THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY

PRACTICAL ELECTRONICS

Vol.31 No.1

CAN $6.99/US $4.95

NOW AVAILABLE TO BUY ON THE WEB

EPE Online www.epemag.com

PIC MAGICK MUSICK

Spell-binding musical entertainment

FOREVER FLASHER

LED flasher with no battery!

TIME DELAY TOUCH SWITCH

Touchpad lighting timeout

PLUS

TEACH-IN 2002 - Part 3
INGENUITY UNLIMITED,
TECHNIQUES, NET WORK

01
0 73361 93008 8
Printed in the UK

http://www.epemag.wimborne.co.uk

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

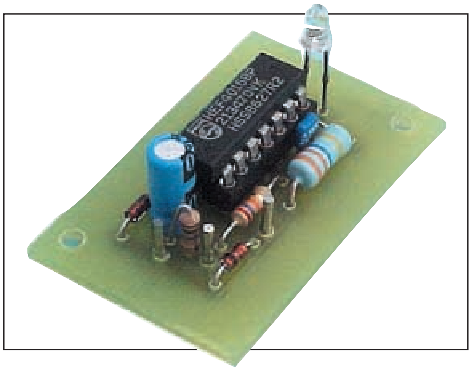
VOL. 31. No. 1 JANUARY 2002
Cover illustration by Jonathan Robertson

EVERYDAY PRACTICAL ELECTRONICS

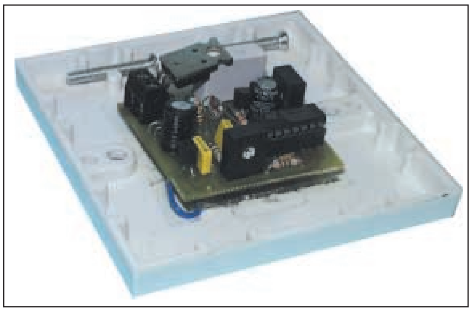
INCORPORATING ELECTRONICS TODAY INTERNATIONAL

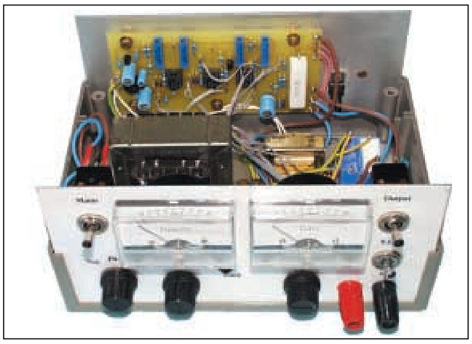
www.epemag.wimborne.co.uk
EPE Online: www.epemag.com

Projects and Circuits



Series and Features



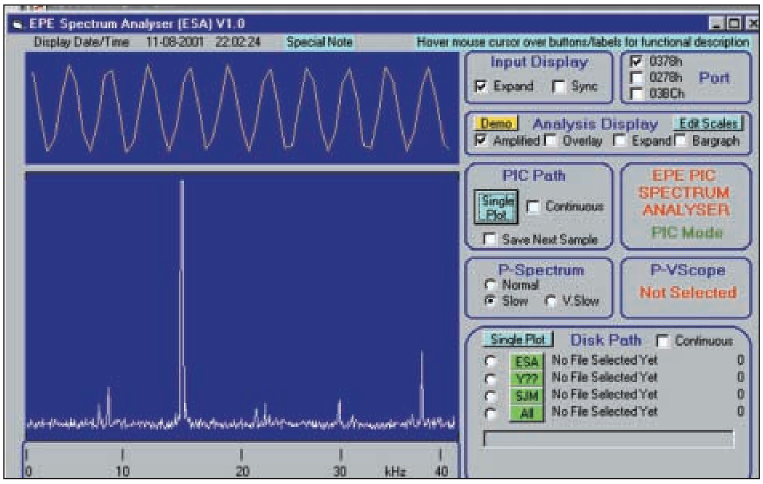


Regulars and Services

Our February 2002 issue will be published on Thursday, 10 January 2002. See page 3 for details

NEXT MONTH

PIC SPECTRUM ANALYSER



A spectrum analyser is a sophisticated workshop tool that allows you to analyse a waveform of any shape and establish which frequencies it contains and at which relative amplitudes.

The design presented here analyses input signals up to about 50kHz and displays frequency content to around 400kHz. A signal interface board is controlled by a PIC microcontroller and outputs digitised data to a PC-compatible computer which analyses the data using a sophisticated, but automatic, mathematical analysis routine and displays it graphically on its v.d.u., the display can also be printed for later analysis. Such displays can assist in improving many types of electronic hardware design.

GUITAR PRACTICE AMP

An easy-to-build, inexpensive, mains powered guitar practice amplifier which will give around 10 watts r.m.s. output, but this can be increased to over 20 watts r.m.s. if required with simple modifications. The unit has inputs for both microphone and guitar, plus loudspeaker and headphone outputs.

HT POWER SUPPLY

This power supply unit is primarily designed for use with battery powered valve radios that require a high tension (HT) supply of about 90 volts at a current consumption of up to 10 milliamps or so. The batteries for these receivers are now unobtainable, and they were pretty expensive when it was possible to buy them.

This simple inverter design provides three switched outputs of 67·5V, 90V and 120V d.c. for use with various "portable" valve radios.

PLUS: TEACH-IN 2002, Part 4
AND ALL THE REGULAR FEATURES

NO ONE DOES IT BETTER

EVERYDAY PRACTICAL ELECTRONICS
INCORPORATING ELECTRONICS TODAY INTERNATIONAL

DON'T MISS AN ISSUE – PLACE YOUR ORDER NOW!

Demand is bound to be high

FEBRUARY 2002 ISSUE ON SALE THURSDAY, JANUARY 10

EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 31 No. 1 JANUARY 2002

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL
WIMBORNE PUBLISHING LTD., 408 WIMBORNE ROAD EAST,
FERNDOWN, DORSET BH22 9ND
Phone: (01202) 873872. Fax: (01202) 874562.
E-mail: epe@wimborne.co.uk
Web Site: http://www.epemag.wimborne.co.uk
EPE Online www.epemag.com
EPE Online Shop: www.epemag.wimborne.co.uk/shopdoor.htm
See notes on **Readers' Enquiries** below – we regret lengthy technical enquiries cannot be answered over the telephone.
Advertisement Offices:
EVERYDAY PRACTICAL ELECTRONICS ADVERTISEMENTS
MILL LODGE, MILL LANE
THORPE-LE-SOKEN, ESSEX CO16 0ED
Phone/Fax: (01255) 861161
E-mail: epeads@aol.com

ELECTRONICS COURSES?

A letter received this month indicates that whilst UK colleges have the facilities to offer electronics courses, many do not get enough suitable applicants so the facilities stand unused and courses are not run. However, we know from enquiries made about projects, circuits, components, training material etc., that there are still a good number of people studying electronics. If you have experience of courses not running, lack of candidates, or simply of non-availability, we would be interested to hear from you.

City & Guilds list over 950 UK centres offering IT courses and last year over 1,600 certificates were issued for the introductory level courses on Digital Electronics and Microprocessors. This number has fallen from a high of approximately 1,800 in 1993 but has increased over the last two years from a low of just over 1,000 in 1996. This pattern is mirrored in our sales of p.c.b.s, back issues, books, videos, CD-ROMs etc., which have recently been at their highest level for a good few years.

What worries us is that some of the syllabuses offered have not been changed in the ten years since they were introduced and it would appear that many of the courses on offer do not meet the present needs of the electronics industry.

INCREASE

EMTA, which is the National Training Organisation for engineering manufacture, aims to increase the number of students on modern apprenticeships from the present 26,000 to 36,000 over the next four years. We understand that approximately one fifth of these are electronics-related apprenticeships.

I wonder if potential students (and their schools) actually know what specialist electronics qualifications and training are presently available. It is an area we hope to investigate and to also let you know more about such things as on-line training, like that provided by learndirect (**www.learndirect.co.uk**) and other on-line resources.

Mike Kenward

AVAILABILITY

Copies of *EPE* are available on subscription anywhere in the world (see below), from all UK newsagents (distributed by COMAG) and from the following electronic component retailers: Omni Electronics and Yebo Electronics (S. Africa). *EPE* can also be purchased from retail magazine outlets around the world. An Internet on-line version can be purchased and downloaded for just $9.99(US – approx £7.70) per year available from **www.epemag.com**

SUBSCRIPTIONS

Subscriptions for delivery direct to any address in the UK: 6 months £15, 12 months £28.50, two years £52; Overseas: 6 months £18 standard air service or £27 express airmail, 12 months £34.50 standard air service or £52 express airmail, 24 months £64 standard air service or £99 express airmail.

Online subscriptions, for downloading the magazine via the Internet, $9.99(US – approx £7.70) for one year available from **www.epemag.com**.

Cheques or bank drafts (in **£ sterling only**) payable to *Everyday Practical Electronics* and sent to EPE Subs. Dept., Wimborne Publishing Ltd. 408 Wimborne Road East, Ferndown, Dorset BH22 9ND. Tel: 01202 873872. Fax: 01202 874562. **E-mail:** subs@epemag.wimborne.co.uk. Also via the **Web** at: **http://www.epemag.wimborne.co.uk**. Subscriptions start with the next available issue. We accept MasterCard, Amex, Diners Club, Switch or Visa. (For past issues see the *Back Issues* page.)

BINDERS

Binders to hold one volume (12 issues) are available from the above address. These are finished in blue p.v.c., printed with the magazine logo in gold on the spine. Price £5.95 plus £3.50 p&p (for overseas readers the postage is £6.00 to everywhere except Australia and Papua New Guinea which cost £10.50). *Normally sent within seven days but please allow 28 days for delivery – more for overseas.*

Payment in £ sterling only please. Visa, Amex, Diners Club, Switch and MasterCard accepted, minimum card order £5. Send, fax or phone your card number and card expiry date with your name, address etc. Or order on our secure server via our UK web site. Overseas customers – your credit card will be charged by the card provider in your local currency at the existing exchange rate.

READERS' ENQUIRIES

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

We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply *must* be accompanied by a **stamped self-addressed envelope or a self-addressed envelope and international reply coupons.** All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers (see *Shoptalk*). **We advise readers to check that all parts are still available before commencing any project in a back-dated issue.**

ADVERTISEMENTS

Although the proprietors and staff of EVERYDAY PRACTICAL ELECTRONICS take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are *bona fide,* the magazine and its Publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or in inserts.

The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture.

TRANSMITTERS/BUGS/TELEPHONE EQUIPMENT

We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

Constructional Project

PIC MAGICK MUSICK

JOHN BECKER

Conjure music from thin air at the mere untouching gesture of a finger-tip.

Having enchanted and puzzled his intimate audience with close-up magic, the lone magician raised his hands and made a grand sweeping gesture of departure, punctuated by the downwards glissando of an ethereal harp, conjured as though from thin air.

Later in conversation with the author, the hotel's magical entertainer showed off the splendid capabilities of his Yamaha keyboard. A superb (and probably very expensive) piece of equipment, it seemed an ideal instrument through which to further spell-bind an audience.

Then, with a less dramatic gesture, he passed his hand over a small hole in the top of the keyboard – again the descending scales of a harp were heard. On being questioned, though, all the magician would say was "there's a magic beam"!

INTRIGUED by the foregoing wizardry, the author continued to puzzle for several days about what had actually been meant by the magician's cryptic reply. He did not have an assistant. Was the triggering done by a laser beam being intercepted? Infra-red? Ultrasonics? Quite naturally, thoughts turned to how a similar effect plus individual note playing could be achieved as a hobbyist electronics project.

This, then, was the inspiration for PIC Magick Musick, and the following discussion tells how it is achieved (without, we hope, triggering the wrath of the Magic Circle)!

HOW TO PERFORM MAGIC?

At first, optical techniques in the form of laser or infra-red diodes and detectors seemed attractive.

It soon became apparent, however, that whilst these could be used to readily trigger a preset series of consecutive notes, it would be extremely difficult to use them if individual notes were to be triggered according to the height at which the optical beam was intercepted.

Theoretically, it is possible to measure the time lag between a light beam being emitted and its reflected return from a passing hand. Regrettably, though, the speed of light is too Einsteinian-fast for its delayed reflection to be timed by the electronic components typically available to the average hobbyist.

The speed of light is generally taken to be 300,000 kilometres per second (186,000 miles per second). To time its transition across one metre, therefore, would require a detector and timing circuit that could respond in at least 1/300,000,000 of a second.

The response time would need to be even greater if distances varying by only a centimetre or two were to be differentiated. No, such cosmic speeds are beyond hobbyist monitoring!

Optically measuring distance can also be done by sensing the amount of light reflected when a beam of known intensity is emitted. This, though, would require the target to have a known and constant reflectivity. Hands, by their very human nature, have widely differing reflective qualities. The target's angle to the source would also be critical so that none of the beam's intensity became reflected away from the detector. This rules out a waving hand as the target.

What about interferometry, measuring the phase difference between emitted and reflected light beams? Huh! Who's going to pack that amount of equipment into a box portable enough for gigging stage work? Not even the National Physical Laboratory, that's for sure!

Ultrasonics, then – what about that? Ah, now we're getting somewhere reasonable. Sound travels at a mere 332 metres per second, roughly. It's far more easy to measure short distances using ultrasonic transmitters and receivers. It has been proved in *EPE* several times, using pulsing timing techniques in the author's *Ultrasonic Tape Measure* (Nov '98), for instance, and phase differences in the rain sensing circuit of his *EPE Met Office* (Dec '95/Jan '96).

Magick Musick can drive almost any sound output, large or small.

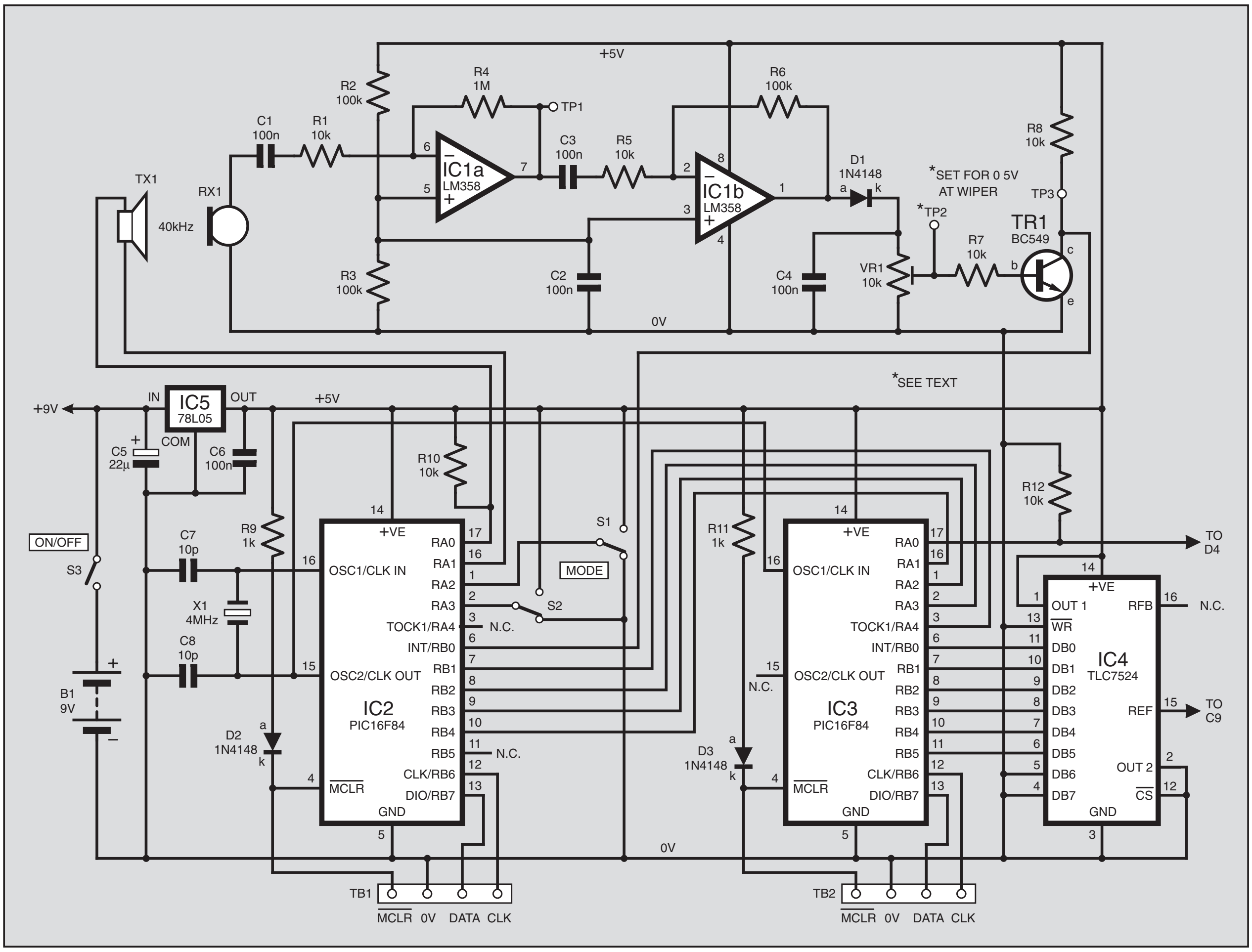


Fig.1. Circuit diagram for the ultrasonic transducers and dual-PIC controllers.

