35...Std 48 step...£9.99
MD200...200 step...£12.99
MD24...Large 200 step...£22.95

PIC PIPE DESCALER

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- SWEPT FREQUENCY
- HIGH POWER OUTPUT
- AUDIO & VISUAL MONITORING

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, P.C.B., coupling coil and all components.
High coil current ensures maximum effect. L.E.D. monitor.

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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/pests away from newly sown areas, play areas, etc. uses power source from 9 to 24 volts.

- **RANDOM PULSES**
- **HIGH POWER**
- **DUAL OPTION**

Plug-in power supply £4.99

KIT 867. . . . .£19.99
KIT + SLAVE UNIT. £32.50

WINDICATOR

A novel wind speed indicator with LED readout. Kit comes complete with sensor cups, and weatherproof sensing head. Mains power unit £5.99 extra.

KIT 856. . . . .£28.00

★ TENS UNIT ★

DUAL OUTPUT TENS UNIT

As featured in March '97 issue.

Set of 4 spare electrodes **£6.50**

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 providing high level dual output drive.

KIT 866. . Full kit including four electrodes £32.90

1000V & 500V INSULATION TESTER

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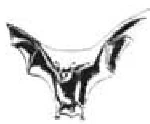

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THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 29 No. 12 DECEMBER 2000

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BUMPER

A bumper issue this month with the extra 16 pages devoted to Christmas projects. We have a regular problem with trying to fit everything into each issue, and I try to balance the content to appeal to a wide range of readers, With regular series like *Teach-In 2000* (Nov 1999 to Oct 2000) and now *The Schmitt Trigger*, plus a range of constructional projects and the regular features it's always a bit of a tight squeeze and sometimes it's difficult to know what to leave out. Only occasionally can we afford to go "over the top" with the number of pages to bring you extra content, we are, however, planning a couple more bumper issues for the Spring.

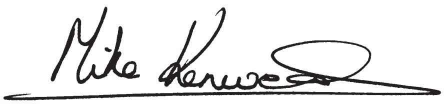
Incidentally, our educational series are always very popular and we are presently working at putting *Teach-In 2000* on a mini CD-ROM. The complete course, together with all the software, should soon be available in this form, hopefully there will be more news on this in the next issue.

DESIGN

We are often asked by readers how to design circuits and sometimes more specifically to tell them how we arrived at the values of each component in a particular circuit design – not something we can offer to provide, I'm afraid.

As an insight to the variations and complexity of circuit design the present *Schmitt Trigger* series should be an eye-opener for many readers. One *EPE* contributor has already commented that he did not realise there was so much to say about Schmitt Triggers – and that was after Part 1! This series is a little above the general level of theory we normally carry in *EPE*, but should interest those of you who are above the beginner level and who want to understand more about circuit design.

We can't promise to tell you everything there is to know about Schmitt Triggers, but you will certainly learn a lot.



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PIC-MONITORED DUAL PSU

JOHN BECKER Part One

Ever keen to add tools to the workshop, the author designs yet another, and finds more uses for a PIC16F877!

THE dual power supply unit (PSU) described here can be built in several forms.

At the simplest level it can be built with a single d.c. output switched for 5V or variable between about 6V and 9V. This shortened version is probably an ideal starter power supply for those who have been following the recent *Teach-In 2000* series and now wish to start adding workshop equipment.

This version will be described in Part 2, as will other constructional options. Some aspects of the main PSU have also been described in such as way as to reinforce the understanding of power supplies by *Teach-In 2000* readers.

It is emphasised that mains a.c. electrical power is dangerous and that construction of any of the versions of this power supply should only be undertaken (or supervised) by those who are suitably qualified or experienced.

FULL VERSION

The full version of the dual power supply provides PIC microcontroller monitoring of voltage and current, displaying the data on a liquid crystal display (l.c.d.). It has the specifications shown opposite.

Specifications

- ***Dual channel***, switchable for series or parallel operation:

  Two outputs per channel (four outputs total).

  Output 1 switchable for fixed voltages of 5V, 6V, 9V, 12V, 15V or 18V.

  Output 2 fully variable from about 0V up to 1V less than the switch-selected fixed voltage.

  In series connection mode, the common rail of Channel B is connected to the selected fixed voltage of Channel A, providing a maximum output of +18V from Channel A and +36V from Channel B, or –18V from Channel A and +18V from Channel B.

  All outputs are "floating" with respect to mains earth (ground) and any output can be regarded as the 0V (common) level.

- ***Output monitoring:***

  PIC16F877 microcontroller simultaneously monitors voltage and current for both outputs of both channels (four outputs).

  Monitored data is output to a 2-line 16-character (per line) alphanumeric l.c.d.

  The PIC controls l.e.d.s and buzzer in response to preset current limits being exceeded.

- ***Display modes:***

  1. Each channel's data shown individually, stating output voltage, output current, preset alarm-trip current. Channels switch-selectable on a cycle of four.
  2. All four monitored voltages shown simultaneously.
  3. All four monitored currents shown simultaneously.

- ***Maximum output currents:***

  Output 1 (switched voltage), 1A but see text and Table 6 later.

  Output 2 (variable voltage), 350mA but see text in Part 2.

- ***Current limiting:***

  Output 2 can be set to limit the power supplied to the load circuit, using a panel control.

Each of the four outputs can have a maximum current limit set via pushbutton switches. If the preset current is exceeded, a light emitting diode (l.e.d.) indicates which channel is overloaded. A buzzer sounds if the total current drawn from either channel exceeds 1A. Physical limitation of the current supplied is *not* controlled by this option.

The PIC's EEPROM data memory retains the limit value set even when the power supply unit is switched off.

The basic block diagram for the power supply is shown in Fig.1. All controls are omitted except for the Series/Parallel switch.

TRANSFORMER

Illustrated in Fig.2 is the circuit diagram for the mains a.c. input and transformer. For use in the UK, transformer T1 should have the primary winding rated for 230V a.c. For the USA, the primary winding should be rated for 110V a.c. Readers from other countries should select the primary

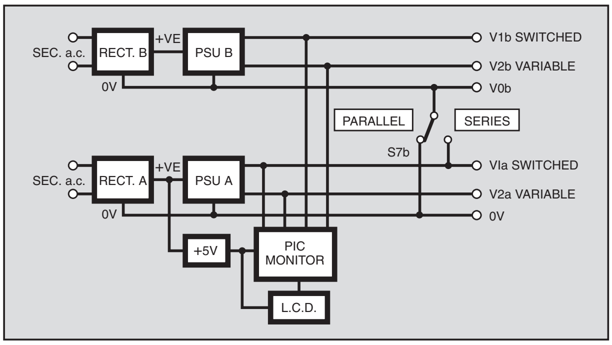


FIg.1. Block diagram for the full dual power supply.

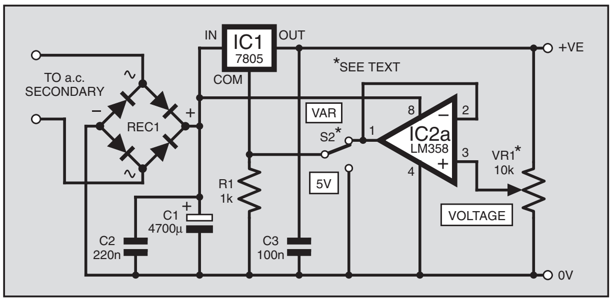


Fig.3. Circuit diagram for one channel of the power supply as a simple concept.

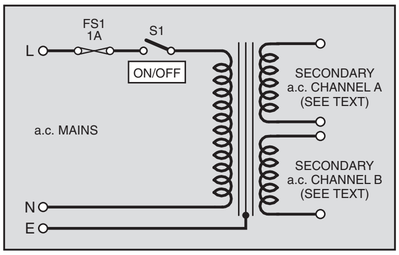


Fig.2. Mains transformer circuit diagram.

winding voltage to suit their domestic mains supply.

The choice of secondary winding voltage and current ratings is somewhat up to the user. In the author's prototype described here, each is rated at 15V a.c. 1·67A (25VA per winding). Lower voltage and current types may be selected instead, but with an accompanying reduction in the power supply's capabilities.

It should remembered that the bridge-rectified d.c. output voltage is approximately 1·414 times the a.c. voltage supplied by the transformer secondary, minus 1·4V for the bridge rectifier voltage drop, and that the voltage regulator requires a minimum voltage drop across it of about 2V d.c.

Thus, for example, the 15V a.c. secondary of the prototype is rectified to produce approximately 20V d.c. at the input to the regulator. In practice, the rectified voltage is likely to be somewhat higher than this when the power supply is not connected to an external load circuit (approx 22·3V on the prototype).

BASIC REGULATION

The circuit diagram of the power supply as a basic concept for a single channel is shown in Fig.3. It is this circuit which will be returned to when construction of the simple power supply is described in Part 2. For the dual supply, two modified versions of this circuit are used.

The bridge rectifier is shown as REC1, with capacitors C1 and C2 providing the initial smoothing to eliminate the ripple voltage from the rectifier. As said earlier, the voltage at this node is likely to be about 20V minimum.

In *Teach-In 2000* it was stated that the working voltage for the smoothing capacitor (C1) should ideally be twice that of the rectified output voltage, to provide a reasonable safety margin in the event of power line spikes or surges.

For the sake of expediency, however, in the prototype a capacitor rated at 35V d.c. is used (the author had them in stock). However, the printed circuit board has been designed to accept the physical size of capacitors rated at greater than 35V should you prefer to use them.

The bridge rectifier used is rated at 50V 1A and is a commonly available device, type W005. It should not be called upon to supply a current greater than the rated 1A.

This factor limits the actual current which can be drawn from each power supply channel, a value which must take into account the current drawn by the controlling and monitoring circuit. For Channel A, allow for an "internal" current of about 50mA maximum should all the monitoring l.e.d.s and the buzzer be on together.

The voltage regulation circuit comprises regulator IC1, op.amp IC2a, potentiometer VR1, resistor R1 and switch S2.

WELL ESTABLISHED

This circuit is based on the "industry standard" that has been around for several decades, as shown in National Semiconductor's linear device data book, for example.

The regulator, a +5V device, tries to maintain a difference of 5V between its output and common pins. If the voltage to which the common pin is connected is 0V, then the output will, of course, be 5V. However, if the voltage at the common pin is raised, then the output voltage will rise similarly, to maintain the 5V differential.

To achieve a practical variable output voltage an op.amp is used as a unity gain buffer whose non-inverting input is fed with a variable voltage, as supplied by potentiometer VR1. The buffer's output thus sets the voltage supplied to IC1's common pin. Resistor R1 provides a minimum current flow from the common pin to 0V.

Because VR1 is supplied by the output of IC1, the circuit configuration maintains the desired 5V output/common differential, and the final output voltage of the circuit is held regulated at the value set by VR1.

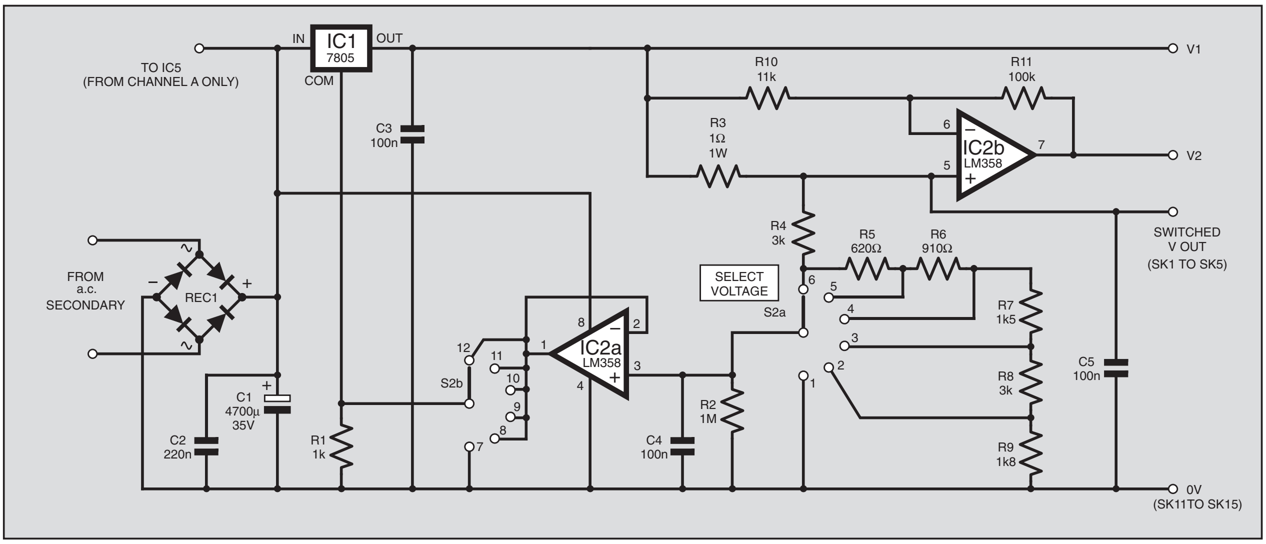


Fig.4. Circuit diagram of a single channel as used in the full power supply discussed. It is an expanded variant of that in Fig.3.

It should be noted, though, that the output of the op.amp (a type LM358) can never fall to 0V. More typically the minimum output voltage available will be about 0·5V. Consequently, the minimum regulated voltage that can be set by VR1 will be about 5·5V. The maximum voltage will about 2V below the rectified voltage fed into the input of regulator IC1.

In Fig.3, switch S2 selects whether IC1's common pin is connected to 0V (for fixed 5V output) or to the op.amp's output (for variable voltage control).

SWITCHED SUPPLY

For the full power supply design, the circuit of Fig.3 is expanded to become that in Fig.4.

Here the single potentiometer of Fig.4 has been replaced by a chain of six resistors, providing a tapped potential divider whose nodes are selected by rotary switch S2a. The reason for the inclusion of resistor R3 will be stated presently.

Capacitor C4 and resistor R2 are included to minimise voltage surges when the voltage range is switched. A smoothing capacitor is NOT connected between the op.amp's output and the 0V line since it was found that this could cause oscillation in the regulated supply.

Switch S2b replaces S2 of Fig.3, selecting between 5V and the preset output voltage from the buffering op.amp.

POTENTIAL CALCULATIONS

When considering the design of this power supply, the author originally believed that the tapped controlling voltages fed to the op.amp would need to be provided via individual preset potentiometers, each set for a different bias voltage, 5V below the required output from the regulator. The first constructed model actually used presets.

Initial calculations for a fixed multi-node potential divider had showed that the required resistors would have unusual values. The calculations were based on a total resistance across the divider of 10kΩ (as used for the basic potentiometer control).

As an example, and referring to Fig.5, consider the situation for Vout = 6V:

Rtotal = Rx + Ry = 10kΩ
Vout = 6V
Vbias = Vout – 5V = 1V
(5V is the voltage differential between IC1's output and common pins)

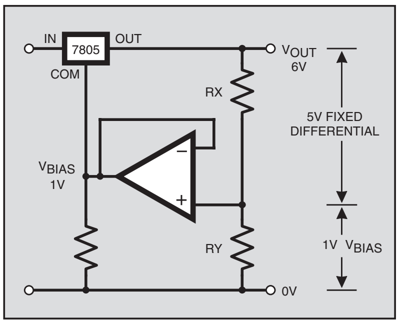


Fig.5. Potential divider use to control the voltage output from regulator IC1 at 6V.

Using the potential divider formula of:

Vbias = Vout × (Ry / Rtotal)

the equation can be stated as:

1V = 6V × (Ry / 10k)

Making Ry the subject produces the equation:

Ry = (1V / 6V) × 10k = 1·666667k

Thus Rx becomes:

Rtotal – Ry = 10k – 1·666667k = 8·333333k

Table 1 shows the individual resistor values in the divider chain of Fig.6 calculated for all five required output voltages. The calculations were produced by the QBasic program in Listing 1, in which Rtotal is the total resistance set at 10 (the "k'' factor being omitted).

Table 1

IDEAL VALUES for Rtotal = 10k

Vout	*Vbias*	*Resistor*
6V	1V	R1 1·666667k
9V	4V	R2 2·777778k
12V	7V	R3 1·388889k
15V	10V	R4 ·8333332k
18V	13V	R5 ·5555557k

R6 = Rtotal–(R1+R2+R3+R4+R5)
= 2·777778k

The calculations were originally done by hand without the computer program. However, in an idle moment some weeks after building the power supply, the author gave the problem to the computer, using Listing 1. Calculations were made for several different values of Rtotal. A value for Rtotal of 11(k) produced the results shown in Table 2.

Table 2

IDEAL VALUES for Rtotal = 11k

Vout	*Vbias*	*Resistor*
6V	1V	R1 1·833333k
9V	4V	R2 3·055556k
12V	7V	R3 1·527778k
15V	10V	R4 ·9166668k
18V	13V	R5 ·6111109k

R6 = Rtotal-(R1+R2+R3+R4+R5)
= 3·055555k

Since these values appeared to be close to the available E24 series values, a second program was written (Listing 2). In the program, the calculated output voltages were derived for a divider chain comprised of E24 values nearest to those in Table 2, i.e. 1k8, 3k, 1k5, 910Ω, 620Ω, 3k. The results are shown in Table 3.

Table 3

E24	*Values*	*Vout*
R1	1k8	5·996678V
R2	3k	8·9801V
R3	1k5	11·95364V
R4	910Ω	14·95856V
R5	620Ω	18·05V
R6	3k	

Rtotal = 10·83k

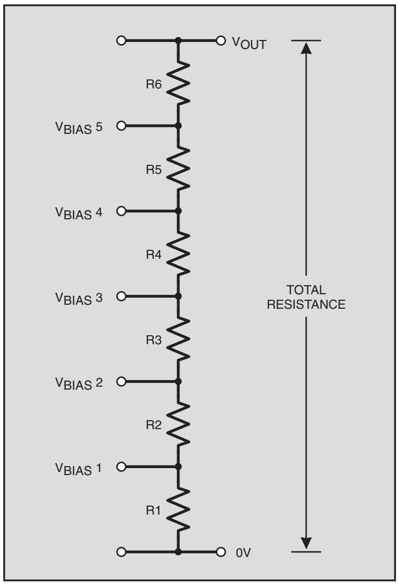


Fig.6. Basic potential divider chain used for voltage control selection.

LISTING 1

```
DATA 6,9,12,15,18: ' required Vout
rtotal = 10: rn = 0
PRINT "IDEAL VALUES for Rtotal";
PRINT " = "; rtotal; "k"
PRINT "Vout"; TAB(10); "Vbias";
PRINT TAB(20); "Resistor"
FOR a = 1 TO 5: READ vout
vbias = vout – 5
r(a) = ((vbias / vout) *  rtotal) – rn.
rn = rn + r(a)
PRINT vout; "V"; TAB(10); vbias;
PRINT "V"; TAB(20); "R";
PRINT LTRIM$(STR$(a));
PRINT r(a); "k": NEXT
PRINT "R6 =
  Rtotal–(R1+R2+R3+R4+R5)";
PRINT " ="; rtotal – rn; "k"
```

LISTING 2

```
DATA 1.8,3.0,1.5,910,620,3.0
PRINT : PRINT "E24 VALUES";
PRINT TAB(16); "CURRENT";
PRINT TAB(31); "Vout"
FOR a = 1 TO 6: READ r(a)
t = t + r(a): NEXT
ry = 0: rx = t
FOR a = 1 TO 5
rx = rx – r(a)
ry = ry + r(a)
I = 5000 / rx
v = (I *ry) / 1000 + 5
PRINT "R"; a; " ="; r(a); "k";
PRINT TAB(15); I; "mA";
PRINT TAB(30); v; "V": NEXT
PRINT "R"; a; " ="; r(a); "k";
PRINT TAB(20); " Rtotal ="; t; "k"
```

Table 4

Ideal	*Chan 1*	*Chan 2*
5V	4·97V	4·98V
6V	5·97V	5·98V
9V	8·93V	8·94V
12V	11·86V	11·87V
15V	14·84V	14·74V
18V	17·91V	17·82V

The values in Table 3 were considered to be close enough to the ideal for them to be acceptable. In practice, they will differ slightly because of resistor tolerance factors. Those obtained with the prototype are given in Table 4 (note that even the "fixed" 5V output of the two regulator i.c.s is not exactly 5V).

The basic formulae used in the programs are those for potential dividers, as given earlier (Listing 1), and Ohm's Law (Listing 2), V = I × R.

Referring to Fig.5, the voltage (call it Vb) across Rx is automatically specified as 5V, and thus the current (I) flowing through Rx is calculated as:

I = Vb / Rx

The current flowing through a potential divider chain is constant at whatever point in the chain it is measured. Consequently, the same current flows through Ry as flows through Rx.

Therefore the voltage drop across Ry (Vbias) simply equals I × Ry, and so the regulated output voltage (Vout) for the specified values of Rx and Ry is Vbias plus 5V.

As an example, and referring to Fig.6 and the resistor values in Table 3, to find Vout when Vbias at the junction of R5 and R6 is selected (Vbias5), the following reasoning is used:

Since a voltage of 5V exists across R6 (3k), then a current of 5V/3k = 1·666667mA flows through R6 (Ohm's Law derivative I = V/R). Consequently the voltage drop (Vbias) across the total of R1 + R2 + R3 + R4 + R5 (7·83k) is calculated as 1·666667mA × 7·83k = 13·05V. Thus the regulated output voltage Vout = Vbias + 5V = 18·05V, as listed in Table 3.

As a result of these calculations, the presets were dropped from the prototype and a resistor chain substituted instead, as shown in Fig.4 earlier. (All of which confirms the author's belief that a computer is one of his most important workshop tools!)

The two programs listed can be modified to calculate other tapped potential divider characteristics, for as many nodes are required.

CURRENT MONITORING

The switched voltage from IC1 (Fig.4) is taken to the output sockets (SK1 to SK5) via a 1Ω resistor, R3. This allows current flow to be monitored, according to the voltage drop across R3 caused by the amount of current flowing (Ohm's Law again). The resistor is included in the bias setting (potential divider) chain to maintain the correct output voltage irrespective of load currents.

Op.amp IC2b is configured as a differential amplifier. The voltage to either side of R3 is fed to the op.amp's inputs (pins 5 and 6) and the amplified difference is routed to the PIC microcontroller (discussed later) from point V2. The gain as seen by changes in voltage on the non-inverting input is about ten, as set by R10 and R11 (R11 / R10 + 1).

If current monitoring is not required, the circuit around IC2b may be omitted and the switched voltage fed to the output sockets, SK1 to SK5, from point V1. R3 must be replaced by a wire link.

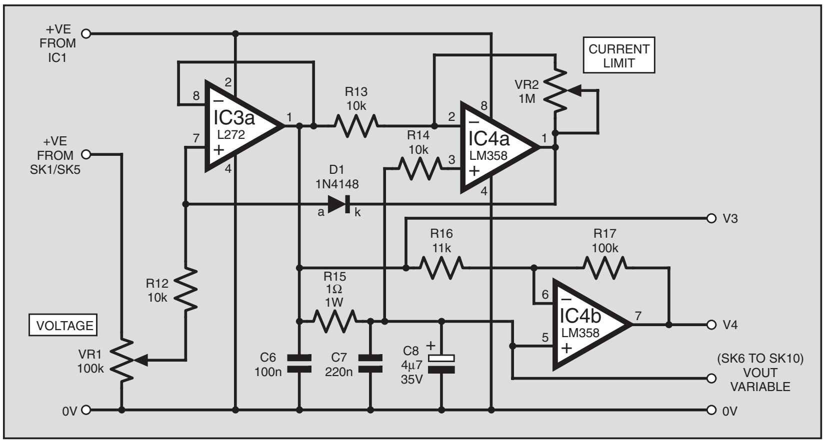


Fig.7. Variable voltage and current limiting circuit.

VARIABLE SUPPLY

As it stands, the circuit in Fig.4 is perfectly usable on its own, with or without current monitoring. However, the author frequently has the need for a control voltage that can be varied from 0V upwards. Whilst a potentiometer across a fixed supply can provide such a voltage via its wiper, the current available is limited by the resistance at the wiper.

Consequently, this power supply has had a buffer circuit added, the circuit diagram for which is shown in Fig.7.

The buffer is formed around op.amp IC3a, one half of an L272 dual power op.amp (the other half is unused). The L272 is capable of supplying a current of 1A, but there are limitations imposed by the circuit, as discussed presently.

Power for the op.amp is taken from the switch-selected voltage output from regulator IC1. Potentiometer VR1 is also connected across the same supply, but following resistor R3, and its wiper voltage is fed via resistor R12 to the non-inverting input of IC3a, pin 7.

The op.amp's output from pin 1 could be used directly as a variable voltage supply via the connection marked V3. However, as with the switched supply, it has a 1Ω resistor (R15) in series with it, through which the voltage is fed to the output sockets (SK6 to SK10). This allows current flow to be monitored via differential amplifier IC4b, which has the same function as IC2b, outputting an amplified current-dependent voltage to the PIC.

CURRENT LIMITING

The variable supply has been given a simple current limiting facility, via the circuit around IC4a.

This circuit is also configured as a differential amplifier, monitoring the voltage across R15 and amplifying it according to the ratio of R13 and the resistance across potentiometer VR2.

The output of IC4a is connected back to the non-inverting input of IC3a via diode D1. If the current through R15 causes the amplified output voltage from IC4a to fall 0·7V (the "diode drop" voltage for a silicon diode) below the voltage on IC3a pin 7, the latter will be pulled down across resistor R12. The result is that the output voltage from IC3a will fall by the same amount, so limiting the power fed to the load circuit.

Potentiometer VR2 permits the threshold gain to be varied from roughly unity (VR2 = 0Ω) to about 100 (VR2 at maximum resistance). By test on the prototype, with VR2 at zero resistance, a current flow of about 350mA through R15 causes the threshold to be reached, beyond which the input to IC3a is progressively reduced. With VR2 at maximum resistance, 5mA across R15 has the same effect.

Any circuit powered from the variable supply must have a smoothing capacitor across its input power lines in order to prevent the current limiting circuit from oscillating when the threshold is reached. Without the capacitor, when the threshold is reached the output voltage falls, and so the current flow decreases, causing the voltage to rise again, etc.

Note that the presence of R15 on its own will also cause a voltage drop at the output sockets in response to increasing current, simply according to Ohm's Law (100mA causes a 0·1V drop).

PIC MONITOR

The PIC microcontroller, IC6 in Fig.8, monitors the voltages input to it from the four power supply circuits, outputting data to the l.e.d.s. and the l.c.d. It interprets and displays the data according to factors input to it from switches S3 to S6. It does not actually *control* the power supply in any way.

As discussed in previous published PIC16F87x designs, this family of devices has several inputs which can be used for analogue-to-digital conversion. The PIC16F877 used here has eight A/D inputs, allowing the twin voltage levels from all channels to be monitored.

For each channel, the twin voltages are tapped prior to the 1Ω current sensing resistor and at the output of the respective differential amplifier.

The voltages can be several times greater than the PIC can safely handle and are attenuated by eight 20k/2k2 potential dividers, formed around R8 to R33. The attenuation ratio is 1:10, which at first sight may seem high.

The reason is that Channel B can be connected in series with Channel A (refer back to Fig.1). In this situation, Channel B can produce a possible maximum voltage of 36V with reference to the PIC's 0V line. The 1:10 attenuation thus results in 3·6V at the input to PIC. Whilst a ratio of 5:36 (1:7·2) would allow slightly greater precision of the digital conversion, a ratio of 1:10 makes the software processing somewhat easier.

The software repeatedly samples the eight inputs, and produces 10-bit conversion values. From these it calculates the source voltages prior to the attenuators. The value of the voltage prior to each 1Ω resistor is stored for output to the l.c.d.

This value is also compared with the voltage from the respective differential amplifier and a value for the current being drawn by the load circuit is calculated. This too is stored for subsequent output to the l.c.d.

The current values are additionally compared with the current limit values preset via switches S3 to S5. If the limit is being exceeded, the appropriate l.e.d. (D3 to D6) is turned on. Resistors R39 to R42 are the l.e.d. ballast resistors.

If the total current being supplied by a channel, via either or both of its outputs, exceeds 1A then *both* l.e.d.s for that channel are turned on, as is buzzer WD1.

The current being drawn must be reduced below the limits before the l.e.d.s and buzzer are turned off.

Remember that the PIC does not control the power supply in response to these limits being reached.

L.C.D. MODULE

Data is sent to the l.c.d. module (X2) in 4-bit mode, with the same physical pin connection order as used with all the author's l.c.d. controlling designs over the last couple of years.

Readers who already have l.c.d.s with connectors that match those designs can simply plug them straight in to this Power Supply's monitor p.c.b. via the matching terminal pins (notated as TB1).

Preset potentiometer VR3 adjusts the l.c.d. screen contrast.

A point worth considering is whether or not to use a back-lit l.c.d. The author's workshop is well lit and the screen of the normal reflective type of l.c.d. used can be clearly seen.

In a less well-lit situation, however, the use of a (slightly more expensive) back-lit version could be beneficial, because the screen is on the front panel and faces forwards, rather than upwards as with the majority of published designs using l.c.d.s.

Typically, back-lit l.c.d.s have illumination provided by internal l.e.d.s. It is possible that the l.e.d.s can be powered from the monitor board's 5V supply (check the l.c.d. data sheet for the backlighting power requirements and connections). If this is the case, it would be prudent to use a 7805 1A regulator for IC5, instead of the 78L05 100mA device listed.

CONTROL SWITCHES

Pushbutton switches S3 to S5 allow the PIC's current limiting data to be changed as required. S6 selects which of three display modes is shown: full data for one output, voltage data for all four outputs, or current data for all four outputs. Each push of S6 steps the display through the modes, on a repeating cycle.

When in the mode for single-output full data display, switch S5 steps the display through each output, on a repeating cycle of four. Typical displays are shown in Part 2.

Top left of the screen shows the output identity. This is notated in the form Ch1 to Ch4, where:

Ch1 = Channel A switched output
Ch2 = Channel A variable output
Ch3 = Channel B switched output
Ch4 = Channel B variable output

Top right of the screen shows the preset current limit for that output. It can be increased by S4 or decreased by S3. The limit is changed in steps of 10mA, with a minimum of 10mA and a maximum of 1A.

When S3 or S4 are released, the value displayed is stored in the PIC's EEPROM data memory. It remains there even after power has been switched off. It is recalled when the unit is again switched on.

Bottom left of the screen shows the voltage presently supplying the selected output (before the 1Ω resistor), in steps of 0·05V.

Bottom right of the screen shows the current being drawn from the output, in steps of 5mA.

Be mindful of the fact that the monitored voltage and current details on the l.c.d. screen are not as precise as those which a multimeter will display. They should be treated only as an approximate guide to prevailing conditions.

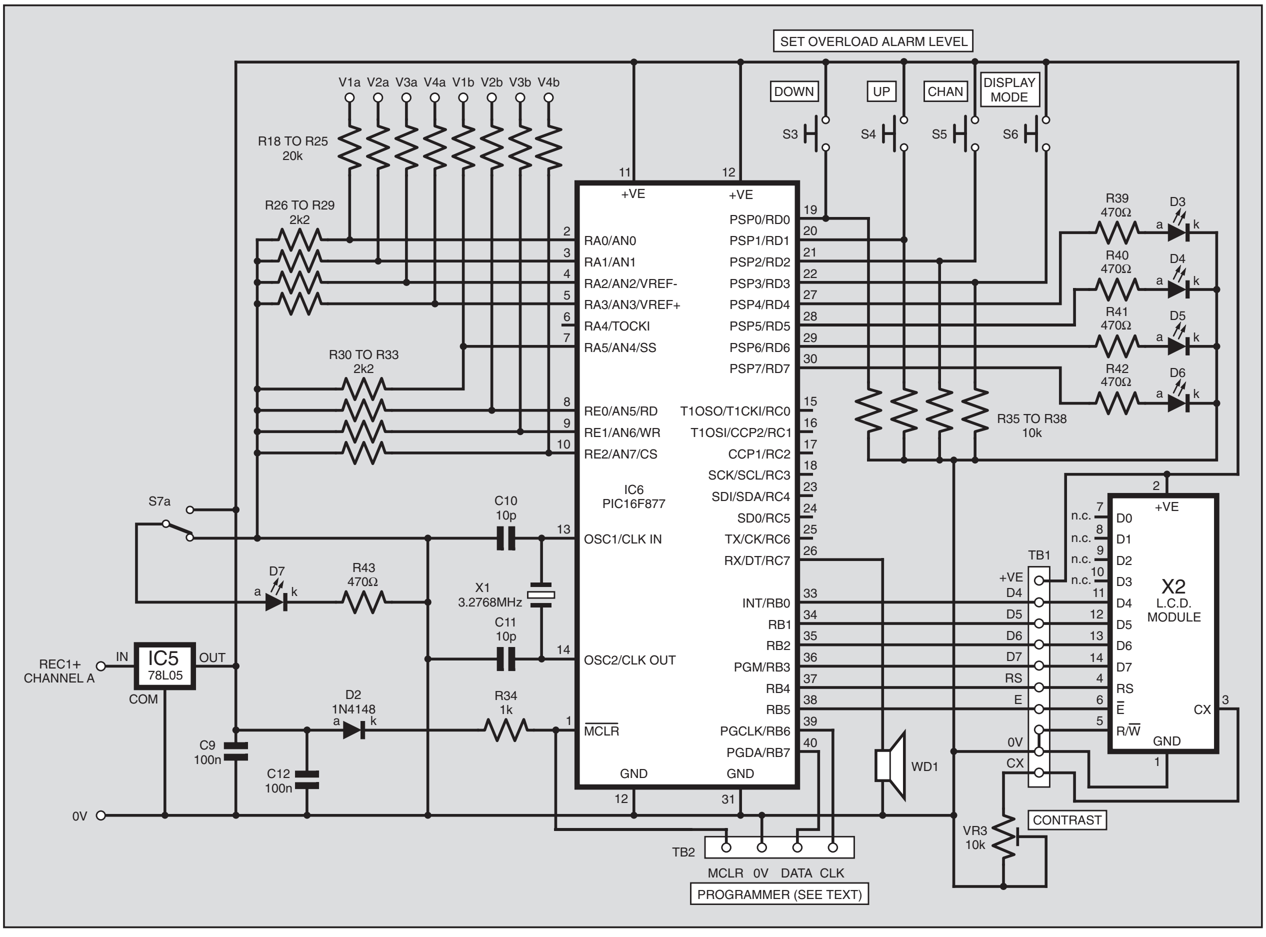


Fig.8. Circuit diagram for the PIC-monitoring option of the full power supply.

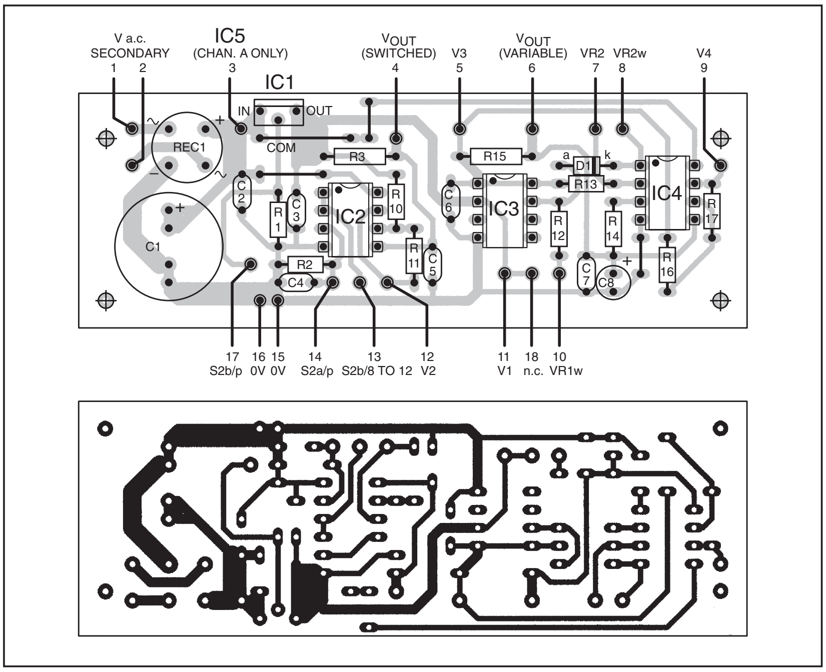
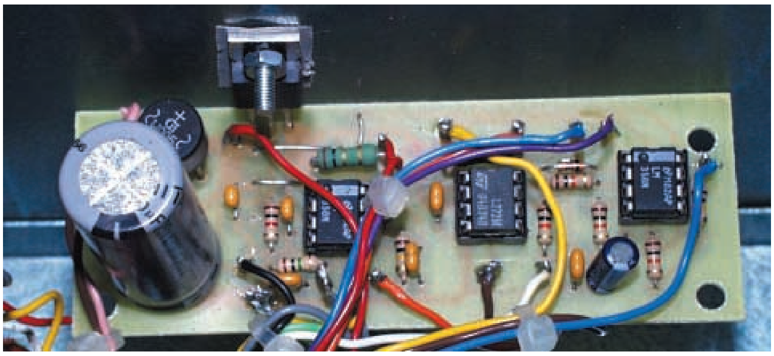


Fig.9. Printed circuit board component layout and full size copper foil master track pattern for the power supply in Fig.4.