ULTRASONIC ECHOES

In pulse timing techniques, allowance has to be made for the fact that the mutual proximity of transmitting and receiving transducers causes a "ringing" in the latter during transmission. Even so, with careful hardware or software design it is possible to "mask-out" the ringing and detect only the echo pulses. Distances as close as a few centimetres can be readily measured using this method.

This is the technique used in PIC Magick Musick. A 40kHz ultrasonic transmitter constantly emits six square wave pulses approximately every 140 milliseconds, about seven batches per second (7Hz). After each batch, and following the conclusion of a "masking" period, the return of an echo signal is timed using a synchronised counter. The count value is then related to a look-up table which allocates a particular note frequency to be generated.

For each new note value allocated, an envelope shaper is triggered, which causes the note to be emitted by a loudspeaker or headphones, or sent to a normal domestic amplifier. It starts at full required signal strength and progressively decays in amplitude until it finally ceases. If the next pulse detects a distance significantly different to the previous one, another note is similarly played.

The circuit is designed so that the detection range starts about 20 centimetres above the transmitter and extends for about a further half metre. There are 15 trigger "zones" within that range allowing two octaves to be covered in eight steps per octave (just the "white" notes on a keyboard – there are no sharps or flats), from C to C″ (131Hz to 523Hz). Approximately two centimetres separate each note.

By inserting a hand or other object into the transmission beam at different heights, different notes can be triggered. Triggering occurs not only vertically above the sensors, but also within a "cone of sensitivity". This means that adjacent notes can be triggered even though the hand remains at the same height.

Triggering can occur as rapidly as the transmission pulses are generated, even though the envelope shaper has not allowed the previous note to die away fully. Only single notes can be played, however. It is not possible to create chords.

MODE VARIETY

Variety is added to the unit in various ways. The preceding description is for the principal mode, in which all 15 notes can be triggered. A secondary mode allows just four notes per octave (seven across two octaves) in musical order 1, 3, 5, 8 – e.g. C, E, G, C′ (the notes that would make up a major chord on a polyphonic instrument).

Two other modes can be switched in as alternatives. In the first of these, there are four repeating preset sequences of notes which are triggered by a single pass of the hand anywhere within the detector's range. The first generates a descending 15-note scale. The next hand-pass causes the same 15 notes, but in ascending note order. Next, a descending 7-note scale (C″, G′, E′, C′, G, E, C) is triggered. At the fourth triggering the same seven notes are repeated in ascending order. The cycle then repeats.

The other option plays notes determined by values held in the PIC's data EEPROM (up to 64 notes). There is a pre-loaded sequence created by the author. Readers having PIC programming facilities, such as offered by *EPE PIC Toolkits Mk2* and *Mk3 (TK3)*, can create their own sequences as text files and program them into the data EEPROM using the Send Message facility (which the leaves the main program itself untouched).

CIRCUIT DESCRIPTION

The circuit diagram for the PIC Magick Musick ultrasonic processing and control system is shown in Fig.1.

The first point of interest is that *two* PIC microcontrollers are used, IC2 and IC3. They operate synchronously at 4MHz as set by crystal X1, which is in circuit with IC2.

Early attempts to use a single PIC to control the ultrasonic signal and generate musical notes simultaneously proved to be unsuccessful. It was decided, therefore, that with PICs being so inexpensive, two would be used. IC2 controls the ultrasonic transmission pulses and performs the timing of their reflected return. It repeatedly transfers the echo delay values to the second PIC, IC3. This generates the required notes in response to the timing values received from IC2.

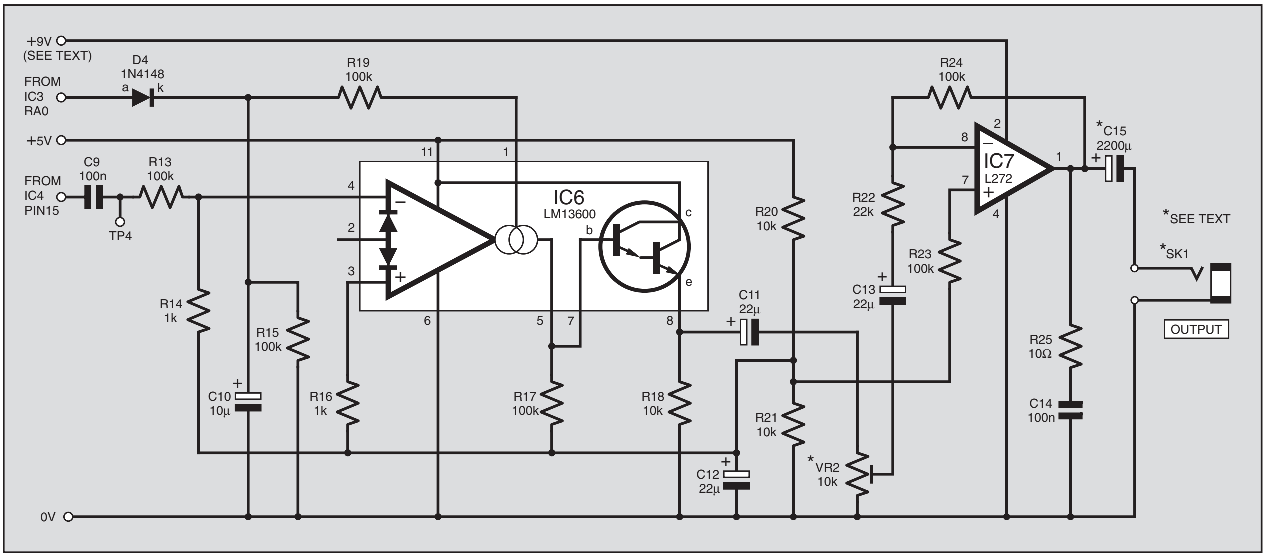


Fig.2. Envelope shaper and audio output stages.

Pins RA0 and RA1 of IC2 output brief push-pull 40kHz pulses to transmitter TX1. Echoes are detected by receiver RX1 and amplified by the serial network comprising op.amps IC1a and IC1b.

The op.amps are biased to a half-rail voltage (2·5V) by the potential divider consisting of resistors R2 and R3. Amplified pulses are output from IC1b pin 1 and are half-wave rectified by diode D1. Capacitor C4 charges to a d.c. level set by the positive-going amplitude of the rectified signals, superimposed on the 2·5V bias.

Preset potentiometer VR1 has two functions: it sets the trigger level to which transistor TR1 responds, buffered by resistor R7, and provides a discharge path for capacitor C4. The voltage at the wiper of VR1 is set to about 0·5V, just below TR1's turn-on level of about 0·6V.

In the absence of an echo pulse, TR1 stays in a turned-off condition, with its collector (c) at +5V. On receipt of pulses above its trigger level, TR1 is turned on and its collector voltage falls to a saturation level close to 0V, as governed by load resistor R8.

MASKED COUNT

Controller IC2, having transmitted each ultrasonic pulse sequence, waits for the brief "masking time" referred to earlier, and then starts a counting sequence. On detecting a negative-going echo pulse from TR1, it stops the count and analyses its value.

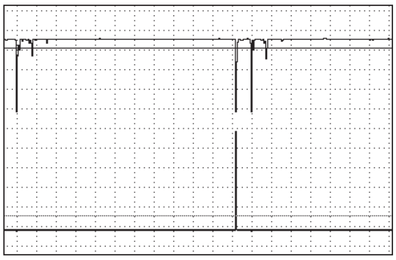


Fig.3. The lower trace shows the ultrasonic transmission pulse. The upper trace shows the "ringing" pulse received during transmission, followed by the required echo pulse, and then by a later, unrequired, minor echo.

If the count is greater than a software-set value, the pulse is considered to have arrived too late. This prevents the unit from being triggered, for example, by echoes from the ceiling above it.

If the count is in range, it is allocated to one of 15 sub-ranges, as a value between 1 and 15. This is output as a 4-bit binary code from pins RB1-RB4 to the second PIC, IC3, which receives them via its pins RA1-RA4.

FREQUENCY GENERATION

The software for IC3 causes Port B to constantly increment through 63 steps, roll over to zero and step upwards again. The rate at which it increments is set by 15 subroutines, each of which has a different rate of increment. The binary code received from IC2 determines which sub-routine is in current use. As soon as the code changes, so does the sub-routine. The rate at which the counter increments determines the audio tone that is ultimately heard.

The output from Port B is fed as a 6-bit value to the 8-bit digital-to-analogue converter (DAC) IC4, Texas Instruments type TLC7524, whose bits 6 and 7 are held permanently low. It is configured in the mode most suited to this application in which a binary input value causes an equivalent d.c. voltage (as opposed to current) to appear at its REF (reference) pin. In this mode the DAC has its two "normal" outputs (OUT1 and OUT2) connected to +5V and 0V, respectively (the device's data sheet, which describes the modes of operation, is downloadable free from **www.ti.com**).

Because the input digital value is constantly counting upwards and then rolling over and so on, the output from DAC IC4 is a rising sawtooth (ramp) waveform. Its frequency is that of the musical note required, lying between 131Hz and 523Hz (musical notes C to C″). The waveform is fed via capacitor C9 and resistor R13 to pin 4 of transconductance amplifier IC6 (see Fig.2).

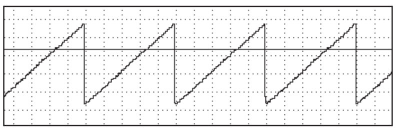


Fig.4. Sawtooth waveform created via DAC IC4.

The reason for using a counter in 6-bit mode is to speed the frequency at which it rolls over (see the later discussion on PIC frequency generation). It also intentionally limits the range of the DAC's output voltage to about 1V peak-to-peak.

ENVELOPE SHAPING

Transconductance amplifier IC6 is a dual device (of a similar type discussed in *Circuit Surgery* Dec '01) of which only one half is used. It is an extremely versatile device that can be used in many signal control applications. Its data sheet and applications notes are well worth studying and using (obtainable via **www.nsc.com**).

In this application it is used as a voltage controlled amplifier (VCA) that is under pulsed control as an envelope shaper (a term much favoured in the "golden" music project days of the 1970s and early '80s). It is controlled by the logic level output from IC3 pin RA0.

On receipt of a value that is greater than zero and different to the previous value received, IC3 briefly sets its pin RA0 high and then returns it low until the next different note value is received from IC2.

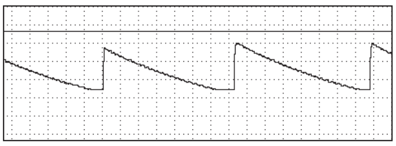


Fig.5. The envelope shaping pulses at capacitor C10.

The output from RA0 is fed via diode D4 (Fig.2) to capacitor C10. The capacitor charges rapidly, and then its voltage ebbs away via resistor R15 (and R19 – more in a moment) once the pulse from RA0 has ended.

The voltage across C10 is also a ramp, rapidly charging to a peak close to 4·3V (+5V – 0·7V voltage drop across D4), and then decaying exponentially in typical capacitor discharge fashion to close to zero volts.

VCA IC6 allows a signal to pass from its input at pin 4 to its intermediate output at

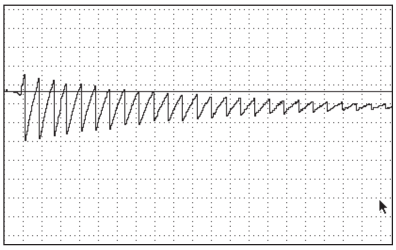


Fig.6. The attack and decay of a note as controlled by the envelope shaper.

pin 5 at an attenuation level set by the current flowing into its control pin 1, and in relation to the value of resistor R17.

The control current is derived from the voltage across capacitor C10 flowing into resistor R19. When C10 is as fully charged as it can be (at the start of the pulse from RA0) the audio signal at pin 4 appears at output pin 8 at the full level required by this application (about 1V peak-to-peak, centred around the midway bias voltage of +2·5V).

When the pulse ceases and the charge on C10 decays, so does the current flowing into IC6 pin 1. As the current falls, so IC6 progressively attenuates the signal appearing at pin 5. When the control voltage on C10 reaches about 0·5V, attenuation is total, and there is no signal output at pin 5. The note length is about three quarters of a second.

Each musical note thus commences at high amplitude and then decays away. This, together with the sawtooth shape of the waveform, creates a sound that is highly reminiscent of a piano string being struck (perhaps a bit more like a harpsichord).

The current available at IC6 pin 5 is only very small and any significant load placed on it in parallel with resistor R17 would cause the signal amplitude to be reduced. However, IC6 also has a built-in buffer stage, formed by an emitter-coupled Darlington transistor, whose base is connected to pin 5 via pin 7.

The emitter at pin 8 is taken to 0V via resistor R18 and the resulting output voltage is about 1·2V below that at pin 7. The output is a.c. coupled via capacitor C11 to potentiometer VR2 (which may be a preset or a panel-mounted control, as preferred). This controls the maximum signal strength that can be fed to the mini-power amplifier IC7.

AMPLIFIER STAGE

Amplifier IC7 is capable of outputting about 1W of power and is suitable for coupling into loudspeakers or headphones having impedances as low as 8Ω. The output is a.c. coupled via capacitor C15 and may also be fed into the line-input of a normal domestic amplifier system.

The op.amp has a gain of about ×5 and the maximum output level is around 3V peak-to-peak. The inclusion of resistor R25 and capacitor C14 give stability to the op.amp. It is a dual device of which only one half is used.

SWITCHING

Returning to Fig.1, PIC Magick Musick's modes are selected via switches S1 and S2, as follows:

S1	S2	Effect
Off	Off	15-note hand-triggering
Off	On	7-note hand-triggering
On	Off	Automatic scale sequences – cycle of four
On	On	Automatic triggering of user's own theme

POWER SUPPLY

The circuit is basically run at 5V as regulated by IC5, except for the power amp, which is powered at the full voltage of the power supply. The latter may be any d.c. source between about 7V and 15V. A 9V battery may be used (e.g. PP3). Capacitor C15's voltage rating should be increased to 25V for voltages above 12V.