MISCELLANY

The PIC and l.c.d. are powered at 5V. This is provided by regulator IC5, whose input is connected directly to the rectified voltage at capacitor C1 (approximately 20V) of Channel A. The current drawn, with the l.e.d.s inactive, is a little under 6mA.

Crystal X1 sets the PIC's clock frequency at 3·2768MHz.

Selection of parallel or serial connection of Channels A and B is made by switch S7b in Fig.1 earlier. In Fig.8, S7a is the second half of the same switch and turns on l.e.d. D7 when the channels are connected in series.

CONSTRUCTION

There are two printed circuit boards, one for the PIC monitoring circuit, the other for the power supply components of a single channel (two are needed if both channels are required).

Their constructional and track layout details are shown in Fig.9 and Fig.10. The boards are available from the *EPE PCB Service*, code 281 for the monitor and 280 for the power supply.

Preferably assemble the components in ascending order of size, commencing with the on-board link wires. Use sockets for IC2, IC3, IC4 and IC6. Do not insert IC6 (the PIC) into its socket until a few circuit tests have been made later. Ensure the correct orientation of all other semiconductors and the electrolytic capacitors.

Mount the rectifier (REC1) and 1Ω resistors (R3 and R15) so that their bodies stand a bit above the p.c.b., allowing air to circulate around them. Also mount regulator IC1 somewhat above the p.c.b. to allow it to be easily bolted to the side of the case during the final stages of connecting up.

For terminal pin blocks TB1 and TB2 use 1mm pin-header strips. For the other off-board connection points insert 1mm terminal pins.

CASE PREPARATION

The case used in the prototype and shown in the photographs is one which the author has had for some years. Regrettably it has been discontinued by the supplier, but an alternative case of a similar size is quoted in *Shoptalk*. The size of the original is 255mm × 160mm × 196mm (l × h × d). The detachable front and rear panels measure 245mm × 135mm. They are made from aluminium, whilst the rest of the case is mild steel.

Referring to the photographs, plan and drill your chosen case with care. Allow ample clearance between all mains powered connections and other items. Use a clamping cable grommet for the mains input lead.

COMPONENTS

SINGLE FULL PSU CHANNEL
Excluding the PIC monitoring circuit

See SHOP TALK page

Resistors

R1 1k 0·25W 5%
R2 1M 0·25W 5%
R3, R15 1Ω 1W 5% (or better) (2 off)
R4, R8 3k 0·25W 1% (2 off)
R5 620Ω 0·25W 1%
R6 910Ω 0·25W 1%
R7 1k5 0·25W 1%
R9 1k8 0·25W 1%
R10, R16 11k 0·25W 1% (2 off)
R11, R17 100k 0·25W 1% (2 off)
R12 to R14 10k 0·25W 5% (3 off)

Potentiometers

VR1 100k lin rotary
VR2 1M lin rotary

Capacitors

C1 4700µF radial elect. (see text)
C2, C7 220n ceramic disc, 5mm pitch (2 off)
C3 to C6 100n ceramic disc, 5mm pitch (4 off)
C8 4µ7 radial elect. 35V

Semiconductors

D1 1N4148 silicon signal diode
IC1 7805 +5V 1A voltage regulator
IC2, IC4 LM358 dual op.amp (2 off)
IC3 L272 dual power op.amp

Miscellaneous

REC1 W005 50V 1A bridge rectifier, or similar
S1 s.p.d.t. switch, mains rated
S2 2-pole 6-way rotary switch
SK1 to SK15 2mm socket, 3 colours, 5 off each (see text)

Printed circuit board (power supply), available from the *EPE PCB Service* code 280; knob (3 off); TO220 insulating washer kit for IC1; 8-pin d.i.l. socket (3 off)
All above parts repeated for second channel.

Also required

FS1 20mm fuseholder, panel mounting, with 1A 20mm fuse, slow blow
T1 mains transformer, 0-15V, 0-15V secondaries, 50VA (25VA per winding)

Metal case, 255mm × 160mm × 196mm (see text); heatsink compound (see text); eyelet tag; mains cable clamping grommet; nuts and bolts for mounting transformer (2 off each); cable ties; 1mm terminal pins; 3-core mains cable, 5A; connecting wire; solder, etc

Approx. Cost Guidance Only **£30** ***excluding case***

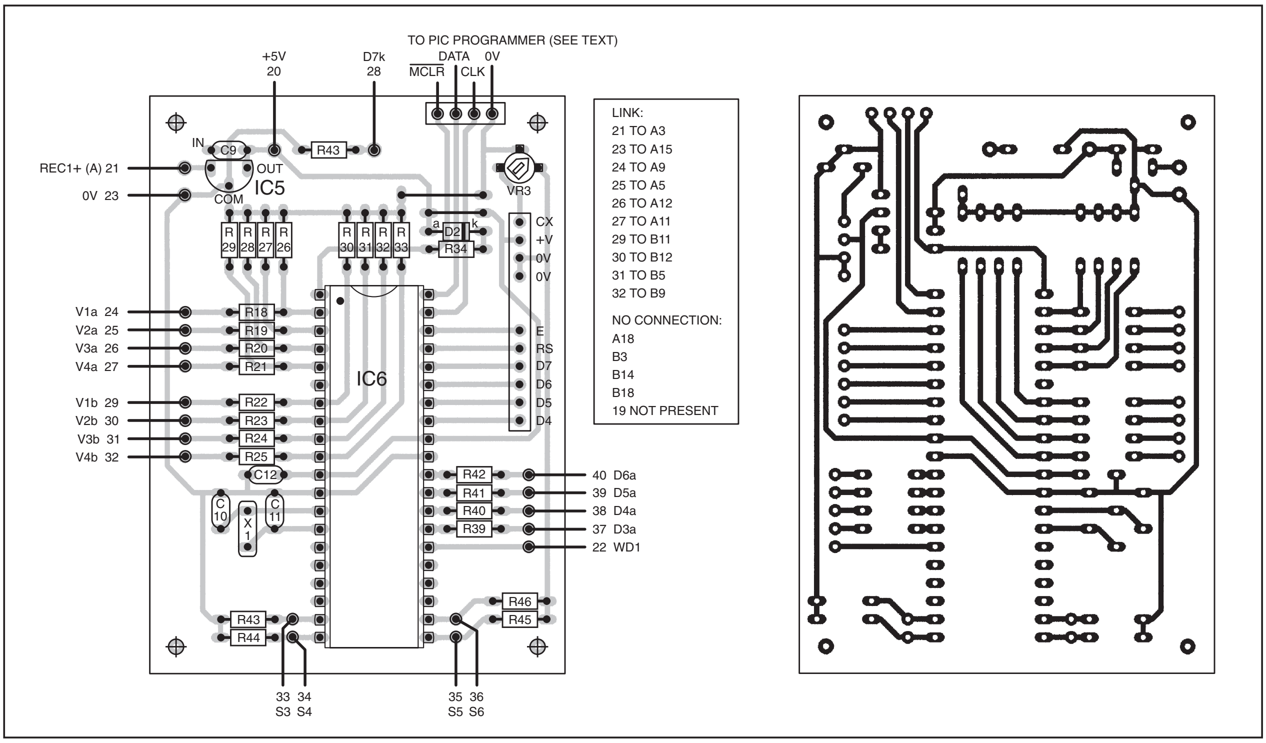
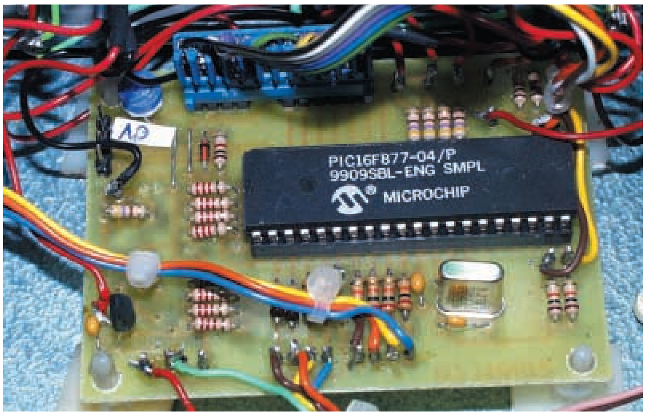


Fig.10. Component layout and full size copper foil master track pattern for the PIC-monitoring circuit in Fig.8.



COMPONENTS

Approx. Cost Guidance Only **£30** *excluding case*

MONITOR UNIT

Resistors

R18 to R25	20k 0·25W 1% (8 off)
R26 to R33	2k2 0·25W 1% (8 off)
R34	1k 0·25W 5%
R35 to R38	10k 0·25W 5% (4 off)
R39 to R43	470Ω 0·25W 5% (5 off)

See SHOP TALK page

Capacitors

C9, C12	100n ceramic disc, 5mm pitch (2 off)
C10, C11	10p ceramic disc, 5mm pitch (2 off)

Potentiometer

VR3	10k min. preset, round

Semiconductors

D2	1N4148 silicon signal diode
D3 to D7	red l.e.d. (5 off) (see text)
IC5	78L05 +5V 100mA voltage regulator (see text)
IC6	PIC16F877-4 microcontroller, pre-programmed (see text)

Miscellaneous

S3 to S6	s.p. min. push-to-make switch (4 off)
S7	d.p.d.t. min. toggle switch
TB1, TB2	1mm pin header strips (see text)
WD1	5V to 9V active buzzer
X1	3.2768MHz crystal
X2	2-line, 16-character (per line) liquid crystal display (see text)

Printed circuit board, available from the *EPE PCB Service*, code 281 (monitor); 40-pin d.i.l. socket; nuts and bolts for l.c.d. (4 off each); cable ties; connecting wire; solder, etc.

If you prefer to use output sockets of a larger size to the 2mm type used in the prototype, you may not have room for the same quantity. The author prefers having several sockets connected to a single power supply output, allowing several circuits to be powered simultaneously from the same source.

Allow reasonable space for the control knobs to be rotated.

Mark the l.c.d. position carefully, then drill a succession of holes inside the perimeter of its screen position to ease the sawed removal of the oblong cut-out. Finish off with a file.

The l.e.d.s in the prototype were purchased as panel mounting components complete with pre-connected leads. Conventional l.e.d.s and mounting clips may be used instead. The wiring diagram in Part 2 shows the connections for the latter type.

Drill a hole in each side panel through which the IC1 regulators have to be bolted, attached to their p.c.b. Insulating washers and bushes should be used with the regulators, together with heatsink compound (some types of washer do not require the compound – consult your supplier when ordering the washers).

It is essential to check that there is no electrical connection between the case and the tabs of the regulators.

NEXT MONTH

In the concluding part next month the wiring up of the full power supply is detailed, heat sinking is discussed, and operation of the software is described. Details of constructing simpler versions will also be given.

See this month's *Shoptalk* page for information on obtaining the software, and general information on buying the components.

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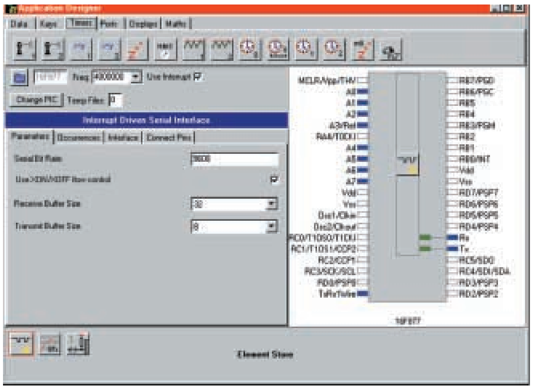

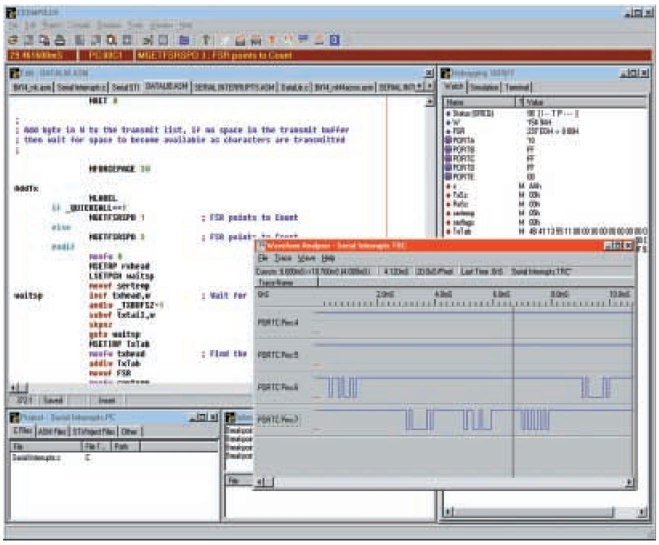

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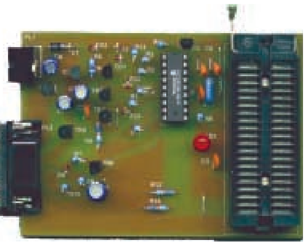

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News . . .

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

MOBILE PROMISES . . . PROMISES . . .

Can Packet Radio make marketplace headway if it does not fulfil promised expectations? Barry Fox reports.

THE cellphone industry risks crippling the fledgling market for GPRS by making the same kind of undeliverable promises that turned users off WAP.

GPRS, the new General Packet Radio Service due for consumer launch this Christmas, is already being wildly over-hyped. It will deliver much slower data speeds than promised and looks sure to disappoint – like WAP before it.

"Who needs 3G (the third generation cellphone system due in a few years), when GPRS is here now," asks Motorola, the first company to deliver GPRS handsets. BT, now trialling the first commercial GPRS service, says "accessing video and multimedia applications on your mobile phone is now a reality."

"GPRS opens the mobile market to wireless multimedia," promises Motorola's web site, "with streaming and live video content."

Technical and medical issues make even the theoretical speeds unattainable.

TIME SLOTS

The European GSM digital cellphone system is now used in most countries. Channels 25kHz wide are sliced into eight time slots. Each slot carries a separate conversation, or data, at 9·6Kbps, one sixth the speed of a fixed phone line and modem. Users are charged for the time they use a slot.

GPRS lets users share time slots, with charges levied for data moved, not time on line. Several coding systems are used to protect against transmission errors. CS-1 has the most powerful error correction, but delivers only 9·05Kbps per slot. Where the radio signal is strong, CS-2 coding delivers 13·4Kbps.

Some of this data is wasted on "headers" needed to label Internet data. The data rate also varies depending on how many people are sharing slots. Most important, four or five slots can eventually be used for reception, a handset or PC card can transmit only one or two slots before the chips get too hot and burn out. Above two slots there is a health risk from excessive radiation (Specific Absorption Rate). Battery drain doubles for two slot working, so life halves.

Motorola's first GPRS phones, such as the Timeport, will handle only one time slot out of the phone and two into the phone. New phones next year will work with one slot out and four down. The first models are not upgradeable. Ericsson will wait and launch with one out and four down.

EXPERT OPINIONS

Rainer Lischetzki of Motorola says, "The realistic maximum rates we can get from GPRS are 64Kbps into the handset and 30Kbps out. We have known for ages about these limitations. We regret the sales talk, and data rate exaggeration."

A BT Cellnet engineer was privately even more conservative, promising only between 7Kbps and 10Kbps per slot, or a best case scenario next year of 10Kbps transmit and 40Kbps receive.

But Motorola's own web site and technical briefing documents promise speeds up to 171·2Kbps with "streaming and live video content", while BT's publicity literature promises the chance to "send and receive data up to five times faster than is currently possible . . . and speeds will increase up to ten times faster in the coming months."

Because GPRS is an always-on system, with charges for the quantity or quality of data handled, rather than time on line, it becomes the ideal tool for receiving E-mail on the move. But people who believe the publicity and buy GPRS as a mobile multimedia tool will be sorely disappointed. Even low quality mono sound needs two time slots; MPEG-4 videophone links can manage only one or two coarse video pictures a second.

IT SUCKS – IN STYLE!

THE new Shesto Pal range of suction pick-up tools is invaluable for model making, craft and hobby uses, and they work without batteries.

Held like a pen, a gentle press of the button or bulb creates the correct amount of pressure to pick up, rotate and easily place small objects. To release them simply press the button again. The tools easily handle electronic components and a variety of other materials without risk of damage or blemish.

There are two models: the Model Pal at £7.95, comprising suction bulb and three cups, and the Hobby Pal at £14.95, which includes suction generator, four cups, two straight holders and two angled holders. The prices are quoted as *post free*.

For more information contact Shesto Ltd., Dept *EPE*, Unit 2, Sapcote Trading Centre, 374 High Road, Willesden, London NW10 2DH. Tel: 020 8451 6188. Fax: 020 8451 5450. E-mail: **sales@shesto.co.uk**. Web: **www.shesto.com**.

GREENWELD AND KITMASTER

TWO well known companies, Greenweld and Kitmaster, have announced that they are to combine.

Greenweld, having been successfully resurrected after the closure of the old company in 1999, have seen high levels of demand for their new and surplus range of electronic bargain buys. During the same period, the arrival of Kitmaster by David Johns has brought back the era of valve radios.

Recently, Greenweld have been featuring Kitmaster products for sale through their own mail order and online shopping services. Realising the potential offered by these popular designs, Greenweld are combining their established mail order infrastructure with David John's expertise in electronics and valve radio design.

Geoffrey Carter of Greenweld tells us that Kitmaster's novel approach to electronic kit building has revived interest in valve technology assembly for both novices and experienced users alike. Models such as the popular Four Valve Regeneration Unit are selling at a high rate. Recent introductions include a range of battery-operated valve radios, which are becoming even more sought after. Each kit contains all the necessary parts, together with a detailed and comprehensive manual.

Greenweld will continue their commitment to offering a huge range of electronic components, together with frequent purchases of surplus electronic equipment of every type which is, as usual, offered at bargain prices. David Johns will continue to develop new products.

For a free catalogue contact Greenweld Ltd, Dept *EPE*, Unit 24, Horndon Industrial Park, West Horndon, Brentwood, Essex CM13 3XD. Tel: 01277 811042. Fax: 01277 812419. E-mail: **service@greenweld.co.uk**. Web: **www.greenweld.co.uk**.

EWB WITH PCB CAD

ELECTRONICS Workbench devotees will be pleased to learn that this superb circuit design and simulation software package has now had printed circuit design facilities added to its pedigree. The sense of making such an addition will be obvious to anyone who is familiar with EWB.

EWB multiSIM is a complete system design tool which offers schematic entry, comprehensive component database, SPICE simulation, VHDL/Verilog entry and simulation, waveform analysis, r.f. capabilities and "seamless" transfer to p.c.b. layout. It is said to offer a unique combination of advanced functionality and exceptional ease of use.

Many of you will recall that we featured the basic EWB software in Mike Tooley's excellent *Electronics from the Ground Up* series of Oct '94 to Jun '95.

For more information contact Adept Scientific plc, Dept *EPE*, Amor Way, Letchworth, Herts SG6 1ZA. Tel: 01462 480055. Fax: 01462 480213.
E-mail: **ewb@adeptscience.co.uk**.
Web: **www.adeptscience.co.uk**.

MAPLIN 2000/2001 CAT

MAPLIN Electronics have launched their new 2000/2001 catalogue with a huge range of products, over £100 worth of money-off vouchers and many brand new lines.

Maplin comment that their catalogue is "widely regarded as *the* electronics product bible." Now in its 28th year, it contains products ranging from individual components to state-of-the-art electronic equipment. It is available in traditional format (cost £3.99) or on a CD-ROM (£1.99).

The products can also be found at 57 Maplin stores nationwide, where specialist staff are available to help with technical and product enquiries. The Maplin website also features full product range details and a secure on-line ordering service with stock checking facilities.

For more catalogue information contact Maplin Electronics, Dept *EPE*, Valley Road, Wombwell, Barnsley S73 0BS. Tel: 0870 264 6002.
Web: **www.maplin.co.uk**.

Sparing DVD Egg-spense?

By Barry Fox

TECHNICS launched DVD-Audio at the Hammersmith HiFi show. Consumers now have the chance to spend £900 on a new format player with no new format software to play on it. The only discs at the show were DVD-R dubs from Universal. None exploited the full DVD-Audio specification of 192kHz.

"It's chicken and egg," says Technics.

Most people may prefer to wait until there are eggs to go with their £900 chickens.

Talking Signs

ON a number of occasions we have mentioned NXT, the inventors of Surface Sound flat panel loudspeaker technology. They tell us that they have unveiled a multilingual talking sign incorporating this revolutionary technology.

Using the latest digital audio techniques (MP3), the sign speaks in nine languages and is installed at the Whittington Hospital in Highgate, London. Research had shown that many public areas encounter a growing number of ethnic issues, including the variety of languages spoken and the need for simple spoken information.

Simply touching the panel gives the user instant access to customised information in a selection of languages. The combination of colourful graphics and clear high quality sound allows a wide range of messages and information to be imparted in a concise and friendly manner to both English and non-English speakers.

A spokesman for the Whittington Hospital said "This is a very exciting development for us, and we are pleased to be the first hospital in the UK with this particular initiative. We serve a culturally mixed community and we are always striving to improve our standards of health and ethnic issues."

For further information contact New Transducer Ltd., Dept *EPE*, 37 Ixworth Place, London SW3 3QH. Tel: 020 7343 5050. Fax: 020 7343 5055.
E-mail: **marketing@nxtsound.com**.
Web: **www.nxtsound.com**.

Patents Rising

APPLICATIONS for patents have risen by six per cent to over 30,000 for 1999, according to figures released by the UK Patent Office. Most patents were granted in the telecomms sector, 865 patents, but electric circuitry also came high, at 429 patents.

The Patent Office web site (**www.patent.gov.uk**) is receiving 50,000 hits daily (up from 20,000 a day last year), signifying that more people are wanting to find out how to protect their ideas and inventions.

The DTI (Department of Trade and Industry) also tells us that 27 per cent of UK businesses are now trading on-line. This puts the UK on a par with the USA and Canada, and ahead of Germany and Sweden (see **www.ukonlineforbusiness.gov.uk**).

Starter Project

STATIC FIELD DETECTOR

ROBERT PENFOLD

Amuse your friends and family with this novel "electroscope'' starter project. – See if they are highly charged characters!

THIS ultra-simple device was designed as a low cost project for complete beginners, but it should also be of interest to those who like to experiment with unusual gadgets. It is a form of electroscope, which is a device that detects static electricity.

No doubt most readers have seen demonstration of purely mechanical devices that use electrostatic forces to show the presence of high static voltages. This device uses some simple electronics to detect much smaller potentials, with a twin l.e.d. display showing any increase or decrease in the detected voltage.

It has to be emphasised that this very simple unit is only intended to be a "fun'' project, and it is not suitable for serious scientific purposes. Those with a serious interest in the subject of atmospheric electricity should refer to the recent *EPE* articles (*Atmospheric Electricity Detector* – June/July 2000) on this subject by Keith Garwell.

BASICS

What is the difference between static electricity and the regular variety, and why is it not possible to measure static electricity using ordinary test equipment?

In normal electronics we are concerned with a flow of electricity, with electrons moving along wires or into and out of components. Static electricity is not fundamentally different to the electrical signals we normally deal with in that it is still comprised of electrons. The difference is that the electrons are not going anywhere.

Although normal matter contains electrons, it does not necessarily have a static charge. Matter has a positive charge when it has fewer electrons than normal, or a negative charge if it has an excess of electrons.

As most readers will be aware, static charges can be generated by friction, and rubbing many plastics will generate quite high voltages. The fact that static charges are present in most environments is probably less well known. Where you are right now there could well be a potential of 50V to 100V between the air near the floor and the air about two metres higher up.

On the face of it, measuring voltages of this order should be easy enough and any multimeter should be able to handle the task. In practice matters are more complicated due to the nature of the signals involved. The voltages may be quite high, but the available current is quite low. To be more precise, an appreciable current is available, but only very briefly.

Although a digital multimeter has a high input resistance of typically over 10 megohms, this will still rapidly leak away the charge being measured. In fact, it will leak it away before a meaningful measurement can be made.

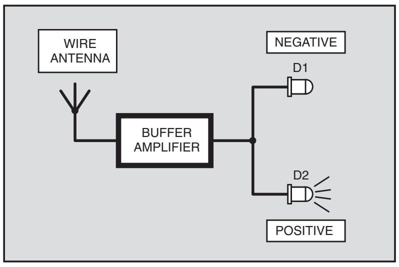


Fig.1. The static detector is basically just a buffer amplifier and two l.e.d.s.

A voltmeter having an extremely high input resistance is needed in order to measure static charges. The amount of current drawn by the test instrument is then so low that it does not significantly reduce the charge voltage during the measurement process.

Obtaining a suitably high input resistance is not difficult, since this is a natural characteristic of field effect transistors (f.e.t.s). It is also an attribute of many operational amplifiers (op.amps) which use field effect devices in their input stages. Op.amps having input resistances of one million megohms or more are commonplace, and this is more than adequate for the present application.

SYSTEM OPERATION

This Static Field Detector uses the simple arrangement shown in Fig.1. An antenna consisting of a short piece of wire is connected to the input of a buffer amplifier that has an ultra-high input resistance. This amplifier has no voltage gain, and its sole purpose is to provide the circuit with an ultra-high input resistance. There are no bias resistors or other components at the input of the amplifier, which is therefore free to float to whatever potential the antenna assumes.

The output of the amplifier drives two l.e.d. indicators. With the output of the amplifier at about half the supply potential both l.e.d.s are switched on fairly brightly.

If the output potential rises, the brightness of l.e.d. D2 increases but l.e.d. D1 becomes dimmer and will switch off if the output potential becomes high enough. A decrease in the output voltage has the opposite effect, with D1 becoming brighter and D2 going dimmer or even switching off altogether. This method is very simple and inexpensive, but it clearly shows any variations in the detected voltage.

MEASURING WHAT?

When measuring voltages in a circuit you do not simply place one test prod on a test point and read its voltage. Most equipment is of the negative earth variety, and voltages are therefore measured relative to the negative supply rail. One test prod is connected to the earth rail (0V), and the other is placed on the test points.

Here we are effectively using a single test prod in the form of the antenna, with voltage measurements being made relative to nothing. Although it might seem as though the same middle reading will always be obtained, this is not actually the case.

When the unit is first switched on the two l.e.d.s will switch on to indicate a middle voltage. If the unit is moved around the l.e.d.s should soon start to indicate changes in potential. The unit is registering changes in voltage relative to the antenna's starting potential. It would be possible to connect the negative supply rail of the unit to an earth and then make measurements relative to the earth's potential.

However, a simple circuit such as this can only handle an input voltage range of about 0V to 9V, whereas signals of either polarity and up to a few hundred volts in magnitude might be encountered. Also, using an earth is relatively awkward and restrictive. The method used here is freer, easier, and works quite well.

CIRCUIT OPERATION

The full circuit diagram for the Static Field Detector appears in Fig.2. The operational amplifier, IC1, is the buffer amplifier, and is a bi-f.e.t. device that uses junction gate field effect transistors in its input stage. A device having a MOSFET input stage should work equally well on the input side of things, as should any other bi-f.e.t. op.amp.

The specified TL061CP op.amp has an output stage that will drive both l.e.d.s from fully switched off to fully switched on, whereas most other op.amps will fail to do this. Consequently, the use of alternative devices is not recommended.

No voltage gain is required in this application, so 100 per cent negative feedback is provided by coupling the output of the amplifier (pin 6) to the inverting input (pin 2) via resistor R1. The output adopts the same voltage as the non-inverting input at pin 3, but there is a massive current gain through IC1.

The input current is probably a few nanoamps or even picoamps, but the output can provide a few milliamps to drive the l.e.d.s at good brightness. Resistors R2 and R3 limit the current fed to l.e.d.s D1 and D2 to a safe level.

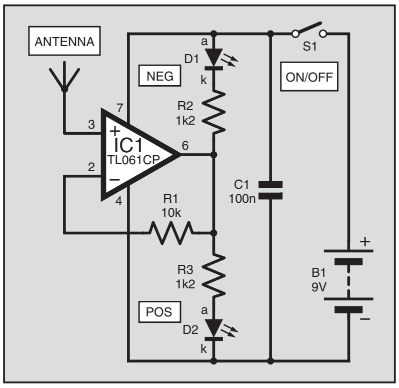


Fig.2. Complete circuit diagram for the Static Field Detector.

The maximum drive current is about 5mA. The TL061CP used for IC1 is a low current device, and the current consumption of the circuit as a whole is never much more than about 5mA.

CONSTRUCTION

The construction of the Static Field Detector is based on the *EPE* multi-project printed circuit board. This board is available from the *EPE PCB Service,* code 932. The component layout, wiring and the actual size foil master pattern are shown in Fig.3.

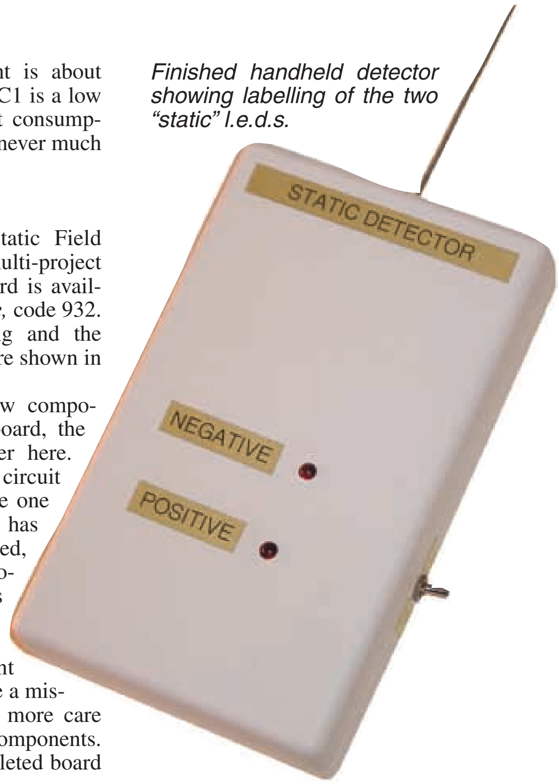
Although there are very few components to fit onto the circuit board, the usual warning is still in order here. Unlike a normal custom printed circuit board, this board does not have one hole per component lead. It has many holes that are left unused, and the small number of components used in this circuit means that the vast majority of them are not used.

The low component count actually makes it easier to make a mistake, so it is essential to take more care than normal when fitting the components. Also, carefully check the completed board for errors.

In all other respects construction of the board offers nothing out of the ordinary. The TL061CP used for IC1 is not a device that is vulnerable to damage from static charges, but it is still advisable to mount it on the board via an i.c. socket.

There are two ways of dealing with the l.e.d.s. One is to mount them in panel holders and then hard wire them to the circuit board. The board should be fitted with single-sided solder pins at the points where the connections to the two l.e.d.s will be made. Incidentally, it should also be fitted with pins at the points where connections will be made to on/off switch S1, the battery, and the antenna.

Finished handheld detector showing labelling of the two "static" l.e.d.s.



The alternative method is to mount the l.e.d.s D1 and D2 on the printed circuit board, and to leave the leadout wires quite long. With the printed circuit board mounted on the base panel of the case, the l.e.d.s will then fit into two 5mm dia. holes drilled at the appropriate positions in the top panel.

Note that l.e.d.s, unlike filament bulbs, will only operate if they are connected with the correct polarity. The cathode (k) leadout wire is normally shorter than the anode (a) lead. Also, most l.e.d.s. have a "flat" on the component's body, next to the cathode lead.

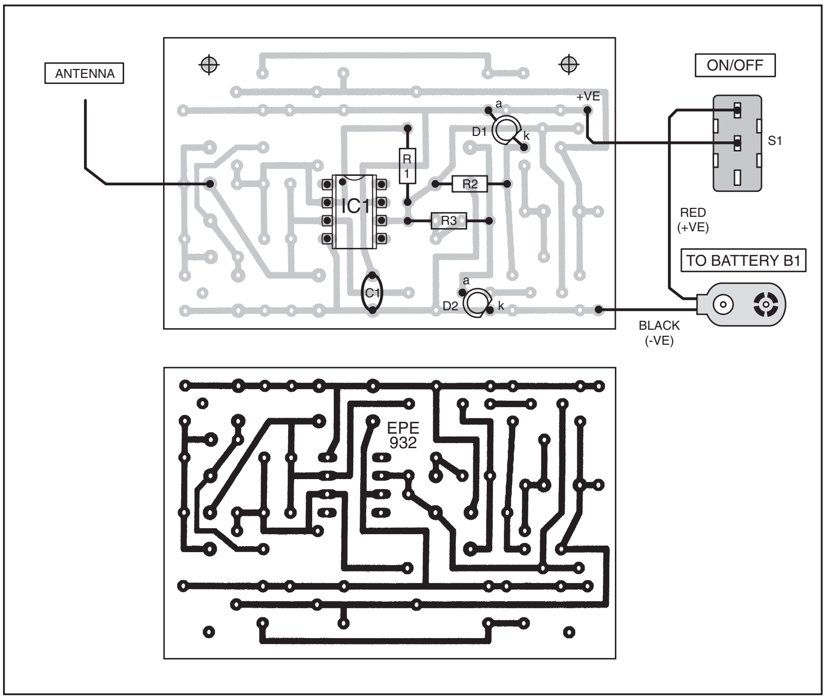


Fig.3. Component layout on the multi-project printed circuit board and full-size copper foil master. Double-check layout as not all holes are used.

COMPONENTS

Resistors
R1 10k
R2, R3 1k2 (2 off)
All 0·25W 5% carbon film

See SHOP TALK page

Capacitor
C1 100n ceramic

Semiconductors
D1, D2 5mm panel l.e.d.s, red
IC1 TL061CP (see text)

Miscellaneous
S1 s.p.s.t. min toggle switch
B1 9V battery (PP3 size)

Small plastic case, size to choice; printed circuit board available from the *EPE PCB Service,* code 932; battery connector; stout tinned copper wire for antenna; plastic stand-off pillars or M3 nuts and bolts (see text); single-sided solder pins (3 off); solder, etc.

Approx. Cost Guidance Only **£10**

CASING-UP

Any small to medium size plastic case is suitable for this project. It is best not to use a metal box as it could interfere with the correct operation of the device, and would complicate fitting the antenna.

The completed printed circuit board is mounted inside the case using either plastic stand-offs or metric M3 bolts and fixing nuts. If bolts are used, spacers a few millimetres long must be fitted between the case and the board.

On/off switch S1 is mounted at any convenient point on the case, and a hole about 2mm dia. is drilled in the top side panel of the case, see photographs. This hole is for the antenna, which is merely a piece of tinned copper wire that protrudes about 75mm to 100mm beyond the front of the case. This wire should be fairly thick, but anything from about 0·7mm to 1·6mm (22 to 16s.w.g.) is suitable.

To complete the unit add the battery connector, fit the antenna, and add the wire from S1 to the circuit board.

TESTING

Start with the lid of the case removed so that you have access to the circuit board. Both l.e.d.s should light up quite brightly when the unit is switched on. Try touching the antenna and the solder pin on the circuit board that takes the connection from the negative (black) battery lead. This should result in l.e.d. D2 switching off and D1 increasing in brightness.

Next touch the antenna and the solder pin that takes the lead from S1. This should have the opposite effect, with l.e.d. D1 switching off and D2 lighting more brightly. If there is any sign of a malfunction switch off at once and recheck the circuit board, etc.

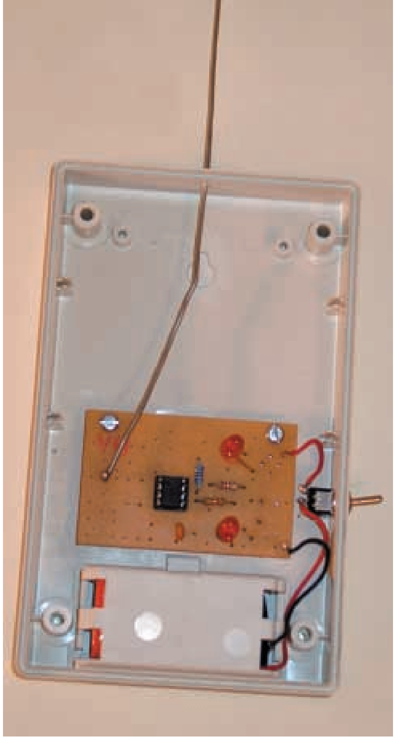
If all is well, refit the lid of the case and make some initial tests with the detector. In general, there is more to detect in a dry atmosphere than in a humid one where charges tend to leak away. Up and down movement will usually produce some change in the display.

Placing the unit near the ground invariably produces a strong positive indication, as will placing the antenna near anything that is earthed. This includes things like the metal case of a computer, a radiator, or the walls of a house.

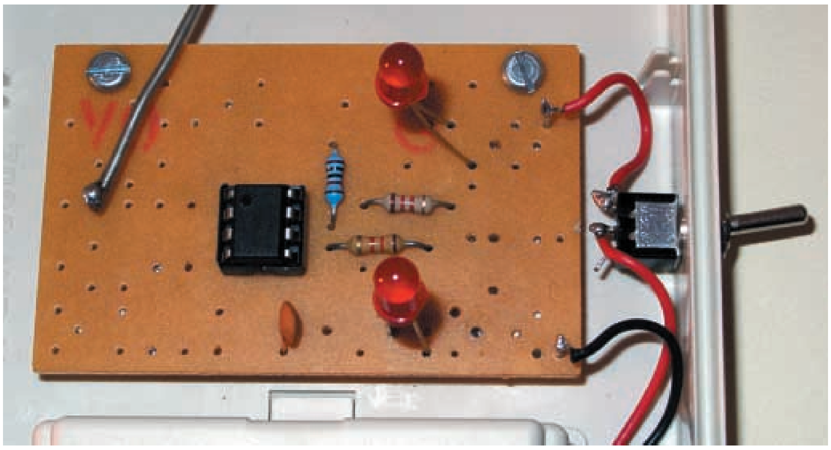
You can amuse you friends and family by checking to see if they are highly charge characters, and whether they emit positive or negative energy. Get them to rub their clothes and then try again to see if different results are obtained.

The device used for IC1 has built-in protection circuitry that should prevent the input voltage from going outside the range that the unit can handle. If the l.e.d.s seem to get stuck showing a fully positive or negative indication try switching off, waiting a second or two, and then switching on again.

Attempts to deliberately "zap" IC1 by placing the antenna near known sources of high static voltages such as television screens proved fruitless. This suggests that the unit is reasonably "zap" resistant, but large static charges *can* destroy most modern semiconductors, so you try this sort of thing at your own risk. □



The simple layout of components inside the handheld case.



Completed circuit board. Note the unused holes.

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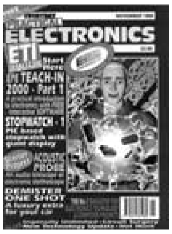

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MAR '00

PROJECTS ● EPE ICEbreaker ● High Performance Regenerative Receiver–1 ● Parking Warning System ● Automatic Train Signal.
FEATURES ● Teach-In 2000 – Part 5 ● Practically Speaking ● Technology Timelines–2 ● Ingenuity Unlimited ● Circuit Surgery ● New Technology Update ● Net Work – The Internet.

APRIL '00

PROJECTS ● Flash Slave ● Garage Link ● Micro-PICscope ● High Performance Regenerative Receiver–2.
FEATURES ● Teach-In 2000–Part 6 ● Ingenuity Unlimited ● Technology Timelines–3 ● Circuit Surgery ● Interface ● Telcan Home Video ● Net Work – The Internet.

MAY '00

PROJECTS ● Versatile Mic/Audio Preamplifier ● PIR Light Checker ● Low-Cost Capacitance Meter ● Multi-Channel Transmission System–1.
FEATURES ● Teach-In 2000–Part 7 ● Technology Timelines–4 ● Circuit Surgery ● Practically Speaking ● Ingenuity Unlimited ● Net Work – The Internet ● *FREE* Giant Technology Timelines Chart.

JUNE '00

PROJECTS ● Atmospheric Electricity Detector–1 ● Canute Tide Predictor ● Multi-Channel Transmission System–2 ● Automatic Nightlight.
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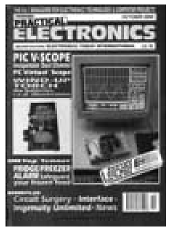

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PROJECTS ● g-Meter ● Camera Shutter Timer PIC-Gen Frequency Generator/Counter ● Atmospheric Electricity Detector–2.
FEATURES ● Teach-In 2000–Part 9 ● Practically Speaking ● Ingenuity Unlimited ● Circuit Surgery ● PICO DrDAQ Reviewed ● Net Work – The Internet.

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PROJECTS ● Handy-Amp ● EPE Moodloop ● Quiz Game Indicator ● Door Protector
FEATURES ● Teach-In 2000–Part 10 ● Cave Electronics ● Ingenuity Unlimited ● Circuit Surgery ● Interface ● New Technology Update ● Net Work – The Internet.

SEPT '00

PROJECTS ● Active Ferrite Loop Aerial ● Steeplechase Game ● Remote Control IR Decoder ● EPE Moodloop Power Supply.
FEATURES ● Teach-In 2000–Part 11 ● New Technology Update ● Circuit Surgery ● Ingenuity Unlimited ● Practically Speaking ● Net Work – The Internet Page.

OCT '00

PROJECTS ● Wind-Up Torch ● PIC Dual-Chan Virtual Scope ● Fridge/Freezer Alarm ● EPE Moodloop Field Strength Indicator.
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NOV '00

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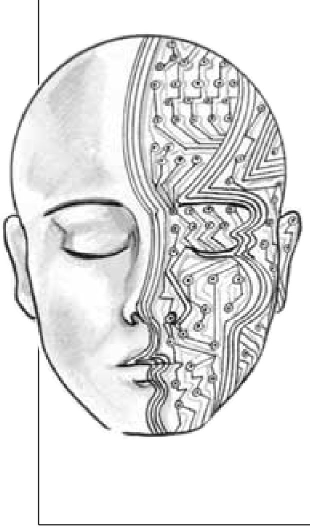

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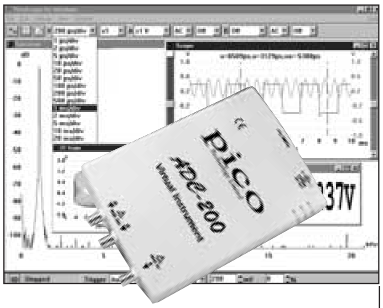
Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited,* Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. (We **do not** accept submissions for *IU* via E-mail.)
Your ideas could earn you some cash **and a prize!**



WIN A PICO PC BASED OSCILLOSCOPE

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

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours.
Every six months, Pico Technology will be awarding an ADC200-50 digital storage oscilloscope for the best IU submission. In addition, two single channel ADC-40s will be presented to the runners-up.

Car Wash-Wipe Latch – More Delays

For cars which have only a simple rear wash-wipe control giving a single sweep of the wiper each time the switch is operated, the latching circuit of Fig. 1 will additionally provide a sweep automatically every few seconds, for use in continuous spray conditions. No extra switches are needed and the normal single-sweep operation can still be used at any time.

In the circuit diagram of Fig.1, IC1a is one half of a 556 dual timer, with the reset terminal (pin 4) connected unusually to the output (pin 5) via resistor R6 to form a latch. This can be set or reset depending on the duration of the wiper switch closure. When power is first applied (probably by switching on the car ignition), capacitor C2 briefly pulls the reset terminal high which enables the timer.

The trigger terminal (pin 6) voltage is low, so the output goes high and maintains the reset terminal high. The timing capacitor C1 charges from the output via R4, R5 and R6, but because of resistor R7 it does not reach the timer's threshold voltage (two-thirds of the supply voltage).

When the wiper switch is closed, capacitor C1 charges further via resistor R2, and will reach the threshold voltage in about 0·4 seconds, at which point the timer output will go low. (If the switch is opened before this, C1 simply discharges again.) The output then holds the reset terminal low after the wiper switch is opened, and C1 then discharges through R7. The latch remains in this state until the wiper switch is closed again, which takes the reset high and allows the output to go high again.

If the wiper switch is then held closed for more than 0·4 seconds cacitor C1 will have charged above the threshold voltage and so when the switch is opened the output will go low, resetting the latch. Releasing the switch in less than 0·4 seconds sets the latch.

While the output of the latch is low it enables IC1b, which is an astable multivibrator with a duty cycle of 5 per cent. The inclusion of diode D3 enables the on and off times to be set independently by resistors R9 and R10 respectively. The output at IC1b pin 9 drives the existing transistorised wiper relay to give one sweep every ten seconds.

The circuit is powered from the car battery via resistor R1 and Zener diode D1 which provide a regulated 6.2V. To prevent damage to the i.c. from any voltage spikes from the wiper switch, the signal from R2 is clamped to the regulated supply rail by diode D2.

N. Jewell,
Ilfracombe,
Devon.

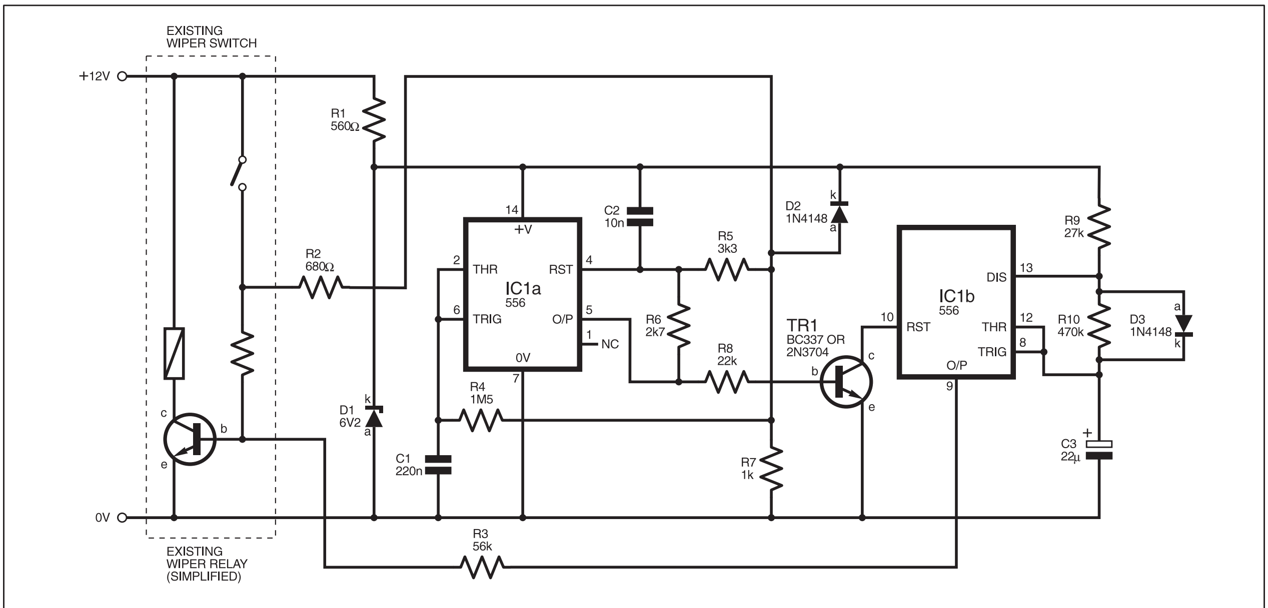


Fig.1. Circuit diagram for the Car Wash-Wipe Latch.

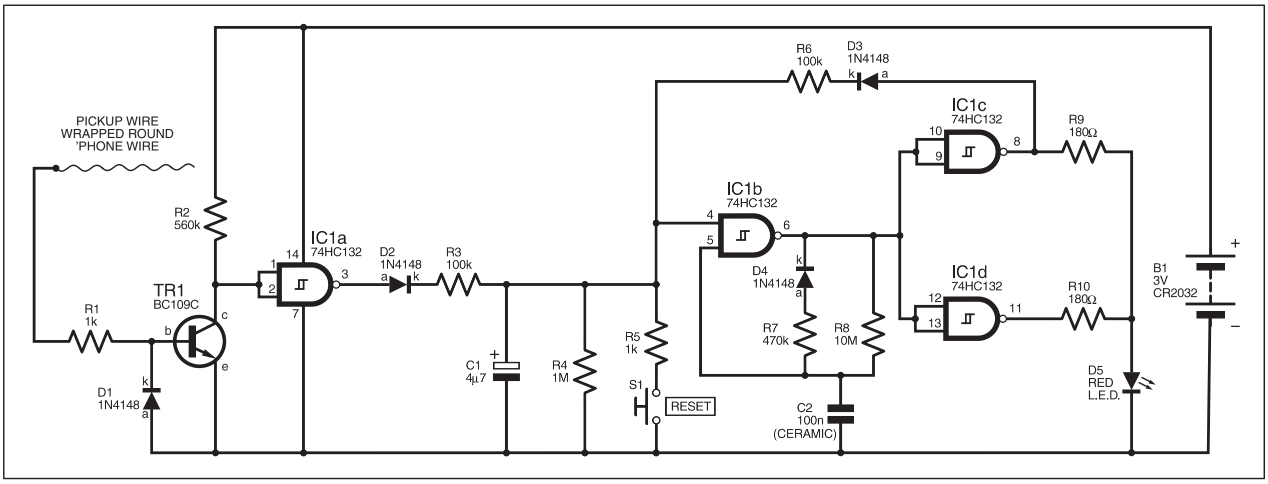


Fig.2. Circuit diagram for a Missed Call Indicator.

Missed Call Indicator – Call Back In A Flash

THIS project can provide an immediate visual indication that a telephone call has been missed. This is particularly useful when services such as the 1471 last call or automated call answer are used, since there is no way of telling if a new call has been missed without actually using the phone to check.

The circuit diagram shown in Fig.2 is designed to avoid the need for any direct connection to the phone line and to be battery operated. When not triggered, the quiescent current is near zero to ensure long battery life.

To avoid the need for a direct connection to the phone line, in accordance with UK regulations, a pick-up wire is instead, wrapped around the wire to the phone. This is connected to a high input impedance amplifier to detect the ringing voltage on the line.

A transistor TR1 with no bias, followed by a Schmitt trigger IC1a, provides sufficient amplification to trigger the circuit from the ringing voltage. Unlike more traditional methods of detecting the phone ring with a microphone and amplifier, this method draws negligible quiescent current.

A second Schmitt trigger gate IC1b is used to implement a gated oscillator to generate the l.e.d. flash rate. An *RC* network formed by R3 and C1 at the input to this gated oscillator helps to prevent false triggering by requiring the equivalent of around three rings before the oscillator triggers. The two remaining gates are used as buffers to drive the l.e.d. and also to provide a feedback signal, via diode D3 and resistor R6, to latch the circuit once triggered.

The project can be built on stripboard and housed in a small plastic case. A 3V lithium cell or two 1·5V cells provides the power supply (B1) and the use of a 74HC series Schmitt trigger ensures that the circuit operates at 3V.

David Corder,
Loughborough, Leics.

WHY NOT SEND US YOUR CIRCUIT IDEA
Earn some extra cash and possibly a prize!

Scissors, Paper, Stone – The Game's Up

AN electronic variation of the Scissors, Paper, Stone game, designed for one player versus a machine, is shown in circuit diagram Fig.3. With pushswitches S1, S2 and S3 open, timer IC2 operates as an astable at approximately 30kHz with its output (pin 3) driving the clock (pin 14) of decade counter IC1. This counts to "3" and then resets so giving three viable outputs "1," "0" and "2".

On closing any one of the switches, one of the l.e.d.s D4, D5 or D6 illuminates and IC2 output is reset by lowering the voltage of pin 4. This stops the astable and the clock of the 4017 (IC1). Now one of the output pins 2, 3 or 4 of IC1 will be held high and the corresponding l.e.d. D1, D2 or D3 connected to it lights up. The machine's "response" to the player's selected diode D4, D5, D6 can therefore be observed.

Diode D7 has a dual purpose. Its primary function is to raise the voltage of IC2 so that when one of the switches S1 to S3 is selected, the input at the Reset pin (4) is low enough to operate the reset function and drive the IC2 output low. It also provides a power-on indicator.

George A. Vicary,
Swayfield,
Grantham.

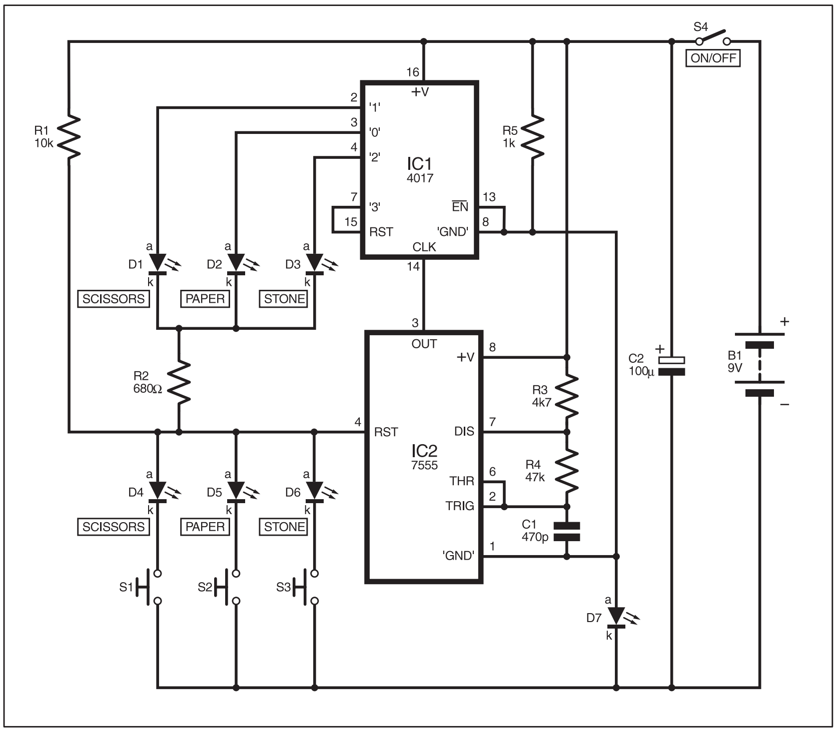


Fig.3. Scissors, Paper, Stone game circuit diagram.

READOUT

E-mail: editorial@epemag.wimborne.co.uk

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

WIN A DIGITAL MULTIMETER

A $3^{1}/_{2}$ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

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

★ LETTER OF THE MONTH ★

BASE-32 CODE

Dear EPE,

Your extension of base-16 (so-called *hexadecimal*) code to provide a compact date/time code for file names in the *PIC Dual-Channel Virtual Scope* project (Oct '00), is easily extended further to provide a full base-32 code and allow even more compactness.

As you point out, the month requires only one digit in base-16 code, and by extending the code as you have done, hours from 0 to 24 can also be represented by only one digit. With a further extension of the code to base 32, the day of the month could also be represented by only one digit, and three digits would suffice to represent any year up to 32,767 AD.

I have been using such a base-32 code for some time, with some modifications (dare I emulate Microsoft and call them *enhancements*?) that I find useful. These are:

1. Leaving out I (eye) and O (oh), which can be confused with 1 (one) and 0 (zero)

2. For those, like me, who prefer to use lower-case letters, also leaving out l (el), easily confused with 1 (one).

So with the above, the code sequence is: 0 to 9, a to f (as in the commonly used base-16 code), g h j k m n, p to y. This leaves z for use as a dummy symbol.

3. I considered devising a base-64 code to represent minutes and seconds, but decided that it would be more bother than it was worth, so like you I have retained base-10 for these.

4. The most significant digit is placed first, i.e. the date and time are expressed as year + month + day + hour + minute + second. This simplifies sorting and arithmetical operations.

5. The code may have uses beyond incorporating date and time information in file names. So for, say, astronomical events, dates BC are expressed by prefixing a minus sign, and the BC/AD discontinuity smoothed out by assigning 000 to 1 BC. Examples:

1. My E-mail user name (pk1V7) comprises my initials and my birth year (yes, 1927 in base-10 code) 1x0 means 1984; this year (2000) is 1xg = 1984 + 16

2. The inventor of the Julian calendar made his first attempt to invade Britain in –01p

To conform with the DOS file-name and extension format of up-to-eight + up-to-three characters, the code for the seconds is placed in the extension. This leaves room to include the Admiralty time-zone designation as well: z for GMT, a for BST, k for my part of Oz. Your example of 7 Sep 2000 at 1:37:13 a.m., which you code as 07913713.Y00, then becomes lxg97137.13a

The advantages of this coding scheme, it seems to me, are its generality and its versatility. There can be a trade-off between time span and precision, with the code truncated at one or both ends to suit the application. thereby leaving room within file-naming conventions for other information.

Peter Kelly,
Woombye, Queensland, Australia

Many thanks Peter for raising this discussion. Your comments are interesting for several reasons.

*First, you highlight the problem of differentiating between several characters. It has long bugged me that some programmers insist on using the letter I (or i) as a variable name. For example: **FOR A = I TO K**, which if seen in print could be taken as **FOR A = (ONE) TO K** when in fact it means **FOR A = (the value stored in the variable represented by letter I) TO K**, a misinterpretation that could have a profound effect on the successful running of the program.*

To me, programming use of characters i, I and l (eye, EYE, el) should be prohibited by cosmic edict (or at least common sense)! I'm currently getting to grips with VisualBASIC and even in its demo software there are frequent instances where I am not immediately sure which of the three characters is meant. (Oh, alright, I've been known to use them myself in my own software!)

Incidentally, my OCR scanner can also be confused by these characters, plus ' ' / \ and ! (lefthand single quote, apostrophe, forward slash, backslash, exclamation) and 5 and S (five, ESS).

You are quite right about using base-32 for coding. For characters that have to be read by a human eye, as in a file name within a computer directory (folder) for example, base-32 seems a reasonable limit. However, if it is only the computer that has to read coded data, almost the full extent of base-256 can be used.

Some years ago, I wrote a fixtures allocation program for a local Sunday football league. This was written for a very low powered machine (Commodore PET) and to economise on memory space (32K bytes) I succeeded in coding each data item within single bytes, one each for date, venue, teams, home/away, score points etc. These bytes only needed to be read by the computer from a single string of characters within a data file, it then translated them according to calculation and lookup tables.

Whilst a few ASCII values within the possible 0 to 255 range could not be used (comma, semicolon, ASCII 0 and 13, for instance) because the computer had its own ideas of their use in a string of characters, most could be used, and were.

*On using the file name extension for seconds coding, I avoided this option in order to simplify file name searching (and possible interpretation by the computer as having a different significance). Using the dot-suffix of **.Y** allows a more ready search for file types. For example keying in **DIR *.Y0?** immediately calls up all PSCOPE (and VSCOPE) files for the years 2000 to 2009 (I don't think I actually coded the year number).*

Lastly, I was interested to read that time zones have officially (Admiralty) allocated letter designations.

BASIC AND DELPHI

Dear EPE,

I would like to make some comments on replacements for GWBasic, QBASIC interpreters and the QuickBASIC compiler for use in simple interfacing projects, and to comment on Delphi.

FirstBASIC, which is shareware and for DOS, can be downloaded from **www.powerbasic.com** and registered within the UK for £30.55, see **www.greymatter.co.uk** for this. It is a very good BASIC compiler with a simple Integrated Development Environment (IDE) and, in the registered version, on-screen help.

Like QBasic and QuickBASIC it has all the constructs for structured programming and the syntax is easy to learn, but the IDE does not support the use of the mouse. See PowerBASIC website for comparisons and some help with translating between Basics.

Having written a number of large programs in QuickBASIC for student use, some of which need to write to or poll the printer port to examine the hardware connected to it, I'm now trying to move them to Delphi. I think this is essential if I'm going to be able to run them under future operating systems.

Until recently all the books and articles I have come across have concentrated almost exclusively on the "components" used to build the various types of windows. This approach quickly allows you to build a "gee whiz" user interface, but to use Delphi seriously it is necessary to learn to use Object Pascal, which in turn requires an understanding of standard Pascal program structure.

Computer Programming in Pascal by David Lightfoot, *Teach Yourself Series*, is old, 1983, but adequate for understanding Pascal program structure. *Delphi in a Nutshell* by Ray Lischner is a new, 2000, desktop quick reference to Object Pascal, and is very comprehensive, 560pp, but it assumes some knowledge of Pascal. It also mentions that Delphi is being ported to Linux.

Delphi 1 is still available from Greymatter for £57.68p (see above) as *Learn to Program with Delphi 1*. This is a thick, 900pp, self-study manual and CD-ROM containing Delphi 1. It covers both the components and the Object Pascal language, though you have to dig a little to find what you want to know about the latter and there are some mistakes and ambiguities in the text. The "hidden gem" tucked away on the CD-ROM is the 300 page Object Pascal manual which can be printed from Adobe Acrobat.

Having no previous knowledge of Pascal, I almost gave up on Delphi because I could not figure out how to store, retrieve and manipulate data. Now I'm hooked. I've concluded that a rule of thumb is to ignore any book with less than 300 pages as it will be too superficial. It's a steep learning curve and I'm still in the foothills, but I'm still climbing!

Dr Les May,
Rochdale, Lancs

Interesting. Thank you Dr Les. It's an aspect that some readers may find it worthwhile looking into. Personally, I'm now just about coming to grips with VisualBASIC 6 and, despite finding the documentation inadequate, believe that this, with its Windows base, is the route to pursue.

BCD CHALLENGE ACCEPTED

Dear EPE,

I was very intrigued by the Binary to BCD conversion routine given in September 2000 *EPE*, as I had always seen this done by some method involving division by ten.

After a lot of thought, I managed to come up with what I think is an improved version. The procedure used to do the conversion is: "Start with a Partial Result (PR) of zero. For each bit in the binary, starting at the left hand end, multiply the PR by two and add the bit."

By doing this arithmetic in decimal, the PR at the end has the converted value which holds the digits as binary coded decimal (BCD) in the lower four bits of each of a succession of bytes, bits 4 to 7 are zeroes (Unpacked BCD). You could also, with a different program, use Packed BCD with two digits in a byte, one in each nibble.

Throughout the process, decimal adjustment (DecAdj) of the PR is necessary to maintain its BCD nature, so that 0 to 9 are unchanged but a result in the range 10 to 15, which is stored as hex 0A to 0F, is converted to 0 to 5 with a 1 carry ready to go in the next BCD, i.e. 0A to 0F become 10 to 15 hex.

The actual process is to add six to the unadjusted result. If this causes a 1 in the fifth bit (bit 4) then the changed pattern is used, otherwise the original unadjusted pattern is retained. For Unpacked BCD the state of bit 4 can be used as the test.

The algorithm in Sep '00 uses "Add 3" before the "times 2" shift. This is best when Packed BCD is converted since for the "top" nibble there is no bit corresponding to bit 4. By "Adding 3" before the shift instead of "Add 6" after, the same effect is obtained using bit 7. However, in this case the carry into the decimal cannot be done until after the shift, hence the two passes through the digits for each bit.

The following is a version using one pass, for Unpacked BCD. I have used the locations BIN0 to BIN2 to hold the three bytes of binary, with the most significant (m.s.) byte in BIN2. The PR goes in the eight bytes DIGIT0 to DIGIT7, with the m.s. digit in DIGIT7. BINCNT and DECCNT hold counts for the two nested loops.

Harry West, via the Net

Congrats on picking up the challenge Harry! In fact I'd already seen in our Chat Zone *that you'd been in contact with Peter Hemsley (who started it all off) and that he'd accepted your improvement. Well done. You now hold the BCD Place of Honour – can you be deposed we wonder? Well, readers, what do you think?*

```
BINDEC:
   CALL CLRDIG     ; Clear decimal digits
   MOVLW 24        ; Decimal count
   MOVWF BINCNT
BITLP:
   RLF BIN0,F      ; Shift binary left
   RLF BIN1,F
   RLF BIN2,F
   MOVLW DIGIT0
   MOVWF FSR
   MOVLW 8         ; Count for the decimal digits
   MOVWF DECCNT
   MOVLW 6         ; The Working Register
                     holds 6 throughout. For
                     each bit the inner loop is
                     repeated 8 times, with shift
                     in of the next bit, "times 2"
                     and DecAdj of each digit
ADJLP:
   RLF INDF,F      ; 2*digit, then shift in "next
                     bit" for DIGIT0 or else the
                     carry from the previous digit
   ADDWF INDF,F    ; Add 6, clears Cf and
                     gives 1 in bit 4 if the
 BTFSS INDF,4      ; addition is needed; zero if
                     not, when
 SUBWF INDF,F      ; we subtract it again. Sets
                     Cf
 BSF STATUS,C      ; Cf could be 0 or 1, so
                     make it 1 as default
 BTFSS INDF,4      ; Bit 4 is the carry to the
                     next digit
 BCF STATUS,C      ; Reset Cf to zero if bit 4 is
                     clear
 BCF INDF,4        ; For BCD clear bit 4 in case
                     it's one
 INCF FSR,F        ; Go to next digit, (Cf not
                     affected)
 DECFSZ DECCNT,F   ; End of inner loop.
                     check digit count and
 GOTO ADJLP        ; round again if it's not zero
 DECFSZ BINCNT,F   ; End of outer loop, one
                     pass through digits,
 GOTO BITLP        ; check bit count and repeat
                     if necessary.
 RETURN
```

E-MAIL VIRUSES

Dear EPE,

Barry Fox's article in *News* of September '00 raised the question of whether a virus can hide in plain text E-mails. He is essentially correct in saying that a computer-executable program cannot be transmitted through a text-only E-mail.

However, viruses are more than just computer programs. A virus is an entity that uses its host to replicate itself. If a text E-mail simply says "Copy this E-mail to everybody you know", it is a virus. It utilises the human user as the host to replicate itself. In 1994 an E-mail virus "Good Times" infected thousands of people's E-mail systems, as detailed in **http://www.mdfsnet.f9.co.uk/Docs/Comp/Viruses/GoodTimes**.

It was essentially a chain letter containing a hoax warning about a virus, recommending that the reader E-mail it on to all their friends. As Clay Skirky on **alt.folklore.urban** put it: "It works by finding hosts with defective parsing apparatus which prevents them from understanding that a piece of E-mail which says there is an E-mail virus, and then asking them to remail the message to all their friends, is the virus itself."

P.S. A super computer is a machine that runs an endless loop in just two minutes.

Councillor Jonathan G. Harston, Sheffield, via the Net

Editor Mike comments that we recently received a "self-executing" virus of the type you refer to. It trusted the user to delete all the files on his hard disk and then send on the E-mail!

We wonder whether by publishing your letter through so many thousands of EPE *copies that it too has persuaded human hosts to perpetuate it as a virus?*

NEW ELECTRONICS eGROUP

Dear EPE,

I wish to inform you of a new electronics egroup which has been set up specifically to address the needs of persons involved in all forms and branches of electronics in the UK, but particularly enthusiasts and students, whatever their experience. The main emphasis is on the sharing of information, designs, advice and support.

Further information, and joining instructions can be found at: **www.egroups.com/group/Electronics-UK**, or from: **Electronics-UK-owner@egroups.com**.

I warmly invite your friends and colleagues to join.

Ross Currie, Belfast, Northern Ireland, UK, via the Net

Thanks Ross. We hope readers will flock to join your worthwhile enterprise.

BINARY TO DECIMAL

Dear EPE,

Thanks for publishing Peter Hemsley's BINDEC routine in Sept '00 *Readout*. However, the second instruction could better be written MOVLW D'24'. If the default radix happens to be hexadecimal, as in MPASM, the program won't work right as written unless the radix is changed to decimal.

Stan Ockers, via the Net

Thanks Stan. Yes, that would be the case with MPASM, although TASM automatically recognises the value as decimal, not having a facility for setting the radix. In TASM, hex is expressed with a $ (dollar) symbol before the value.

DATA SHEETS

Dear EPE,

I refer to *Readout* of Sept '00 and Roger Nightingale's query regarding data sheet availability on the web. Since I work in a computer workshop at the University of Dundee, information is a prime requirement to efficiency and fault finding and data sheets are crucially important. Having 24 hours a day access to the web I have been able to find numerous sites for data sheets but none to rival the one at **www.bgs.nu/sdw/a.html**.

If Roger can't find his required data sheet on this site, then he is in deep trouble.

Sandy Smith, Dundee, via the Net

Most useful info Sandy, thanks.

PIC PULSOMETER

Dear EPE,

You published my *PIC Pulsometer* project in the Nov '00 issue. It was written in TASM and I owe you a word of thanks. This was my first PIC project, and your *PIC Tutorial* (Mar-May '98) and excellent *Toolkit Mk1* (Jul '98) programmer gave me an easy route into picking up the basics to add to my previous if different experience.

Richard Hinckley, Congleton, Cheshire

Thank you Richard. We are sure that many readers will appreciate the result your of efforts! Why not give Toolkit Mk2 *(May-Jun '99) a try now? It has even more facilities and the software has been updated again (see Nov '00 issue).*

ANTI-TAMPER LOOP

Dear EPE,

In the application of Alan Bradley's *Anti-Tamper Loop Alarm* in *Ingenuity Unlimited* Oct '00, particularly when being deployed for the protection of a bicycle, motorcycle or car steering wheel, a good practice is to use coaxial cable such as RG58 or similar for the loop. This cable is then threaded through a chain with links of a suitable diameter, leaving several links at either end for the purpose of securing the chain with a padlock.

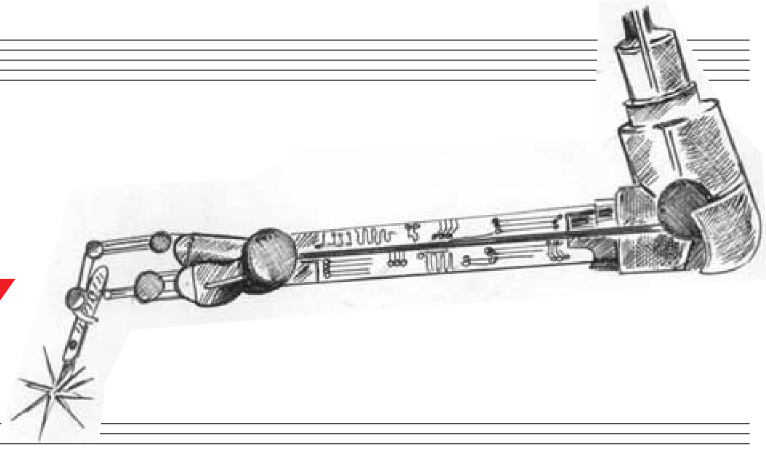
The cable may then be terminated with BNC connectors, which offer not only good connection reliability, but also, from the point of reducing false alarms, would be unlikely to become inadvertently disconnected through, for example, vibration or innocent, inadvertent movement of the protected item.

In this situation, good security is provided by not only having the security factor of the loop alarm, but also the physical security of the chain, which, if the loop is assembled within it correctly, will be very difficult to cut without cutting the loop and therefore activating the alarm. It also restricts access to the loop for bypass measures.

Ross Currie, Belfast, Northern Ireland, via the Net

Ah, hello again Ross! As a cyclist (in good weather only!) I agree with your suggestion. Also see Please Take Note *this month.*

CIRCUIT SURGERY



ALAN WINSTANLEY
and IAN BELL

Our intrepid circuit surgeons explore switched-mode power supplies, whilst under heavy sedation!

Switched Mode Supplies

Richard Torpey of Merseyside writes by E-mail, asking for advice about designing step-up voltage regulators:

A friend of mine has recently asked me to construct a microphone pre-amplifier for portable use, running from a 9V PP3 cell. The microphone he's using requires a +48V (in practice, anything from +40V to +50V) supply (phantom powering) to operate.

I have identified a circuit which provides the necessary gain and d.c. blocking to satisfy this function, and it runs quite happily off a bench PSU. However, I cannot find an easy solution for obtaining a +48V supply.

A method considered was generating a sinewave to feed a step up transformer primary, and rectifying and smoothing the secondary output, but finding a suitable transformer for this application seems difficult.

I have heard of a solution involving use of a "Cockroft Ladder" voltage-doubling network, but am unsure as to how such a system would be put into practice for the desired application. The most important considerations are, primarily, obtaining a clean, steady +48V output, and also efficiency to preserve battery life. Current consumption will be in the order of milliamps.