Maximum current consumption will depend on the amplitude output from the power amp. In the prototype the current was about 14·5mA with no audio output, rising to about 80mA when driving an 8Ω speaker at full amplitude with IC7 powered at 9V.

CONSTRUCTION

The printed circuit board (p.c.b.) component layout and tracking details are shown in Fig.7. This board is available from the *EPE PCB Service*, code 332. Assemble in any convenient order you prefer, use sockets for the d.i.l. (dual-in-line) i.c.s, and observe the correct orientation for the polarity sensitive components.

Treat all i.c.s as static sensitive and discharge static electricity from your body before handling them (touch a water pipe or the bare metal of a grounded item of

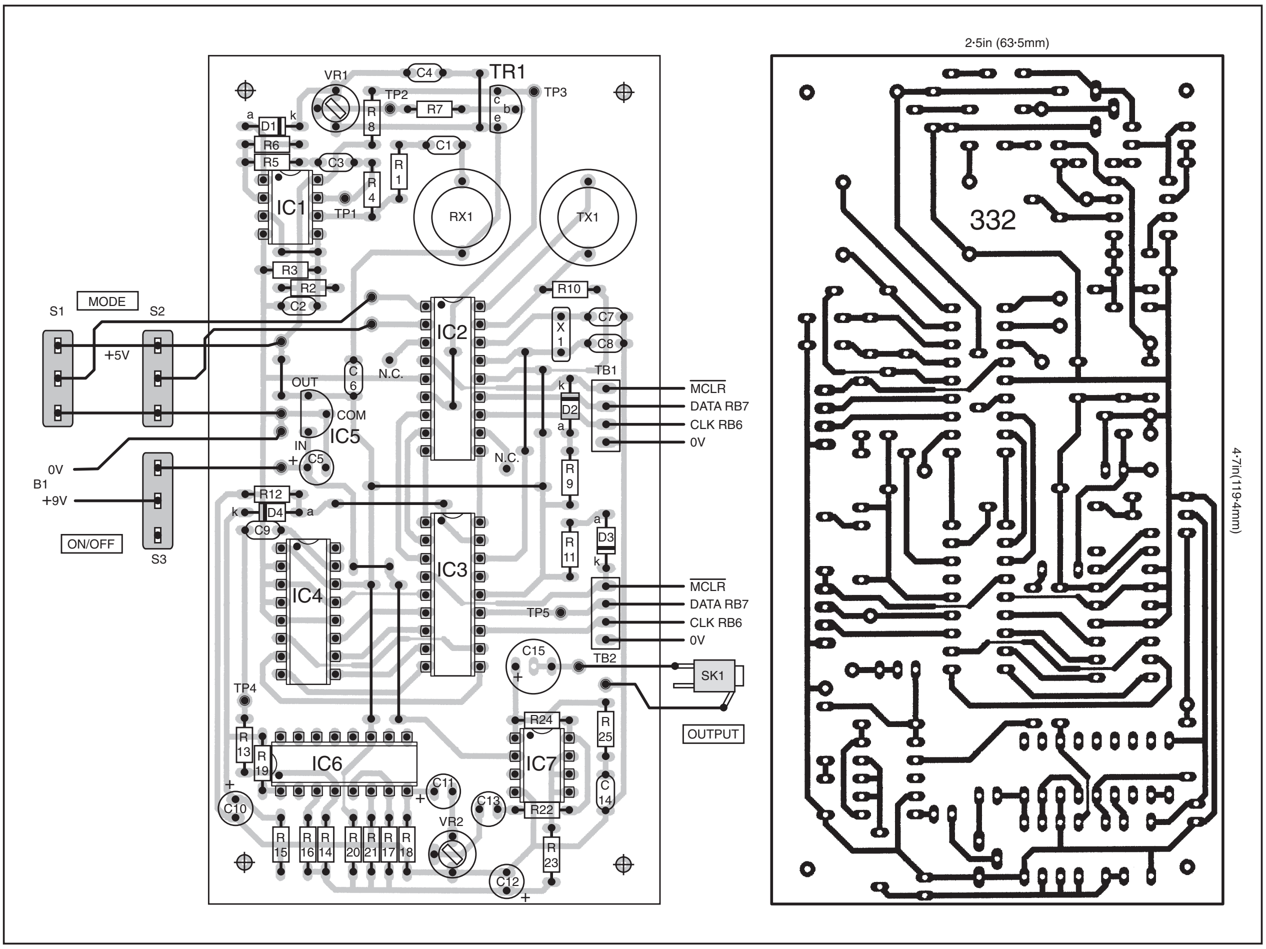


Fig.7. Component layout and full-size copper foil master track pattern.

workshop equipment). Do not insert them until the correctness of your 5V power supply has been established. Once this has been done and assembly completed, you are ready for a bit of magic of your own.

The transducers TX1 and RX1 were mounted on 24s.w.g. enamelled wire 'stalks'' so that they were close to the holes drilled in the lid of the case.

SOFTWARE

Both PICs (IC2 and IC3) are identically programmed. *It does not matter which of your two PICs is put into which IC2/IC3 socket*. The correct transmission or music generation routines are automatically selected depending on the logic level connection made to pin RA0. With IC2, the connection is to the +5V rail via resistor R10. For IC3 it is to the 0V line via resistor R12.

If programming your own PICs using *Toolkits Mk2* or *TK3*, also send file MagicM04.MSG to the data EEPROM via the Send Message option. (It only needs to go to PIC IC2.)

SOFTWARE SOURCES

The software for PIC Magick Music is available on 3·5 inch PC-compatible disk from the *EPE* Editorial office, for which a nominal handling charge is made. It is available for free download from the *EPE* ftp site. More details are given on the *EPE PCB Service* page.

The easiest way into the ftp site, however, is via our UK web site at **www.epemag.wimborne.co.uk**. From the entry screen click on **FTP Site (Downloads)** at the top, drill down through folders PUB and PICS and open folder MagicMusic.

There are three main software files, the source code (ASM written in TASM), and code for sending to the PIC in two formats: OBJ (TASM) and HEX (MPASM). PIC configuration details for TASM users are given at the top of the ASM file. They are automatically embedded in the HEX file.

There are also four example "notes" files for the data EEPROM, MagicMxx.MSG (where xx = 01, 02, 03 and 04).

Readers with *Toolkit Mk2* or *TK3* programmers can program the PICs while in circuit via pin-headers TB1 (IC2) and TB2 (IC3). Components R9, R11, D2 and D3 prevent programming voltages from distressing the +5V supply line.

TESTING

For initial testing, place the assembled p.c.b. on a flat surface facing the ceiling and switch on the power. Adjust preset VR1 so that a voltage of about 0·5V appears at its wiper (and at the base of transistor TR1). Set VR2 to maximum volume position (fully clockwise). Plug in a loudspeaker or headphones.

With the switches set to normal "hand-control" mode (both Off), slowly move your hand in from the side to about half a metre above the ultrasonic transducers. *Let there be music* – and hopefully there will be as a note is triggered by a returning echo!

Moving your hand up and down above the transducers, different notes should be played. You should find that there are minimum and maximum hand distances beyond which the notes will not be triggered (see earlier). Experimenting, you should also find that there is a "cone of sensitivity" around the transducers that causes notes to be triggered when it is entered.

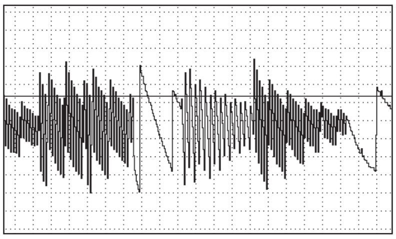
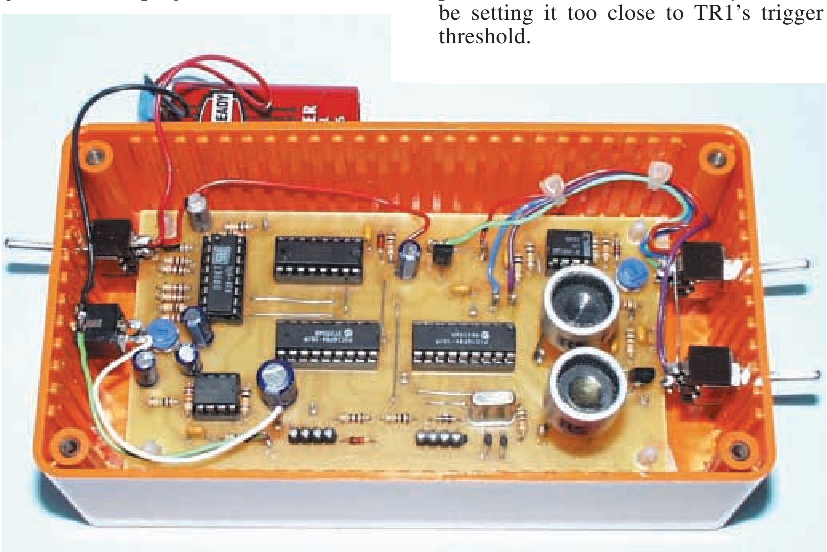


Fig.8. Finger-triggered note sequence.

If you don't achieve immediate success, slightly readjust preset VR1. If the presence of the ceiling is causing triggering (as would be indicated by lifting the board up and down above the bench), reduce VR1's wiper voltage fractionally.

If the triggering range is too small, or non-existent, increase VR1's wiper voltage a bit – but regard 0·55V as being the practical maximum, otherwise you could be setting it too close to TR1's trigger threshold.



Interior layout arrangement. The transducers are mounted on "stalks", see text.

COMPONENTS

See SHOP TALK page

Resistors

R1, R5, R7, R8, R10, R12, R18, R20, R21	10k (9 off)
R2, R3, R6, R13, R15, R17, R19, R23, R24	100k (9 off)
R4	1M
R9, R11, R14, R16	1k (4 off)
R22	22k
R25	10Ω

All 0·25W 5% carbon film or better

Potentiometers

VR1	10k sub-min preset, round
VR2	10k sub-min preset, round, or 10k log rotary, panel mounting (see text).

Capacitors

C1 to C4, C6, C9, C14	100n ceramic, 5mm pitch (7 off)
C5, C11 to C13	22µ radial elect, 16V (4 off)
C7, C8	10p ceramic, 5mm pitch (2 off)
C10	10µ radial elect. 16V
C15	2200µ radial elect, 16V (see text)

Semiconductors

D1 to D4	1N4148 signal diode (4 off)
TR1	BC549 or similar gen. purpose *npn* transistor
IC1	LM358 dual op.amp
IC2, IC3	PIC16F84-4P microcontroller (2 off, identically pre-programmed, see text)
IC4	TLC7524 8-bit digital-to-analogue converter
IC5	78L05 +5V 100mA voltage regulator
IC6	LM13600 or LM13700 dual transconductance amplifier
IC7	L272 dual power op.amp

Miscellaneous

RX1, TX1	40kHz ultrasonic transducer matched pair (transmitter plus receiver)
S1, S2	s.p.d.t. min. toggle switch (2 off)
S3	s.p.s.t. or s.p.d.t. min. toggle switch
SK1	3·5mm jack socket
X1	4MHz crystal

Printed circuit board, available from the *EPE PCB Service*, code 332; 8-pin d.i.l. socket; 14-pin d.i.l. socket; 16-pin d.i.l. socket; 18-pin d.i.l. socket (2 off); 1mm 4-way pin-headers, 0·1in pitch (2 off) (see text); plastic case to suit, 150mm x 80mm x 50mm; 9V battery and clip (see text); enchantable audience (many); connecting wire; solder, etc.

Approx. Cost Guidance Only **£35** *excluding case & batt.*

THEME TUNES

Users of *EPE PIC Toolkits Mk2* and *TK3* will find that writing theme tunes for downloading into PIC IC2's data EEPROM is as easy as writing program code – perhaps easier!

Using your preferred text editor, one way is to write a sequence of 64 numbers whose values lie between 0 and 15, as illustrated in file MagicM02.MSG. Save them as a *Toolkit* Message file (extension .MSG). Then send the file contents to PIC IC3 via *Toolkit's* Send Message option. Job done! Next time you trigger PIC Magick Musick when switch S1 and S2 are both in the On position, your programmed notes will be generated.

A second melody writing technique is to use alphabet letters relating to the notes required, as illustrated in file MagicM01.MSG. Lower case a-f are the notes for octave 1, upper case A-F for octave 2, and upper case H for top C (C″). A further example is in MagicM03.MSG.

But, you may ask, what numbers should I use? Ah, that's where your talents as a composer come into play! The options are shown in Table 1.

Column 1 shows the value to be written into your MSG text file. Column 2 shows the letter that could be entered instead. Column 3 shows the name that is given to the resulting note when its frequency equals that in column 4. Column 5 shows the approximate frequency that should be expected from PIC Magick Musick.

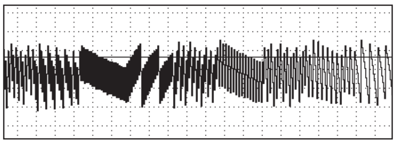


Fig.9. Part of the downwards 15-notes scale.

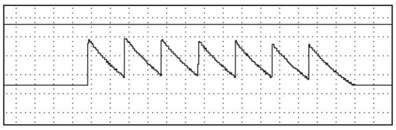


Fig.10. Envelope shaping waveform when 7-note scale is played.

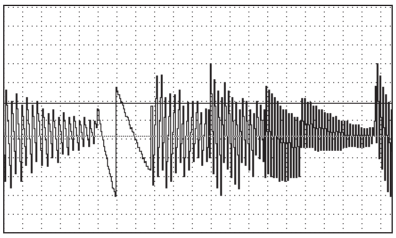


Fig.11. Ascending 7-note scale.

Another option is to use a random melody, created by loading any 64 characters of a text file. This is how the theme pre-installed (MagicM04.MSG) into the PICs is created. It consists of the first 64 characters of the first line in this article (*Having enchanted . . .*).

The software automatically ANDs the ASCII values of the characters with 15, so that they trigger one of the 15 notes available. Spaces, punctuation etc. may all be left in. Any resulting zero value simply creates a pause.

Once triggered, the scales and melody run their full course before another hand movement or switch setting comes into effect.

Table 1. PIC music program note values, musical names, ideal (calculated) and prototype-generated frequencies (the latter may vary slightly between units).

Value	*Alpha*	*Note*	*Ideal Hz*	*Prototype Hz*
0	–	–	none (pause)	
1	c	C	130·813	129·9
2	d	D	146·832	146·9
3	e	E	164·814	163·9
4	f	F	174·615	175·0
5	g	G	195·998	194·5
6	a	A	220·000	222·1
7	b	B	246·941	246·7
8	C	C′	261·625	263·3
9	D	D′	293·664	292·9
10	E	E′	329·627	330·1
11	F	F′	349·229	352·4
12	G	G′	391·995	397·1
13	A	A′	440·000	442·0
14	B	B′	493·883	498·4
15	H	C″	523·251	532·4

FREQUENCY PRECISION

As the author has discussed in previous PIC controlled music generating designs, such as *PIC-olo* (Aug '97) and the *PIC Musical Sundial* (Jun '99), it is impossible to actually program a PIC to generate *truly* accurate musical notes. A compromise has to be accepted.

Software-generated frequencies depend on the time between a register value being taken high and low. For instance, if bit 0 of a Port register is taken high, held there for half a second, and then taken low for half a second, and the cycle constantly repeated, the resulting output at Port register pin 0 is a 1Hz square wave.