As Richard indicates, there are a number of possible approaches to this problem. We will look at a number of solutions to step-up voltage converter design in general over the next couple of months, hopefully Richard will then be able to select a circuit suitable for his application. But before we start, let's check some basic concepts.

Efficiency is often a key parameter in power conversion. Power is given by voltage multiplied by current ($V \times I$), so if a power converter is 100 per cent efficient then $P_{in} = V_{in}I_{in} = P_{out} = V_{out}I_{out}$. If the converter is less than 100 per cent efficient, then P_{out} will be less than P_{in} by the efficiency factor.

In this application we need a high efficiency so that the battery is not drained too quickly. The ideal situation of $V_{in}I_{in} = V_{out}I_{out}$ also shows us that if we increase the voltage ($V_{out}>V_{in}$), the current available at the output will be proportionally less than I_{in}. With a perfect converter, 5mA at 48V output would draw 27mA from a 9V input. A real converter would draw more current, which should be borne in mind when considering battery life.

Regulation

Another important power supply specification is regulation. In fact, there are two factors to consider here – *line regulation* and *load regulation*. Line regulation indicates how much the output voltage changes as the input voltage changes, and it's calculated using:

$$\text{Line regulation} = \frac{V_{out}\text{ at max input} - V_{out}\text{ at min input}}{V_{out}\text{ required}} \times 100\%$$

Load regulation indicates how much the output varies with varying load and is calculated using:

$$\text{Load regulation} = \frac{V_{out}\text{ at 50\% load} - V_{out}\text{ at full load}}{V_{out}\text{ required}} \times 100\%$$

There may be a small a.c. signal superimposed on the d.c. output of a supply. This is known as a "ripple voltage" and is usually expressed simply in volts, but could also be given a percentage of the supply voltage.

Richard suggests the use of a sinewave generator feeding a transformer as a possible approach. The transformer provides the voltage step-up in accordance with its turns ratio and must be driven by a varying voltage (only a.c. signals are coupled to the secondaries of transformers).

In mains power supplies the input to the transformer primary is a 50Hz or 60Hz sinewave, depending where you live. For d.c. to d.c. "converters" (a power supply circuit that raises a lower d.c. voltage to a higher one), neither a sinewave nor a frequency as low as this need be used. Higher frequencies enable smaller transformers to be used, and furthermore if it operates above audio frequencies, then it will allow for silent operation (otherwise some transformers may emit an annoying whine or whistle).

Pulsed inputs to the transformer (or other type of inductor) are commonly used in "switching power supplies" (ones which use an oscillator to generate pulses which can be converted into a higher voltage output), as they are relatively easy to generate using control logic. This logic often uses pulse modulation (switching pulses on or off, or modifying their length) to control the output voltage as the load varies.

Royer Converter

A classic power converter circuit in which the transformer input is a switched waveform rather than a sinewave, is the "Royer Converter" described by G.H. Royer in 1954. This is shown in its basic form in Fig.1.

The circuit is self-oscillating, with feedback provided from a transformer winding. The oscillation is "square wave" in nature rather than sinusoidal because the transformer is driven into saturation (an appropriate transformer must be used to achieve efficient operation).

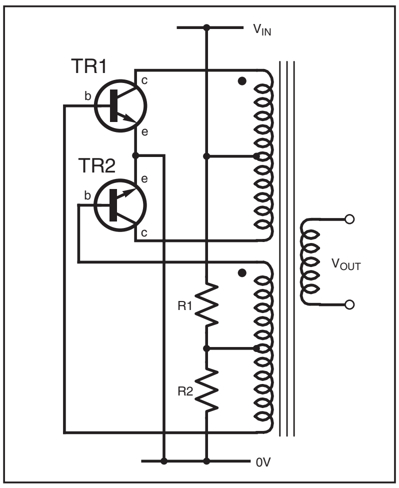


Fig.1. Basic Royer power converter.

The resistor network provides bias and ensures that the circuit starts oscillating when power is applied. The transistors switch on and off out of phase with each another, with a duty cycle of 50 per cent. The voltage induced in the secondary winding depends on V_{in} and the transformer turns ratio. Appropriate transistors should be used which have a high gain (h_{FE}), low $V_{CE(sat)}$, low on-resistance ($R_{CE(sat)}$) and high collector-base breakdown voltage. Transistors specifically designed for high current switching applications should be used.

In Fig.2 is shown a modified Royer converter based on a circuit from a design note by Zetex (**www.zetex.com**), who are renowned for high current, high performance transistors including the ZTX650, ZTX849 and ZTX449, which are suitable for use in these circuits. The circuit is a slight modification of Fig. 1, which itself does not need a centre-tapped feedback winding.

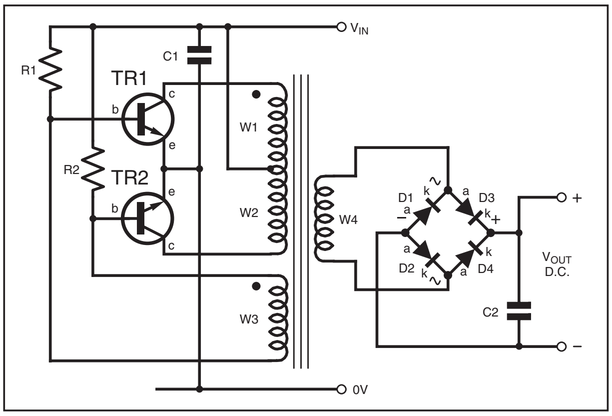


Fig.2. Royer step-up d.c. to d.c. converter.

The Zetex circuit uses two ZTX449 transistors, two 560 ohm resistors and two ceramic 100nF decoupling capacitors, together with a suggested toroidal transformer, with windings W1 and W2 (primary) having 10 turns, W3 (feedback) at 4 turns and W4 (secondary) at 28 turns. Note that this circuit has not been proven by us: if you decide to wind your own toroid, simply wind the correct number of turns using as thick an enamelled copper wire as can be accommodated by the ferrite core.

The output is 12V at 2W from a 5V supply at 77 per cent efficiency, and has an operating frequency of over 80kHz. Increasing the input voltage or number of secondary windings will give a higher output voltage (adjust the resistors and capacitors to suit).

Other Zetex switching transistors (or equivalent) may be used in more demanding versions of the circuit. We have shown the rectifier and smoothing capacitor in Fig. 2, but will not do so in all the circuits in order to save space. As Zetex says, circuits like this look deceptively simple, but many components interact in a complex way.

Having said that "the use of sinewaves is not necessary", there are step-up converters that *do* use sinusoidal oscillation, which can be useful at times. The use of sinewaves cuts the level of harmonics of the basic switching frequency, which can otherwise be responsible for radio frequency noise and interference (r.f.i.). A modified Royer circuit, in which sinusoidal operation occurs due to the presence of the inductor L1 and capacitor C1, is shown in Fig.3.

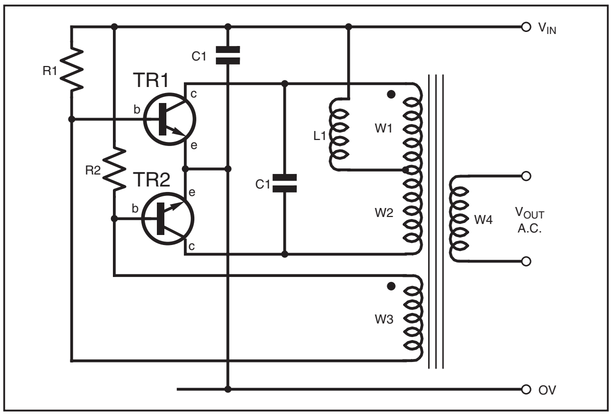


Fig.3. Version of Royer circuit with sinusoidal operation.

Switch Mode

Finding a suitable transformer for a particular step-up power supply design can be very difficult; it is possible to wind your own transformer using the various ferrite core kits etc. which are sold for this purpose, but this adds another dimension to the design problem that not everyone would want to tackle. Useful results can often be obtained by experimenting to optimise the circuit.

However, it is not necessary to use a transformer to produce a step-up converter – some switch mode power supply (SMPS) configurations only require an inductor, and certain voltage multipliers and charge-pump circuits achieve step-up neatly by using capacitors (but voltage multipliers are usually driven from a transformer secondary). We will look at each of these options next, and also in next month's column.

An example SMPS circuit, using a National Semiconductor LM2586-ADJ device, is shown in Fig.4. An SMPS design is often regarded as being quite difficult – which is true if you do not follow manufacturer's design guidelines, and also because they are demanding circuits requiring the use of appropriately specified components together with high quality construction. At this point it should be mentioned that the higher voltages generated with ease by these efficient circuits must be treated with due respect, using suitably-rated parts, with good insulation and reasonable standards of assembly.

Design On-line

Rather than struggle, we took the easy, modern route and obtained this circuit using on-line tools available on National Semiconductor's Power Web Site at **www.national.com/appinfo/power/**. This is a particularly interesting site which allows you to design and simulate SMPSs on-line using National's versatile *WebBench*(tm) and *WebSIM*(tm) tools. The web site even allows you to organize your designs with secure password protected storage. Design details including your specifications, bill of materials, schematic, and simulations results are stored on the server, and are available on-line.

Note that the WebSIM simulation tools are installed on a server owned by National Semiconductor, not on the user's machine, as would be the case with most simulators. The user gains access to the simulator using a browser, executing the simulation on the server instead of on their own machine.

This enables very large amounts of computing power and memory to be used by the simulator environment. The simulation tools can be constantly upgraded, ensuring that users always have the most up-to-date version.

We created an SMPS for an 8V to 10V input and 47V output using National's on-line tools, and we simulated the steady state output from the circuit using WebSIM to obtain the results shown in Fig.5. Note that there is about 400mV of ripple on the supply. Using a large value for C_{out} could reduce this.

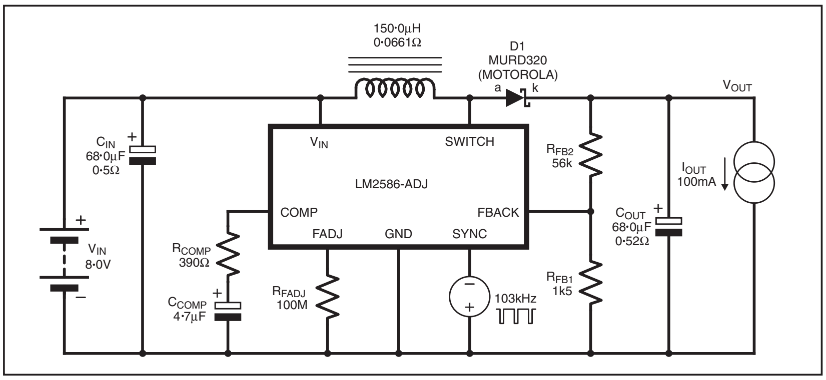
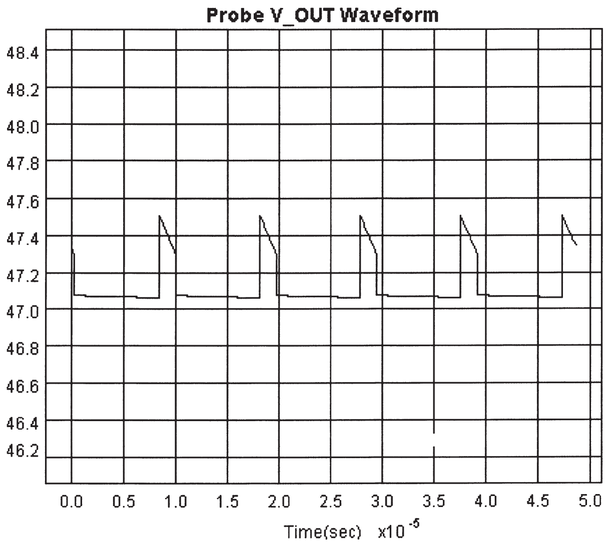


Fig.4. Switched-mode step-up converter for 8V to 10V input giving 47V output. Courtesy National Semiconductor's web site (see text).



This SMPS may not be very appropriate for the reader's application though (which calls for a few milliamps only) as its efficiency will be impaired at low output currents. This circuit is not particularly suitable for output currents less than 100mA. However, we did not attempt to find an optimal SMPS for this purpose.

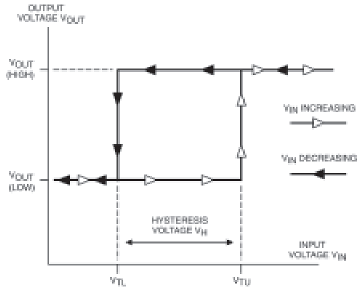
As we said earlier, SMPS circuits are demanding on the components used: you cannot use any old diode from the junk box for D1 for example – you must use a suitable high-speed power switching diode. SMPS and similar circuits tend to destroy low frequency rectifier diodes such as the 1N4001 very quickly. In switched-mode power supplies, circuit capacitors must be able to stand high pulse currents and also have a low effective resistance, and inductors should have low resistance as well.

Next month, we'll take a good look at voltage multiplier circuits which use diode-capacitor networks. These are often used where a higher d.c. voltage is needed. For many users, they form a more practical proposition than a demanding switched-mode power supply. *I.M.B.*

Fig.5 (left). Simulation of the steady state response of the SMPS circuit in Fig.4 using National Semiconductor's WebSIM^{TM} on-line simulator.

Special Series

THE SCHMITT TRIGGER



ANTHONY H. SMITH

Part 2

In this short series, we investigate the Schmitt trigger's operation; explore the various ways of implementing its special characteristics and also look at how we can use it to create oscillators and pulse width modulators.

Op.amp and Comparator Triggers

In the first part of this series, we looked at discrete Schmitt triggers based on bipolar transistors. Although effective and flexible, we saw how they could be somewhat difficult to design, especially where the interconnection of several transistors demanded careful attention to biasing levels and resistance values.

In this article, we look at Schmitt triggers based on operational amplifiers (op.amps) and comparators, devices which free us from most of the effort required in designing discrete, transistor-based circuits. By considering the op.amp or comparator as a "black box" having just input and output terminals and power supply pins, we can ignore its inner workings to a large degree, and instead concentrate on using it as a highly versatile circuit building block.

However, designing with op.amps and comparators is not a trivial undertaking: they bring their own set of requirements, terminology, and design rules, and if not applied correctly they will either malfunction or suffer permanent damage. The practice of designing with op.amps and comparators is a vast subject that is way beyond the scope of this article. Nevertheless, we'll deal with the main points and examine several practical circuits that illustrate different aspects of Schmitt triggers based on them.

INVERTING SCHMITT TRIGGER

In Fig.2.1a (next page) is shown a simple, inverting Schmitt trigger requiring only two resistors (R1 and R2), an op.amp (IC1), and an optional voltage reference (V_{REF}). In some cases, a small "speed-up" capacitor, C_S, may be connected across R2 to improve the transient response. Before examining the operation of the circuit, we'll deal with some basic op.amp behaviour.

The op.amp's input terminals are denoted "**+**" for the *non-inverting* input, and "**–**" for the *inverting* input. The term *non-inverting* implies that a voltage applied to that terminal will cause the output voltage to "move" in the same direction, i.e., with the same polarity.

For example, applying a small negative voltage to the non-inverting input will result in a much larger negative voltage at the output. The opposite is true of the inverting input, where a small negative voltage would be "inverted" at the output and result in a much larger *positive* voltage.

The op.amp is a *differential* amplifier, meaning that it amplifies the voltage *difference* between the input terminals. Ideally, an op.amp would have infinite open-loop differential gain. In practice, this can never be achieved, but most op.amps do have very high differential gain, usually in the order of 100,000 or more. The venerable 741, for example, has a typical open-loop gain of around 200,000, meaning that a differential voltage of just $10\mu V$ will swing the output by 2V.

If the input terminals of an ideal op.amp were shorted together to make the differential input voltage zero, the output voltage would also be zero. In practice, however, all op.amps feature a small "input offset voltage" (usually denoted V_{IO}, or sometimes V_{OS}) which results in a non-zero output voltage when the inputs are shorted together.

For example, an input offset voltage of +2mV would require applying an actual differential voltage of –2mV in order to "neutralise" the offset and make the output voltage zero. General-purpose op.amps like the 741, LM358 and MC33171 have V_{IO} in the millivolt range, whereas precision devices such as the OP177 have offsets that are a thousand times smaller, typically just $10\mu V$.

For the circuits we'll be examining in this article, we can assume V_{IO} is negligible, although for precision Schmitt triggers it must be taken into account.

One thing we cannot ignore, however, is the effect of input bias currents. Ideally, an op.amp's input terminals would have an infinitely large impedance, such that they would draw no current from an input voltage source. In practice, all op.amps exhibit an "input bias current" which, as the name suggests, is the current necessary to bias the input transistors.

Usually denoted I_B, the input bias current may flow into or out of the input, depending on the op.amp type, and tends to be larger for devices fabricated using a bipolar process.

For example, the inputs of bipolar op.amps like the LM358 and MC33078 draw bias currents of a few tens or hundreds of nanoamperes. Devices fabricated using JFET or MOSFET technology, on the other hand, exhibit much smaller bias currents. The TLC271, for example, has a MOSFET input stage with typical input bias currents of just 0·7 picoampere at room temperature. More about input bias currents later.

POWER SUPPLIES

The diagram in Fig.2.1a shows the op.amp connected to positive and negative power rails, $+V_S$ and $–V_S$, respectively. Typically, dual supplies like this may range from ±5V to ±15V, depending on the application, although some op.amps and comparators can operate on rails as low as ±1V.

For dual rail (sometimes called "split supply") circuits, it's important to remember that there is a third power supply connection, namely 0V (or "ground"). Although the op.amp is not usually connected directly to 0V, the power supply, the input voltage source(s) and the output load usually are connected to 0V in some way, and the input and output voltages are almost always measured with respect to 0V.

A slight variation on this arrangement is found in "single rail" applications, where the negative rail is omitted and the op.amp's negative supply terminal is connected to 0V. Single rail circuits are increasingly used in applications where an analogue signal of some kind must interface with digital logic operating on a single rail, typically +5V or +3·3V. The Schmitt trigger provides an extremely powerful way of interfacing analogue and digital circuits, and we shall look at single rail Schmitt triggers later.

COMMON MODE

We've mentioned that the op.amp amplifies *differential* signals: ideally, any *common-mode* voltage will be totally rejected and will have no effect on the output. A common-mode voltage is one which appears in common to both inputs.

Suppose, for example, we shorted both inputs together and connected them to +2.5V (with respect to 0V), the common-mode voltage would be +2.5V. If we then connected one input to –1V and the other to –2V, the differential voltage would be 1V, and the common-mode voltage would be the mean voltage between the inputs, in this case –1·5V.

In practical circuits, op.amps do not provide total rejection of the common-mode voltage, although the *common-mode rejection* (the degree to which the common-mode signal is rejected) is usually so good that common-mode effects can be ignored.

Still on the subject of common-mode signals, the "common-mode input voltage range" defines the range of common-mode voltages that can be tolerated by a given op.amp. This is not usually the same as the "differential voltage range" which defines the range of voltage that can appear between the inputs without causing malfunction or damage.

Both of these parameters depend on the supply voltage. The LM741, for example, has a maximum differential input voltage rating of ±30V. Exceeding this limit could cause permanent damage. When operating on ±15V supply rails, the common-mode input voltage range is typically ±13V, which means that the voltage at each input must not go within 2V of either supply rail or the op.amp might not function properly.

The LM358, however, is specifically intended for single rail applications. For example, when operating on a single +5V rail, the common-mode input voltage may go as high as +3·5V and may go all the way down to 0V. Modern op.amps and comparators frequently offer "rail-to-rail" performance. This means that the input voltage range, or output voltage range, or sometimes both, may cover the entire range from one supply rail to the other.

The LMC6482, for example, is a "Rail-to-Rail Input and Output" op.amp. When operated on, say, ±5V rails, the input voltage may be permitted to take any value between –5V and +5V, and the output voltage will typically swing to within 20mV of each rail (i.e., ±4.98V) for load resistances greater than 100kΩ.

When used in "linear" applications (i.e., applications in which *negative* feedback is applied to keep the op.amp within its linear range), the op.amp's input voltage ratings are often not excessively taxed. However, when used in Schmitt trigger circuits, the *positive* feedback frequently forces the inputs to cover a wide range, resulting in large common-mode and differential voltages.

Consequently, it's essential to check the worst-case, maximum input voltage range for a given application to ensure the op.amp or comparator will function correctly.

POSITIVE FEEDBACK

Having discussed basic op.amp theory, we can now return to Fig.2.1a and examine the operation of the inverting Schmitt trigger.

To simplify the analysis, assume the reference voltage V_{REF} is zero (i.e., R1 connected to 0V) and that V_{IN} is at some negative voltage, such that the voltage at the op.amp's inverting input is lower (more negative) than that at the non-inverting input, denoted V+. If the resulting positive differential input voltage is greater than a few millivolts, the op.amp's output will be in positive saturation, V_{SAT+}, i.e., the output will be at its maximum positive level.

The non-inverting input voltage, V+, will sit at a value determined by the ratio of R1 and R2, and by the value of V_{SAT+}. If V_{IN} now rises above the level of V+, the differential input voltage becomes negative forcing V_{OUT} also to go negative. This causes V+ to go negative, which increases the negative differential voltage, and ultimately forces V_{OUT} into negative saturation, V_{SAT-}.

As with the discrete Schmitt triggers described in Part One, the positive feedback via R2 causes *regenerative* behaviour which reinforces the switching action, causing a rapid transition from one output state to the other.

The value of V_{IN} required to "trigger" this change of state is denoted the "upper threshold voltage", V_{TU}, and is given by:

$$\text{Upper Threshold Voltage, } V_{TU} = \frac{R1 \times V_{SAT+}}{R1 + R2} \quad \text{(volts)}$$

Since V_{OUT} has gone into negative saturation, V+ now sits at a negative voltage. If V_{IN}, and hence the inverting input terminal, is now taken more negative than V+, the differential voltage will again become positive and regenerative action will force V_{OUT} into positive saturation, V_{SAT+}. The value of V_{IN} required to initiate this opposite change of state is denoted the "lower threshold voltage", V_{TL}, and is given by:

$$\text{Lower Threshold Voltage, } V_{TL} = \frac{R1 \times V_{SAT-}}{R1 + R2} \quad \text{(volts)}$$

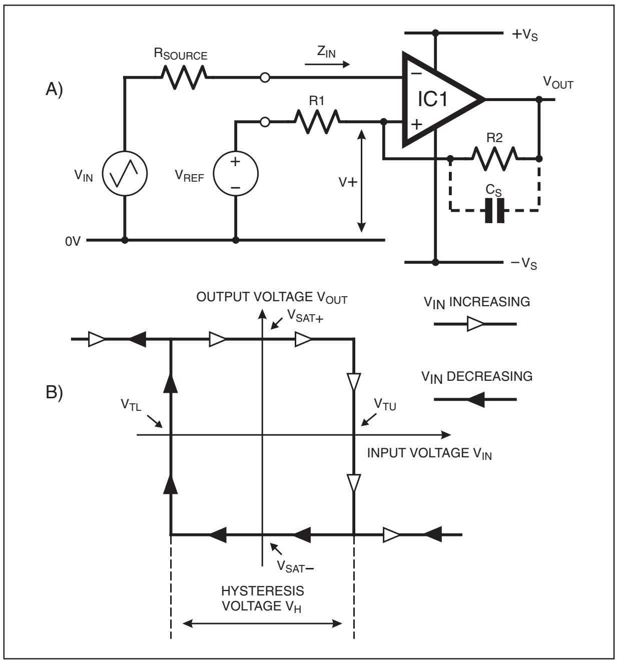


Fig.2.1. Circuit diagram for an Inverting Schmitt Trigger (a) and its voltage transfer characteristic (b).

Note that when V_{IN} goes positive and crosses the upper threshold, the output goes negative, hence the term *inverting* Schmitt trigger. We can see at a glance that the circuit is inverting because V_{IN} is applied to the op.amp's inverting input terminal.

The diagram in Fig.2.1b shows the circuit's "voltage transfer characteristic", i.e., the relationship between input and output voltage. Starting at the top left-hand corner and following the white arrows as the input voltage increases, we see that the output remains at V_{SAT+} until V_{IN} crosses the upper threshold, V_{TU}, at which point the output rapidly changes state and goes into negative saturation, V_{SAT-}.

Further increases in V_{IN} have no effect on V_{OUT}. As V_{IN} decreases (shown by the black arrows), V_{OUT} remains at V_{SAT-} until V_{IN} crosses the lower threshold, V_{TL}, where V_{OUT} abruptly changes state and goes back into positive saturation.

The transfer characteristic shown assumes that V_{SAT+} is equal and opposite to V_{SAT-} and that V_{TU} is equal and opposite to V_{TL}, resulting in a "hysteresis loop" that is symmetrical about the origin. However, this is not always the case: depending on the application, it may be necessary to make the magnitude of the thresholds unequal, or to make them both positive or both negative. Also, as we shall see shortly, V_{SAT+} is not always equal and opposite to V_{SAT-}.

The thresholds can be varied by appropriate choice of R1 and R2, and by introducing a non-zero reference voltage (so far, we have assumed that $V_{REF} = 0$).

Referring again to Fig.2.1a, assume we apply a positive value of V_{REF} : whatever the value of V_{OUT}, this will result in V+ becoming more positive. The effect of making V_{REF} positive is to shift the thresholds "upward", i.e., more positive. Similarly, making V_{REF} negative would shift the thresholds negative. To incorporate the effect of V_{REF}, the threshold equations become:

$$\text{Upper Threshold Voltage, } V_{TU} = \frac{(V_{REF} \times R2) + (R1 \times V_{SAT+})}{R1 + R2} \quad \text{(volts)}$$

and:

$$\text{Lower Threshold Voltage, } V_{TL} = \frac{(V_{REF} \times R2) + (R1 \times V_{SAT-})}{R1 + R2} \quad \text{(volts)}$$

The "hysteresis" voltage is the difference between the thresholds:

$$\text{Hysteresis voltage, } V_H = V_{TU} - V_{TL} = \frac{R1 \times (V_{SAT+} - V_{SAT-})}{R1 + R2} \quad \text{(volts)}$$

Note that V_H is completely independent of V_{REF}: this is an important aspect of the circuit, since it allows the thresholds to be shifted by varying V_{REF} *without* affecting the hysteresis voltage.

The circuit's response to a triangle wave input voltage is shown in Fig.2.2a. V_{REF} has been set to a sufficiently large positive voltage, such that both thresholds are also positive; in Fig.2.2b, a negative value of V_{REF} has shifted both thresholds negative.

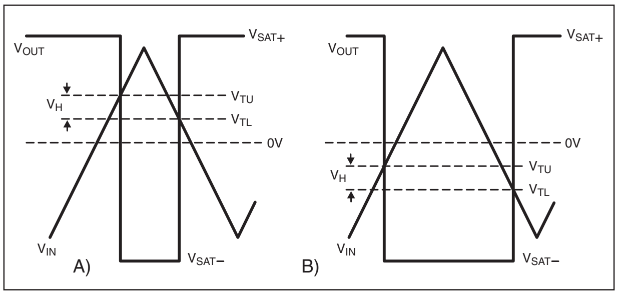


Fig.2.2. Response to a triangle wave input for positive (a) and negative (b) V_{REF}.

Varying V_{REF} allows the thresholds to be shifted over a wide range of positive and negative values. This can be a particularly useful feature: having chosen R1 and R2 to set the desired hysteresis voltage, V_{REF} may then be selected to set the mid point of the hysteresis band equal to the quiescent value of the input signal, such that the circuit can accommodate small-amplitude input signals whilst providing maximum noise immunity.

INPUT IMPEDANCE

Our analysis of the circuit has ignored the effects of input offset voltage, V_{IO}: this is a reasonable approach provided the circuit does not demand absolute precision. However, the op.amp's input impedance cannot always be neglected.

Generally, the impedance Z_{IN} seen "looking into" the inverting input can be represented by the same kind of model introduced in Part One, namely a parallel combination of resistance, capacitance, and a current sink (or source) to represent the input bias current.

At low frequencies we can usually ignore the effects of input capacitance, and if we assume the input resistance is large (several megohms) we can concentrate on the effects of input bias current.

For example, consider the LM6171, a high speed op.amp capable of operation at frequencies in excess of 10MHz. The input bias current, I_B, is typically 1μA, but can be as high as 3μA. If the input voltage source resistance, R_{SOURCE}, is very small, I_B will have negligible effect.

However, for a source resistance of, say, 100kΩ, a bias current of 2μA would drop 0.2V across R_{SOURCE}, resulting in significant errors in the threshold levels.

Even if R_{SOURCE} is zero, we must still consider the effects of I_B at the non-inverting input: if R1 and R2 are relatively large, the input bias current will cause a voltage drop across them which again will offset the threshold levels. To avoid these problems, either use small values for R1 and R2, or select an op.amp (or comparator) that has very small input bias currents.

TESTING THE CIRCUIT'S PERFORMANCE

To demonstrate the circuit's performance, it was decided to use an LF351 op.amp. As well as offering fast response, the LF351 has a JFET input stage with typical input bias currents of just 50 picoamperes, allowing it to accommodate large resistance values without affecting the thresholds.

With R1 = 10kΩ ±1%, R2 = 100kΩ ±1%, and with the supply rails set to precisely ±15.00V, the circuit's response to a 100Hz triangle wave input voltage was measured. It was found that the op.amp's output saturation levels were V_{SAT+} = +14·25V and V_{SAT-} = –13·55V.

Therefore, with V_{REF} = 0, the thresholds should be V_{TU} = +1·30V and V_{TL} = –1·23V. The actual, measured values were V_{TU} = +1·31V and V_{TL} = –1.21V. Pretty good!

Next, a reference voltage was introduced. With V_{REF} = +5·00V, the thresholds were V_{TU} = +5·88V and V_{TL} = +3·36V, very close to their theoretical values of V_{TU} = +5·84V and V_{TL} = +3·31V.

Finally, with V_{REF} = –5.00V, the thresholds were V_{TU} = –3·26V and V_{TL} = –5·80V, again in close agreement with their theoretical values of V_{TU} = –3·25V and V_{TL} = –5·78V.

Note that for each value of V_{REF}, the hysteresis voltage, V_H, remains fairly constant at ≈2·5V.

ZENER CLAMP OUTPUT SCHEME

We see from the previous example that the output saturation levels are not equal in magnitude, i.e., $|V_{SAT+}| \neq |V_{SAT-}|$, which results in an asymmetry in the thresholds. Furthermore, the output saturation levels may change from part to part, and may also vary with temperature and load.

Since V_{TU} and V_{TL} depend directly on V_{SAT+} and V_{SAT-}, this can make it difficult to establish the thresholds precisely and repeatably. To some extent, this problem can be resolved by using an op.amp (or comparator) with rail-to-rail output swing, but even then the saturation levels would be affected by any variation in the supply voltages.

In Fig.2.3 are shown two methods which can be used to establish greater control over the output voltage levels. In Fig.2.3a, a back-to-back Zener "clamp" has been added to the output and feedback is now taken from the clamp via R2, rather than from the op.amp's output.

The Zener clamp is "bi-directional": as the op.amp output swings between its positive and negative saturation levels, the output voltage, V_{OUT}, at the junction of R3 and ZD1 also swings positive and negative. We can define these levels V_{Z+} and V_{Z-}, such that $V_{Z+} = V_{Z1} + V_{D2}$ and $V_{Z-} = V_{Z2} + V_{D1}$, where V_{Z1} and V_{Z2} are the reverse Zener voltages, and V_{D1} and V_{D2} are the Zeners' forward diode drops.

If the Zeners are well matched, i.e., if $V_{Z1} = V_{Z2}$ and $V_{D1} = V_{D2}$, the magnitude of V_{Z+} and V_{Z-} will be equal.

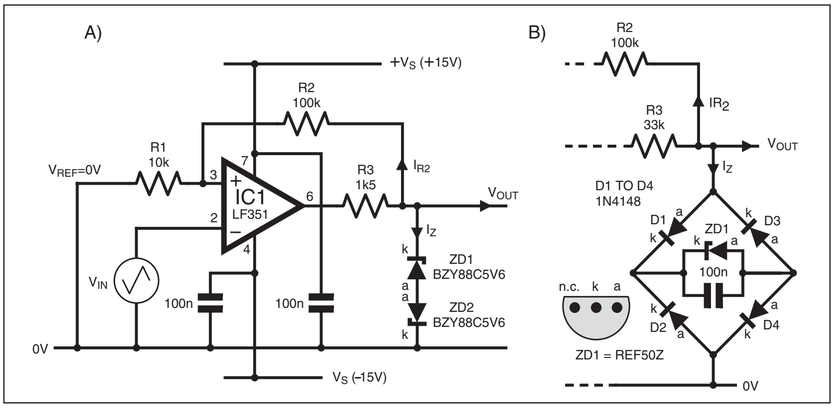


FIg.2.3. Two methods which can be used to give greater control over output voltage levels, (a) using a back-to-back Zener clamp and (b) using a diode bridge.

For example, using 5·6V Zeners as shown in Fig.2.3a, it was found that the voltage at V_{OUT} was perfectly symmetrical at ±6·60V, and with R1=10kΩ ±1% and R2=100kΩ ±1% as before, and with V_{REF} = 0, the thresholds were also symmetrical at ±0·63V.

Note that R3 must be small enough to provide adequate current, I_Z, to bias the Zeners properly, and must also provide the feedback current, I_{R2}, that flows in R2. Provided R3 is chosen carefully, this technique will provide a relatively constant, symmetrical bipolar voltage swing at V_{OUT}.

A STABLE BRIDGE

The output clamp method can be improved still further using the scheme shown in Fig.2.3b. Here, the D1-D4 diode bridge maintains a positive potential at the cathode of regulator diode ZD1 for both positive and negative swings at V_{OUT}. If we assume the forward voltage drops across each of the bridge diodes are equal and denoted V_D, the output voltage swing is $V_{OUT} = \pm(2V_D + V_Z)$, where V_Z is ZD1's reverse voltage.

Although ZD1 could be a Zener, even better performance can be obtained using a precision shunt voltage reference diode. Here a choice was made to use the REF50Z, a micropower 5·0V reference diode, although other devices such as the REF12Z (1·26V) and REF25Z (2.5V) could be used to provide different clamping voltages.

Note that R3 has been increased from 1·5kΩ to 33kΩ, since the REF50Z requires much less bias current than the back-to-back Zeners.

This "reference-in-a-bridge" approach generated an output voltage swing of ±6·02V, and with R1=10kΩ ±1%, R2=100kΩ ±1% and V_{REF} = 0 as before, the thresholds were V_{TU} = ±0·575V and V_{TL} = –0·570V.

USING COMPARATORS AND SINGLE RAILS

The examples so far have focused on a circuit using an op.amp working on dual supply rails. However, in many applications, it may be better to take advantage of the superior switching qualities offered by a comparator (see panel "Comparator Essentials''). We must also consider the biasing requirements of single rail applications and the use of "open-collector'' (or "open-drain'') outputs.

In Fig.2.4a is shown an inverting Schmitt trigger using one half of the popular LM393 comparator. Although the LM393 can work on dual supplies from ±1V to ±18V, it is particularly suited to single rail operation since the common-mode input range goes all the way down to the negative rail (0V for single rail applications).

The reference voltage is generated by the potential divider comprising resistors R1a, R1b and the positive supply:

$$V_{REF} = \frac{+V_s \times R1b}{R1a + R1b} \quad \text{(volts)}$$

For dual rail applications, a negative reference may be generated by connecting R1a to $-V_S$.

Since the LM393 has an open-collector output, pull-up resistor R_{PU} is required to pull the output voltage up toward $+V_S$ when the output transistor turns off. However, R_{PU} must be included in the expression for V_{TU} since it effectively appears in series with R2.

The thresholds are given by:

Upper Threshold Voltage,

$$V_{TU} = \frac{V_{REF} \times (R2 + R_{PU}) + R_{TH} \times (+V_S)}{R_{TH} + R2 + R_{PU}} \quad \text{(volts)}$$

and: Lower Threshold Voltage,

$$V_{TL} = \frac{(V_{REF} \times R2) + (R_{TH} \times V_{SAT-})}{R_{TH} + R2} \quad \text{(volts)}$$

R_{TH} is the Thévenin equivalent resistance of the R1a-R1b potential divider:

$$R_{TH} = \frac{R1a \times R1b}{R1a + R1b} \quad \text{(ohms)}$$

Note that the expression for V_{TU} is only true for a lightly loaded output (for example, driving a CMOS logic gate). For heavier loads which prevent R_{PU} pulling the output all the way up to $+V_S$, the expression must be modified by removing R_{PU} and replacing $+V_S$ with V_{SAT+}, the maximum positive output voltage, which must be determined for the particular application.

CUT THE CHATTER

A problem sometimes encountered when comparators are misapplied is "chatter'' at the output. With slowly varying input signals, comparators tend to produce multiple output transitions when the input signal crosses the reference potential.

As the input traverses the linear region, the comparator behaves as a very high gain, open-loop amplifier. The slightest noise on the input is amplified by the enormous gain of the comparator causing "chatter'' at the output.

For example, the LM393 has a typical open-loop voltage gain of 200V/mV (i.e., 200,000), so to cause a 5V output transition requires an input noise amplitude of only 5/200,000 = 25μV.

Stray capacitances around the comparator can result in a.c. feedback from output to input causing oscillation around the threshold, another source of output chatter.

Fortunately, hysteresis may be used to eliminate these problems. Usually, applying just a little positive feedback, say a few millivolts, may be enough to prevent the chatter. Naturally, for signals with larger noise content, the hysteresis, and hence the positive feedback, must be increased.

Chatter can sometimes be difficult to spot on an oscilloscope, but causes unacceptable errors in counting circuits.

SINGLE RAIL TESTS

A single rail version of the circuit in Fig.2.4a was built by connecting the comparator's negative supply terminal (pin 4) to 0V. Resistance values were selected for R1a = R1b = 36kΩ ±1% to give R_{TH} = 18kΩ ±1%. With R2 = 100kΩ ±1%, R_{PU} = 10kΩ ±1%, and $+V_S$ = +5·00V, the "negative'' saturation voltage, V_{SAT-}, was measured as +50mV. The thresholds were V_{TU} = 2·82V and V_{TL} = 2·10V, in close agreement with the theoretical values, namely V_{TU} = 2·85V and V_{TL} = 2·13V.

The value of V_{SAT-} is so small that it can almost be ignored and eliminated from the expression for V_{TL} which reduces to:

$$V_{TL} = (V_{REF} \times R2) / (R_{TH} + R2)$$

Bear in mind, however, that V_{SAT-} will tend to increase as R_{PU} is reduced. For example, if R_{PU} is reduced to, say, 1kΩ, the LM393's output transistor will sink around 4mA when it turns on, and the corresponding saturation voltage may be as large as 400mV.

HIGH FREQUENCY RESPONSE

So far, we've looked at circuit response using low frequency signals, on the order of 100Hz. However, at high frequencies, where the input signal has a very fast rate of change, the comparator's response time causes an apparent shift in the thresholds.

The waveforms in Fig.2.5 illustrate those obtained from the single rail LM393 circuit when a 250kHz triangle wave input was applied. Initially, the non-inverting input, V+, sits at a potential equal to V_{TU}, but when V_{IN} crosses this threshold the output does not change state immediately. Instead, there is a delay denoted t_{PD-} (for "negative-going propagation delay'') before the output leaves its positive saturation level and starts to head negative.

However, it cannot change from positive to negative saturation instantaneously, but takes a finite time to "slew'' from V_{SAT+} to V_{SAT-}. The combined effects of propagation delay and slew rate constitute the response time, and result in the *apparent* value of V_{TU} being significantly higher than the real value of V_{TU}.

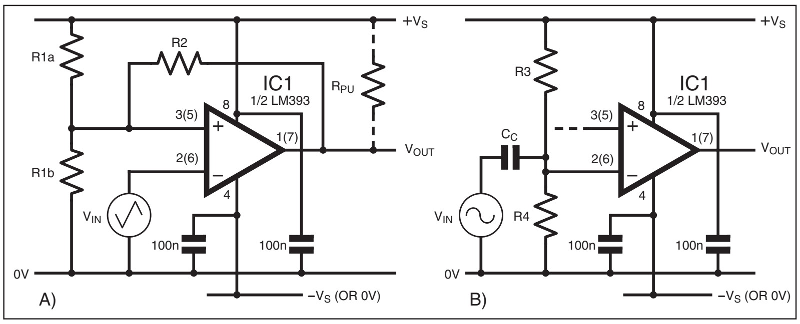


Fig.2.4. A single rail Schmitt trigger circuit using an "open-collector" comparator.

A similar effect occurs when the input signal crosses the lower value of V+, i.e., V_{TL}. Again, there is a delay denoted t_{PD+} (for "positive-going propagation delay'') before the output leaves its negative saturation level and starts to move positive. However, this time, the slew-rate effects are more pronounced since the open-collector output depends on the pull-up resistor to swing the output positive.

Since the resistor must charge the comparator's output capacitance plus any stray and load capacitance, the output waveform now acquires an exponential shape. By the time the output waveform crosses the input signal, the *apparent* value of V_{TL} is considerably lower than the real level of V_{TL} .

At low frequencies, where the input signal changes at a relatively slow rate, the effects of comparator response time are usually negligible. However, you should be aware of these effects at high frequencies since they limit the Schmitt trigger's ability to respond to rapidly changing signals.

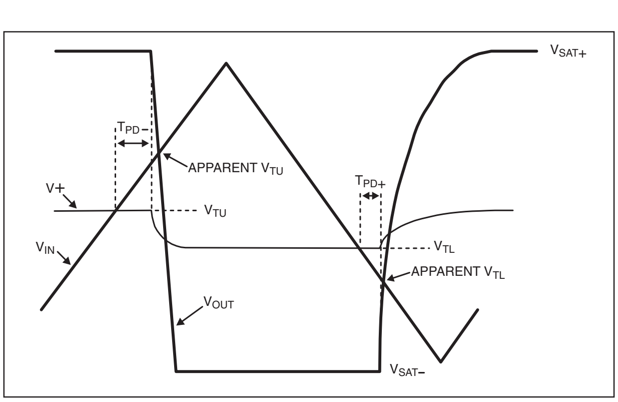


Fig.2.5. Effects of comparator response time on apparent thresholds.

Comparator Essentials

Although op.amps can be used to compare one voltage level with another, the *voltage comparator* is often the better choice. Like the op.amp, the comparator is essentially a high-gain differential amplifier, in that a very small differential input voltage will drive the output into positive or negative saturation.

However, by enhancing certain characteristics such as gain and slew rate, the comparator is optimised for non-linear applications in which the main function is to compare rather than to amplify voltages.

An important comparator a.c. parameter is *response time*, the time delay between an input step voltage and the resulting large-scale change in output voltage. Response time includes the propagation delay through the i.c. and the effects of output slew rate, and varies considerably from one type of comparator to another. For example, the typical response time for the National Semiconductor LM393 is 1·3µs, whereas for the LM360 it is just 14ns.

Comparators are expected to be operated with non-zero differential voltages; this is not necessarily so with op.amps which are mainly intended to be operated "closed-loop" where the differential voltage is close to zero. For example, the TLC372 dual comparator has a differential input range equal to the supply voltage (which can be as high as 18V), whereas the OP97 precision op.amp has input protection diodes which limit the differential input voltage to just ±1V. Always read the data sheet thoroughly to check that a given device is being used properly.

OUTPUT STAGE

Although comparators occasionally feature "push-pull" output stages like op.amps, they often have "open-collector" (or "open-drain") outputs. For example, the NE521 (a high speed, dual comparator) has a push-pull output stage, which means the output voltage is constrained to lie between ground (0V) and the positive supply.

The dual LM393, on the other hand, has an open-collector output (emitter connected to ground), which allows it to drive loads connected to rails higher than its own supply voltage.

The output stage of the LM311 is even more flexible, since both the collector and emitter of the output transistor are "floating", such that it can drive loads referred to ground, to the positive supply or to the negative supply. With the emitter grounded, the collector can drive loads connected to voltages as high as 40V and can sink currents up to 50mA.

Open-collector outputs can be very flexible when interfacing to logic devices, and are also suited to "wired-OR" operation, rather like open-collector TTL gates.

INPUT PARAMETERS

Input bias current, I_B, can vary considerably from one comparator type to another. For example, the LM393 has I_B = 25nA (typical) at 25°C, whereas the TLC393 (dual, open drain) has I_B = 5pA (typical) at 25°C – five thousand times less! Also, note that the TLC393 supply current is approximately one-twentieth that of the LM393, even though the devices are functionally equivalent.

For certain devices, bias current can vary with differential input voltage. The LM311, for example, has a typical input bias current of 100nA at 25°C for zero differential input voltage, but this can vary by ±75nA if the differential input is taken beyond ±8V. Note that 100nA will drop 10mV across a 100kΩ input resistance.

Always check the common-mode input range: this is not necessarily equal to the supply voltages, and is often significantly less. For example, when working on ±15V supplies, the LM311's input voltage range is –14·5V to +13·0V.

WIDE VARIETY

Like op.amps, comparators come in a many different "flavours". Speed (response time), input offset voltage and bias current are some of the parameters to be considered when choosing a suitable device, although supply current, output type and cost can often be equally important. Table 1 lists some of the most popular comparators and details some of the main parameters. Note that this is not an exhaustive list and there are many others to choose from!

If you would rather use an op.amp as a comparator, consider its speed (bandwidth and slew-rate), its ability to drive loads, and its output swing (especially if interfacing to logic circuits). Lastly, remember that comparators are not meant to be operated in linear mode, and so are not internally frequency compensated. Generally, therefore, comparators do not make good op.amps and should not be used as such!

Table 1: Popular Comparators and Their Main Characteristics

Part Number	Manufacturer	Single/ Dual/ Quad	t_R typ.	I_B max.	V_{IO} max. (mV)	I_S max.	Total Supply Voltage (V) min	Total Supply Voltage (V) max	Single Rail Operation?	Output Type	Comments
CA3290	Harris	D	1.2µs	40pA	20	3mA	5	36	Yes	OC	BiMOS design
LM311	National Semiconductor	S	200ns	250nA	7.5	7.5mA	5	36	Yes	OC	popular; inexpensive; flexible output stage
LM319	National Semiconductor	D	80ns	1µA	8	12.5mA	5	36	Yes	OC	fast, but input current is high
LM339	National Semiconductor	Q	1.3µs	250nA	5	2.5mA	2	36	Yes	OC	popular; inexpensive; very low operating voltage
LM361	National Semiconductor	S	14ns	30µA	5	20mA	11	30	No	PP	very fast, but input and supply currents are high; differential output may be strobed
LM393	National Semiconductor	D	1.3µs	250nA	5	2.5mA	2	36	Yes	OC	popular; inexpensive; dual version of LM339
LMC6762	National Semiconductor	D	10µs	0.04pA (typ.)	15	20µA	2.7	15	Yes	PP	input and output voltage range is rail-to-rail; very low power; extremely low input current
LT1016	Linear Technology	S	10ns	10µA	3	35mA	5	10	Yes	PP	very fast, but power hungry; differential outputs may be latched.
LT1017	Linear Technology	D	20µs	15nA	1	90µA	1.2	40	Yes	PP	micropower; very low operating voltage
LT1018	Linear Technology	D	6µs	75nA	1	250µA	1.2	40	Yes	PP	low power; very low operating voltage
MAX931	Maxim	S	12µs	1nA	10	3.2µA	2.5	11	Yes	PP	micropower; includes 1.18V bandgap voltage reference; comparator has adjustable hysteresis
MAX941	Maxim	S	80ns	300nA	2	700µA	2.7	6	Yes	PP	fast; low power; rail-to-rail input voltage range
NE521	Philips Semiconductors	D	10ns	20µA	7.5	35mA	9	11	No	PP	very fast; outputs may be strobed
NE529	Philips Semiconductors	S	15ns	20µA	6	25mA	10	20	No	PP	very fast; differential outputs may be strobed
TLC372	Texas Instruments	D	650ns	5pA	5	300µA	2	18	Yes	OD	low power; very low supply voltage and input current
TLC393	Texas Instruments	D	2.5µs	5pA	5	40µA	3	16	Yes	OD	micropower; very low supply voltage and input current; compare with LM393
TLC3702	Texas Instruments	D	2.7µs	5pA	5	40µA	3	16	Yes	PP	push-pull output version of TLC393
TLC3704	Texas Instruments	Q	2.7µs	5pA	5	80µA	3	16	Yes	PP	quad version of TLC3702

NOTES: All specifications are given for an operating temperature of +25°C. t_R = Response Time (depends on input overdrive). I_B = Input Bias Current. V_{IO} = Input Offset Voltage. I_S = Supply Current. Total Supply Voltage = difference between positive and negative supply rails. OC = Open Collector; OD = Open Drain; PP = Push-Pull.

A.C. COUPLING

We've seen how the Schmitt trigger's reference voltage can be set to match the mid-point of the hysteresis band to the quiescent, or average, voltage level of the input signal. However, for signals that lie outside the common-mode range of the comparator, a.c. coupling can be used to remove the d.c. level and thus bring the a.c. content of the signal within the comparator's input range.

The circuit diagram in Fig.2.4b shows how the single rail Schmitt trigger can be modified for a.c. coupling. Resistors R3 and R4 establish a suitable d.c. potential at the comparator's inverting input. Usually, it is best to make this potential equal to the mid-point of the comparator's common-mode input range.

For example, when operating on a single +5V rail, the LM393's common-mode input range is zero to 3·5V, so R3 and R4 would be selected to set the d.c. level at the inverting input to 1·75V. The a.c. signal is capacitively coupled via C_C to the inverting input, allowing the circuit to accept a.c. signals up to ±1·75V in amplitude, or 3·5V peak-to-peak.

Resistors R1a and R1b would be chosen to set the mid point of the hysteresis band equal to 1·75V, and by selecting R2 and R_{PU} to set the hysteresis voltage just less than the minimum peak-to-peak amplitude of the input signal, the Schmitt trigger will provide maximum noise immunity.

A word of warning, though. When dealing with a.c. signals such as pulse trains whose duty cycle can vary enormously, capacitive coupling can cause problems: as the duty cycle changes, so, too, does the average d.c. level of the waveform, such that the waveform at the inverting input tends to shift up and down. If this shift is excessive, the signal fails to cross one of the thresholds, and the circuit doesn't trigger. Always check that the circuit will respond properly at the extremes of the input signal's duty cycle.

NON-INVERTING SCHMITT TRIGGER

By swapping over the input voltage and reference voltage connections of the inverting Schmitt trigger (Fig.2.1), we obtain the non-inverting Schmitt trigger shown in Fig.2.6a.

The voltage V+ at the non-inverting input now depends not only on V_{OUT}, R1 and R2, but also on V_{IN}. We can understand the circuit's operation by referring to the voltage transfer characteristic in Fig.2.6b, which shows the case for $V_{REF} = 0$ and assumes V_{SAT+} is equal and opposite to V_{SAT-}.

Starting at the bottom left-hand corner, where V_{IN} is at its most negative value, the output is in negative saturation and so V+ is also a negative voltage. As V_{IN} increases (shown by the white arrows) it eventually reaches a positive level where V+ just rises above 0V, causing the comparator output to change state. The value of V_{IN} where the output rapidly changes from V_{SAT-} to V_{SAT+} is the upper threshold voltage, V_{TU}.

If V_{IN} is now reduced (shown by the black arrows), the output remains in positive saturation until V_{IN} has gone sufficiently negative to make V+ go just below 0V. At this point, where $V_{IN} = V_{TL}$, the output abruptly changes from positive to negative saturation, V_{SAT-}.

Notice how the hysteresis loop moves in an "anti-clockwise" direction, whereas that of the inverting Schmitt trigger (Fig.2.1b) follows a clockwise path.

By introducing the reference voltage, V_{REF}, we can shift the thresholds up or down: when V_{REF} is positive, the thresholds are moved in a positive direction, and vice-versa. The expressions for the thresholds (assuming $R_{SOURCE} = 0$) are:

Upper Threshold Voltage,

$$V_{TU} = \frac{V_{REF} \times (R1 + R2) - (R1 \times V_{SAT-})}{R2} \quad \text{(volts)}$$

and:

Lower Threshold Voltage,

$$V_{TL} = \frac{V_{REF} \times (R1 + R2) - (R1 \times V_{SAT+})}{R2} \quad \text{(volts)}$$

The "hysteresis" voltage, the difference between the thresholds, is:

Hysteresis voltage,

$$V_H = V_{TU} - V_{TL} = \frac{R1 \times (V_{SAT+} - V_{SAT-})}{R2} \quad \text{(volts)}$$

Again, like the inverting Schmitt trigger, we see that V_H is completely independent of V_{REF}.

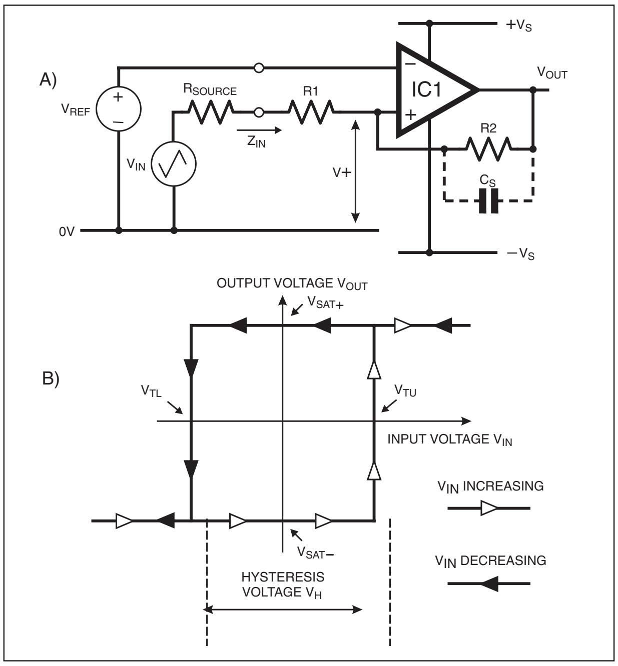


Fig.2.6. Circuit for a non-inverting Schmitt trigger (a) and its voltage transfer characteristic (b).

POSITIVE AND NEGATIVE RESISTANCE

We saw that the inverting Schmitt trigger's input impedance was dominated by the input bias current of the op.amp or comparator. For the non-inverting circuit, the impedance Z_{IN} seen by the voltage source depends largely on R1, R2 and V_{OUT}, and appears as either a positive or negative resistance.

For example, when V_{IN} is above V_{TU}, V_{OUT} is in positive saturation and current flows from IC1's output, through R2 and R1 and into V_{IN}. Thus, Z_{IN} appears as a *negative* resistance.

On the other hand, when V_{IN} is below V_{TL}, V_{OUT} is in negative saturation, and current flows from V_{IN}, through R1 and R2 and into IC1's output, such that Z_{IN} now behaves like a *positive* resistance.

If R_{SOURCE}, the output resistance of the voltage source, is very small or zero, the changing nature of Z_{IN} has negligible effect on circuit behaviour. However, if R_{SOURCE} is similar, or greater, in size to R1 and R2, the changing input current will cause a changing voltage drop across it, causing the apparent thresholds to shift relative to their nominal values.

In these circumstances, it is necessary to modify the threshold and hysteresis voltage equations by replacing R1 with (R_{SOURCE} + R1), since R_{SOURCE} effectively appears in series with R1.

NON-INVERTING DESIGN PROCEDURE

The values for V_{SAT+} and V_{SAT-} can be obtained from the data sheet or determined from in-circuit measurements: the latter can often be more accurate, especially where saturation levels are heavily dependent on output loading.

For a desired hysteresis voltage, R1 and R2 can be selected by rearranging the expression for V_H:

$$R2 = R1 \times (V_{SAT+} - V_{SAT-}) / V_H.$$

Then, knowing the desired value for V_{TU}, the appropriate reference voltage may be evaluated from:

Reference Voltage,

$$V_{REF} = \frac{V_{TU} \times (V_{SAT+} - V_{SAT-}) + (V_H \times V_{SAT-})}{V_H + V_{SAT+} - V_{SAT-}} \quad \text{(volts)}$$

We'll follow a design example based on the LM6482, a dual, rail-to-rail input and output op.amp. Let's assume we require a hysteresis voltage of 1·0V and V_{TU} = 1·5V, and the circuit is to run on a single 5V supply.

With the output lightly loaded, it was found from in-circuit measurements that V_{SAT+} = 5·00V and V_{SAT-} = 20mV. Using the above equations, we find that R2 = 4·98 × R1, and V_{REF} = 1·253V.

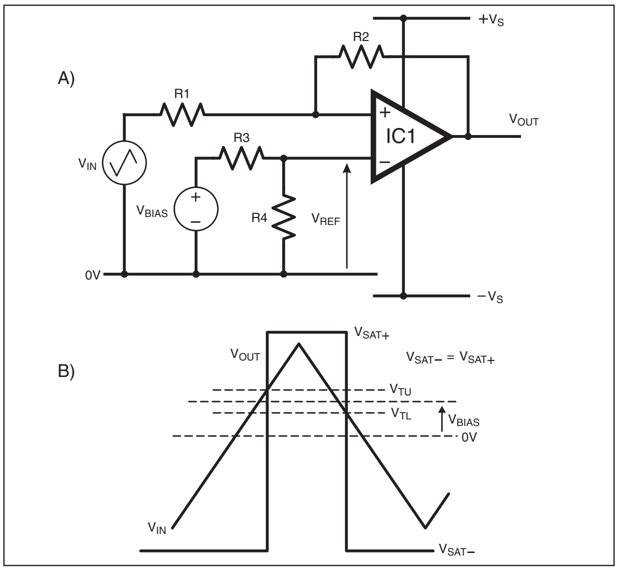


Fig.2.7. Using a bias voltage to control the mid-hysteresis level.

Using R1 = 20kΩ ±1%, R2 = 100kΩ ±1%, and with the supply voltage set to precisely 5·00V and V_{REF} set to 1·25V, measurements showed the upper threshold voltage as V_{TU} = 1·53V and the hysteresis voltage as V_H = 1·06V.

Note that these results were obtained using a 200Hz triangular input waveform. It was found that performance was good up to around 2kHz: at higher frequencies, the op.amp's response time started to affect the thresholds in the manner described earlier.

For example, with V_{REF} increased to 2·5V, the nominal thresholds are V_{TL} = 2·00V and V_{TU} = 3·00V. At 2kHz, the measured values were V_{TL} = 1·87V and V_{TU} = 3·09V, whereas at 20kHz the apparent thresholds were V_{TL} = 1·50V and V_{TU} = 3·45V. Clearly, if accurate performance were to be required at frequencies above 2kHz, it would be necessary to use a faster op.amp.

MID-HYSTERESIS LEVEL

We saw earlier that the hysteresis voltage $V_H = R1 \times (V_{SAT+} - V_{SAT-}) / R2$. If we can arrange for the output saturation levels to be equal and opposite, i.e., if $V_{SAT+} = -V_{SAT-}$, the expression can be written $V_H = (2 \times R1 \times V_{SAT+}) / R2$.

Now, the mid-point of the hysteresis band is simply the lower threshold plus half of the hysteresis voltage, or $V_{TL} + (V_H/2)$. So, for the case when $V_{SAT+} = -V_{SAT-}$ (and assuming $R_{SOURCE} = 0$), we find that:

Mid-point of Hysteresis Voltage =

$$V_{TL} + (V_H/2) = \frac{V_{REF} \times (R1 + R2) - (R1 \times V_{SAT+})}{R2} + \frac{(R1 \times V_{SAT+})}{R2} \quad \text{(volts)}$$

which simplifies nicely to:

$$V_{TL} + (V_H/2) = V_{REF} \times \frac{(R1 + R2)}{R2} \quad \text{(volts)}$$

If we apply a d.c. bias voltage, V_{BIAS}, to the inverting input using the R3-R4 potential divider as shown in Fig.7a, we see that $V_{REF} = (V_{BIAS} \times R4) / (R3+R4)$, and so:

$$V_{TL} + (V_H/2) = V_{BIAS} \quad \frac{R4}{(R3 + R4)} \times \frac{(R1 + R2)}{R2} \quad \text{(volts)}$$

Therefore, if we make the ratio of R2 / R1 = R4 / R3, we get:

$$V_{TL} + (V_H/2) = V_{BIAS}$$

In other words, the mid-point of the hysteresis band will equal the bias voltage V_{BIAS}, as shown in Fig.2.7b for a positive value of V_{BIAS}.

This technique can be useful where the average level of the a.c. input signal changes unpredictably, a problem that can make it difficult or impossible to set appropriate thresholds using the simple Schmitt trigger of Fig.2.6.

By using the circuit of Fig.2.7a, and by arranging for V_{BIAS} to track the average level of the input signal, the thresholds will shift automatically such that the hysteresis band will always be centred on the a.c. signal. Remember, however, that this technique can only be used when the output saturation levels are equal and opposite.

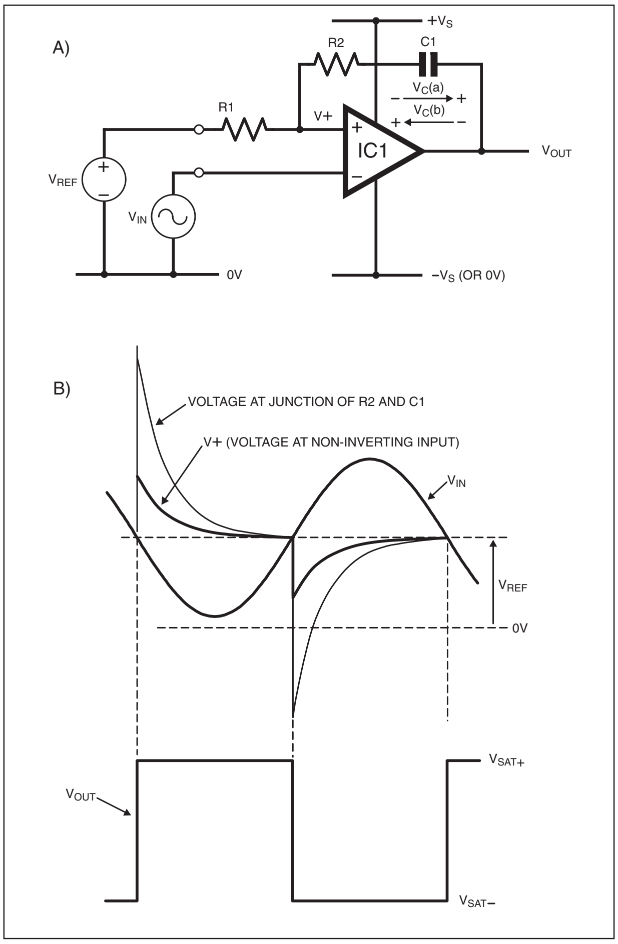


Fig.2.8. Using capacitive feedback provides temporal hysteresis.

SINGLE THRESHOLD VOLTAGE

For applications that demand only a single threshold voltage and yet still require noise rejection, we must find a way of introducing hysteresis without having two separate thresholds. This apparent paradox is achieved using "temporal" hysteresis, usually implemented with capacitive positive feedback as shown in the inverting Schmitt trigger of Fig.2.8a. The circuit works as follows:

Assume that V_{IN} is lower than V+, the voltage at the non-inverting terminal, such that V_{OUT} is in positive saturation. Capacitor C1 charges via R1 and R2 until its voltage, V_C(a) equals $(V_{SAT+} - V_{REF})$.

When C1 is fully charged, no current flows through R1 and so V+ = V_{REF}. If V_{IN} now rises above V+, V_{OUT} abruptly changes state from V_{SAT+} to V_{SAT-}, causing the voltage at the R2-C1 junction to go to $V_{SAT-} - V_C(a) = V_{SAT-} - V_{SAT+} + V_{REF}$.

Thus, V+ is suddenly pulled down to a voltage lower than V_{REF}, resulting in the regenerative action needed for proper Schmitt trigger operation. (The actual voltage that V+ goes to depends on the ratio of R1 and R2).

However, V+ does not stay at this low level because C1 starts to charge via R1 and R2 until its voltage, V_C(b) equals $(V_{REF} - V_{SAT-})$. Once C1 is fully charged, V+ again settles back to equal V_{REF}.

If V_{IN} now falls below V+, V_{OUT} snaps into positive saturation, and V+ is rapidly pulled to a voltage greater than V_{REF}. Once again, positive feedback causes the required regenerative action. C1 now charges until its voltage, V_C(a) equals $(V_{SAT+} - V_{REF})$, at which point V+ again falls back to equal V_{REF}.

The waveforms in Fig.2.8b are those typically occurring in response to a sinusoidal input voltage, where $V_{REF} = V_{SAT+} / 2$ and $V_{SAT-} = 0$ (i.e., a single rail application).

Notice that when V_{IN} crosses the V_{REF} threshold, V+ jumps above or below V_{REF} and then decays back to a level equal to V_{REF}. Provided the (R1 + R2) × C1 time constant is less than one-tenth the period of V_{IN}, V+ will always return to V_{REF} before V_{IN} next crosses the V_{REF} threshold.

Knowing the maximum input signal frequency, the appropriate (R1 + R2) × C1 time constant may be determined. Then, having chosen C1, the ratio of R1 and R2 must be selected to maximise the voltage swing at the non-inverting input (thereby maximising the circuit's noise rejection properties) whilst ensuring that V+ remains within the common-mode input limits for the op.amp or comparator used.

Temporal hysteresis can be demonstrated using the circuit of Fig.2.9, a single rail circuit which again uses one half of an LMC6482 op.amp (although other op.amps or comparators with rail-to-rail input and output capability could be used).

Making R1a and R1b both equal to 100kΩ sets V_{REF} = 2·5V and provides an effective (Thévenin) value of R1 = 50kΩ. With R2 = 100kΩ and C1 = 6·8nF, the feedback network's time constant is 1ms, allowing the circuit to accommodate input signal frequencies as high as 100Hz.

The maximum voltage swing at the non-inverting input is V_{REF} ±1·7V, i.e., 0·8V to 4·2V, well within the op.amp's common-mode input limits.

The circuit's response to a noisy input signal is illustrated in Fig.2.10. The top trace shows the input signal, a sinewave containing over 30 per cent of "triangular" noise. The middle trace is the output of the circuit in Fig.2.9. Notice how there is only one transition each time the sinusoid crosses the 2·5V reference threshold.

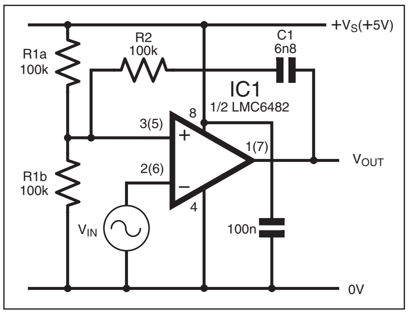


Fig.2.9. Single rail Schmitt trigger with temporal hysteresis.

The bottom trace shows the circuit's output with R2 and C1 removed (i.e., no positive feedback at all). The circuit now behaves as a simple comparator, such that its input is triggered each time the noise crosses the 2·5V reference: the multiple transitions caused by the noise can clearly be seen on the output wave-form.

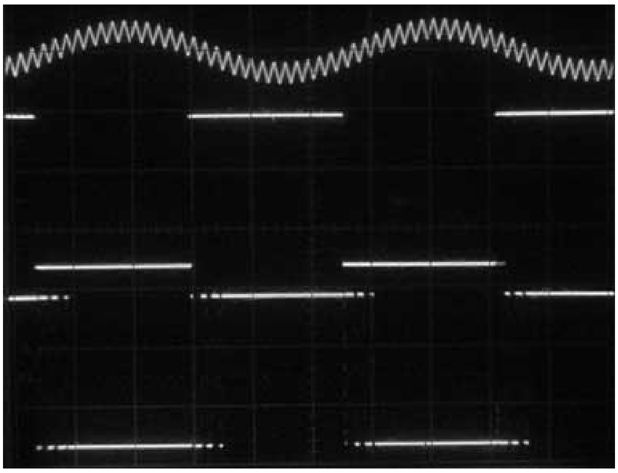


Fig.2.10. Waveforms showing that temporal hysteresis provides noise rejection. Top trace: V_{IN} (5V/div.). Middle trace: Output waveform of circuit with temporal hysteresis (2V/div.). Bottom trace: Output waveform with no positive feedback (2V/div.). Timebase: 2ms/div.

PRECISION AND VERSATILITY

In Part Three of this series, we'll examine methods for improving the Schmitt trigger's precision and flexibility. We'll also see how this versatile circuit element is used as the basis for other circuit functions, such as oscillators and pulse generators.

SHOP TALK

with David Barrington

PIC-Monitored Dual PSU

We have a minor problem concerning the metal case for the *PIC-Monitored PSU.* The original one used in the author's model is no longer stocked. However, although the dimensions are not exactly the same, our investigations have thrown up two possibilities and they are both RS types.

The first one measures 305mm x 178mm x 177mm, is coded 223-972 and listed at £19.55. The other one is coded 671-242, measures 254mm x 197mm x 159mm and is listed at £40.21. Readers should be able to order these through any *bona-fide* RS stockists in their area. Alternatively, they can be ordered through **Electromail** (☎ ***01536 304555*** or ***http://rswww.com***), their mail order outlet. No doubt, readers will have their own ideas regarding the case.

The 50VA mains transformer, code 805-142, and the L272 dual power op.amp, code 635-167, also came from the above source.

Regarding the monitor section. The alphanumeric 2-line 16-character per line liquid display module used in the prototype has an integral cable and connector. It was purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***). Other advertisers will no doubt be able to offer something similar, without cable.

For those readers unable to program their own PICs, a ready-programmed PIC16F877-4P can be purchased from Magenta (see above) for the inclusive price of £10 (overseas readers add £1 for postage). Software for the *PIC-Monitored Dual PSU* is available on a 3·5in. PC-compatible disk from the *EPE* Editorial Office – see *PCB Service* page 946. It is also available *free* via the *EPE* web site: **ftp://epemag.wimborne.co.uk/pubs/PICS/PICmonpsu**.

The two printed circuit boards are available from the *EPE PCB Service,* codes 280 (Power Supply, of which two are needed for the full PSU) and 281 (Monitor).

Static Field Detector

This month's Starter Project is a low-cost *Static Field Detector* and we do not expect any "sticky" component problems.

The specified TL061CP op.amp has an output stage that will drive both l.e.d.s from fully switched off to fully on, whereas many other op.amps will fail to do this. Therefore, the use of alternative devices is not really recommended. The TL061CP should be readily available from component advertisers.

The printed circuit board for the "Detector" is the Multi-project board available from our *PCB Service,* code 932.

Motorists' Buzz-Box

Prices for panel meters tend to vary quite considerably and it may pay you to shop around when collecting together parts for the *Motorists' Buzz-Box* project.

The LM334N adjustable current source chip came from Maplin (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code WQ32K. They also have a "large" 50μA panel meter, code RX54J, but you will need a larger plastic box for this one. The printed circuit board is available from the *EPE PCB Service,* code 278.

Festive Fader

The 3VA mains transformer, with twin primary and secondary windings, and the MOC3020 opto-isolated triac for the *Festive Fader* were purchased from **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***), codes 159-438 and 280-320. They also supplied the 1μF multilayer ceramic capacitor, but you will probably have to buy in multiples of 5. It is also listed by **Electromail** (☎ ***01536 304555*** or ***http://rswww.com***), code 264-4977 (packs of 5).

The printed circuit board is available from the *EPE PCB Service,* code 277 (see page 946). The Euro mains connector, with fuseholder, should be widely stocked.

PICtogram

All of the components called up for the *PICtogram* project appear to be "off-the-shelf" items except, of course, a ready-programmed PIC16F84 microcontroller. The 2mA l.e.d.s certainly seem to be in abundant supply, in various colours.

For those readers unable to program their own PICs, the author is able to supply ready-programmed PIC16F84 microcontrollers for the sum of £6 each, inclusive of postage (overseas add £1 per order). Orders should be sent to: **Andy Flind, 22 Holway Hill, Taunton, Somerset, TA1 2HB**. Payments should be made out to *A. Flind.* 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 *PCB Service* page 946. It is also available *free* via the *EPE* web site: **ftp://epemag.wimborne.co.uk/pubs/PICS/PICtogram**.

Finally, the printed circuit board is available from the *EPE PCB Service,* code 271 (see page 946).

Christmas Bubble and Twinkling Star

Regarding the *Christmas Bubble* and *Twinkling Star* projects, both sets of components appear to be "run of the mill" items and should not cause any sourcing problems.

Jumbo l.e.d.s (10mm) should cost you just under £1 on average. You may also be able to buy the standard l.e.d.s at quantity discounts from some advertisers, it's worth trying.