It will be obvious that with a PIC's oscillator running at a high rate, timing of the pause lengths between the cycle phases of a slow frequency square wave can be very accurately adjusted, because there are many PIC program cycles that take place during them. Frequency adjustment can be made minutely just by increasing or decreasing the count values between each phase by just one cycle.

In the case of a PIC running at an effective rate of 1MHz (i.e. its crystal clock is running at 4MHz), the precise value of a nominal 1Hz output frequency can be adjusted by a mere one millionth of a second, the duration of just one command.

Look at the other extreme, though. Again suppose the PIC's effective rate is 1MHz and we want to output a frequency via PORTB pin 0 (RB0). The fastest output frequency generating routine is:

```
HERE: INCF PORTB,F
      GOTO HERE
```

Two commands are involved, between them taking 2μs, thus to complete a full square wave cycle takes 4μs, an output frequency rate of 250kHz.

This rate cannot be increased without changing the basic clock rate. It can, however, be slowed by the addition of one command, NOP for example. There are now six commands to the square wave cycle, and an output rate of approximately 167kHz. Adding another NOP reduces the rate to 125kHz.

There are no intermediate frequencies that can be generated between either of the above frequency pairs with a 4MHz crystal controlled clock.

LOOPED DELAYS

Although the required output frequencies for a PIC music-generating design are much slower than these examples, a similar principle prevents truly accurate music frequencies being developed.

A simplified example of frequency generation as it is done in PIC Magick Musick is shown in Listing 1.

Listing 1a provides a look-up table in which the PORTA value causes a jump to the correct note generating routine, one of which is shown in Listing 1b.

Here the routine is for note G, which has an approximate frequency of 195Hz. LOOPB is loaded with a delay value of 21, and then is decremented to zero. After two additional delaying commands, a jump is made to the OUTIT routine in which PORTB is incremented, and a jump made back to label TONE.

LISTING 1a

```
ROUTE:  movf VALUE,W    ; VALUE holds code received via
                          PORTA
        andlw 15        ; it's limited to 15
        addwf PCL,F     ; added to the Program Counter, to
                          cause a value related jump:
        goto BVL        ; 0 not used
        goto CL         ; 1
        goto DL         ; 2
        goto EL         ; 3
        goto FL         ; 4
        goto GL         ; 5
        goto AL         ; 6
        goto BL         ; 7
                        ; etc
```

LISTING 1b

```
TONE:   goto ROUTE      ; do required table jump
GL:     movlw 21        ; set loop val for note 5, G 195Hz
        movwf LOOPB
GLa:    decfsz LOOPB,F  ; decrement loop until zero
        goto GLa
        nop             ; timing adjustment
        nop             ; timing adjustment
        goto OUTIT      ; go and increment PORTB output
                          value
                        ; other note generators here
OUTIT:  incfsz PORTB,F  ; is PORTB value zero?
        goto TONE       ; no
        (yes, so get PORTA value routine here)
        goto TONE
```

Even though it is known that the PORTA value has not been changed at this time, the seemingly unnecessary jump again to the look-up table helps to keep the frequency generation even.

When PORTB rolls over to zero, PORTA is read for its current value. If the value is the same as the previous sample, note G routine is again repeated. If a new value is found, the table automatically routes to the appropriate delay routine.

Each note's delay routine has a different LOOPB value, and varying quantities of NOP commands. These help to "tune" the frequency as close as possible to that ideally required.

In the note G example shown, the actual frequency required is 195·998Hz. The prototype produced a frequency of 194·5Hz (measured on *PICGEN* of July '00). Deleting one NOP to raise the frequency generated 196·9Hz. Adding one more NOP to slow it, resulted in 192·2Hz.

As illustrated earlier, the higher the required frequency, so it becomes increasingly difficult to tune software to produce it. Where the decision has been marginal, the author has generally erred for a frequency fractionally higher than the ideal.

WAVEFORM SHAPE

It may at first sight seem that the note loops have a low value compared to the frequency expected when using a 4MHz crystal clock. Had just PORTB pin 0 been the frequency output source, generating a square wave, much higher loop counts could have been used, allowing much tighter control of the actual frequency being output.

However, the aim with PIC Magick Music was to generate a non-square waveform. Experiments were tried using sine and triangle generating algorithms, but a sawtooth was felt to produce a more interesting sound.

Its generation, though, takes 64 clock cycle steps at PORTB (used as the 6-bit counter referred to earlier), bringing the note delay loop rates down by the same amount. Originally, 256 PORTB steps were tried, but the frequency results were too low to be acceptable.

Using 256 steps (8-bit) also produced a waveform amplitude greater than required to suitably drive the power amp via the envelope shaper. The 6-bit value basically results in a DAC output swing of about 1V peak-to-peak.

WIZARD FUN!

Whilst music "purists" may wonder if some notes have a frequency that might not be fully welcomed in a concert hall, remember that PIC Magick Musick is an inexpensive *fun* design. Had greater tuning accuracy really been desired, considerably more complex techniques would have been needed – at much greater cost.

When PIC Magick Musick was demonstrated at *EPE* HQ, the author was delighted by the positive response it received. It is, he has to say proudly, a super little design which can generate lots of fun for anyone using or hearing it. You've just got time before the festives to build one, and maybe even program it with an appropriate jingle.

Magick Season's Greetings from a would-be PIC Wizard!

The waveform "screen dumps" were created via the author's *PIC Dual-Channel Virtual Scope* of Oct '00. □

News . . .

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

BLOWING UP THE AUDIO

Patented inflatable audio speakers are capable of producing stereo sound - whatever NXT? asks Barry Fox.

LOUDSPEAKERS are big heavy boxes containing air, that are awkward and expensive to move around. Soundtube in Utah and Ellula in the UK have been thinking laterally about this. Both companies are working on inflatable speakers which fold flat. Users just put air in when they get where they are going.

Conventional speakers use an electromagnetic transducer with cone diaphragm that pumps air. The transducer is mounted on the front panel of a sealed cabinet, sometimes with an air vent. Large transducers in large boxes are needed to generate loud sound. Rock groups must hire large trucks to ship speakers around the country, with tough "roadies" to hump and heave them onto the stage.

Soundtube Entertainment (**www.soundtube.com**) makes speakers for entertainment and sports venues, as well as churches. The company says it takes a "unique approach to design" and is now developing inflatables that rock groups can carry flat and blow up when they arrive. The company is cagey about details but patents filed around the world (WO 01/54541) describe an "inflatable speaker assembly".

A conventional cone transducer is bolted to a flat rigid board, and the board is bonded to a large bladder. When compressed gas is released into the bladder, it expands to form a light enclosure that resembles a conventional cabinet. Fire retardant gas or powder can be used for safety, and the bladder has several chambers so that a puncture does not collapse the entire structure. At the end of the gig, the roadies use a vacuum pump to flatten the bladder.

"Getting the structure rigid is the challenge" admits a company spokesman.

Watered Down

Twenty years ago British speaker company Wharfedale had a similar idea; light hollow cabinets would be shipped empty and then filled with water to give them strength, mass and rigidity. But the clever design never escaped from Wharfedale's research lab.

British company Ellula Sounds (**www.ellula.com**) is a spin-off from Loughborough University which licensed the flat panel speaker system developed by British company NXT. Ellula will soon sell small inflatable speakers, like gaily-coloured audio beachballs, for use with portable stereos and PCs. The flat panel produces sound which makes the entire inflatable resonate. Ellula's inflatable portables will cost around £30 a pair.

The Ellula inflatable neatly sums up the way NXT's plans have changed in the five years since the company was founded.

NXT's Arrival

New Transducers Ltd was launched in late 1996 by Farad Azima of Mission and parent Verity, with high profile plans for flat hi-fi loudspeakers. The industry was pleasantly surprised at the sound quality, although low bass had to be generated by a separate, conventional driver. Verity had bought public address technology from the MoD's Defence Research Agency, and given it hi-fi potential.

Since then NXT has filed literally thousands of patents around the world on virtually every conceivable use for flat speakers. This is a very expensive strategy, which commits the company to payment of official Government fees, patent attorney fees, translation costs, the cost of arguing the applications through Patent Offices and then paying annual renewal fees for up to 20 years.

Although NXT will not say how much this is costing, its annual report shows operating expenses and losses of around £15 million a year; share price has fallen from inflated highs of over £25 to the current depressed and depressing level of around £1.

"What the city worries about", says Andrew Williams, NXT's new marketing director, "is whether we have enough money to see us through until the business starts making a profit".

Currently NXT has around £22 million in the kitty, most of it raised from investors who bought shares in the company and have now seen their value plummet. Farad Azima has stepped down as chairman and David Pearson, formerly with Sony UK, came in as chief executive in March 2000.

Short on Hi-Fi

There is still only one genuine hi-fi product, the Icon, costing £2500 per pair and made by Cyrus, owned by NXT. The Icons are floor-standing cabinets with built-in conventional low frequency drivers. All the other NXT speakers are lo-fi, mid-fi, packaged with home cinema system or novelties like the Ellula inflatables.

"There are more projects in the automobile industry, and for phones and consumer audio, but we are not allowed to talk about them until they are ready", says Andrew Williams. "We expect to see car systems in 2004 or 2005 and telephones by 2003."

"We are committed to husbandry of our resources and rationalizing costs", says Andrew Williams, confirming that this means no longer patenting everything in all countries and "prioritising with different levels of protection in different countries, based on different levels of importance".

For more information contact New Transducers Ltd, 37 Ixworth Place, London SW3 3QH. Tel: 020 7343 5050.
Fax: 020 7343 5055.
Email: marketing@nxtsound.com.

BROTHERLY LABELLING

THE Brother P-Touch 1250 labelling machine seems just the job for the home electronics constructor who wishes to label workshop storage boxes and other containers.

The unique navigation dial and true QWERTY keyboard make the PT-1250 simple and convenient to use. Not even scissors are necessary as the machine will cut the label to your required length with one click of a button. Different text sizes, fonts and formats and two-line printing are also easy to achieve, and you can clearly see what's been typed via the 8-character display screen.

The PT-1250 costs around £50 and can be run off either a mains adaptor or batteries. It can be purchased through branches of stationery company Staples. Other stockist information and brochure requests can be obtained through Brother, tel: 0845 6060 626, or via web site: www.brother.co.uk.

TABLE-TOP TV REDEFINED

LG Electronics tell us that they have demonstrated a prototype of what they call a "table-top" TV screen – size 52 inches (132cm)!

Apparently, the screen uses Texas Instruments' Digital Light Processing technology. At its heart is the Digital Micromirror Device optical sensor chip. This has an array of up to 1,310,000 hinged, microscopic mirrors which operate as optical switches to create a high resolution, full colour image (visit **www.dlp.com**).

The technology is widely used in a broad range of projection and display applications. It is said to achieve the clearest, sharpest, brightest and most accurate images.

A number of manufacturers are expected to announce home entertainment products based on the technology during 2002. But calling a 132cm screen "table-top" seems extraordinary. Where do you put the food plates with *that* in front of you? Puts a new light on the phrase *TV Dinners*, though!

ESR's New Cat

ESR Electronic Components have sent us their latest catalogue, 54 pages of it, not to mention the numerous additional flyers and enclosures. ESR have established themselves as company upon whom readers can rely for an extensive range of those components that are vital to the everyday business of managing our hobby. You will no doubt be aware that ESR have a selected range of kits for *EPE* constructional projects.

Not only does the catalogue contain wide varieties of passive and active components, from capacitors to semiconductors, but it also has a good range of printed circuit board production materials, from drills to laminates, chemicals to etching tanks and guillotines. Also featured are books and camera modules.

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

Email: sales@esr.co.uk.

Web: www.esr.co.uk.

Mini Humanoids

FUJITSU Automation and Fujitsu Laboratories have announced that they have jointly developed a new miniature humanoid robot, named HOAP-1 (Humanoid for Open Architecture Platform). HOAP-1 has been designed for wide applications in research and development of robot technologies.

Weighing 6kg and standing 48cm tall, the light and compact HOAP-1 and accompanying simulation software can be used for developing motion control algorithms in such areas as two-legged walking, as well as in research on human-to-robot communication interfaces.

For more information: **www.fujitsu.com**.

Anti-vandal Cam

STORTECH Electronics' Pecan range of security cameras has been installed onto 550 West Midlands buses and they are successfully deterring vandalism, which is reported to cost the bus company, Travel West Midlands, around £1 million a year on its fleet of 1800 buses.

The buses typically have three to four cameras strategically placed and connected to a duplex multiplexer that rapidly scans between cameras. The driver has a small liquid crystal display in the cab which can show one or four images at any one time. All camera video activity is recorded for possible police use. Originally recording was made onto tape, but more recent installations record the data digitally.

Stortech's Pecan range of high quality CCTV cameras includes vandal-proof, covert, discreet and weatherproof cameras.

For more information contact Paul Freeman-Sear at Vector Marketing Communications. Tel: 01442 877167. Email: paul.freeman-sear@vector.co.uk. Stortech Electronics of Harlow, Essex can be contacted directly through Paul Elsey, tel: 01279 419913.

Robot Show

PRACTICALLY everyone with an interest in robots will no doubt wish to attend *The Robot Show* at Olympia in London next year.

For three days, 5 to 7 July 2002, thousands of professionals, research students, enthusiasts and consumers, are expected to visit Olympia to see the biggest display of all the latest robotic devices, developments and applications ever under one roof.

Manufacturers will have an opportunity to attract the best emerging talent in robotics and demonstrate just how far robot automation influences our lives now. They will also meet production/processing heads who will receive personal invitations to the show.

The show will bring researchers and manufacturers together and help hundreds of companies and organisations to successfully target an audience fascinated with robots. Interactivity is a feature of the show with many exhibitor-led demos and competitions, in addition to the show demos.

Visit web site **www.robotshow.co.uk** for information on the exhibition, demonstration arena, seminar programme, floor plans and visitors. Otherwise, phone Malcolm McGow on 0207 610 3001, mentioning *EPE*.

FML Electronics

THE 2002 mail order catalogue for FML Electronics has arrived at HQ. "Extremely detailed" is the first phrase that comes to mind when looking at its 24 A4-size pages full of compact columns of condensed type. The first 12 pages are entirely filled with semiconductors - it seems that if it's not listed here it's probably not available anywhere!

The remaining pages cover non-semiconductor items, such as resistors, capacitors, switches, p.c.b. materials, relays and solenoids. Computer and office equipment is featured, as are surface mount devices and development packs.

FML welcomes all enquiries, including those from schools, Government and the Trade, and of course, hobbyists.

For more information contact FML Electronics, Dept *EPE*, Freepost NEA 3627, Bedale, N.Yorks DL8 2BR.

Tel: 01677 425 840.

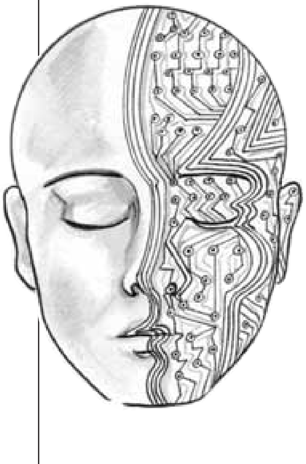
Email: fml.electronics@breathemail.net.

Lighter Snoring

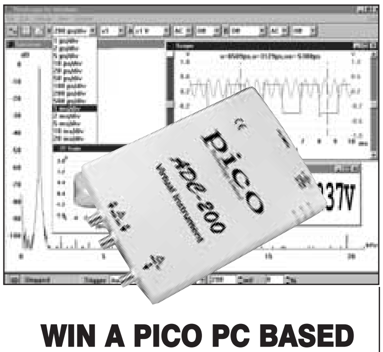
SLEEPING partners, and their pets, may be excused hoping that Graham Brooks of Stockport does not have too much success with his recent patent, GB 2359 490.

Brooks noticed that people stop snoring when there is lightning. Because lightning is not available to order, he built a modified xenon photo strobe which is placed near the snorer's head and emits 12 flashes a second for five seconds. The flasher is triggered by a sound sensor which has memorised the individual snore pattern of the snorer.

He says the system has also been "successfully used to abate snoring in dogs and other animals".



INGENUITY UNLIMITED



Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit 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., 408 Wimborne Road East, Ferndown Dorset BH22 9ND. (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.

Precision UV Timer – Get It Right

FOR consistent results when producing printed circuit boards, precise control of the ultra-violet exposure period is important. The circuit diagram shown in Fig.1 is intended to control a UV exposure box, but it could easily be adapted to control any mains powered device that needs to be switched off after a few minutes.

The circuit works by dividing the very accurate 50Hz (UK) mains signal by 1500 to give a high output every 30 seconds, which is then used to clock a decade counter for a pre-determined amount of time. This in turn operates a relay to cut the power to the controlled device.

Mains power is applied via switch S1 to the primary of transformer T1, which can have an output from 5V to 15V a.c. (the writer used 12V – *ARW*). Before the output from T1 is rectified and smoothed, the a.c. waveform is rectified via diode D7 and passed to the clock input of IC1, a 12-stage binary counter. When the circuit is initially turned on, a high pulse is produced by capacitor C2 which resets IC1 and decade counter IC3 via diodes D5 and D6; the logic can also be manually reset by pressing switch S2.

After 30 seconds, the Q3 to Q5, Q7 to Q9 and Q11 outputs of IC1 as shown, go high and are fed into IC2, a triple 3-input AND gate configured as a 7-input AND gate. Both IC1 and IC2 combine to act as a divide by 1500 circuit, which produces a high output pulse every 30 seconds. This output is used to reset IC1 via diode D8 and is also used as the input for IC3.

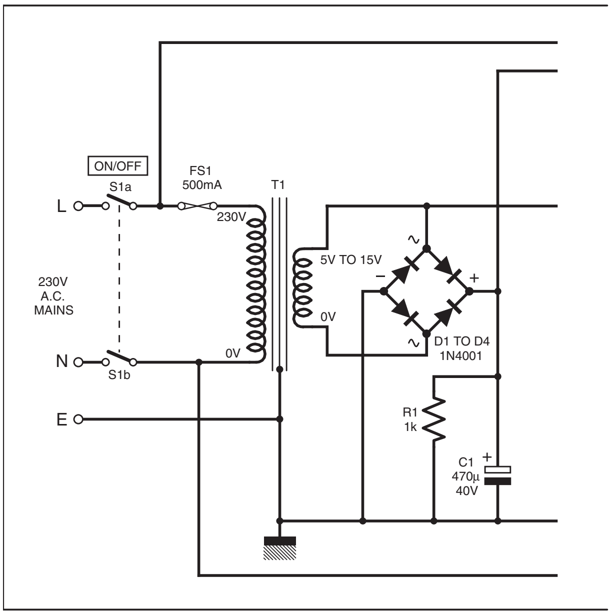
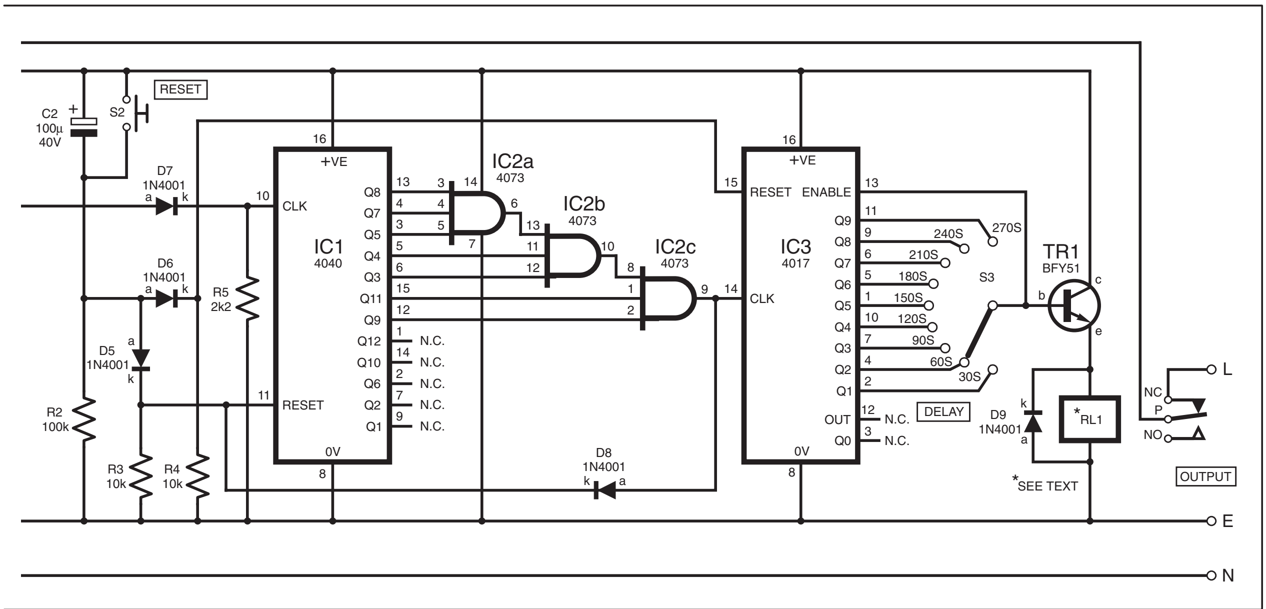
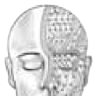


Fig.1. Precision UV Timer circuit diagram. Switch S3 gives a delay of 30 seconds to 4½ minutes.



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



Delay switch S3 selects the desired Q1 to Q9 outputs of IC3; Q1 produces a 30 second delay after which the load will be switched off. The other outputs increment in 30 second steps up to 4½ minutes.

Once the pre-determined period has elapsed, the Enable input (pin 13) of IC3 is held high which disables further counting. With the output of IC3 latched high, transistor TR1 (any general purpose medium *npn* transistor) switches on relay RL1. This must have the same coil voltage to match mains transformer T1 and have mains-rated contacts. It breaks the normally-closed contacts thus turning off the load.

If you live in a country that uses a 60Hz mains frequency then IC1 and IC2 should be re-arranged to make a divide by 1800 circuit.

Ian Hill, Crabtree, Plymouth, Devon

Our apologies for omitting the author's name for the **AM Tuning Aid** *published in December 2001 issue (p.879) – it was written by one of* **EPE's** *longest-standing and most popular contributors, George Hylton, best known for his "Down to Earth" column in* **EPE.**

Transistor/Diode Checker – Go/No Go

THE simple but useful Transistor/Diode Checker circuit shown in in Fig.2 was designed to check the basic function of transistors i.e. *go* or *no-go*. As none of the component values are critical it can be built with components from the scrap box. The circuit diagram is based around a 4011 quad 2-input NAND gate but because the inputs of all the gates are tied together as an inverter, a 4001 could be used.

The main part of the circuit is an oscillator (IC1a and IC1b) of approx. 250Hz which drives the emitter probe (E). Gate IC1c inverts the pulse and drives the base terminal (B) of the transistor under test via resistor R2. The collector (C) is driven through l.e.d. D1 (a bi-colour type was used but two single l.e.d.s would be fine).

With an *npn* transistor connected a low pulse from pin 4 is inverted by IC1c thus making base current flow, now with the transistor conducting, current flows through the red section of l.e.d. D1 to the collector. A *pnp* transistor is detected on a high pulse from the clock and short-circuited devices are shown by both l.e.d.s being on (or amber if a bi-colour l.e.d. is used).

Discrete diodes can also be checked using the collector and emitter test points.

M. James, Billingham, Cleveland

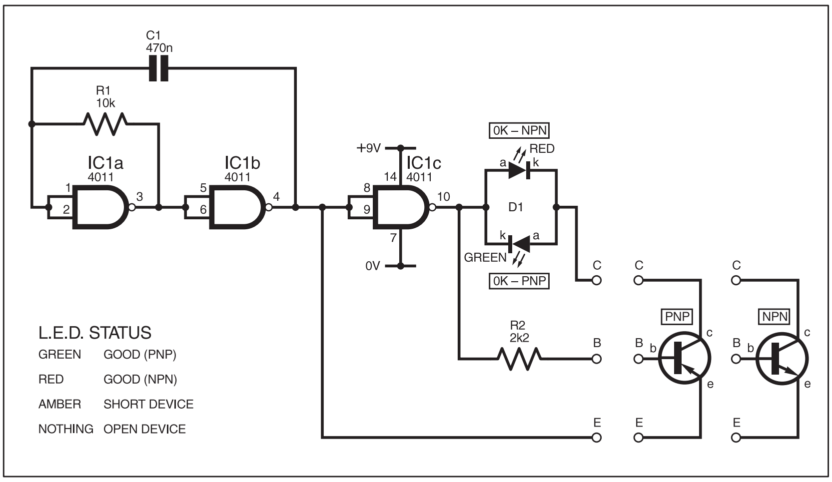


Fig.2. Circuit diagram for a simple "go/no go" Transistor/Diode Checker.

TIME DELAY TOUCH SWITCH

BART TREPAK

Automatically turns off lights after a preset period

GLOBAL warming in relation to our use of energy is a subject that is heavily debated. A major use of energy is the consumption of electricity in our homes and industries. Perhaps the most obvious waste of electricity in our homes (although certainly not the largest) is caused by lights being left on in areas when the occupants have left. Nowhere, perhaps, is this more common than in halls and stairways.

Fitting switches which turn off automatically after a preset time in these locations can reduce the electricity consumed quite significantly. A single 100W bulb left burning all night (say eight hours) would consume 800W/hrs. The same bulb fitted with a switch which turned off automatically after say five minutes would consume only 83W/hrs, even in the unlikely event that it were to be activated ten times during this period.

MECHANICAL DELAYS

Commercial time delay switches for stairs and halls are generally mechanical devices which work on the basis of a leaky cylinder. When the button is pressed, air is expelled from the cylinder and a contact is made, so switching on the light. A spring now slowly pushes the cylinder back to its rest position at the limited rate at which air can re-enter the cylinder, eventually causing the contact to be broken and turning off the light.

Although simple enough, being a mechanical system it has many drawbacks. With repeated use, the components making up its valve can become worn allowing air into the cylinder faster, thus reducing the time delay. Additionally, dust and dirt can find their way into the switch, causing it to stick and preventing it from switching off.

Furthermore, the delay also depends on the depth to which the button is pressed, which determines how much air is expelled from the cylinder. As some force is required to do this fully, it can be difficult for elderly or infirm persons. Consequently, those who require the most time to make it up the stairs can end up with the least!

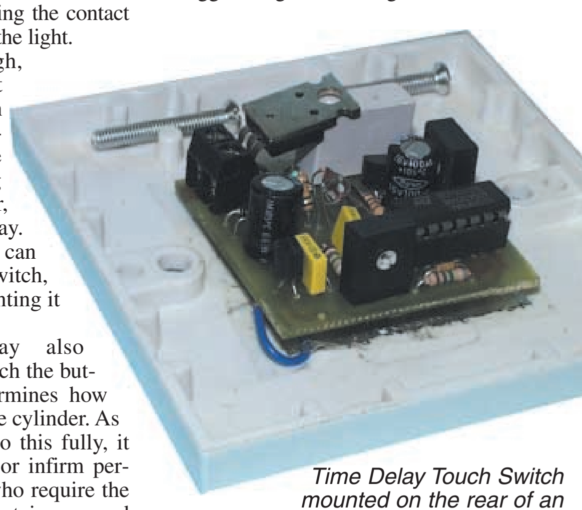
This circuit overcomes these problems by having no moving parts. It is activated by touch and has the added bonus of a small neon light which enables it to be easily located in the dark. The finished unit is mounted on a standard electrical blanking plate and can replace any conventional light switch.

Although intended primarily for conventional incandescent light bulbs, the circuit has also been found to work with low energy fluorescent types.

TRIAC CONTROL

There are two major problems to solve when designing a touch switch to replace a conventional mechanical light switch and these concern the power supply and noise immunity.

The main switching element used to control the light is a triac, a semiconductor a.c. switch. This is normally in its off or non-conducting state but can be switched into conduction by means of a small trigger current fed to its gate terminal. Once triggered it will remain conducting until the current through it drops below a certain value (known as the holding current). This occurs normally on a.c. supplies when the voltage drops to zero at the end of every mains half-cycle, and the triac must be re-triggered again if the light is to remain on.



Time Delay Touch Switch mounted on the rear of an electrical blanking plate.

As with any switch, the voltage across a triac when it is in its off state will be the supply voltage (in this case 230V a.c.). When the triac is on, the voltage across it will be around 1V a.c., depending on the current. The triac therefore dissipates very little power so no heatsink is required.

With normal house wiring, only the Live wire and its feed to the lamp are accessible at the wall-mounted light switch. The Neutral wire from the lamp is left inaccessible in the ceiling. Thus it is not possible to simply reduce and rectify the mains to provide a d.c. voltage for the triac control circuit, which must therefore be powered "through" the lamp, i.e. from the voltage across the triac.

An adequate d.c. voltage can be derived by delaying the point at which the triac is triggered in a mains half-cycle. This allows a higher voltage to develop across it which can be rectified and used to power the rest of the circuit.

The disadvantage is that it gives rise to EMI (electromagnetic interference) which can interfere with radio reception and computer systems. As a result, bulky and expensive chokes and capacitors have to be fitted to suppress it. This is unavoidable in light *dimmers* where we *have* to delay the triggering so that the power to the lamp can be controlled. For an on/off control, though, triggering should occur as early as possible so that full power is available to the lamp and without interference being generated.

IN CONTROL

In this circuit, a small Zener diode is connected in series with the triac. This causes sufficient voltage drop so that after rectification a 3V to 4V d.c. supply is available for the control circuits. The Zener has the load (light) current flowing through it during operation and therefore dissipates power, but for the kind of currents used in lighting this only amounts to a few hundred milliwatts, a value well within the ratings of small wire-ended Zener diodes.

The circuit provides sufficient current to enable the triac to be triggered by d.c. pulses instead of the short a.c. trigger pulses normally used. As a result, the triac does not turn off between half-cycles, and so does not cause interference to the mains supply. This point is important as it also enables the circuit is to be used with low power fluorescent lamps if required.

TOUCH CONTROL

Touch control circuits, by their very nature, tend to be prone to spurious switching in response to the many glitches and pulses which normally occur on the mains supply due to other equipment being switched on or off. This is often difficult to overcome, but it can be very much reduced by building a delay into the circuit so that short pulses, which characterise most of the interference, are ignored and the circuit only responds to longer inputs.

By fitting a delay of a few hundred milliseconds, users will not notice any delay in switching, and interference, which rarely lasts for more than a few tens of milliseconds, will be largely ignored by the circuit. This is not a complete solution to the problem, but in this case there is also the advantage that even if the circuit should switch on accidentally, it will only remain on for a few minutes anyway.

of a standard light switch blanking plate. The foil forms one plate of a capacitor. When it is approached by a hand, which becomes the other plate, the capacitor formed effectively connects the base of transistor TR1 to earth. (The human body is a fairly good conductor and exhibits a capacitance to earth of around 100pF, depending on size and area!)

Since the emitter circuit of *npn* transistor TR1 is connected via resistor R2 to the Live rail, which is at 230V a.c. with respect to earth, this is equivalent to a 230V input to the base of TR1 via the combined capacitance of the body plus that the hand and foil.