If you must run these two projects using mains adaptors, most of our components advertisers seem to stock good quality, multi-voltage types. The small printed circuit board for the *Twinkling Star* is available from the *EPE PCB Service,* code 276 (see page 946).

PLEASE TAKE NOTE

Anti-Tamper Alarm *(Ingenuity Unlimited)* *Oct '00*

Page 766. The i.c.s should be types 4001 and not as shown on the circuit. Also, note capacitor C1 should be 10n (nano) and not as shown.

Versatile Mic/Audio Preamplifier *May '00*

It would appear that supplies of the SSM2166P mic. preamp chip have now "dried-up". If any readers know of a source please let us know so that we can pass it on.

New Technology Update

Inkjet and optical technologies combine to provide greater comms bandwidth. Ian Poole reports.

THE telecommunications industry is one of the major growth areas in today's business arena. Increasing amounts of information are required and they are needed faster than ever before. Much of this has been fuelled by the phenomenal growth of the Internet, with applications like e-commerce and the transmission of audio and video providing ever-increasing levels of traffic.

Such is the growth that it has been predicted that the capacity required will have risen by a factor of thirty-six in the eight years from 1995.

Optical Data Rates

Many of the transmission paths use optical technologies. New techniques like Dense Wavelength Division Multiplexing (DWDM) are being used more widely. In this, a single fibre is used to carry several channels, each having a different wavelength.

Optical fibre data rates are also increasing, with transmission speeds set to quadruple in the next two years. This will enable network builders to move from the existing backbones running at 10 Gigabits per second to 40 Gigabits.

To ensure that the required speeds can be met, many organisations are moving to all-optical networks. This alleviates a number of the problems found in mixed technology systems. It also gives additional levels of flexibility, for example allowing operators to lease a wavelength, whereby the entire wavelength channel is leased out to a user.

This gives the potential of desk-top to desk-top optical communications, which can be very attractive to the system provider as there could be many thousands of optical channels available within a single fibre.

Switched Solution

To achieve these goals, optical devices need to be developed further. At the moment many are very expensive, but there are a number of developments that are under way that are likely to resolve many of the problems being encountered.

One of these areas is in optical switching, where Agilent (formerly the non-computer related areas of Hewlett Packard) have developed an optical switch. This uses a combination of inkjet activators and optical planar waveguides to give a simple and scalable optical switch with no moving parts.

Agilent's new switch is the N3565A, which provides a 32 × 32 photonic switching platform. It innovatively uses inkjet printer technology, combined with planar lightwave circuit technologies.

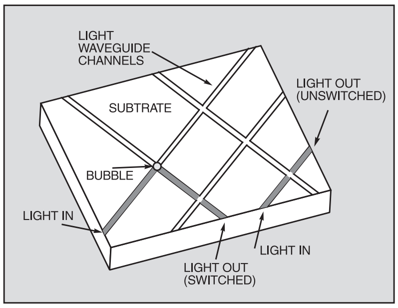


Fig.1. The light waveguide switching platform.

The switch consists of intersecting silica waveguides as shown in Fig.1. At each intersection a trench is etched into the waveguide. This is filled with a fluid that has a refractive index matching that of the light path, and accordingly it allows unimpeded transmission of the light across the intersection.

When a command to switch is issued. A bubble is created at the intersection and this causes the light to be reflected down the intersecting light path by total internal reflection (Fig.2). It is this bubble that is formed using inkjet printer technology.

Switching Technique

Switching is performed using the piezo-electric actuators that are based on those found in inkjet printers. These are solid state devices that are comprised of a pump chamber, inlet mechanism and a bubble nozzle. When a voltage is applied to the piezo-electric actuator, it contracts and then relaxes when the voltage is removed. This action increases and then reduces the pump chamber volume, drawing in liquid and ejecting droplets under pulsed control.

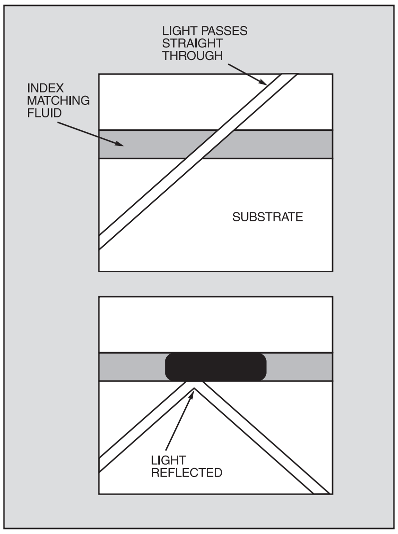


Fig.2. Principle of switching.

Using this system, switching can occur in less than ten milliseconds, and this is sufficiently fast for the systems on which it is anticipated the switch will be used.

The absence of moving parts is the key to the reliability of the system. The inkjet elements have been switched many millions of times in tests and have been shown to be exceedingly reliable. Additionally, the fluid that is used is non-corrosive and stable, which are key elements in the reliability of the whole system.

System Aspects

The basic principle can be used to create very large switching matrices that enable a considerable amount of flexibility to be introduced into optical data systems. Whilst there is about 5dB of loss from one fibre, through the switch, into the output fibre, for what is termed a wavelength selective cross-connect, this is quite acceptable, especially when it is compared to other technologies.

Crosstalk is surprisingly low at –50dB, demonstrating the very high level of isolation that is achieved. This is particularly important where large numbers of optical paths are switched, because if the levels were higher then it would also lead to high levels of interfering noise that would result in data errors.

Future

This development is likely to achieve widespread use. It is flexible, cheap and effective. It shows that optical technology for data transmission can now be used even in small installations.

The development is also indicative of the growing use of optical technology. It has several advantages, even for the small user. Not only are much higher data rates possible than for an electrical wire system, but it also has greater immunity to electrical noise. For those interested in security, the optical fibres do not radiate the signals in the same way that wired systems do, thereby making eavesdropping much more difficult.

In view of all these advantages, many commentators anticipate that optical technology will grow considerably in importance in the coming years.

Further information about these optical switches can be found on the Agilent web-site at **www.agilent.com**.

Information about radio and electronics in general can be found at **www.radio-**

INTERFACE

Robert Penfold

EXTENDED TEMPERATURE PC INTERFACE SOFTWARE

As pointed out in the past, this series is primarily concerned with the hardware side of add-on projects for PCs. However, without software the projects are of no use, and the software topics have to be considered from time to time.

Interestingly, it is the software that tends to bring the most feedback from readers. Over the last year software matters seem to have generated three or four times as many letters and E-mails as hardware related topics.

Some of the letters contain suggestions for better ways of doing things. Thanks to those who have made suggestions, some of which have been incorporated into the software featured in recent months.

Others are interested in using improved software to extend the capabilities of the projects featured in this series. Arrays and data logging is a topic that turns up from time to time, and is one that has not been covered significantly in this series.

Arrays

Usually the software has to do nothing more than take a reading from a port, do some simple arithmetic on the returned value, and then display the value on the screen. This is achieved by storing the reading in a variable, doing any necessary mathematics with the result being stored back in the variable, and then writing the contents of the variable to the screen via a label or text box.

Data logging is more complex in that it requires what could be hundreds or even thousands of readings to be taken and stored in the computer's memory. The results can then be read via a text box, printed out, or presented on the screen in some graphic form.

Arrays are used to store blocks of data, and each element of an array is just a special form of variable. The exact way in which arrays are handled varies slightly from one programming language to another, but here we will consider the Visual BASIC 6 version, which is fairly typical.

Each element in an array has the same name, but a number in parentheses (brackets) follows this name. This number gives each element in the array a unique identity. In the normal scheme of things the numbering starts at 0 and goes up to the number that is specified when the array is dimensioned. In Visual BASIC you can declare variables or simply make them up as you go along.

This same flexibility is not available when using arrays, and they must be declared and dimensioned before they are used. By telling the programming language the type of variable used in the array and the number of elements, it is then able to reserve a suitably sized block of memory to store the data.

Going Public

When declaring variables and arrays in Visual BASIC it has to be borne in mind that there are public and private variables. If the declaration is made within a subroutine, the variable can only be used within that routine.

This can be very useful, but with interfacing software it is often the public version that is of more use. By declaring a variable outside a subroutine it becomes a public type that can be accessed by any part of the program. The following line, for example, would declare an array containing 100 elements, with each element an integer:

```
Dim Reading(99) As Integer
```

Note that there are 100 and not 99 cells in this array, because the numbering starts at 0 and not 1. In order to read a set of data into an array a loop is used, together with a variable that acts as a counter. For example, the followings routine would read the printer port data lines at address 888 one hundred times, placing the readings in the elements of the array called Reading:

```
Dim Reading(99) As Integer
Out 890,32
For Counter = 0 To 99
Reading(Counter) = Inp(888)
Next Counter
```

The first line dimensions the array, and the second one sets the printer port data

Listing 1: Extended Temperature Interface Program

```
Dim Port1 As Integer
Dim Port2 As Integer
Dim Port3 As Integer
Dim Reading As Integer
Dim Counter As Integer
Dim Readings(99) As Integer

Private Sub Command1_Click()
Port1 = 632
Port2 = 633
Port3 = 634
Timer1.Enabled = True
End Sub

Private Sub Command2_Click()
Port1 = 888
Port2 = 889
Port3 = 890
Timer1.Enabled = True
End Sub

Private Sub Command3_Click()
Label1.Caption = Readings(Text1.Text)
End Sub

Private Sub Form_Load()
Counter = 0
End Sub

Private Sub Timer1_Timer()
Out Port3, 1
Out Port3, 3
Out Port3, 2
For D = 1 To 2000
Next D
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = 128
        Else Reading = 0
Out Port3, 3
Out Port3, 2
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 64
Out Port3, 3
Out Port3, 2
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 32
Out Port3, 3
Out Port3, 2
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 16
Out Port3, 3
Out Port3, 2
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 8
Out Port3, 3
Out Port3, 2
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 4
Out Port3, 3
Out Port3, 2
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 2
Out Port3, 3
Out Port3, 2
Dta = Inp(Port2) And 8
If Dta = 8 Then Reading = Reading + 1
Out Port3, 3
Out Port3, 1
Label1.Caption = Reading / 2
Readings(Counter) = Reading / 2
Counter = Counter + 1
If Counter = 100 Then Label1.Caption =
        "STOPPED"
If Counter = 100 Then Timer1.Enabled =
  False
End Sub
```

lines as inputs. The port must obviously be a bidirectional type for this to work. Note that Visual BASIC does not have built-in Inp and Out commands, and that these must be added using **Inpout32.dll**, as described in previous *Interface* articles. The rest of the routine is a For...Next loop that executes 100 times, incrementing the variable called Counter from 0 to 99 in the process. Counter is used as the element number in the program line that reads the printer port and the result into the array.

Therefore, on the first loop the returned value is read into Reading(0), on the next it is placed into Reading(1), and so on until the value read from the port is placed in Reading(99) on the one hundredth loop.

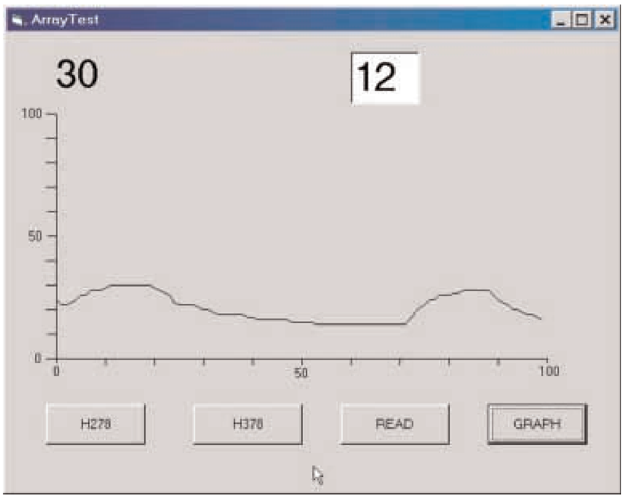


Fig.2. Extended program in action. Some simple calibration marks have been added to the graph to make it easier to interpret results.

Perfect Timing

In practical applications the readings will usually have to be taken at regular intervals, and it may be necessary to have a substantial gap from one reading to the next. This could be achieved by adding a delay routine in the For...Next loop, but with Visual BASIC the obvious way of handling things is to assign the routine that reads the port to a timer component.

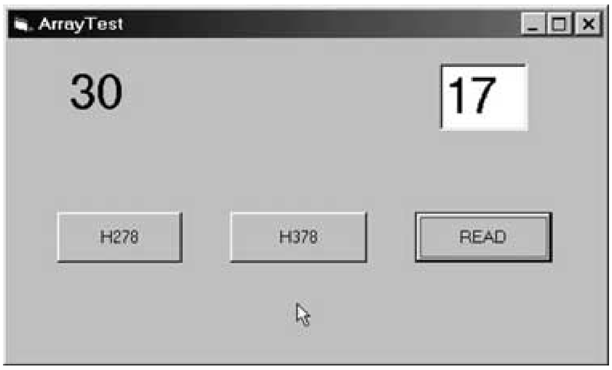


Fig.1. Screen shot showing display text box window and READ "button".

Readings are then taken at whatever interval is used for the timer. The method used to obtain readings might be more complex than simply reading a port, but the basic method outlined here can still be applied.

Program Listing 1 is an extension of the thermometer program featured in the previous *Interface* article. It takes 100 temperature readings at one-second intervals and places them in an array. See the October 2000 issue for details of the Temperature Interface.

As in the original program, operating either the button marked H278 or the one captioned H378 selects the required base address and starts the timer. The routine that reads the analogue-to-digital converter is relatively long because the data is read one bit at a time and then reconstituted into an 8-bit value. However, once the final value has been obtained it is displayed on Label1 and placed in the array.

Numbers Count

A variable called Counter is used to provide the element number, and this variable is incremented by one each time the routine is performed. Eventually the value of Counter reaches 100, and the last line in the routine then switches off the timer so that no further readings are taken and stored. The penultimate line prints STOPPED on Label1 so that you know that things have come to a halt.

Once the data has been safely stored in an array the PC can manipulate it in a variety of ways. This program simply has a third button and a text box that enable individual samples to be displayed on the screen. Just type a number from 0 to 99 into the text box and then press the READ button. The relevant reading will then be displayed on Label1, as in the screen dump that is shown in Fig.1.

There are plenty of other possibilities. The PC can be used to find and display the maximum and minimum readings, calculate and display various types of mean reading, and so on.

Graphics

A modern PC is also well equipped to display various types of graph and chart. The following routine can be applied to a fourth command button, and it draws a simple graph on the screen once a set of readings have been taken. The form must be large enough to accommodate the graph, and the middle section that the graph occupies must be left free of other components.

```
Private Sub Command4_Click()
Counter = 0
T1 = 600
T2 = 660
For Loops = 0 To 98
Lft = Readings(Counter)
Counter2 = Counter + 1
Rght = Readings(Counter2)
Lft = Lft * 30
Rght = Rght * 30
Lft = Lft + 1000
Rght = Rght + 1000
Lft = 5000 – Lft
Rght = 5000 – Rght
Line (T1, Lft) – (T2, Rght)
Counter = Counter + 1
T1 = T1 + 60
T2 = T2 + 60
Next Loops
End Sub
```

An enlarged version of the program in action is depicted in the screen dump of Fig.2. Some simple calibration marks have been added to make it easier to interpret results.

The routine starts by setting three variables at their initial values. T1 and T2 are variables used to provide the X1 and X2 co-ordinates for each section of the graph. Counter is used to select the required element of the array, and is initially set at 0. The routine then goes into a For...Next loop that actually draws the graph.

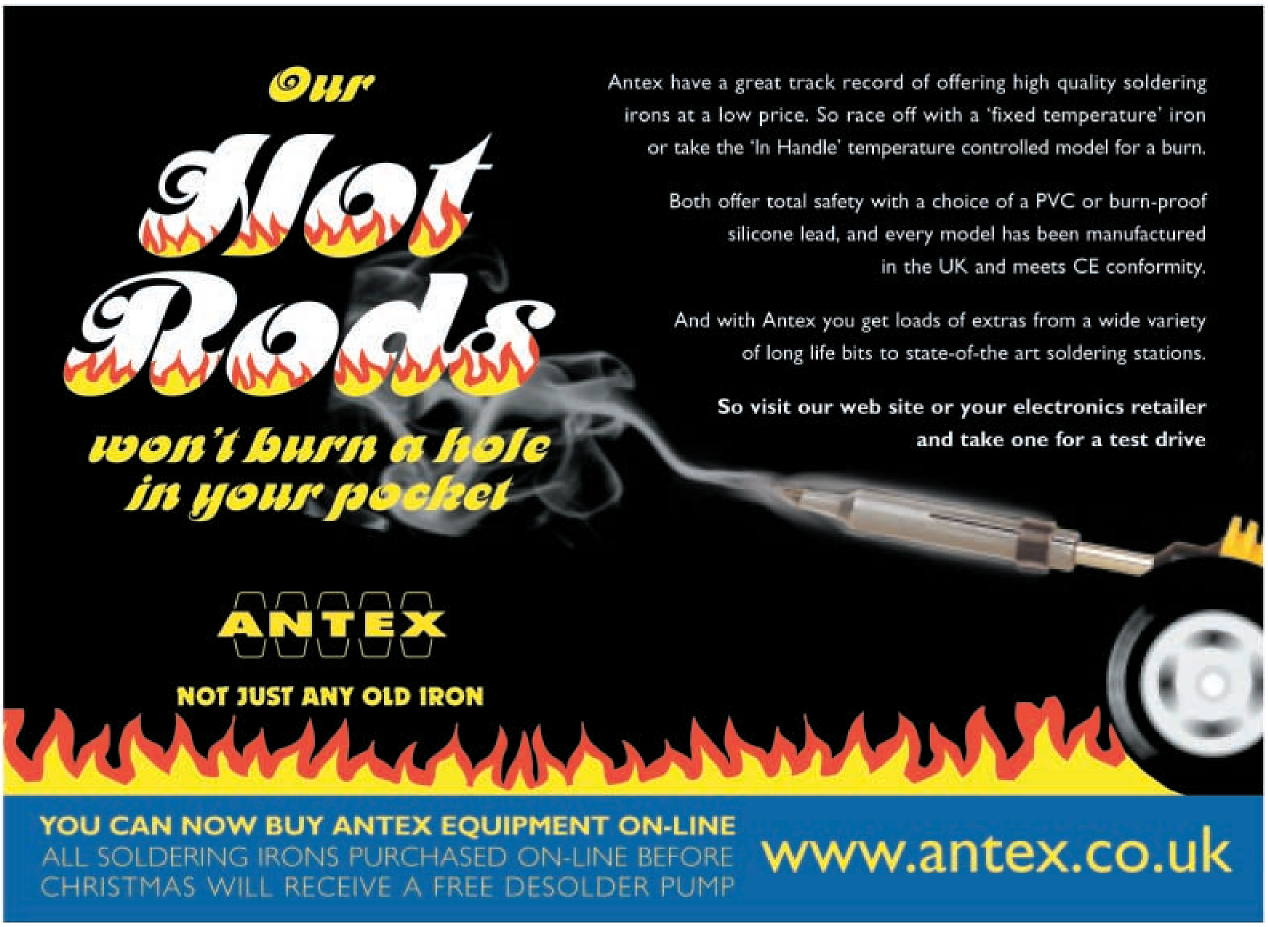
The first and second readings are used to provide the Y1 and Y2 co-ordinates for the first section of the graph. Both require some mathematical manipulation in order to match up with the Visual BASIC co-ordinate system. Incidentally, the graphics area extends from 600,4000 at the bottom left corner to 6600,1000 at the top right hand corner.

A Line command is then used to actually draw the line, and this operates in much the same way as the QBASIC Line command. Counter is then incremented by 1, and T1 plus T2 are incremented by 60 (one second's worth of co-ordinates). The loop causes this process to be repeated a further 98 times until all 99 sections of the graph have been completed.

The routines provided here are quite basic, and do not contain any error trapping for example. However, they do demonstrate that reading data into an array is very straightforward. Processing the captured data and displaying it on the screen in various ways is then just a matter of using conventional programming techniques.

On Disk

Should you wish to experiment with them, the source files for the graph program are available on the *EPE* web site, as is the compiled version of the program. It is also available on the *EPE Interface* Disk 1, see *EPE PCB Service* page elsewhere in this issue for details.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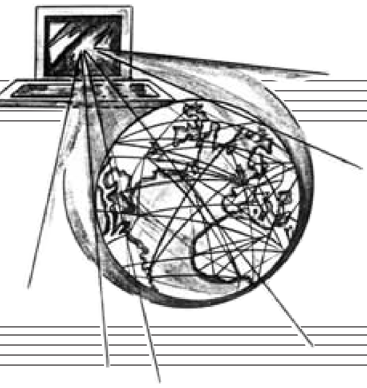


NET WORK

ALAN WINSTANLEY

ONE of the downsides of writing a column dated several months ahead of reality is that it doesn't half make time fly. Here I am in early October already writing for the December 2000 issue, with the year 2001 arriving "next month"! This year started on an optimistic note, with promises of unmetered Internet access and broadband services wetting our appetites. Spring 2000 saw the attempt by Alta Vista UK to pre-empt the market by promising an unmetered package. Other unmetered tariffs have come and gone since then, all of them proving a financial drain for their operators, or in the case of Ezesurf, ruining them altogether.

Freeserve (**www.freeserve.net**) was amongst the very first to offer BT Surftime unmetered tariffs in Summer 2000, but has gone underground with its advertising, apparently having been heavily subscribed, even more so when other users, finding themselves turfed off other failed unmetered packages, migrated to Freeserve instead. Users were soon complaining of slow connections, engaged tones and poor bandwidth as the networks creaked under the strain.

On the Hog

Predictably, a minority of Freeserve incumbents decided to hog some lines to themselves, therefore spoiling the show for everyone else. More than 750 customers have since been served with a month's written notice because of their disproportionate drain – said to be up to 10% – on Freeserve's bandwidth.

The UK Consumer's Association said in October: *"ISPs offering an unmetered service have seemed more interested in increasing their customer numbers than in delivering the services that consumers were originally promised when they signed up.*

"Recent press reports suggesting that Freeserve would withdraw its unmetered access service from heavy users seems like another example of an unmetered offer that can't live up to the hype. If Freeserve has found itself caught out by the heavy usage of its customers it should accept its share of the blame.

"The ISPs have got themselves into a mess" says the CA. *"Rather than luring consumers in and then kicking them off schemes, what is needed on their part is better planning, realistic projections of customer usage and clearer advertising for new schemes."*

However, no ISP can reasonably cater for, say, a quarter of a million users all suddenly commandeering a cheap leased line 24×7, because the capacity just isn't there and probably never will be. Expectations are still running unrealistically high on both sides: consumers demand "excessive" levels of bandwidth on the cheap, and ISPs hope their customers will show restraint when using it.

The times are a'changing

I decided the time was ripe to review my Internet provision, if only to see what could be done to bring the cost down from its interstellar trajectory. I soon saw that confusion marketing reigned supreme. I started by checking my regular ISP, Demon Internet, who pioneered the flat-rate "TAM" (tenner-a-month) account in the early 1990's. Recently Demon felt sufficiently moved to incorporate a BT Surftime package, the idea being that the BT portion of the cost would be charged directly to your phone bill to provide for unmetered tariffs.

Under Surftime the standard TAM account will then benefit from reduced call costs – 2p/minute daytimes, 0·6p evenings, 0·5p weekends. For its proposed evenings and weekends package, Demon offers the standard Surftime £5.99 monthly rate paid direct to BT. This provides 100 per cent discount on all evening and weekend Internet calls, remembering Demon's £11.75 monthly subscription is extra.

Demon also proposes an enhanced package called *Premier Connect Plus* which costs nearly twice the standard account rate. For a monthly sum of £19.99, the Surftime numbers can be used throughout the working day as well as during evenings and weekends. Under this package, call costs drop to 1p/min. weekday daytimes, 0·6p evenings and 0·5p weekends.

Demon continues: *"Again, if you make a fixed extra payment to BT* (a further £19.99 per month) *you can get a 100 per cent discount on some or all of your Surftime calls so that they become 'free' . . . or you can pay £5.99 per month to cover evening and weekend calls only."* Demon puts a price of £119.94 ($167) per quarter on 100 per cent unmetered access. This service was due to roll out on 9 October.

This typifies the sort of stuff most users have to grapple with when comparing the best deals. Your cable operator may have packages comparable with any BT service (*ntl* hasn't replied to my query about cable modems). Personally, I sought a credible Surftime ISP offering a reasonable compromise to help slash daytime access costs, and maybe provide free calls in the evening and weekends.

As mentioned in previous columns, the choice of Surftime-enabled ISPs listed on BT's web site is meagre. A glitch with my Demon dial-in access – Demon changed their access software which rendered my modem obsolete – finally caused me to start shopping around.

Enter an ISP which bowed out from offering unmetered access earlier this year: LineOne (**www.lineone.net**). Their new Surftime tariff is simple and to the point: for a fee of £9.99 added to your phone bill – £5.99 is BT's Surftime evening and weekend portion, £4 is LineOne's ISP subscription – I could enjoy 1p a minute during the business daytime and completely free access during the evenings and weekends.

LineOne's on-line sign-up was soon completed and three days later an E-mail confirmed that my BT account had been updated for LineOne Surftime. This will cost £29.97 per quarter including VAT. Quickly dialling in via the new 0844 number, I was soon in business at 1p/minute or completely free altogether, and have high hopes of dramatically cutting costs. Note that LineOne telephone support costs 50p/minute, whilst Demon's is free, but this won't worry proficient users.

On your bike, ET

I was feeling quite pleased at this point. However, there's just enough room left this month to describe a perverse coincidence which rained on my parade. On the very same day I started to celebrate new lower prices, I spied a BT engineer shinning up the telegraph pole outside. In giving a neighbour a second line, the engineer did something to my own Internet access line which has resulted in my line speed being crippled to 33·6Kbps maximum, and it now takes several noisy attempts of my new modem to access any ISP at all, and connection speeds are suddenly 40 per cent slower.

This has all the makings of having a phone line "DACSed" (Digital Access Carrier Service), multiplexing two signals down a copper wire where no new circuits are available, to channel two phone lines down one wire. It's a common BT trick.

A maximum line speed of 33·6K every time is a dead give-away that something is wrong, but my problem makes no sense as two separate properties are involved. I have already had the "we don't guarantee any modem speeds down a voice line" argument with several unsympathetic BT reps.

I am therefore, at a single stroke, back to the sort of line speed I endured half a decade ago. British Telecom uses E.T. the Extra Terrestrial as their TV advertising mascot and I can tell you that at the time of writing, I am more incandescent than E.T.'s finger-end.

You can E-mail me at **alan@epemag.demon.co.uk**. See you next month.

Constructional Project

MOTORISTS' BUZZ-BOX

TERRY de VAUX-BALBIRNIE

A multi-purpose test instrument for the intrepid car owner.

THIS easy-build Buzz-Box is a test instrument having six useful functions. It would be ideal for anyone involved with fitting car accessories and for checking bulbs, fuses, switches, ignition leads and "earth" points. Since the unit receives power from the car electrical system, it does not need any internal batteries so will always be ready to use.

One particular advantage of this circuit is that most of the tests are provided by audible signals. This means that the user can concentrate on the task in hand without having to look at a display!

NEGATIVE ONLY

The Buzz-Box is suitable only for vehicles having a 12V ***negative earth*** system. That is, the negative terminal of the car battery is connected directly to the vehicle's metal structure ("earth" or "ground"). It is usual for the car body to provide the return path for the various circuits and this saves a lot of wiring.

Practically all cars in use today use the negative earth system although certain old models are "positive earth" (where the positive terminal of the battery is connected to the chassis). It is a simple matter to check this point if in doubt. ***Damage will be caused to the unit if it is connected with incorrect polarity.***

OVERVIEW

The instrument is built in a small plastic box. On top there is a meter, a rotary control with scale, a pair of terminals, pair of sockets and two metal contact "rails" (see photograph). On the side, there is a further socket which accepts a test meter type probe. A long piece of twin wire is used to connect the unit to the car cigar lighter socket for powering it.

The Buzz-Box provides the following functions:

1. ***Earth Test***. When the probe is applied to some point which has a small resistance with respect to the car chassis, an internal buzzer will emit a short bleep. This will be found useful for finding a good "earth" point when wiring an accessory or for checking the quality of an existing connection. Rust at a securing screw is a common problem and will result in increased resistance.

2. ***12V Test***. When the probe is touched on to some point which is within approximately 300mV of supply voltage (nominally 11·7V), the buzzer will emit a long bleep.

3. ***Low Resistance Test (20Ω)***. When the terminals of a low-resistance component bridge the test rails, the buzzer will sound continuously providing its resistance lies between zero and 20 ohms approximately. Several items associated with the car electrical system have near-zero resistance. Examples include fuses, pieces of wire and "closed" switch contacts.

However, the "cold" resistance of a low-power bulb may exceed ten ohms. A facility for giving a bleep with a resistance less than 20 ohms or thereabouts is therefore useful. This may be used as a quick "continuity" check on any low-resistance item.

4. ***Ignition Lead Test (Hi-R)***. The lead is connected to the Hi-R (high resistance) test position. The knob on the rotary control is turned until the buzzer just sounds and the resistance read off on a scale from ten kilohms (10kΩ) to 50 kilohms (50kΩ).

5. ***Battery Voltmeter***. While the unit is connected to the car system, a narrow-scale analogue meter gives a read-out of the battery voltage from 10V to 14V. This may be used to check the charge state of the battery.

It also provides a "crank test". This gives a battery "goodness" check by measuring the voltage under the heavy load over the starter motor.

6. ***Loudspeaker Test***. When loudspeaker leads are connected to the terminals, the loudspeaker will emit an audible tone. This is useful when it is not known which set of loudspeaker leads is which. It will also identify faulty units and connections. *Note that this test does not determine how well the loudspeaker is working.*

In order to set up the voltmeter section at the end of construction, you will need brief access to a good-quality test meter.

Since the circuit receives current from the car system, the 0V line will be automatically connected to the car chassis through the low resistance of the feed wire. The positive line will be at whatever voltage exists across the car battery terminals. This will be approximately 12V but will vary to some extent depending on the state of charge of the battery.

HOW IT WORKS

The full circuit diagram for the Motorists' Buzz-Box is shown in Fig.1. In the descriptions which follow, the supply voltage is assumed to be 12V. However, it turns out that the exact value of the voltage (within operating limits) does not matter and this point will be explained later.

Note that there is *no* reverse-polarity protection provided. This would introduce a voltage drop which would interfere with correct operation of the circuit.

However, providing the unit is correctly wired to the cigar lighter plug, the circuit cannot be connected incorrectly. Fuse FS1 provides some protection against overheating if a short-circuit were to occur. However, it does not provide any protection against reverse-polarity.

DOWN TO EARTH

The "earth test" centres around IC1a which is one section of quad op.amp (operational amplifier), IC1. This contains four identical units – the other three are associated with other tests.

The non-inverting input (pin 3) of IC1a is connected to a potential divider having fixed resistor R1 as the top arm. Resistor R2 appears in series with the resistance between the probe and the 0V line. This is labelled "*R*" (the "earth resistance") in Fig.1. Resistor R2 and *R* form the lower arm of the potential divider.

It will be noted that resistors R7 and R8 connected in series, appear in parallel with *R*. When the probe is connected to an earth point there will be only a very small resistance between itself and the 0V line so the effect of resistors R7 and R8 (having a combined resistance much higher than R) is negligible.

When the probe is left unconnected, the non-inverting input (pin 3) will be at 9·7V approximately. This is due to the potential divider which now consists of resistor R1 in the top arm and R2 in series with R7 and R8 in the lower one.

When the probe is connected to an "earth" point, *R* will have a very low value. Assume for the moment that this is zero. The upper and lower arms of the potential divider connected to IC1a non-inverting input will now be equal. The voltage here will then be one-half that of the supply – that is, 6V approximately.

However, if the earth resistance was, say, 0·5 ohm the lower arm would have a greater resistance that the upper one. In this case, calculation shows that the voltage at IC1a non-inverting input would be 6·03V, 30mV more than before.

POTENTIALLY MORE

The inverting input of IC1a (pin 2) is also connected to a potential divider. This comprises resistor R3 (the top arm) and the network of resistors R4, R5 and preset potentiometer VR1 connected in series (the bottom one). When preset VR1 is set to minimum, the voltage at the inverting input will be 5·8V and when at maximum, 6·1V approximately.

By adjusting preset VR1 at the end of construction, the inverting input voltage can be made to exceed that at the non-inverting one when *R* is between zero and some chosen value. The op.amp will then have its output (pin 1) low.

Some adjustment is needed to provide the required "low" point taking account of component tolerances and the resistance already existing in the connecting wires. In the prototype unit, the low point was set at 0·3 ohm approximately.

With the probe unconnected, the voltage at IC1a pin 3 (9·7V) exceeds that at pin 2 (6V approx.) so the op.amp output is high. This has no further effect.

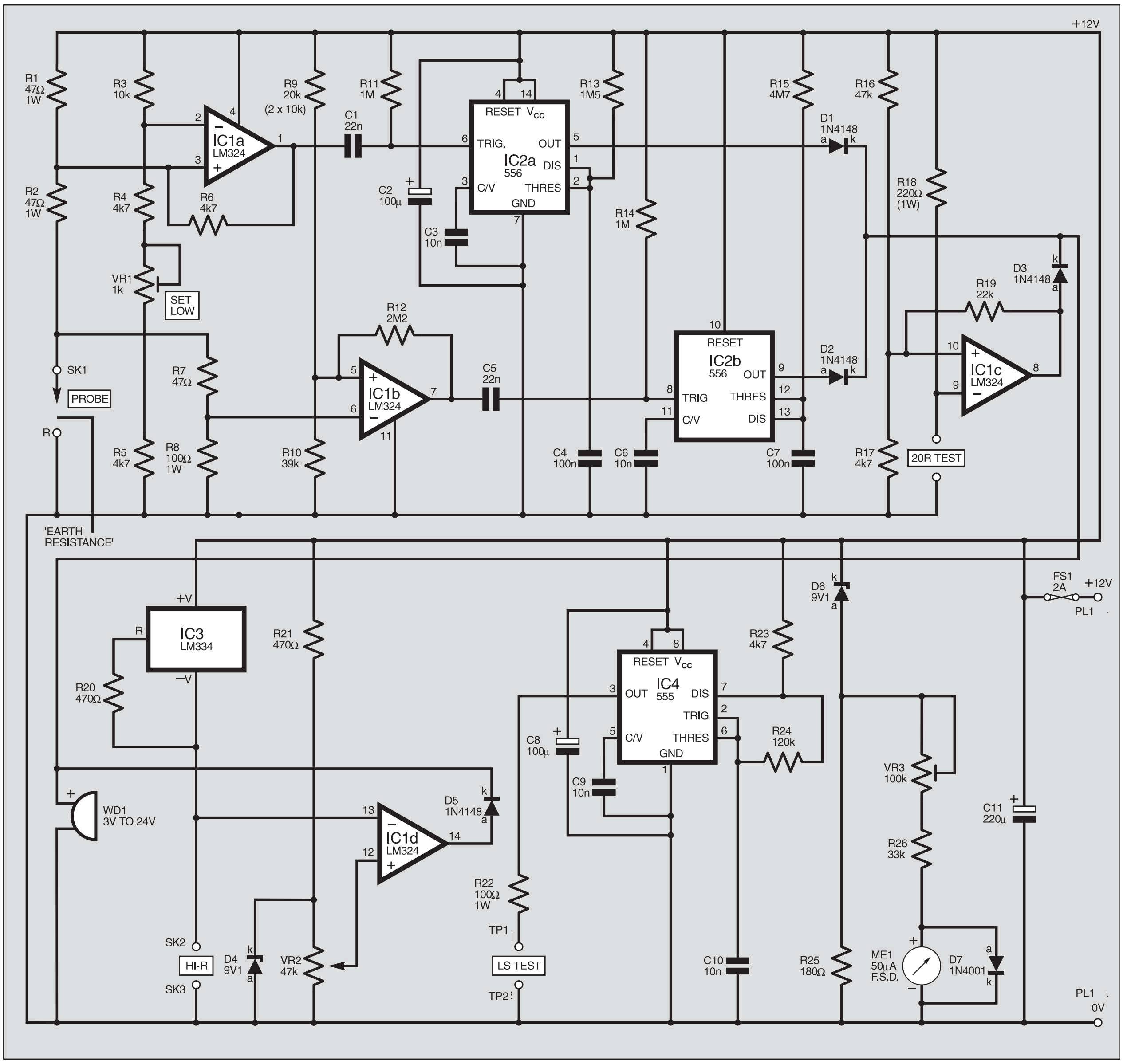


Fig.1. Complete circuit diagram for the Motorists' Buzz-Box. Note that some resistors must be rated at 1W.