Not surprisingly, transistor TR1 turns on when the input polarity is correct and charges capacitor C1. Resistor R1 and preset resistor VR1 set the sensitivity of the circuit, allowing it to be activated by placing one finger or the whole hand on the plate. Resistor R2 discharges the capacitor when the hand is removed.

When the input threshold of gate IC1a is exceeded, the output switches low causing time for which the triac remains triggered and the lamp turned on.

With the components specified, the turn-on time can be made variable from around 20 seconds to 2¼ minutes. This may be increased if required by increasing either R4 or C3, or both.

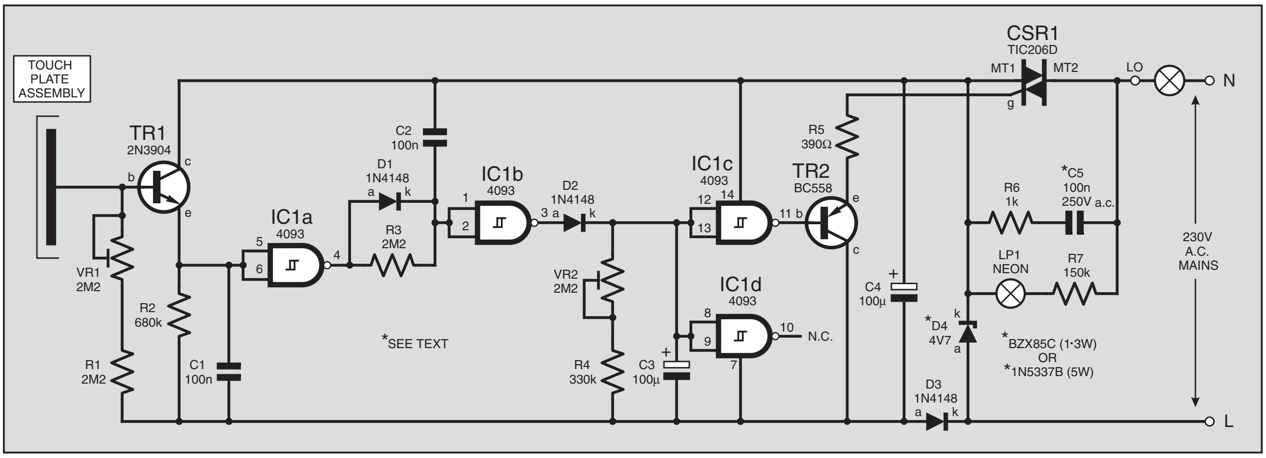


Fig.1. Complete circuit diagram for the Time Delay Touch Switch.

COMPONENTS

Resistors
R1, R3 — 2M2 (2 off)
R2 — 680k
R4 — 330k
R5 — 390Ω
R6 — 1k
R7 — 150k
All 0·25W carbon film

See SHOP TALK page

Potentiometers
VR1, VR2 — 2M2, min preset, vertical (2 off)

Capacitors
C1, C2 — 100n ceramic, 5mm pitch (2 off)
C3, C4 — 100µ radial elect, 16V (2 off)
C5 — 100n class X2, 250V a.c. (see text)

Semiconductors
D1 to D3 — 1N4148 signal diode (3 off)
D4 — 4V7 BZX85, or 1N5337 Zener diode (see text)
CSR1 — TIC206D 400V 4A triac
TR1 — 2N3904 *npn* transistor
TR2 — BC558 *pnp* transistor
IC1 — 4093 quad Schmitt trigger NAND gate

Miscellaneous
LP1 — neon, wire-ended

Printed circuit board, available from the *EPE PCB Service*, code 331; 2-way p.c.b.-mounting terminal block; plastic electrical blanking plate; aluminium foil; insulating materials; connecting wire; solder, etc.

Approx. Cost Guidance Only* £9 *excluding elec. plate

CIRCUIT DESCRIPTION

The circuit diagram for the Time Delay Touch Switch is shown in Fig.1. Triac CSR1 and Zener diode D4 are connected in series with the lamp as previously discussed. The voltage appearing across the Zener is rectified and smoothed by diode D3 and capacitor C4 to provide a d.c. supply of around 4V.

As this voltage only appears when the triac is on, capacitor C5 is connected as a capacitive mains dropper to provide a small current to the Zener to maintain the d.c. supply when the triac is off. Resistor R6 is included to limit the Zener current should the circuit be powered when the capacitor is discharged (very likely) and also to limit the discharge current which could destroy the triac when it switches on (also very likely).

The rest of the circuit is quite conventional and is based on a quad CMOS Schmitt trigger NAND gate, although the gates are used as logic inverters by having both inputs connected together. This type of gate has the advantage of switching cleanly once the input threshold voltage has been exceeded.

The input sensor is formed by placing a conducting foil *behind* the insulating front capacitor C2 to charge via resistor R3, which introduces the switch-on delay required to improve the noise immunity of the circuit. Should the output of IC1a go high again because TR1 turned on for only a short period due to noise, C2 would be quickly discharged via diode D1 so that the input of IC1b would not have time to go low.

Assuming a moderately long input period during which the output of IC1a remains low, however, IC1b's input will also become low, causing its output to go high, so quickly charging capacitor C3 via diode D2. This, of course, causes the output of IC1c to go low and allow gate current to flow to the triac via *pnp* transistor TR2 and resistor R5. In turn, this causes the triac to be triggered and so switch on the lamp.

Note that the circuit uses negative triggering (i.e. a current flows *out of* the triac gate rather than into it) because triacs are generally more sensitive in this mode and require less gate current to ensure triggering.

When the hand is removed from the touch plate, diode D2 will become reverse biased and capacitor C3 will only be able to discharge via resistor R4 and preset VR2. These two components, together with C3, therefore determine the length of

Note also that the time can easily be extended by touching the plate during the on period. This will recharge C3 so that if you stop on the stairs for a chat, you need not be plunged into darkness half way through the conversation!

In any event, even if this should happen, with the triac turned off 230V a.c. will appear across it and the small neon lamp LP1 will light. This is arranged to shine through a hole in the printed circuit board, illuminating the touch area so that it should be an easy matter to find the switch in the dark. Resistor R7 limits the current through the neon, which generally strikes at about 90V.

CONSTRUCTION

As this circuit is always live at mains voltage, its construction should only be undertaken by those who are suitably experienced or qualified.

The circuit *should not be constructed on stripboard*, and ***it must not be earthed***, either intentionally or accidentally as this will cause the instant destruction of many of the components.

The recommended printed circuit board (p.c.b.) component and tracking layouts are shown in Fig.2, together with the triac and transistor pinouts in Fig.3. This board is available from the *EPE PCB Service,* code 331.

Care should be taken to ensure that the correct orientation of all polarity-conscious components is observed. The use of a socket is recommended for IC1, which is a CMOS device, and you should discharge static electricity from your body before handling it.

The neon should be mounted slightly above the p.c.b. to enable it to be bent to lie directly above the central hole. Insulating sleeving should be fitted over the leads to prevent them touching other components.

The triac should be a 400V a.c. sensitive-gate device and the type specified has a maximum gate current requirement of 5mA. Any substitute should have a similar specification.

Zener diode D4 will dissipate about 1W with a 100W lamp so a 1·3W type, such as the BZX85 series, should suffice. For higher lamp powers a 5W device such as the 1N5337B should be used.

The choice of capacitor for C5 is **very important** as this device *must* be rated for connection across the mains. On the face of it, a 400V rating would appear suitable but this is not usually the case as this is often a d.c. rating and many such capacitors have only a 200V a.c. specification. It is *essential* that a Class X2 type should be used as these are guaranteed for operation up to 275V a.c.

TESTING

Before testing, ensure that there are no solder splashes or short circuits on the board and the soldering is of a good standard.

As the circuit operates at mains potential, do not touch any part of the p.c.b. when it is powered and ensure that the mains supply is off when fitting or adjusting it. Under no circumstances should any part of it be connected to earth.

Having said that, the circuit is safe to use once it is mounted in its wall box. There is, however, the problem of testing it safely

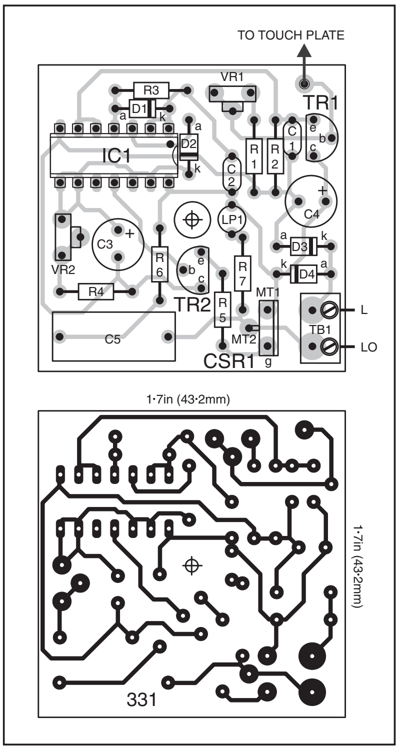


Fig.2. Printed circuit board component layout and full-size copper foil master. Note, a small "window" is cut in the centre of the p.c.b. for the neon light to shine through.

and to do this it is best to use a temporary d.c. supply and not fit the triac at this stage. For this testing an l.e.d. should be connected between the two holes adjacent to the terminal block where the triac will be mounted, with the l.e.d. cathode (*k*, usually denoted by a shorter lead) nearest the edge of the board.

Solder a temporary lead to the junction of components C5 and R6 and connect this to the positive terminal of a 9V d.c. power supply or battery. Secure another lead to the L terminal and connect this to the negative terminal of the power supply. The circuit can now be tested at low voltage and should work as described.

It will probably not be possible to switch the circuit on by touching the plastic front panel but it should switch when the transistor base is touched directly. If not, a 1MΩ resistor connected from the supply positive to the transistor base should cause the l.e.d. to light.

The operation of the circuit can easily be followed by monitoring the outputs of the gates with a multimeter or oscilloscope and the status of the triac will be displayed by the l.e.d. In this way the time delay, and to a certain extent the sensitivity, can be set up by adjusting presets VR2 and VR1, respectively.

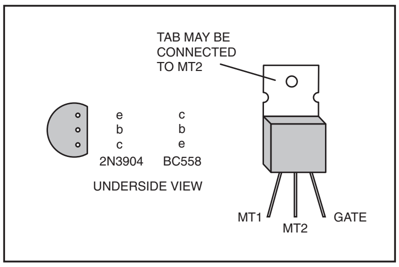


Fig.3. Pinout connection details for the transistors and triac.

If all is well the wires should be removed and the l.e.d. replaced by the triac. This will probably need to be mounted as shown in Fig.4. to ensure that its height does not exceed 1·5cm from the board. This is important if the unit is to be mounted in a plaster-depth wall-box but is not so vital if a deeper box is available.

The triac leads will need to be bent to suit and this should be carried out carefully by holding each lead in a pair of pliers at the point where the bend is required. Do not bend the leads too close to the body of the device or bend them repeatedly as they may break.

To stop the device from moving and placing a further strain on the leads, it may be a good idea to glue the triac tab to capacitor C5 with epoxy adhesive. Many triacs (including the device specified) have the heatsink tab internally connected to the centre pin and in these cases, **this must be insulated by means of insulating tape or suitable plastic sheet as shown to ensure that it cannot touch the wall box**.

TOUCH PLATE

The touch plate assembly is made by using a piece of aluminium kitchen foil about 4cm square stuck behind the centre of an electrical blanking plate, as shown in Fig.5.

Most blanking plates have a central area made of thinner plastic than the surrounding plate. This forms an ideal area for the

Completed circuit board. Note the neon has been bent over to lie directly over the centre hole in the p.c.b.

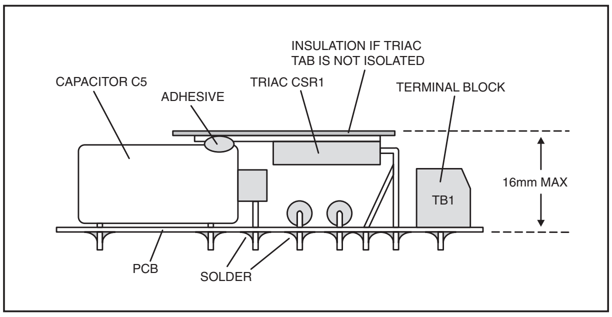
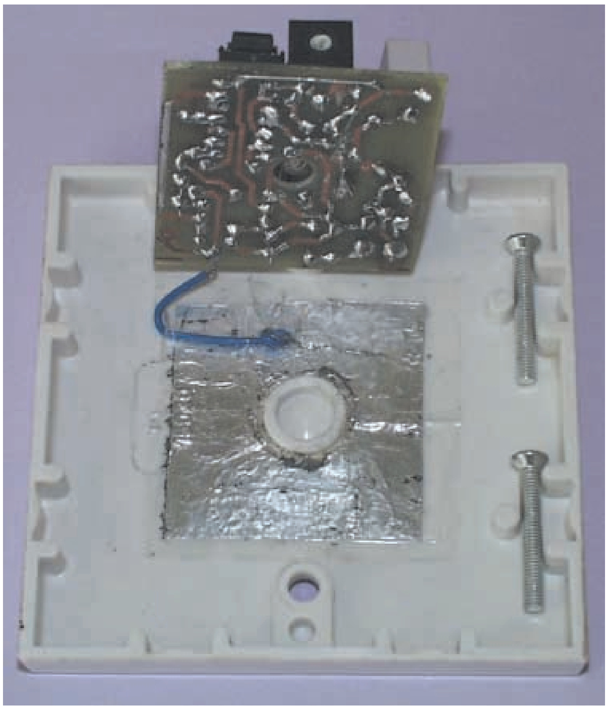


Fig.4. Suggested method of mounting the triac on the circuit board.



The circuit board held clear of the electrical blanking plate to reveal the foil sensor. A centre hole is cut in the foil to allow light from the neon to be seen through the plate. The foil must be covered with several layers of insulating tape.

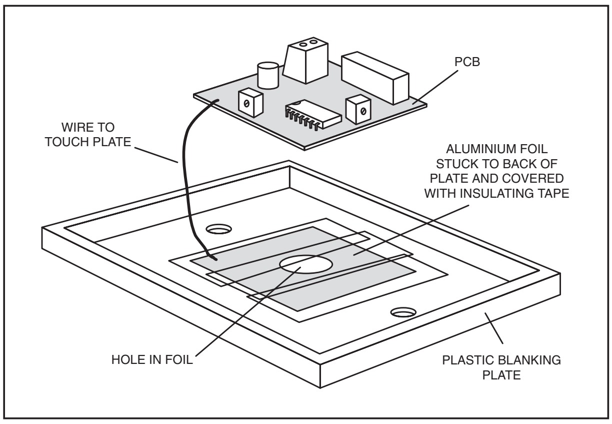


Fig.5. Suggested touch switch assembly.

neon light to shine through. (***Do not make a hole in the blanking plate***.) The aluminium foil should be removed from this area as shown in Fig.5. The surface of the foil should then be covered with strips of insulating tape.

A short piece of wire with about 1cm of insulation removed should be trapped beneath the insulation to enable the foil to be connected to the transistor on the circuit board. A small knot tied in the wire under the insulating tape may help to prevent the wire from being pulled out during final assembly.

After soldering the other end of the wire to the base of transistor TR1, the p.c.b. should be mounted on the back of the touch plate. Double-sided self-adhesive pads are ideal for this but as these grip immediately on contact, care should be taken to ensure that the board is fitted to the centre of the plate. The position of the neon should be adjusted so that it shines directly over the central hole in the foil.

INSTALLATION

Once this has been completed, the unit can be mounted in the wall box. *The mains must be switched off before the existing switch is removed, and when making any adjustments*. The two cables inside the wall box should be connected to the terminal block on the unit. Because of the way the circuit operates, it is important that the Live wire is connected to the L terminal on the p.c.b. as shown in Fig.2.

This wire is normally coloured red but it may not be, depending on the installation. If you are not sure which of the two wires is the Live one, connect them either way around. If you have chosen the wrong one no damage will result but the circuit will not switch on and the

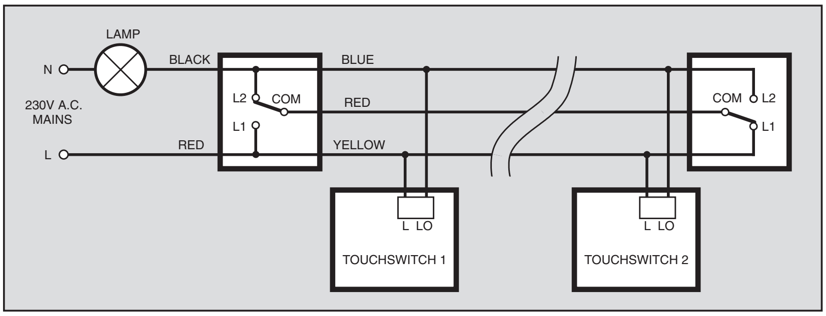


Fig.6. Two-way switching circuit. It is most important that the mains Live is connected to the correct touch switch terminal.

procedure will need to be repeated with the wires reversed.

Note that modern installations will also have an earth wire which is not connected to the switch terminals but is usually connected to a terminal on the wall box. This should be left in place and not disturbed.

Before fixing the switch, *make sure that none of the components on the board can touch any part of the box* and if there is any danger of this (especially if a shallow plaster depth box is involved) a piece of plastic sheet or a scrap piece of p.c.b. material should be fitted to the back of the box to prevent the components shorting to the (earthed) box.

Once this is done, the switch can be secured to the wall box and the mains switched on. Make sure that the light can be switched on when the plate is touched and ensure that it goes out at the end of the previously set time.

If the circuit cannot be switched on, increase the sensitivity of the circuit by turning VR1 clockwise (*switch off the mains before doing this*). If it is still impossible to switch the circuit on, turn the preset fully anticlockwise and reverse the wires to the terminal block before repeating the procedure.

Do not increase the sensitivity beyond the point at which it switches on easily as this can make it more susceptible to random switching, or even prevent the unit from switching off at the end of the preset period. The latter can be increased by turning VR2 clockwise.

Should you wish to use the unit with a two-way switching circuit, to enable the lights to be switched on and off from two locations, this can be done quite easily with no re-wiring being involved. Fig.6 shows a typical two-way switching arrangement and the new switches may be used to replace the existing switches as shown.

The wire colours stated in Fig.6 are those normally used although they may be different depending on the installer. In any event, one of the existing wires will not be required and the touch switches should be wired in parallel as shown. It is important to ensure that the mains Live is connected to the correct terminal on each switch. □

New Technology Update

Smoothing out the bumps promises to extend chip densities up to a figure of one billion transistors, reports Ian Poole.

FEATURE sizes in integrated circuits are continuing to fall, despite fears many years ago that the limits of current technology would soon be reached. These fears have so far been unfounded and companies like Intel have continued to make giant leaps forward in technology.

For many years *Moore's Law* has been the benchmark that has been used. In 1965 Gordon Moore predicted that the number of transistors on an integrated circuit would double every 18 months, and that the trend would continue until about 1975. However, the law has held true right up until the present day.

New Billennium

Now Intel has broken new barriers by developing transistors featuring structures that are 20 nanometres in size. This will ultimately enable the company to build microprocessors that contain around a billion transistors and be capable of running at speeds of 20GHz. This will also extend the life of Moore's Law for another decade.

The transistors operate with supply voltages of less than a volt. This reduces the power consumption, an increasing problem as integrated circuits become larger. The minute size of the transistors also means that speed can be increased as lengths are smaller and transition times are reduced. In these transistors the gate oxide layers are only three atomic layers thick, but they still provide the necessary insulation needed.

A further advantage of the new technology is that devices can be fabricated using the same materials and physical structure used in today's chips. This feature will enable them to be introduced into production more easily. However, it is expected that a different oxide material will be used in the transistors used for the final production.

Although the basic process has been proved, there is still a considerable amount of work to be undertaken before chips using these transistors can be manufactured. The process needs to be optimised and, of course, chips using the new transistors need to be designed. Accordingly it is anticipated the first chips using the new transistors will not appear until around the year 2007.

New Packaging

In a further announcement made in October '01, Intel have developed a new semiconductor packaging technology that complements the new high speed transistor technology. Called a "Bumpless Build-Up Layer" the new BBUL package takes a completely different approach to integrated circuit packaging.

Inside an i.c. package there are several layers and Fig.1 shows how a conventional package is connected to the silicon die using solder bumps inside the package. When the silicon is manufactured, these solder bumps are the last structures put on.

The purpose of these is to make electrical connection between the very finely spaced bumps on the die and the external connections that are much further apart. To achieve this, current packages consist of three layers. The middle layer, known as the core, is a sheet of plastic with via holes (copper interconnections that pass vertically through the core). The top and bottom layers of the package contain a network of copper interconnections that make sure the right bump is routed to the right pin.

Manufacturing of the package starts with the core. Via holes are placed in the core by laser-drilling holes and filling them with copper. Then the interconnection layers are built up on both sides of the core. The specifications of the via holes and interconnect layers are unique to each chip. Finally the external package connections are added, and in the case of a BGA (ball grid array) these are the solder bumps on the base of the package.

Bumpless

In the case of the BBUL, the package is grown around the chip, enabling many of the problems to be overcome. The silicon die is embedded in the package, not attached to its surface.

Electrical connections between the die and the package are made with copper lines rather than the solder bumps. These enable the package to be made thinner and lighter than today's existing packages. They are also able to deliver a higher level of performance while reducing power consumption. The BBUL process is also able to allow multiple silicon components to be placed in a single package.

It can be seen from Fig.2 that the top interconnection layer is not required, nor are the internal bumps. Instead the silicon is embedded in the package core and only the lower interconnection layer needs to be built up. This gives rise to the term "Bumpless Build Up Layer" or BBUL.

Advantages

There are several advantages to the new package. Firstly it is much thinner and lighter as a result of the reduction in the number of layers.

Because the interconnections are much shorter, the levels of spurious inductance are considerably reduced. Capacitors that are placed on the pin side of the package (but not shown on the diagram) are much closer to the silicon, enabling much better power delivery. In turn this allows for higher frequency operation.

The new construction also allows the chip to operate at a lower voltage because of the reduced level of electrical noise. This provides considerable power savings because the power is proportional to the square of the voltage.

The new technology also provides considerably more flexibility. It enables much higher interconnection densities to be achieved and as well as allowing signals to be routed from one part of the die to another more easily.

Finally, it allows multiple chips to be contained within the same package, and this feature alone could bring significant advantages.

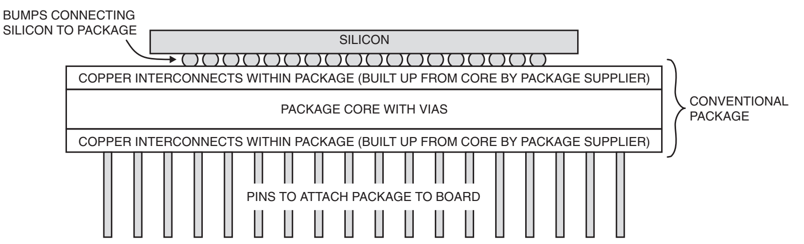


Fig.1. Conventional package using solder bumps.

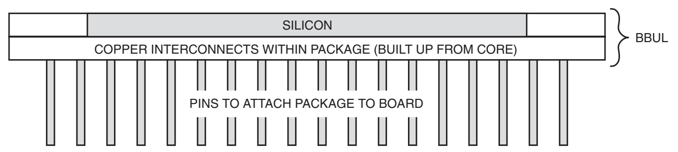


Fig.2. The new BBUL (bumpless build-up layer) package.

PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

BEGINNERS at electronic project construction usually start by copying published projects that include full construction details. This "cloning" of published designs can be achieved with a minimum of technical knowledge, and it is perhaps more craft than science.

Eventually, most constructors will wish to "do their own thing", and rely less on the construction information provided in articles. There are countless circuits published in magazines, books, and on the Internet, and most constructors like to build some of these. In most issues of *EPE* there are useful circuits featured in *Ingenuity Unlimited* and *Circuit Surgery.*

The obvious problem for those of limited experience is that they have to start designing their own component layouts, etc., in order to turn one of these circuits into a working unit. Even assuming that a sensible approach is taken, and the constructor starts with something simple, designing a circuit board for the first time can be a daunting task. Always start with battery powered projects, and do not even think about working out layouts for mains powered projects until you have a few years experience.

Symbolism

An obvious first requirement in converting a circuit into a real world component layout is the ability to read circuit diagrams. This is not particularly difficult, but it is necessary to learn the more common circuit symbols. A selection of circuit symbols and the names of the components that they represent are shown in Fig.1. With anything like this, it is necessary to bear in mind that there are stylistic differences from one source to another. The symbols you see in published circuits will not be exact matches for those shown in Fig.1, but they should closely resemble them.

The rectangular symbols are the "proper" ones for the various types of resistor. Although they are not the current British standard, the old zigzag symbols are still used a great deal in the UK. The zigzag symbols are, of course, used for the circuit diagrams in *EPE*. Both sets of symbols are shown in Fig.1.

Some years ago there was a move towards using the rectangular symbol for any component having two leads. The marking beside the symbol (R1, C1, L1, etc.) indicated what type of component the symbol represented. This system made it easy for the crude computer based drawing systems of the time to deal with circuit diagrams. It made circuit diagrams difficult to read though, and this method has now been largely phased out. However, you may still encounter circuit diagrams of this type. In fact, you are very likely to encounter them if you search the Internet for circuits.

Circuits published on the Internet can be a bit difficult to interpret, because there seems to be no international standard for circuit symbols. In most cases the symbols are the same or quite close to the British standards and there are no problems. In American circuits for example, a capacitor has one straight line and one curved line instead of two straight lines. The symbol is still very obviously a capacitor though, and the diagrams are easy to interpret.

In other cases, and particularly with some semiconductors, there are marked differences in the symbols from one country to another. The obvious way around the problem is to look at the component number for any unrecognised symbol. The letter or letters in the component number tell you the type of component. This is also useful when you are first learning to read circuit diagrams. The

Table 1: Component Identification Letters

Letter(s)	*Component*
B	Battery
BY	Battery
C	Capacitor (any fixed value type)
CH	Chassis
CRT	Cathode ray tube
CSR	Thyristor or triac (controlled silicon rectifier)
D	Diode (any type including rectifiers, Zener diodes, photodiodes, and l.e.d.s)
E	Earth
FL	Filter (usually a ceramic, crystal, or mechanical type)
FS	Fuse
JK	Jack socket (any type)
IC	Integrated circuit
IFT	Intermediate frequency transformer
L	Inductor
LP	Lamp (neon or filament, but not an l.e.d.)
LS	Loudspeaker
M	Motor
ME	Meter
Mic	Microphone
PCC	Photo conductive cell (a photoresistor such as a cadmium sulphide cell)
PL	Plug (any type)
Q	Transistor
R	Resistor (fixed value)
RL	Relay (coil or contacts)
S or SW	Switch
SK	Socket (any type, but JK is often used for jack types)
SW	Switch
T	Transformer (any type including r.f.)
TC	Trimmer capacitor (preset variable capacitor)
Th	Thermistor
TL	Earphone or headphones
Tr	Transistor
TR	Transistor
U	Integrated circuit
V	Valve (any type except CRT)
VC	Variable capacitor
VR or RV	Potentiometer or variable resistor
WD	Warning device (buzzer, bell, etc.)
X	Crystal

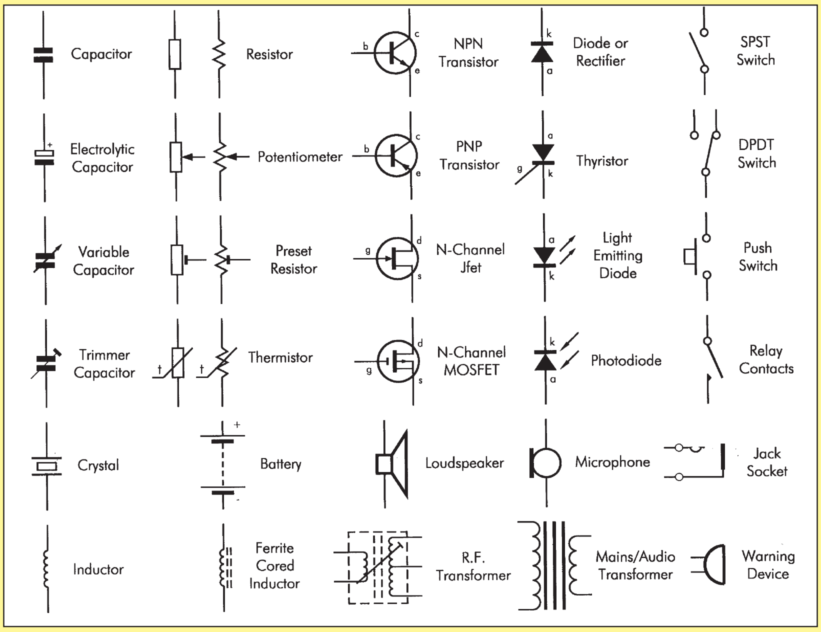


Fig.1. A selection of some commonly used circuit symbols.

component numbers should come to the rescue if you forget what components some of the symbols represent. Table 1 provides a list of component identification letters for some common components.

Crossing the Line

The connections from one component to the next are represented by lines in circuit diagrams. In most cases the connections do not work on the basis of a lead on one component connecting to just one other component. Particularly with the supply lines, connections often run from component to component, perhaps connecting more than a dozen components together.

There is no difficulty in representing complex wiring on circuit diagrams, but it is inevitable that some lines have to cross other lines. To avoid confusion, a dot is used where two lines meet and join, and no dot is used where lines cross without any connection being made. In the distant past it was the convention to have one wire loop over the other at points where there were crossovers with no connections. This method is still used to a limited extent, but is no longer part of the British Standard. The dummy circuit of Fig.2 helps to explain how the diagrammatic wiring operates.

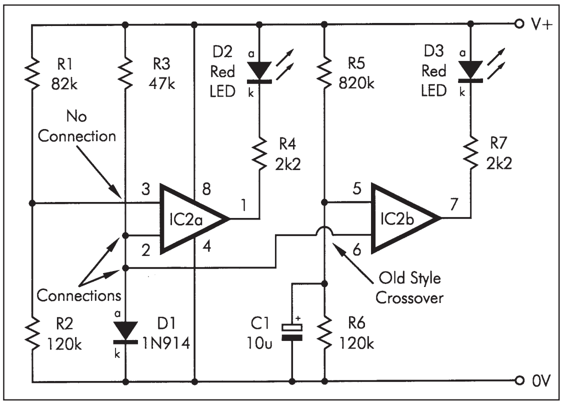


Fig.2. Dots indicate that two wires connect. No dot means that the wires cross without connecting.

Translation

It is easy enough to see how everything connects together on the circuit diagram, but translating a circuit diagram into a working project is a little trickier. The first task is to make sure that you know how each terminal of a component on the circuit diagram equates to its real world equivalent. Provided you have some experience of project construction this should not be too difficult. With resistors and non-polarised capacitors there are only two terminals, and it does not matter which way around they are connected.