GOOD ENOUGH!

When the probe detects a sufficiently "good" (that is, low resistance) earth point, the low logic state of IC1a output (pin 1) applies a short duration low pulse to IC2a pin 6 (the trigger input) via capacitor C1. IC2 is a dual timer with both sections, IC2a and IC2b configured as monostables.

In the case of IC2a, the time period is set by the value of resistor R13 and capacitor C4 and with those used here, it will be rather less than 0·2 second. During this time, the output (pin 5) goes high then reverts to low. While high, current flows through diode D1 to buzzer WD1, which gives a *short* bleep.

Resistor R11 maintains IC2a pin 6 in a high state in the absence of a trigger pulse and this prevents false operation. Resistor R6 applies a little positive feedback to the op.amp (IC1a) system and this sharpens the switching action.

12 VOLT TEST

For the 12V Test, op.amp IC1b (another section of quad op.amp, IC1) and IC2b (the other section of dual timer IC2) are used. It will be noted that the same probe is used for both the "Earth" and "12V" tests and this is particularly convenient when making checks.

The action of the 12V test is best described by considering what voltage exists at IC1b inverting input (pin 6) when the probe is (a) connected to a point at +12V, (b) unconnected and (c) when connected to 0V (that is, while performing an earth test).

In the case of (a), IC1b pin 6 may be considered to be connected to a potential divider having resistors R7 in the upper arm and R8 in the lower one (remembering that the top end of R7 is now connected to +12V). This gives a voltage of 8·16V.

In the case of (b) pin 6 is connected to the potential divider comprising resistors R1, R2 and R7 in series in the upper arm and R8 in the lower one. This provides a voltage of almost 5V. In the case of (c) the top end of R7 and the bottom end of R8 are both connected to 0V so the voltage at pin 6 is zero.

MORE POTENTIAL

The non-inverting input of IC1b is connected to another potential divider comprising resistor R9 in the upper arm and R10 in the lower one. With the values specified, the voltage applied to this input will be 7·93V.

If the probe is touched on a point within about 0·3V of the positive supply voltage, the inverting input voltage will exceed the non-inverting one. The output at pin 7 will then go low. This low state is applied, via capacitor C5, to the trigger input (pin 8) of the monostable based on IC2b.

The time period of this section is related to the values of resistor R15 and capacitor C7, and with those specified it will be 0·5 second approximately. During this time, the output at pin 9 goes high and current passes via diode D2 to the buzzer. This then emits a *long* bleep.

The trigger input at pin 8 of IC2b is maintained in a normally-high state using resistor R14. Resistor R12 provides a little positive feedback to op.amp IC1b and this sharpens the switching action.

COMPONENTS

Approx. Cost Guidance Only **£15** *excluding case & meter*

See SHOP TALK page

Resistors

R1, R2	47Ω 1W (2 off)
R3	10k
R4 to R6, R17, R23	4k7 (5 off)
R7	47Ω
R8, R22	100Ω 1W (2 off)
R9	20k (2 off 10k units – see text).
R10	39k
R11, R14	1M (2 off)
R12	2M2
R13	1M5
R15	4M7
R16	47k
R18	220Ω 1 watt
R19	22k
R20, R21	470Ω (2 off)
R24	120k
R25	180Ω
R26	33k

Plus 0·22W test resistor – see test. Also 10kΩ and 47kΩ test resistors.

All resistors, apart from the 0·22Ω test resistor, are of the 1% metal film type. Unless otherwise indicated, they should be rated at 0·6W. The 0·22Ω test resistor may be of any type.

Potentiometers

VR1	1k min. preset, vert.
VR2	47k min. rotary carbon, lin.
VR3	100k min. preset, vert.

Capacitors

C1, C5	22n polyester, 5mm pin spacing (2 off)
C2, C8	100μ radial elect. 25V (2 off)
C3, C6 C9, C10	10n polyester, 5mm pin spacing (4 off)
C4, C7	100n polyester, 5mm pin spacing (2 off)
C11	220μ radial elect. 25V

Semiconductors

D1 to D3, D5	1N4148 signal diode (4 off)
D4, D6	9V1 Zener diode (2 off)
D7	1N4001 50V 1A rect. diode
IC1	LM324N dual op.amp
IC2	556N dual timer
IC3	LM334N adjustable current source
IC4	555 timer

Miscellaneous

ME1	50μA full-scale deflection (f.s.d.), moving coil panel meter – see text
SK1, SK2, SK3	4mm chassis sockets (3 off) matching plugs (2 off) – see text.
TP1, TP2	small terminal posts (2 off)

Printed circuit board available from the *EPE PCB Service*, code 278; plastic box, size 150mm x 100mm x 60mm external; 8-pin d.i.l. socket; 14-pin d.i.l. socket (2 off); test meter probe to fit SK1; screw terminals (2 off); 5A terminal block (2 sections); 5A flexible twin wire (or ready-made cigar lighter extension lead (PL1)) – see text; materials for test rails; strain relief bush; control knob for VR2; self-adhesive p.c.b. stand-off pillar (2 off); solder etc.

TWENTY OHM TEST

The 20 Ohm Test or "low resistance test" is centred on IC1c, the third section of quad op.amp IC1. The non-inverting input (pin 10) is held at a potential of just over 1V due to the potential divider R16/R17. The inverting input (pin 9) is held at +12V due to resistor R18.

The metal rails on top of the unit form the "20R test" position. When a low-resistance item bridges the rails, this becomes the lower arm of a potential divider with resistor R18 as the upper one.

If the component on test has a resistance less than 22 ohms approximately, the inverting input voltage will fall below that at the non-inverting one. The output at IC1c pin 8 will then go high. The high state will pass, via diode D3, to the buzzer, which will sound.

When the test position is not occupied, the inverting input voltage exceeds the non-inverting one and the output will be low. This state is blocked by diode D3 and has no effect.

Timer IC2 is a robust bipolar device. It needs small-value capacitors connected between the control voltage pins (pin 3 and pin 11) and the 0V line (C3 and C6 respectively. Also, because momentary large current "spikes" occur on the supply rails, capacitor C2 is included to provide a charge reservoir.

In the Earth Test, 12V Test and 20 Ohm Test, both inputs of the op.amp involved have applied voltages which are derived from potential dividers. These are connected to the same supply lines. Thus, as the supply voltage rises or falls, the voltages at both op.amp inputs will rise or fall in sympathy. It, therefore, does not matter what battery voltage actually exists within operating limits.

TAKING THE LEAD

Ignition leads have a relatively high resistance and this is built into the design to suppress RFI (radio-frequency interference). This would otherwise cause severe noise in the loudspeaker connected to audio equipment and it would even affect radios in nearby cars.

The voltage used in the ignition system is very high (tens of kilovolts) so the relatively high resistance of the leads still enables sufficient current to flow to provide an effective spark at each plug gap.

However, if the resistance rises too much mis-firing occurs. This usually varies with factors such as engine speed and load. If the lead becomes open-circuit, the corresponding cylinder will not fire at all. Any such faults will plays havoc with a catalytic converter.

Unfortunately, problems with ignition leads are fairly common so some means of quickly measuring their resistance is useful. This enables the user to check how the resistance of the various leads compare and to determine whether or not they fall within manufactures' tolerances if this data is available. By "wiggling" the leads as the tests are made, it is possible to check for intermittent faults.

The High Resistance test is centred on IC1d, the fourth section of the quad op.amp. The lead is connected between the inverting input, pin 13, and the 0V line. A fixed current is now passed through it from the adjustable current source device IC3. This is programmed using resistor R20 and with the specified value, will be some 140μA.

With a constant current flowing through the lead, the voltage across its ends will be proportional to its resistance. It turns out that with a resistance of 64kΩ, the voltage across it will be nearly 9V and, of course, with zero ohms it is 0V. With no lead connected, virtually no current flows so IC3 obviously cannot maintain its regulation. However, this is of no consequence.

RESISTANCE TRACKING

Operational amplifier IC1d non-inverting input (pin 12) is connected to the sliding contact of panel-mounted potentiometer VR2. The track is connected in series with fixed resistor R21 across the supply.

Zener diode D4 operates in conjunction with R21 to provide a stable 9·1V (regarded as 9V) across VR2 track despite changes in supply voltage (down to around 9·5V). The difference between these two voltages appears across resistor R21. Since VR2 is a linear device, its angle of rotation will be approximately proportional to the voltage at the sliding contact rising from zero to 9V.

With the ignition lead in "Hi-R" position, VR2 control knob is slowly rotated. At some point, the voltage at the non-inverting input will exceed that at the inverting one. The output at pin 14 of IC1d will then go high and provide a feed to the buzzer WD1 through diode D5.

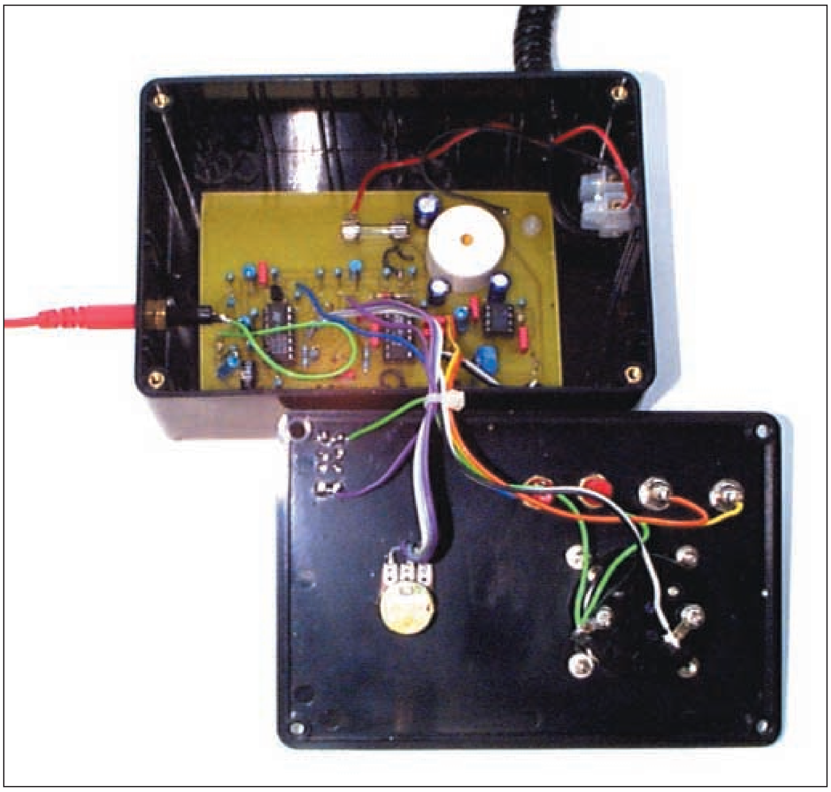
By adjusting the control knob, the position can be found where the buzzer just sounds. The resistance of the lead may then be read off a scale. Marking the scale 0 to 50kΩ (50 kilohms) is a simple matter and will be carried out at the end.

LOUDSPEAKER TEST

For the Loudspeaker Test a single 555 timer, IC4, is used. This is of the same type as the dual unit used for IC2. However, here it is configured as an astable. Thus, as long as a supply exists, the output at pin 3 of IC4 will provide a continuous train of on-off pulses.

The output from IC4 pin 3 is connected to one of the loudspeaker terminals (TP1), via resistor R22, while the other one (TP2) is connected to 0V. Providing the pulse frequency lies within the audible range, a loudspeaker connected to the terminals will produce a sound. Remembering the description of IC2, capacitor C9 is the control voltage capacitor and C8 provides a charge reservoir.

The components which determine the pulse frequency are resistors R23, R24 and capacitor C10. Using the specified values, this frequency will be 600Hz approximately. The ears are sensitive to this frequency and the loudspeaker will reproduce the sound well.



Layout of components inside the plastic box and wiring to components mounted on the lid.

Because the signal is a simple square wave, the power has been kept low to prevent possible damage. This is the reason for including resistor R22 in series with the output. This limits the peak current to 120mA or thereabouts.

This is not a precision signal designed to assess the performance of the loudspeaker. It is used simply to find which pair of leads is which and to identify non-working units, loose connections and so on.

VOLTMETER

The read-out of the supply voltage is provided by panel meter ME1. This is scaled 0 to 50μA but it is modified to show a d.c. range voltage from 10V to 14V.

The supply is connected to a 9·1V (regarded as 9V) Zener diode, D6, connected in series with fixed resistor R25. As long as the supply is a little more than the Zener breakdown voltage, the diode will conduct and this voltage will appear across it. The difference between the supply voltage and 9V will then appear across R25.

If the supply voltage is less than the Zener breakdown voltage, the diode will not conduct and therefore the voltage across resistor R25 will be zero. With a supply voltage of 14V (the maximum value in practice), the voltage across R25 will be 5V.

Meter ME1 operates in conjunction with preset potentiometer VR3 and fixed resistor R26 to provide a voltmeter having a full-scale reading of 14V. With an applied voltage less than about 9·5V, it will read zero.

The region between 9V and 10V must be regarded as a "grey area". This depends on exactly when the Zener diode begins to conduct. Also, at the beginning it does not do this sharply.

Values below 10V are therefore not known with any accuracy. At 10V the Zener diode will be behaving as it should and the scale after that will be more-or-less linear (equal changes in voltage producing equal steps on the scale). This is why there is space between the rest position of the pointer and 10V (see photograph).

METER CHOICE

The values of components have been chosen for a meter having a full-scale deflection of 50μA (although a 100μA unit would also work). Preset VR3 will be adjusted to give the correct full-scale reading at the end of construction. The internal resistance of the meter itself will be a few kilohms. However, the exact value does not matter because it is taken into account when VR3 is adjusted.

Diode D7 is connected in parallel with the meter movement as a protection device. Thus, if due to a fault an excessive current would otherwise flow through the meter, the voltage across it would be limited to 0·7V approximately (the forward voltage drop).

Normally, a smaller voltage than this exists across the meter (with the specified device carrying 50μA it is about 0·2V). Under normal conditions, therefore, the diode will have no effect. Under fault conditions, the current will be around 200μA but the meter will probably not be damaged.

CONSTRUCTION

Construction is based on a single-sided printed circuit board (p.c.b.). The topside component layout and full size underside copper track foil master are shown in Fig. 2. This board is available from the *EPE PCB Service,* code 278.

Begin construction by drilling the two fixing holes then solder the sockets for IC1, IC2 and IC4 in position (but do not insert the i.c.s themselves yet). Solder the fuse clips in place. If these are not available, you could use a small fuse block instead. If necessary, this could be mounted off board and hard-wired to the FS1 points on the p.c.b. later. Solder in position the single link wire, just above IC2 socket.

Add all resistors and the preset potentiometers. Note that some of the fixed resistors *must* have a power rating of one watt minimum. This is because they can become quite warm in prolonged tests.

Although five per cent tolerance would be sufficient for some of the resistors, some must have a tolerance of one per cent. To avoid confusion, one per cent tolerance resistors have therefore been specified throughout.

Resistor R9 must have a value of 20kΩ. It will probably be easier to use two 10kΩ units connected in series. Space has been left for two such resistors on the p.c.b. Note that they are *both* labelled R9 on the component layout, Fig.2.

Solder the capacitors in place. It is essential to place the electrolytic capacitors – C2, C8 and C11 – with the correct polarity. Solder all diodes in position taking care over their polarity, noting particularly the orientation of Zener diodes (D4 and D6). Add the audible warning device (WD1), taking note of its polarity (which is marked on top).

Next, solder 15cm pieces of light-duty stranded connecting wire to the following points on the p.c.b.: +12V; 0V; ME1 (2 off); VR2 (3 off); Probe; TP1; TP2; HI-R and 20Ω. By using different coloured wires (pieces of "rainbow" ribbon cable), problems will be avoided later.

Solder IC3 in position (the flat face is towards the left-hand side of the p.c.b.) keeping its end leads at least 5mm in length. Solder it quickly to avoid damage. If necessary, use a simple heat shunt – this may be nothing more than a pair of fine-nose pliers. These are used to grip each lead between the body of the device and the p.c.b. as it is soldered.

BOXING-UP

Begin the boxing-up procedure by making the holes for the meter. Mark out the large one and the small fixing ones using the template supplied with it. The large hole can be made by drilling a series of small holes around the outline. These are then joined together using a small hacksaw blade. The holes will be covered by the meter face so there is no point in trying to make a perfect job.

Place the p.c.b. in position on the base of the box. Mark through the fixing holes. Remove the p.c.b. and drill these through.

Decide on positions and drill holes for VR2 bush, also for terminals TP1/TP2 (for the loudspeaker test) and sockets SK2/SK3 (for the Hi-R test). Place the control knob on the potentiometer spindle and measure how much needs to be cut off. Mark this, remove the knob and cut off the excess using a small hacksaw.

While doing this, hold the spindle (not the potentiometer body) in the vice. *Gripping the body of the device is likely to damage it.* File the cut edge smooth.

Place the potentiometer bush through its hole and secure it loosely. Mark a suitable position for the anti-rotation lug on the inside. Remove the potentiometer again and drill a small hole to be a tight fit with the lug.

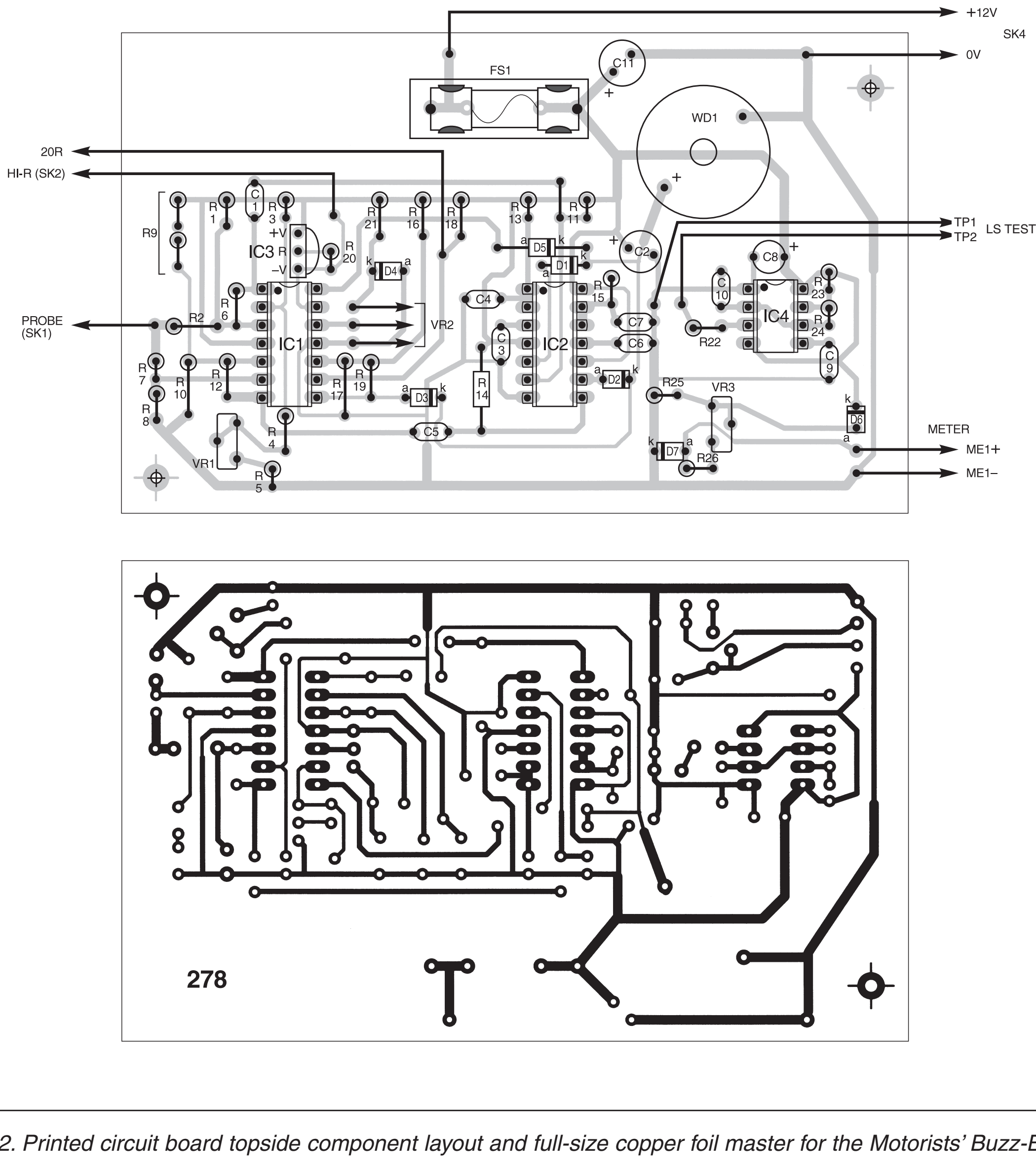
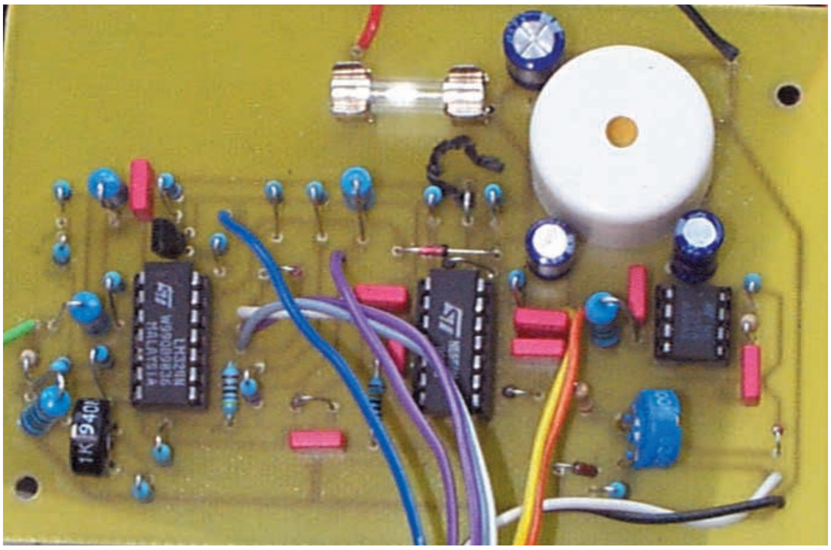


Fig.2. Printed circuit board topside component layout and full-size copper foil master for the Motorists' Buzz-Box.



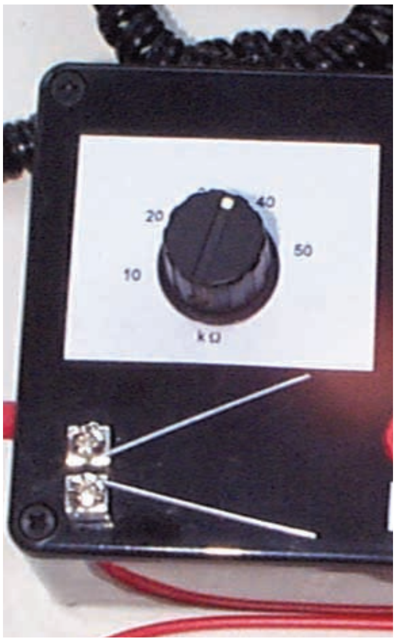
Completed prototype circuit board. Use different coloured wires (rainbow ribbon cable) to ease identification.

Drill the hole for probe the socket, SK1, in one side panel of the box and attach it. Drill a hole in the rear of the box for entry of the input wire. This must be large enough to accommodate the strain relief grommet.

ON THE RAILS

Refer to the photographs and make the test "Rails''. In the prototype unit, these were constructed using paper clips which were secured in place using screw terminals of the type shown. This method gives a neat finish and also allows the rail wires to be easily replaced if they become damaged in use.

The screw terminals used in the prototype were of the p.c.b. mounting type. These had four lugs which were made to be pushed through holes in a panel and soldered into position. However, if tight holes are drilled in the box, the lugs may be pushed through then secured by bending them slightly.



The "test" rails made from paper clips and the cardboard "resistance" scale.

The narrow end of the rails should be only a few millimetres apart (to allows for the testing of small bulbs) and about 35mm apart at the other end to enable testing of 1¼in fuses. The suggested method raises the rails above the top face of the case and this allows for the easy testing of small bulbs.

Attach potentiometer VR2 securely with the anti-rotation lug engaged in its hole. This lug prevents the body from possibly rotating in service (due to harsh use or loosening of the fixing nut). This would result in incorrect readings and could even snap off the connecting wires. Mount the p.c.b. on short plastic spacers and all remaining components.

Refer to Fig.3 and complete all the interwiring between the p.c.b. and off-board components. This should be done slowly to avoid errors in view of the fact that there are several components involved. Note particularly which wire from the p.c.b. connects to which VR2 tag (the diagram gives a rear view). Only if they are correct will the high resistance (Hi-R) section work properly with clockwise rotation corresponding with increasing resistance.

SUPPLY LEAD

The cable used for the supply voltage input lead ***must be rated at 5A minimum.*** This will avoid excessive voltage drops due to resistance. In the prototype, a ready-made "curly'' extension lead was used with the line socket end cut off.

Fit the 2-core cable wire through the strain relief bush. *Make sure it is secure.* Leaving a little slack, connect the ends to a 2-section piece of screw terminal block mounted inside the case. Connect the p.c.b. wires to this making certain that the polarity is correct.

Adjust preset VR1 fully clockwise (with respect to the left-hand side of the p.c.b.) and preset VR3 to approximately mid-track position.

TESTING

Double-check that the polarity to the circuit is correct before plugging in.

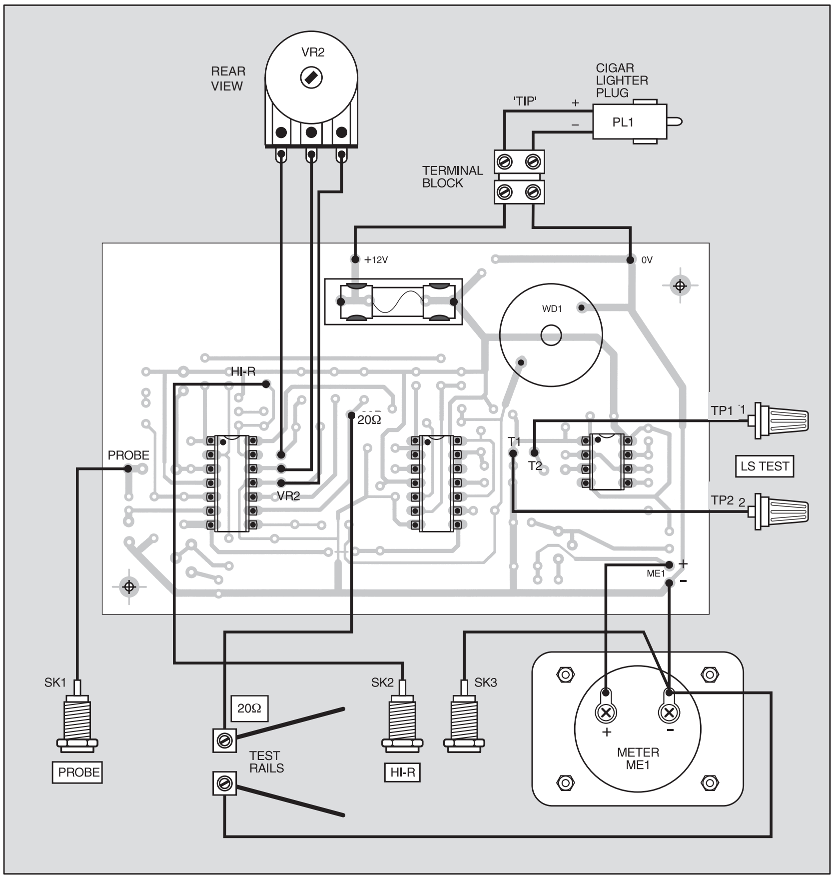


Fig.3. Interwiring from the printed circuit board to off-board components. The general layout within the case can be seen in the photographs.

Connect the unit to the lighter socket. In some cars the ignition must be switched on for this to operate. The monostables will probably self-trigger and the buzzer give a bleep. The meter should read somewhere on the scale. Adjust preset VR3 slightly if necessary.

Plug the probe into socket SK1. Touch this on an "earth" point. The buzzer should give a short bleep. If not, adjust preset VR1 so that it does. Touch the probe on a point at positive supply voltage. The buzzer should give a longer bleep.

Check that the 20Ω test works by bridging the rails with a piece of wire. The buzzer should sound continuously.

METER SCALE

Remove the front cover from the meter by *gently* pulling or careful levering using a thin knife blade. Exercising great care, remove the scale fixing screws using a small screwdriver. Slide out the scale taking care not to touch the pointer.

Cut out a paper scale to glue on top of the existing one. By pressing them in contact, you will see through sufficiently to mark with a pencil the positions of 10µA, 20µA, 30µA, 40µA and 50µA. Mark these 10V, 11V, 12V, 13V and 14V respectively using dry print lettering. Put a light pencil dot at the zero position.

You can, if you wish, "Tippex" or white-out the old scale (so that it does not show through the paper). Glue the new scale over it and re-assemble the meter. Attach the front taking care that the adjustment peg engages with the fork in the movement.

Check that the pointer rests at the zero dot. If not, adjust the screw on the top face until it does.

MAKING ADJUSTMENTS

Start the adjustment procedure with the Voltmeter. If you have access to a variable voltage power supply unit, you could use that to set VR3 to give a full-scale reading when 14V is applied. You will then find that the other markings correspond fairly well. Adjust preset VR3 to give the best compromise on these figures.

However, if you do not have access to a suitable power supply, plug the unit into the cigar lighter, measure the battery terminal voltage and adjust preset VR3 to correspond. The whole of the scale will then be reasonably accurate.

GOOD OLE' EARTH

To adjust the Earth Test low point, take the 0·22 ohm test resistor (or some other chosen value) and connect the probe to one end of this. Connect the other end to the negative terminal of the battery or a good earth point. Adjust preset VR1 until the buzzer just sounds.

R-SCALE CALIBRATION

Now for potentiometer VR2's front panel "resistance" scale and calibration. Make a thin cardboard scale and secure it temporarily behind the control knob. Pencil in the zero position (knob turned full anti-clockwise).

There is no point in marking the scale with great accuracy. It may be assumed that this is linear – that is, equal increases in resistance correspond with equal steps.

Testing an ignition (plug) lead. The new meter scaling can also be seen here.

Take the 10kΩ test resistor and connect it to the Hi-R test position. Rotate VR2 control knob to the point where the buzzer just sounds. Make a pencil mark. Repeat using the 47kΩ (regarded as 50kΩ) test resistor, again, making a mark.

Remove the scale and, by measurement, make marks for each 10kΩ step from 10 to 50. Mark these permanently. Label the scale "kΩ" then attach the scale in its original position. Check that the "zero" point is still correct.

USING THE BUZZ-BOX

There are several points to observe when using the test probe. ***This must be applied with care and with reference to the car wiring diagram. It may be used on items which carry supply current direct to some accessory (e.g. at a fuse, switch or connector) or an earth point. Do not probe around indiscriminately.***

On no account use it inside pieces of electronic equipment. If, for example, it was used inside an electronic control unit severe damage could result to the control unit.

Do not apply it to any connector associated with an engine management system, ABS unit or any other electronic system or sensor. Do not apply it to any wires inter-connecting such circuits.

Do not apply it to points on any diagnostic socket. Do not use it in the engine compartment with the engine running.

When using the loudspeaker test, disconnect **both** of the wires involved *before* connecting them to the unit.

CRANK TEST

The unit is not really designed to be used with the engine running except for a "crank test". To do this, watch the voltmeter as the starter motor is operated. If the needle drops immediately below 10V and the battery is known to be well charged, it is likely to be at the end of its useful life.

It would be worth checking the battery connectors (for tightness and lack of corrosion) and the connection of the earth strap to the car chassis since trouble here could produce a similar result. A good battery should be capable of maintaining a voltage of 10V or more for a few seconds until the engine fires.

STATE OF CHARGE

The charge state of the battery is found by measuring the voltage but this needs some interpretation. It will only be meaningful if the battery has not been charged for a few hours before the test is made.

A terminal voltage less than 11·5V indicates a battery which is "flat" (possibly irreversibly so). A voltage of 12·5V or more indicates a good state of charge and near 13V indicates full charge.

Take great care to avoid touching the probe on a +12V point and the car chassis or other earth point at the same time. *If you did, there would be a short circuit and damage could be caused.* In the prototype unit, the end of the probe was insulated using heat-shrinkable sleeving so that only a little bare tip remained. This reduced the likelihood of causing a short circuit.

UP TO YOU

Ignition leads could be connected to the test position in various ways. The method used in the prototype was to solder short pieces of stiff wire to the 4mm plugs. The other ends of the wire were bent into a loop to make contact with the connectors when inserted in the ends of the leads (see photograph).

Several ignition leads were tested and these had a resistance between 5kΩ and 20kΩ. Without specific data, compare the resistances of the leads. If one has a markedly higher value than the rest, it should be replaced and, preferably, the whole set renewed. □

QUASAR KITS REVIEW

ROBERT PENFOLD

Examining the merits of a dozen electronic kits from Quasar.

WE NORMALLY receive things for review one or two at a time, but no less than a dozen units are under consideration in this review. This is perhaps a slight exaggeration since there are only six different units, but each one has been supplied in kit form and ready-made. All marketed by Quasar Electronics.

It is not practical to consider every device in detail, so we will take a detailed look at one kit and then consider the other units in more general terms. It is kit number 3113, the PC-based dual stepper motor driver that will receive the in-depth coverage.

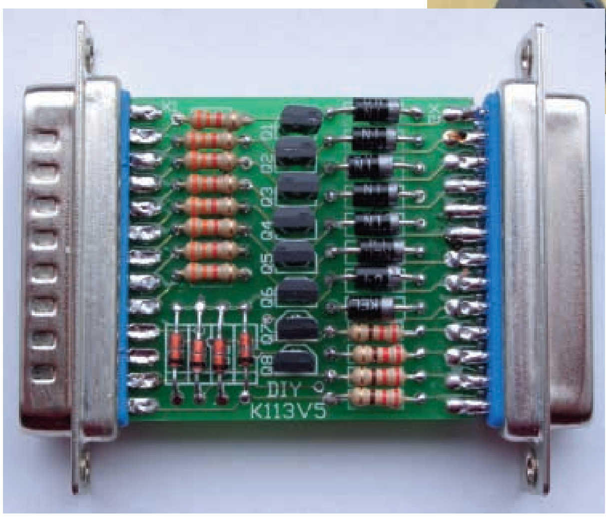
STEP-BY-STEP

A stepper motor has two centre-tapped coils, effectively giving four solenoids for the driver circuit to control. By pulsing the solenoids in the correct fashion the motor can be made to rotate in either direction in small steps of typically about 15 degrees.

Stepper motors produce little torque, but are used in applications that require precise positioning rather than high power. One way of driving a stepper motor is to use a special integrated circuit to simplify control. With this method there are two control inputs, one of which controls the direction of rotation. The other input is pulsed each time the motor must be moved on by one step.

The more simple method, and the one adopted in this case, is to control the solenoids from four output lines of the computer. Software is then used to generate the appropriate control pulses for whatever actions are required. This slightly complicates the software side of things, but direct control of a stepper motor is not that difficult.

This dual stepper motor interface is basically just eight open collector driver transistors controlled by the data outputs of a PC printer port, plus an MS-DOS program to make the unit operate as a dual stepper motor driver.



Completed twin stepper motor driver unit.

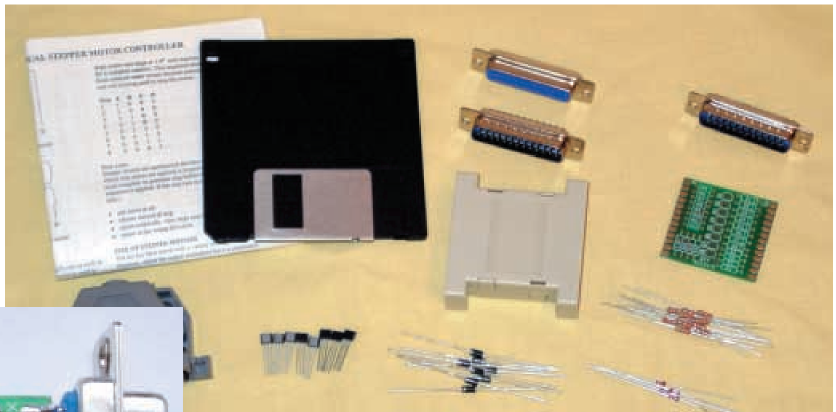
The interface takes the form of a small box having a 25-way D-type connector at each end. The male connector plugs into the PC's printer port, or it can be connected via a "straight" 25-way D connector cable (not supplied). Connections to the motors and power source are by way of the female connector at the other end of the case, and the supplied male connector. You have to supply your own connecting wires. The electronics fits on a tiny printed circuit board that fits between the two D connectors.

GETTING IT TOGETHER

Two A4 size sheets contain the building instructions, notes on use, the circuit diagram, etc. Quite a lot of information is crammed onto these two sheets, and it is definitely advisable to read through them once or twice before starting construction.

The fibreglass printed circuit board is a good quality double-sided type that is printed with a component overlay. Construction starts by fitting the two D connectors, and then the 32 small components are added.

There is no problem in identifying the components, and it is fairly obvious where everything fits. One slight problem is that the board is designed to take eight resistors in the form of a 16-pin d.i.l. package, but the kit is supplied with eight individual resistors. However, the instruction sheets do point out this discrepancy, and make it clear where the resistors are fitted. *(The p.c.b. has now been redesigned to overcome this – Ed.)*



The contents of the stepper motor driver kit.

Having some 32 components squeezed into about nine square centimetres makes construction fiddly rather than difficult. The situation is eased somewhat by the solder resist on the board which helps to avoid accidental short circuits. Also, the board is through-plated so there is no need for any pins to carry connections from one layer to the other.

It is still necessary to take reasonable care to avoid short circuits, and a magnifying glass is as essential as a soldering iron when building this type of board.

The instruction sheets give advice about using the interface with various types of stepper motor. It acknowledges the fact that many of the motors used by electronics hobbyists are surplus components that are supplied with little or no technical data.

Having sorted out some basic information about the motors it is often a matter of using some trial and error to get everything working properly. I tried the interface with an old Maplin stepper motor for which I did still have the connection data, and I am pleased to say that the unit worked first time.

SOFTWARE

The only supplied software is a DOS program on a 3.5-inch floppy disk. This did not work properly when run in a DOS window under Windows 98, but it worked fine when the computer was rebooted in DOS mode, or when the computer was booted into DOS from a floppy disk.

The program provides a command line interpreter that can be used to issue various commands to the motors, such as spin, stop, dir (direction) and wait. The commands seem to work well enough, and the program is easy to use.

It is possible to have the software process a series of commands contained in a text file, rather like running a DOS batch file. This enables what is effectively a simple program to be written and executed, but for many purposes something more sophisticated than this will be needed. It should not be too difficult to control the motor using a Windows programming language such as Delphi or Visual BASIC.

The output port of the interface also provides access to four handshake inputs of the printer port, which makes it possible to have control of the motor to some extent dependent on feedback from sensors. However, you are completely on your own with this type of thing.

CONCLUSION

Although this is a fairly simple kit, it is not really suitable for beginners, and is not aimed at those of limited experience. Constructing the kit is actually quite easy, but a fair amount of technical expertise is needed to get the finished unit do anything worthwhile.

Considering the simplicity of the unit, at a VAT inclusive cost of £17.95 it is not particularly cheap, but the price is reasonable considering the quality of the components. The printed circuit board is as good as any I have seen, and better than most. As the ready-made interface costs some £29.95 including VAT, it seems to be well worthwhile spending half an hour or so building the kit version.

PIC/ATMEL PROGRAMMERS

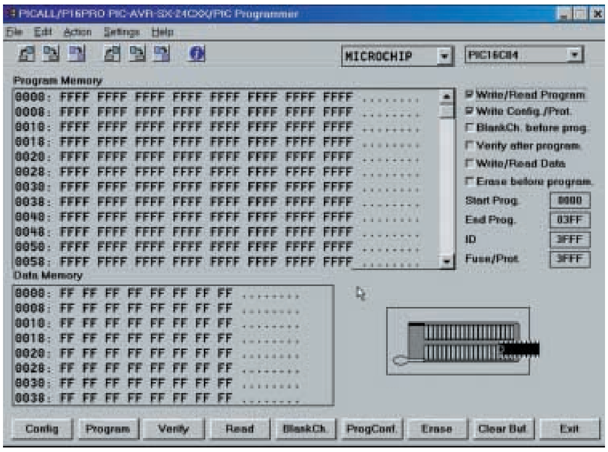
The other kits and ready-made boards received for review are for programming PIC or ATMEL microcontrollers. The Quasar kits seem to be based on designs that are available on the Internet. The original instruction leaflets were quite brief at just one A4 sheet with printing on one side, but these have now been updated and improved. Further assistance is often available from one or more web sites, as are more recent versions of the software. The latter is shareware, although in some cases the full registered version is supplied in the kit price. In general, the kits seem to be quite easy to put together.

The printed circuit boards are good quality fibreglass boards, but are mostly single-sided types that require some link-wires. The boards have a solder resist layer that helps to avoid short circuits due to excess solder, and this makes it much easier to get things working first time.

Some of the kits have attractively low prices, but bear in mind that all you get is a kit of parts to build the board, together with a floppy disk containing the software. The cable to connect the board to the computer and the mains adapter are optional extras at £4.95 and £5.95 each.

The kit versions of the programmers are supplied with an ordinary 40-pin d.i.l. socket, and a universal ZIF socket costs an additional £15.95. The ZIF socket has to be regarded as an essential buy. Apart from other considerations, many PIC chips will simply not fit an ordinary 40-pin holder with its 0·6-inch row spacing.

As already pointed out, there is also a software registration fee with some kits if the full version is required, and this adds a further £14.95 to the cost. These extras can substantially boost the basic kit price, although the overall cost still seems to be reasonable.



Windows version of the PICALL software.

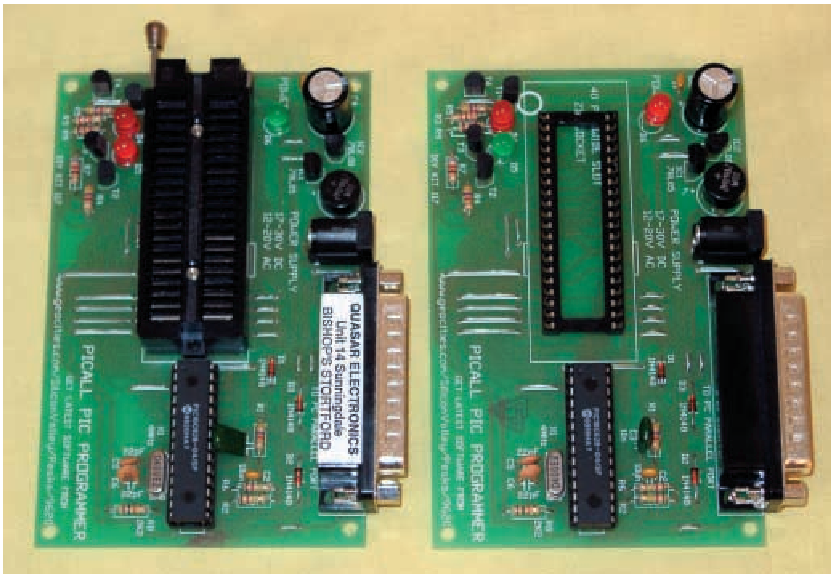
The programmers are mostly quite easy to use. The P16PRO serial PIC programmer supports a range of PIC microcontrollers and has MS-DOS software, but it is very simple and straightforward to use. The PICALL programmer supports a wide range of PIC microcontrollers, plus a limited range of non-PIC devices, and has the option of MS-DOS or Windows software. The Windows version of the program is easier to use, but the diagram showing how to connect the selected device to the ZIF socket makes things "as clear as mud". It is best to resort to the MS-DOS version for connection details.

FINAL CONCLUSION

Building any of these kits should not present any major problems for someone who has a small amount of experience at electronic project building. However, none of the kits can really be recommended for beginners, since a fair amount of technical know-how is needed in order to utilize the finished units. For the same reason, the ready-made boards are only suitable for those who know what they are doing.

It is a pity that neither the kits nor the ready-made units are supplied with more documentation as this would substantially broaden their appeal. *(This point has now been addressed with new documents plus an electronic manual that is provided with the software – Ed.)* As things stand, the kits and ready-made units are of excellent quality, represent reasonably good value for money, and represent a worthwhile proposition for someone having the requisite technical expertise and an Internet connection.

For more information contact Quasar Electronics, Unit 14 Sunningdale, Bishop's Stortford, Herts CM23 2PA. Tel: 01279 306504. Fax: 08707 064222.
Email: **epesales@QuasarElectronics.com**.
Web: **www.QuasarElectronics.com**. □



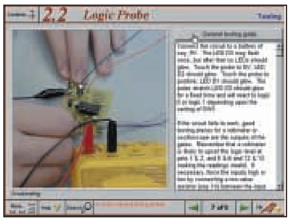
The ready-made (left) and kit version of the PICALL programmer.

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

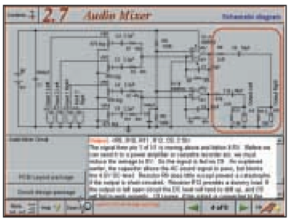
ELECTRONICS CD-ROMS

NEW

ELECTRONICS PROJECTS



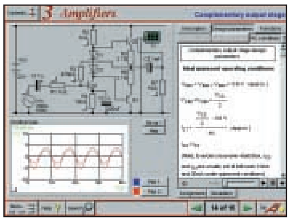
Logic Probe testing



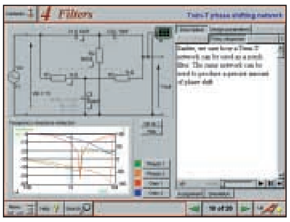
Audio Mixer circuit description

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture**, **circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ANALOGUE ELECTRONICS



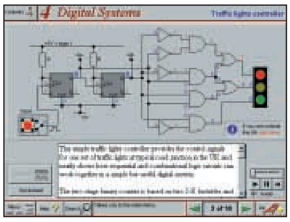
Complimentary output stage



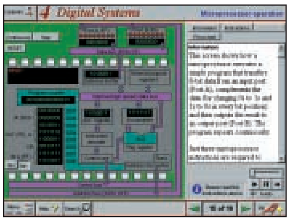
Twin-T phase shifting network

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS



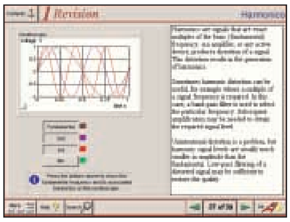
Virtual laboratory – Traffic Lights



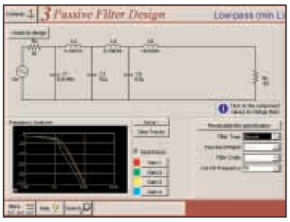
Microprocessor

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates and their operation, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters and their parameters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units.

FILTERS



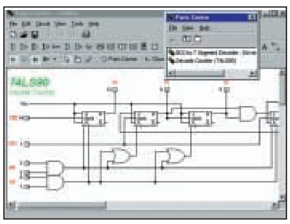
Filter Theory



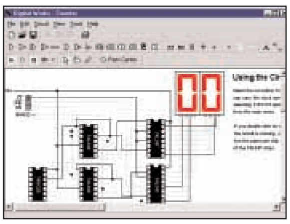
Active filter synthesis

Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

DIGITAL WORKS 3.0



Macro screen



Counter project

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- Easy-to-use digital interface
- Animation brings circuits to life
- Vast library of logic macros and 74 series i.c.s with data sheets
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Interested in programming PIC microcontrollers? Learn with **PICtutor** *by John Becker*

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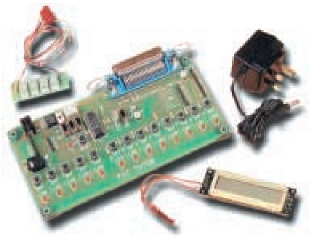

Deluxe PICtutor Hardware

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

HARDWARE
Whilst the CD-ROM can be used on its own, the physical demonstration provided by the **PICtutor Development Kit**, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work.
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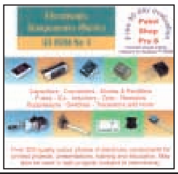

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Minimum system requirements for these CD-ROMs: PC with 486/166MHz, VGA+256 colours, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98, mouse, sound card, web browser.

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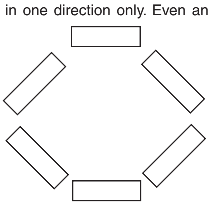

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The other is **Amplifier Ref. No. 109G**. This is in a case size 80mm wide, 130mm high and 35mm deep. Price £1. Order Ref: 7R2.

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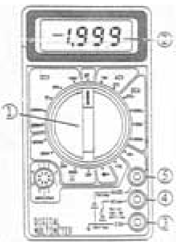
THIS MONTH'S SPECIAL



IT IS A DIGITAL MULTI-TESTER, complete with backrest to stand it and hands-free test prod holder. This tester measures d.c. volts up to 1,000 and a.c. volts up to 750; d.c. current up to 10A and resistance up to 2 megs. Also tests transistors and diodes and has an internal buzzer for continuity tests. Comes complete with test prods, battery and instructions. Price £6.99. Order Ref: 7P29.

YOUR CHANCE TO BUY SOME POPULAR LINES AT BARGAIN PRICES

250W WOOFER. Made by Challenger, this is 10in. 4 ohm, very high quality make. Our normal price £29, we are reducing to £20, which is almost a third off. Order Ref: 29P7L.

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MOTORISED DISPLAY. This could control up to 120A of lighting or other equipment. The mains operated motor drives 12 x 10A microswitches, each of which can be set to come on at a different time, so giving running lights or other interesting displays. Regular price £10, reduced to £8. Order Ref: 1P191L.

BRUSH TYPE MAINS MOTOR. Probably ¼hp but being brush type it is easily speed controllable. Normal price £5, special offer price £4. Order Ref: 5P275L.

SOLAR KITS. To make an old fashioned gramophone which will operate in sunlight or under a light bulb. Normal price £7.50, reduced to £6. Order Ref: 7P16L.

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MOST USEFUL MAINS TRANSFORMER. This is a 12V-0-12V 35W rated, has mounting legs so can stand directly on base panel, price £2.50. order Ref: 2.5P15.

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5A BRIDGE RECTIFER FOR 12V or 24V CHARGER. With heatsink coupler if used on full current, 2 for £1. Order Ref: 1070.

ENGINEERS BENCH PANEL. This has 2 x 13A mains sockets which are switched and illuminated, thus saving you having to keep pulling out the plugs. Nicely cased, only £2. Order Ref: 2P461.

OVEN THERMOSTAT with knob calibrated so you can set it to cut out at any temperature up to 600 degrees F. Price £3. Order Ref; 3P229.

BUY ONE GET ONE FREE

ULTRASONIC MOVEMENT DETECTOR. Nicely cased, free standing, has internal alarm which can be silenced. Also has connections for external speaker or light. Price £10. Order Ref: 10P154.

CASED POWER SUPPLIES which, with a few small extra components and a bit of modifying, would give 12V at 10A. Originally £9.50 each, now 2 for £9.50. Order Ref: 9.5P4.

3-OCTAVE KEYBOARDS with piano size keys, brand new, previous price £9.50, now 2 for the price of one. Order Ref: 9.5P5.

RECHARGEABLE 12V JELLY ACID BATTERIES. Yuasa 12V 2.3AH. These are 7in. long, 3in. high and 1½in. wide with robust terminals protruding through the top. Price £3.50. Order Ref: 3.5P11.

DITTO, but 12V 18AH. This is 7in. long, 7in. high and 3in. wide. Brand new with 12 months guarantee, price £12.50 or pack of 4 for £48, including VAT and carriage. Order Ref: 12.5P3.

Note – This battery will start a car and is ideal for golf trolleys, etc.

CHARGER for these batteries and other sealed lead acid batteries, £5. Order Ref: 5P269.

RECHARGEABLE NICAD BATTERIES. AA size, 25p each, which is a real bargain considering many firms charge as much as £2 each. These are in packs of 10, coupled together with an output lead so are a 12V unit but easily divideable into 2 × 6V or 10 × 1·2V. £2.50 per pack, 10 packs for £25 including carriage. Order Ref: 2.5P34.

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

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VERY THIN DRILLS. 12 assorted sizes vary between 0·6mm and 1·6mm. Price £1. Order Ref: 128.

EVEN THINNER DRILLS. 12 that vary between 0·1 and 0·5mm. Price £1. Order Ref:129.

TWIN TELEPHONE PLUG. Enables you to plug 2 telephones into the one socket for all normal BT plugs. price £1.50. Order Ref: 1.5P67.

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

BT TELEPHONE EXTENSION WIRE. This is proper heavy duty cable for running around the skirting board when you want to make a permanent extension. 4 cores properly colour coded, 25m length. Only £1. Order Ref:1067.

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

TWIN 13A SWITCHED SOCKET. Standard in all respects and complete with fixing screws. White, standard size and suitable for flush mounting or in a surface box. Price £1.50. Order Ref: 1.5P61.

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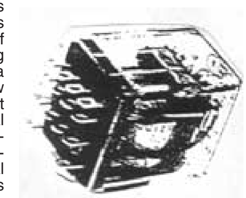
RELAYS



We have thousands of relays of various sorts in stock, so if you need anything special give us a ring. A few new ones that have just arrived are special in that they are plug-in and come complete with a special base which enables you to check voltages of connections of it without having to go underneath. We have 6 different types with varying coil voltages and contact arrangements. All contacts are rated at 10A 250V AC.

Coil Voltage	Contacts	Price	Order Ref:
12V DC	4-pole changeover	£2.00	FR10
12V DC	2-pole changeover	£1.50	FR11
24V DC	2-pole changeover	£1.50	FR12
24V DC	4-pole changeover	£2.00	FR13
240V AC	1-pole changeover	£1.50	FR14
240V AC	4-pole changeover	£2.00	FR15

Prices include base

NOT MUCH BIGGER THAN AN OXO CUBE. Another relay just arrived is extra small with a 12V coil and 6A changeover contacts. It is sealed so it can be mounted in any position or on a p.c.b. Price 75p each, 10 for £6 or 100 for £50. Order Ref: FR16.

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ELECTRONICS TEACH-IN No. 7
ANALOGUE AND DIGITAL
ELECTRONICS COURSE
(published by *Everyday Practical Electronics*)
Alan Winstanley and Keith Dye B.Eng(Tech)AMIEE

This highly acclaimed *EPE Teach-In* series, which included the construction and use of the *Mini Lab* and *Micro Lab* test and development units, has been put together in book form.

An interesting and thorough tutorial series aimed specifically at the novice or complete beginner in electronics. The series is designed to support those undertaking either GCSE Electronics or GCE Advanced Levels, and starts with fundamental principles.

If you are taking electronics or technology at school or college, this book is for you. If you just want to learn the basics of electronics or technology you must make sure you see it. *Teach-In No. 7* will be invaluable if you are considering a career in electronics or even if you are already training in one. The Mini Lab and software enable the construction and testing of both demonstration and development circuits. These learning aids bring electronics to life in an enjoyable and interesting way: you will both see and hear the electron in action! The Micro Lab microprocessor add-on system will appeal to higher level students and those developing microprocessor projects.

160 pages **Order code TI7** **£3.95**

Circuits and Design

ELECTRONICS PROJECTS USING ELECTRONICS WORKBENCH plus FREE CD-ROM **FREE CD-ROM**
M. P. Horsey

This book offers a wide range of tested circuit modules which can be used as electronics projects, part of an electronics course, or as a hands-on way of getting better acquainted with Electronics Workbench. With circuits ranging from 'bulbs and batteries' to complex systems using integrated circuits, the projects will appeal to novices, students and practitioners alike.

Electronics Workbench is a highly versatile computer simulation package which enables the user to design, test and modify their circuits before building them, and to plan PCB layouts on-screen. All the circuits in the book are provided as runnable Electronic Workbench files on the enclosed CD-ROM, and a selection of 15 representative circuits can be explored using the free demo version of the application.

Contents: Some basic concepts; Projects with switches, LEDs, relays and diodes; Transistors; Power supplies; Op.amp projects; Further op.amp circuits; Logic gates; Real logic circuits; Logic gate multivibrators; The 555 timer; Flip-flops, counters and shift registers; Adders, comparators and multiplexers; Field effect transistors; Thyristors, triacs and diacs; Constructing your circuit; Index.

227 pages **Order code NE29** **£14.99**

A BEGINNER'S GUIDE TO MODERN ELECTRONIC COMPONENTS
R. A. Penfold

The purpose of this book is to provide practical information to help the reader sort out the bewildering array of components currently on offer. An advanced knowledge of the theory of electronics is not needed, and this book is not intended to be a course in electronic theory. The main aim is to explain the differences between components of the same basic type (e.g. carbon, carbon film, metal film, and wire-wound resistors) so that the right component for a given application can be selected. A wide range of components are included, with the emphasis firmly on those components that are used a great deal in projects for the home constructor.

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PRACTICAL REMOTE CONTROL PROJECTS
Owen Bishop

Provides a wealth of circuits and circuit modules for use in remote control systems of all kinds; ultrasonic, infra-red, optical fibre, cable and radio. There are instructions for building fourteen novel and practical remote control projects. But this is not all, as each of these projects provides a model for building dozens of other related circuits by simply modifying parts of the design slightly to suit your own requirements. This book tells you how.

Also included are techniques for connecting a PC to a remote control system, the use of a microcontroller in remote control, as exemplified by the BASIC Stamp, and the application of ready-made type-approved 418MHz radio transmitter and receiver modules to remote control systems.

160 pages **Order code BP413** **£5.99**

DISCOVERING ELECTRONIC CLOCKS
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This is a whole book about designing and making electronic clocks. You start by connecting HIGH and LOW logic signals to logic gates. You find out about and then build and test bistables, crystal-controlled astables, counters, decoders and displays. All of these subsystems are carefully explained, with practical work supported by easy to follow prototype board layouts.

Full constructional details, including circuit diagrams and a printed circuit board pattern, are given for a digital electronic clock. The circuit for the First Clock is modified and developed to produce additional designs which include a Big Digit Clock, Binary Clock, Linear Clock, Andrew's Clock (with a semi-analogue display), and a Circles Clock. All of these designs are unusual and distinctive.

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DOMESTIC SECURITY SYSTEMS
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crime-ridden streets in the world.

The designs include all elements, including sensors, -detectors, alarms, controls, lights, video and door entry systems. Chapters cover installation, testing, maintenance and upgrading.

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Mike James

The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

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A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold

This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages **Order code BP332** **£4.95**

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Owen Bishop

This book describes over 60 modular electronic circuits, how they work, how to build them, and how to use them. The modules may be wired together to make hundreds of different electronic systems, both analogue and digital. To show the reader how to begin building systems from modules, a selection of over 25 electronic systems are described in detail, covering such widely differing applications as timing, home security, measurement, audio (including a simple radio receiver), games and remote control.

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Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

256 pages **Order code BP53** **£4.99**

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order to your door. Full ordering details are given on the last book page.

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Note our UK postage costs just £2.00 no matter how many books you order!

Computing & Robotics

WINDOWS 95 EXPLAINED
P. R. M. Oliver and N. Kantaris

If you would like to get up and running, as soon as possible, with the Windows 95 operating system, then this is the book for you.

The book was written with the non-expert, busy person in mind. It explains the hardware that you need in order to run Windows 95 successfully, and how to install and optimize your system's resources. It presents an overview of the Windows 95 environment.

Later chapters cover how to work with programs, folders and documents; how to control Windows 95 and use the many accessories that come with it; how to use DOS programs and, if necessary, DOS commands and how to communicate with the rest of the electronic world.

170 pages **Order code BP400** **£5.95**

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages – large format **Order code BP901** **£12.99**

INTRODUCTION TO MICROPROCESSORS
John Crisp

If you are, or 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, nor a technical or mathematical background. 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 difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

Contents: The world changed in 1971; Microprocessors don't have ten fingers; More counting; Mathematical micros; It's all a matter of logic; Registers and memories; A microprocessor based system; A typical 8-bit microprocessor; Programming, High level languages; Micros are getting bigger and faster; The Pentium; The PowerPC; The Alpha 21164 microprocessor; Interfacing; Test equipment and fault finding.

222 pages **Order code NE31** **£16.99**

Theory and Reference

Bebop To The Boolean Boogie

By Clive (call me Max) Maxfield

ORDER CODE BEB1

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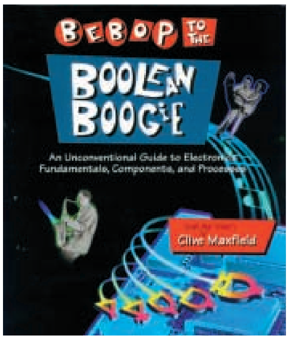
470 pages. Large format

Specially imported by EPE – Excellent value

An Unconventional Guide to Electronics Fundamentals, Components and Processes



This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!).

Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day. . . .

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DIGITAL ELECTRONICS – A PRACTICAL APPROACH
With FREE Software: Number One Systems – EASY-PC Professional XM and Pulsar (Limited Functionality)
Richard Monk

FREE SOFTWARE

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchronous and synchronous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer-aided design including the FREE software.

There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

Those who prefer the 'Teach-In' approach or would rather experiment with some simple circuits should find the book's final chapters on printed circuit board production and project ideas especially useful.

250 pages **Order code NE28** **£16.99**

DIGITAL GATES AND FLIP-FLOPS
Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explainend, 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 other than a basic 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 digital logic.

200 pages **Order code PC106** **£8.95**

Bebop Bytes Back

By Clive "Max" Maxfield and Alvin Brown

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An Unconventional Guide To Computers

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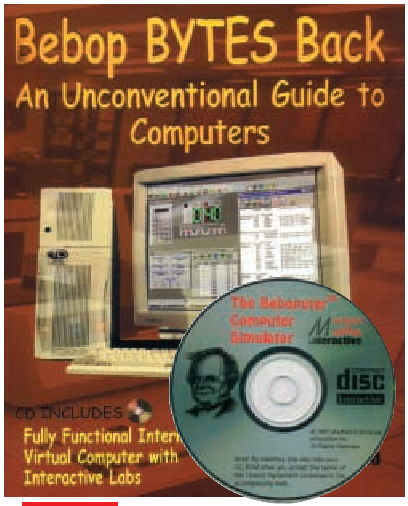

FREE CD-ROM

This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the accompanying CD-ROM (for Windows 95 machines only) contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the book contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this one!

Over 500 pages – large format **Order code BEB2** **£29.95**

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Edited by Owen Bishop

CD-ROM

An expert adviser, an encyclopedia, an analytical tool and a source of real design data, all in one CD-ROM. Written by leading electronics experts, the collected wisdom of the electronics world is at your fingertips. The simple and attractive Circuits Environment(TM) is designed to allow you to find the circuit or advice notes of your choice quickly and easily using the search facility. The text is written by leading experts as if they were explaining the points to you face to face. Over 1,000 circuit diagrams are presented in a standardised form, and you are given the option to analyse them by clicking on the Action icon. The circuit groups covered are: Amplifiers, Oscillators, Power, Sensing, Signal Processing, Filters, Measurement, Timing, Logic Circuits, Telecommunications.

The analysis tool chosen is SpiceAge for Windows, a powerful and intuitive application, a simple version of which automatically bursts into action when selected.

Newnes Interactive Electronic Circuits allows you to: analyse circuits using top simulation program SpiceAge; test your design skills on a selection of problem circuits; clip comments to any page and define bookmarks; modify component values within the circuits; call up and display useful formulae which remain on screen; look up over 100 electronic terms in the glosary; print and export netlists.

System Requirements: PC running Windows 3.x, 95 or NT on a 386 or better processor. 4MB RAM, 8MB disk space.

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Audio and Music

AN INTRODUCTION TO LOUDSPEAKERS AND ENCLOSURE DESIGN
V. Capel

This book explores the various features, good points and snags of speaker designs. It examines the whys and wherefores so that the reader can understand the principles involved and so make an informed choice of design, or even design loudspeaker enclosures for him – or herself. Crossover units are also explained, the various types, how they work, the distortions they produce and how to avoid them. Finally there is a step-by-step description of the construction of the *Kapellmeister* loudspeaker enclosure.

148 pages **Order code BP256** **£3.99**

PREAMPLIFIER AND FILTER CIRCUITS
R. A. Penfold

This book provides circuits and background information for a range of preamplifiers, plus tone controls, filters, mixers, etc. The use of modern low noise operational amplifiers and a specialist high performance audio preamplifier i.c. results in circuits that have excellent performance, but which are still quite simple. All the circuits featured can be built at quite low cost (just a few pounds in most cases). The preamplifier circuits featured include: Microphone preamplifiers (low impedance, high impedance, and crystal). Magnetic cartridge pick-up preamplifiers with R.I.A.A. equalisation. Crystal/ceramic pick-up preamplifier. Guitar pick-up preamplifier. Tape head preamplifier (for use with compact cassette systems).

Other circuits include: Audio limiter to prevent overloading of power amplifiers. Passive tone controls. Active tone controls. PA filters (highpass and lowpass). Scratch and rumble filters. Loudness filter. Audio mixers. Volume and balance controls.

92 pages **Order code BP309** **£3.99**

HIGH POWER AUDIO AMPLIFIER CONSTRUCTION
R. A. Penfold

Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs.

96 pages **Order code BP277** **£3.99**

ELECTRONIC MUSIC AND MIDI PROJECTS
R. A. Penfold

Whether you wish to save money, boldly go where no musician has gone before, rekindle the pioneering spirit, or simply have fun building some electronic music gadgets, the designs featured in this book should suit your needs. The projects are all easy to build, and some are so simple that even complete beginners at electronic project construction can tackle them with ease. Stripboard layouts are provided for every project, together with a wiring diagram. The mechanical side of construction has largely been left to the individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing in this respect.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

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Testing, Theory, Data and Reference

SCROGGIE'S FOUNDATIONS OF WIRELESS AND ELECTRONICS – ELEVENTH EDITION
S. W. Amos and Roger Amos
Scroggie's Foundations is a classic text for anyone working with electronics, who needs to know the art and craft of the subject. It covers both the theory and practical aspects of a huge range of topics from valve and tube technology, and the application of cathode ray tubes to radar, to digital tape systems and optical recording techniques.

Since *Foundations of Wireless* was first published over 60 years ago, it has helped many thousands of readers to become familiar with the principles of radio and electronics. The original author Sowerby was succeeded by Scroggie in the 1940s, whose name became synonymous with this classic primer for practitioners and students alike. Stan Amos, one of the fathers of modern electronics and the author of many well-known books in the area, took over the revision of this book in the 1980s and it is he, with his son, who have produced this latest version.

400 pages **Order code NE27** **£19.99**

ELECTRONICS MADE SIMPLE
Ian Sinclair
Assuming no prior knowledge, *Electronics Made Simple* presents an outline of modern electronics with an emphasis on understanding how systems work rather than on details of circuit diagrams and calculations. It is ideal for students on a range of courses in electronics, including GCSE, C&G and GNVQ, and for students of other subjects who will be using electronic instruments and methods.

Contents: waves and pulses, passive components, active components and ICs, linear circuits, block and circuit diagrams, how radio works, disc and tape recording, elements of TV and radar, digital signals, gating and logic circuits, counting and correcting, microprocessors, calculators and computers, miscellaneous systems.

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Hans-Günther Steidle
The tables in this book contain information about the package shape, pin connections and basic electrical data for each of the many thousands of transistors listed. The data includes maximum reverse voltage, forward current and power dissipation, current gain and forward transadmittance and resistance, cut-off frequency and details of applications.

A book of this size is of necessity restricted in its scope, and the individual transistor types cannot therefore be described in the sort of detail that maybe found in some larger and considerably more expensive data books. However, the list of manufacturers' addresses will make it easier for the prospective user to obtain further information, if necessary.

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ELECTRONIC TEST EQUIPMENT HANDBOOK
Steve Money
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Everything from Oscillators, through R, C & L measurements (and much more) to Waveform Generators and testing Zeners.

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GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

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NEWNES ELECTRONICS TOOLKIT – SECOND EDITION
Geoff Phillips
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Have you ever wished for a concise and comprehensive guide to electronics concepts and rules of thumb? Have you ever been unable to source a component, or choose between two alternatives for a particular application? How much time do you spend searching for basic facts or manufacturer's specifications? This book is the answer, it covers resistors, capacitors, inductors, semiconductors, logic circuits, EMC, audio, electronics and music, telephones, electronics in lighting, thermal considerations, connections, reference data.

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PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain
This is not a book of theory. It is a book of practical tips, hints, and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialized.

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

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F. A. Wilson
This book is not for the expert but neither is it for the completely uninitiated. It is assumed 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 Displays are discussed. Chapter 7 details four different types of Lasers before concluding with a chapter on Fibre Optics.

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F. A. Wilson C.G.I.A., C.Eng., F.I.E.E., F.I. Mgt.
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 processes. It then looks at the part digital has to play in the ever expanding Information Technology, especially in modern transmission systems and television. It avoids getting deeply involved in mathematics.

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183 pages **Order code BP376** **£4.95**

Project Building

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including:

Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

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R. Bebbington
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Most of the projects can be simply screwed together, by following the layout diagrams, in a matter of minutes and readily unscrewed if desired to make new circuits. A theoretical circuit diagram is also included with each project to help broaden the constructor's knowledge.

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R. A. Penfold
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IC555 PROJECTS
E. A. Parr
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Included in this book are over 70 circuit diagrams and descriptions covering basic and general circuits, motor car and model railway circuits, alarms and noise makers as well as a section on 556, 558 and 559 timers. (Note. No construction details are given.)

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NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photostats of articles are available if required – see the *Back Issues* page for details.

Please check price and availability in the latest issue.

Boards can only be supplied on a payment with order basis.

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(Multi-project PCB)		932	£3.00
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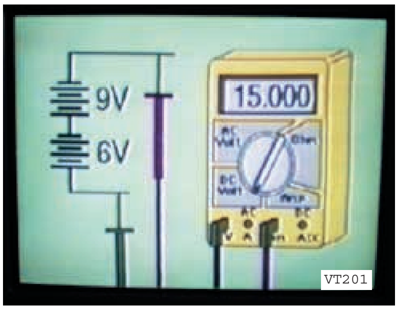

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VT103 35 minutes: A step-by-step easy to follow procedure for professionally cleaning the tape path and replacing many of the belts in most VHS VCR's. The viewer will also become familiar with the various parts found in the tape path. **Order Code VT103**

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VT304 59 minutes. Digital Four; **DAC and ADC** shows you how the computer is able to communicate with the real world. You will learn about digital-to-analogue and analogue-to-digital converter circuits. **Order Code VT304**

VT305 56 minutes. Digital Five; **Memory Devices** introduces you to the technology used in many of today's memory devices. You will learn all about ROM devices and then proceed into PROM, EPROM, EEPROM, SRAM, DRAM, and MBM devices. **Order Code VT305**

VT306 56 minutes. Digital Six; **The CPU** gives you a thorough understanding in the basics of the central processing unit and the input/output circuits used to make the system work. **Order Code VT306**

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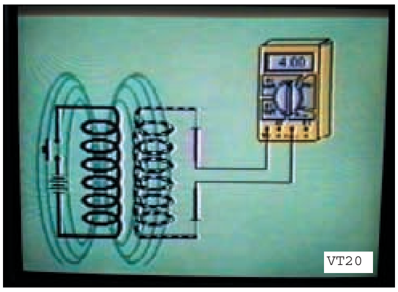
VT402 58 minutes. **F.M. Radio Part 1.** F.M. basics including the functional blocks of a receiver. Plus r.f. amplifier, mixer oscillator, i.f. amplifier, limiter and f.m. decoder stages of a typical f.m. receiver. **Order Code VT402**



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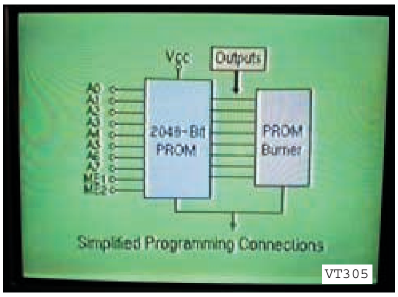

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