Polarised capacitors such as electrolytic types must be connected the right way around. The filled line of the circuit symbol represents the negative terminal and the "hollow" line represents the positive one. The positive terminal is usually marked with a plus sign as well, and the polarity is marked with plus and (or) minus signs on the actual components.

A number of case styles and leadout configurations are used for transistors, so it is only possible to identify the terminals of an unfamiliar device with the aid of a leadout diagram. These can be found in the larger electronic component catalogues, and masses of semiconductor data is available on the Internet. Remember that transistor leadout diagrams are base views, i.e. looking at the side from which the leads emanate.

The bar in a diode symbol is at the cathode (k or +) end of the component. Most diodes and rectifiers have a bar marked around the body of the component next to the cathode lead. A few types are slightly narrower at this end of the body, which roughly equates to the arrowhead section of the symbol. Either way, the physical similarities between the symbols and actual components make it easy to remember how the circuit symbol relates to real world diodes and rectifiers (Fig.3).

Some integrated circuits are represented by certain shapes in circuit diagrams, such as the triangle that is used for amplifiers. Most integrated circuits are just represented by rectangles. In the current context, all that matters are the pin numbers for each device. Most integrated circuits have d.i.l. (dual-in-line) encapsulations, and the pin numbering always runs counter clockwise from pin 1 (Fig.4). Pin 1 can be indicated by a notch at the appropriate end of the encapsulation, or a dot or a bar next to pin 1. Many devices have two or even three of these markings. With the more exotic devices it is necessary to resort to component catalogues or the Internet to sort out the pin numbering. Note that, unless stated otherwise, integrated circuit diagrams show the components viewed from above. In other words, the devices are shown with the pins pointing away from you. This is the opposite of the convention for transistors.

Potentiometers

How the potentiometer circuit symbol relates to a rotary potentiometer is shown in Fig.5. As one would probably expect, the middle tag is the wiper or moving contact. The awkward part is determining which way around the two track terminals should be connected. Circuit diagrams sometimes include "cw" and "ccw" markings, which denote the clockwise and counter-clockwise ends of the track (with the control viewed from the front). Without these markings, there is no easy way of telling the correct method of connection. Volume controls have the tag indicated in Fig.5 connected to the earth rail. With other applications that have a track connection connected to earth, this is almost certain to be the tag that connects to earth. Beyond that, it is not possible to determine the correct method of connection without some technical knowledge. However, the "suck it and see" method can be used. If connecting the track one way around results in the control working "backwards", reverse the connections to the track terminals.

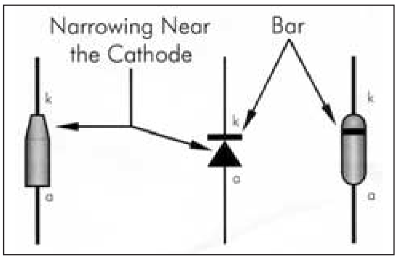


Fig.3. There is a clear correlation between diodes and their circuit symbol.

Sockets, etc.

Multi-way sockets can be a bit confusing because the pin numbering is sometimes less than completely logical. Some DIN connectors certainly have some odd pin numbering arrangements. Fortunately, many multi-way connectors have the pin numbers moulded into the components themselves. They are present on DIN sockets, D-connectors, and most other computer related connectors.

With simple two-way audio connectors such as jack and phono types it is essential to get the two tags connected the right way around. Usually one of the tags can clearly be seen to connect to the metal chassis of the component, and it is this tag that connects to the earth rail of the circuit. Sockets that are enclosed in plastic cases are more difficult to deal with, and there may be no outward clues as to which is the earth tag. However, a few simple continuity tests will show how the socket connects to the plug, and should solve the problem. If the socket has any switch contacts, continuity tests should show how these operate. Continuity tests are also useful with switches where the functions of the tags are not entirely obvious. In fact, it is a good idea to check any switch of a type that you have not used previously. This ensures that you are not misinterpreting things, and avoids the possibility of having to do a lot of rewiring.

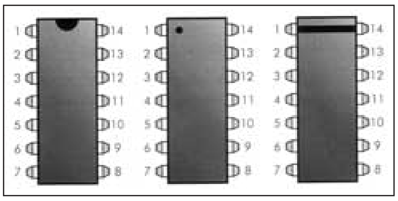
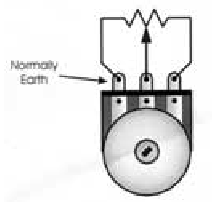


Fig.4. Dual-in-line packages all use the same basic method of pin numbering and are normally shown viewed from above.

Fig.5. The tag indicated here is earthed in volume control and many other applications.



Constructional Project

VERSATILE BENCH POWER SUPPLY

ANDY FLIND

A well-proven power supply that provides 0V to 20V with current limiting in two ranges of 100mA and 1A.

ONE of the most useful pieces of equipment an electronics experimenter can possess is a good workbench power supply. Indeed even for those who already have one, a second will often prove useful for projects requiring more than one source of supply or for the occasional design that requires long-term testing.

POWER SUPPLY IDEALS

Ideally a workbench supply should have an output voltage that can be adjusted right down to zero as it is occasionally useful to be able to power a circuit gradually from this when fault-finding. There should also be a fast and effective current limiting facility, again adjustable from zero as this also provides valuable protection when testing circuits.

If the supply can be set to deliver a constant output current instead of a voltage it can also be used as a charger for the many types of re-chargeable battery that are available nowadays, both alkaline and small sealed lead-acid types. The latter are normally charged to a constant voltage but until this is reached a current limit is often required to prevent an excessive charge rate.

Preferably the supply should have two meters so that the voltage and current supplied to the load can be seen at a glance, and most users would probably prefer analogue meters to the digital type for this.

Power supplies meeting these specifications can be expensive, but this project can be constructed at reasonable cost, especially if some of the parts such as the case and meters are already to hand, or are purchased from inexpensive sources such as surplus stores or amateur radio rallies.

The power supply described here provides an output of up to 20V with current in two ranges of 100mA or 1A, which should be more than sufficient for most of the projects which appear in *EPE*.

DESIGN POINTS

The design of a good power supply is more complex than might be supposed. It must provide a constant voltage or current whilst being able to react rapidly to any changes in the load it is supplying. This means that the circuit must have a fast response and remain stable for a wide range of output loads, voltages and currents, so the circuit is inevitably a compromise between speed and stability.

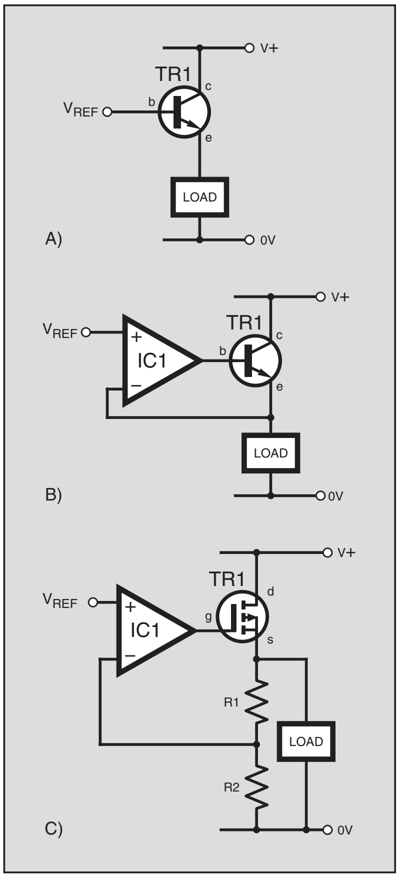


Fig.1. Various methods of voltage control: (a) transistor, (b) op.amp and transistor and (c) op.amp and power MOSFET.

The design used for this project should be fast enough for most purposes and has good output stability.

The method of voltage control used may be a little difficult to follow so a simplified explanation is in order before a description of the full circuit. Some of the more common methods of controlling voltage are shown in Fig.1.

In Fig.1a the controlling device is a simple transistor. A reference voltage is applied to the base and this is reproduced at the emitter to supply the load, minus about half a volt for the base-emitter drop of the transistor. This can suffice for simple designs but suffers from small changes with variations in load, partly because it draws a small current from the reference source, which is usually a variable resistor connected to a fixed voltage.

Use of a power MOSFET in place of the transistor would cure this, but these have a much larger and less predictable gate-source voltage drop.

An op.amp can be used to partly overcome these problems, as shown in Fig.1b, but there are still some disadvantages. As the required output voltage rises, the input voltage to the transistor must also rise so there is effectively less control voltage available as the output approaches the supply voltage. Also, this simple circuit cannot supply an output voltage greater than the reference.

A somewhat better solution is shown in Fig.1c. A power MOSFET is controlled by an op.amp and a pair of resistors causes the op.amp to multiply the reference voltage. But the problem of low drive voltage at high output voltages remains and it is difficult to sense the output current from any of these circuits.

BETTER CONTROL

An arrangement which overcomes these difficulties is shown in Fig.2. It uses two power supplies, a "main" one of about 25V capable of supplying up to 1A of current for the output, and an auxiliary "split" supply of +12V for the controlling circuit. The "0V" rail of this is the "ground" for the control section. It operates as follows:

A reference voltage is produced using regulator IC1 and applied to resistor R1. During normal operation op.amp IC2 uses feedback to maintain equal voltages at its inputs, so a constant current flows into R1. This current also flows through resistor R2, developing a voltage across it directly proportional to its value. If a linear variable resistor (potentiometer) is used for R2 it will provide linear control of the output.

Perhaps the easiest way to understand the action of the circuit is to consider what would happen if the voltage at the junction of R1 and R2 were to rise slightly. The output of IC2 would start to rise and thus turn on the MOSFET TR1 a little more. This would cause the 0V rail to rise with respect to the main negative supply rail so that more current would flow through R2 to bring the input to IC2 down again, restoring the balance.

The 0V rail, of course, is the positive output so the voltage developed across R2 is what is delivered to the load. Naturally, as the 0V rail rises with respect to the main supply, so do the positive and negative 12V rails, so that even when the output voltage is close to the maximum of the main supply there will still be a full 12V available for IC2 to use in controlling the gate of power MOSFET TR1.

OUTPUT CURRENT

It is also simple to measure the output current in this arrangement using the sensing resistor R3, which develops a current-dependent voltage with respect to the control circuit "ground". The only disadvantage of this arrangement is that the return path for the reference current from resistor R1 is via the main supply, TR1 and R3, so this current should be kept small to prevent any noticeable effect on the measured output current.

This also applies to the voltmeter which is connected directly across the output.

MAINS SUPPLY

The full circuit diagram for the Versatile Bench Power Supply is shown in Fig.3. The incoming 230V a.c. mains passes through a 2-pole isolating switch S1 to the two transformers T1 and T2, whilst the transient suppressor VDR1 removes any brief high voltage spikes that may occur.

No supply fuses are fitted to the prototype, a 3A fuse in the mains plug being considered adequate.

Transformer T1 is a 20V 20VA (1A) type and, with bridge rectifier REC1 and reservoir capacitor C2, produces a no-load voltage of about 30V. Under full-load conditions this drops to about 24V which is still sufficient to maintain the 20V output. Capacitor C1 and resistor R1 also help to eliminate transient voltage spikes.

Transformer T2 is a smaller 100mA type with a centre-tapped 9V-0V-9V output. Arranged as shown with bridge rectifier REC2, it develops both positive and negative supplies of about 12V each. A 5V reference voltage is generated by IC1, a standard 78L05 regulator.

DOWN TO EARTH

The earthing arrangements used in this project are slightly unusual and require some explanation. Earthing of a mains-powered project is essential both for safety and because capacitive coupling between windings in the transformer can transfer potentially damaging a.c. voltages to the output, even though from a very high impedance.

However, the output of a bench power supply is often required to have d.c. isolation from earth so that other earthed equipment, such as oscilloscopes, can be safely connected to any part of the circuit on test.

Commercially produced bench supplies often overcome this problem by using transformers with internal foil screens between the primary and secondary windings which are earthed to eliminate the capacitive coupling. These are not readily available to the home constructor, so a different method must be used.

Switch S2 allows the mains earth to be connected directly to either the positive or negative output terminal or left "floating", where capacitively coupled a.c. voltage is grounded through capacitors C3, C4 and resistor R2. Although not ideal, this system works well in practice and reduces noise and a.c. voltage at the output to a few millivolts

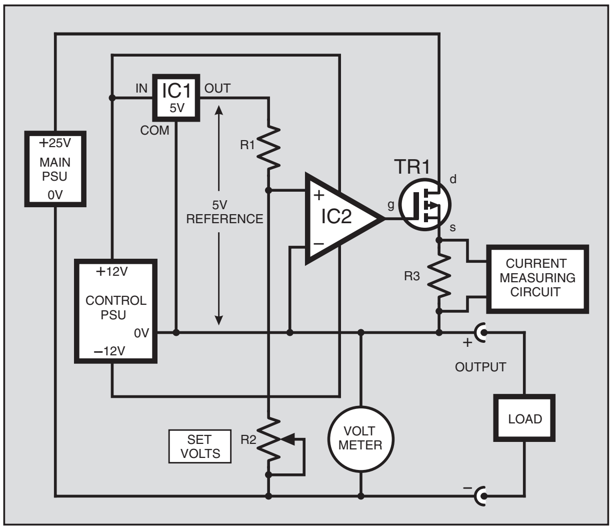


Fig.2. Simplified schematic of the voltage control method used.

COMPONENTS

Resistors

R1, R2	10Ω (2 off)
R3, R6, R8, R9	4k7 (4off)
R4	22k
R5	220k
R7, R15, R19	1k (3 off)
R10	1Ω (7W wirewound)
R11	180k
R12	1k8
R13	220Ω
R14	2k2
R16	27k
R17, R18	10k (2 off)
R20	820Ω
R21	68k
VDR1	250V a.c. transient supp.

All 0·6W 1% metal film, except where stated.

See SHOP TALK page

Potentiometers

VR1	10k 18-turn cermet preset
VR2	100k, rotary carbon, lin.
VR3, VR4	50k 18-turn cermet preset (2 off)
VR5	1k rotary carbon, lin.
VR6	500Ω 18-turn cermet preset

Capacitors

C1, C3, C4	470n 250V, class X2 suppression (3 off)
C2	2200µ radial elect. 63V
C5, C7, C9, C11, C14 to C16	100n ceramic, resin-dipped (7 off)
C6, C8	470µ radial elect. 16V (2 off)
C10	10µ radial elect. 50V
C12	22p ceramic, resin-dipped
C13	100µ radial elect. 63V

Semiconductors

REC1	PW01, 6A 100V bridge rectifier
REC2	W005 1·5A 50V bridge rectifier
D1 to D5	1N4148 signal diode (5 off)
D6	BZX61C30V 30V 1·3W Zener diode
D7	red l.e.d. 3mm
TR1	BUZ11 power MOSFET
TR2	BC214L *pnp* transistor
IC1	78L05 +5V 100mA voltage regulator
IC2 to IC4	TL071 op.amp (3 off)

Miscellaneous

ME1, ME2	100µA moving coil meter (2 off)
S1, S3, S4	d.p.d.t. toggle switch, 250V a.c. (3 off)
S2	1-pole 3-way rotary switch
T1	20V 20VA transformer
T2	9V-0V-9V 100mA trans.
SK1, SK2	4mm screw terminal post/socket (1 red, 1 black)

Printed circuit board, available from the *EPE PCB Service*, code 333; case with metal front and rear panels or metal case, 205mm x 140mm x 110mm; plastic feet (4 off); cable ties (see text); knob (2 off); 8-pin d.i.l. socket (3 off); heatsink, 100mm x 65mm; fixings; connecting wire; solder, etc.

Approx. Cost Guidance Only **£39** *excluding meters & case*

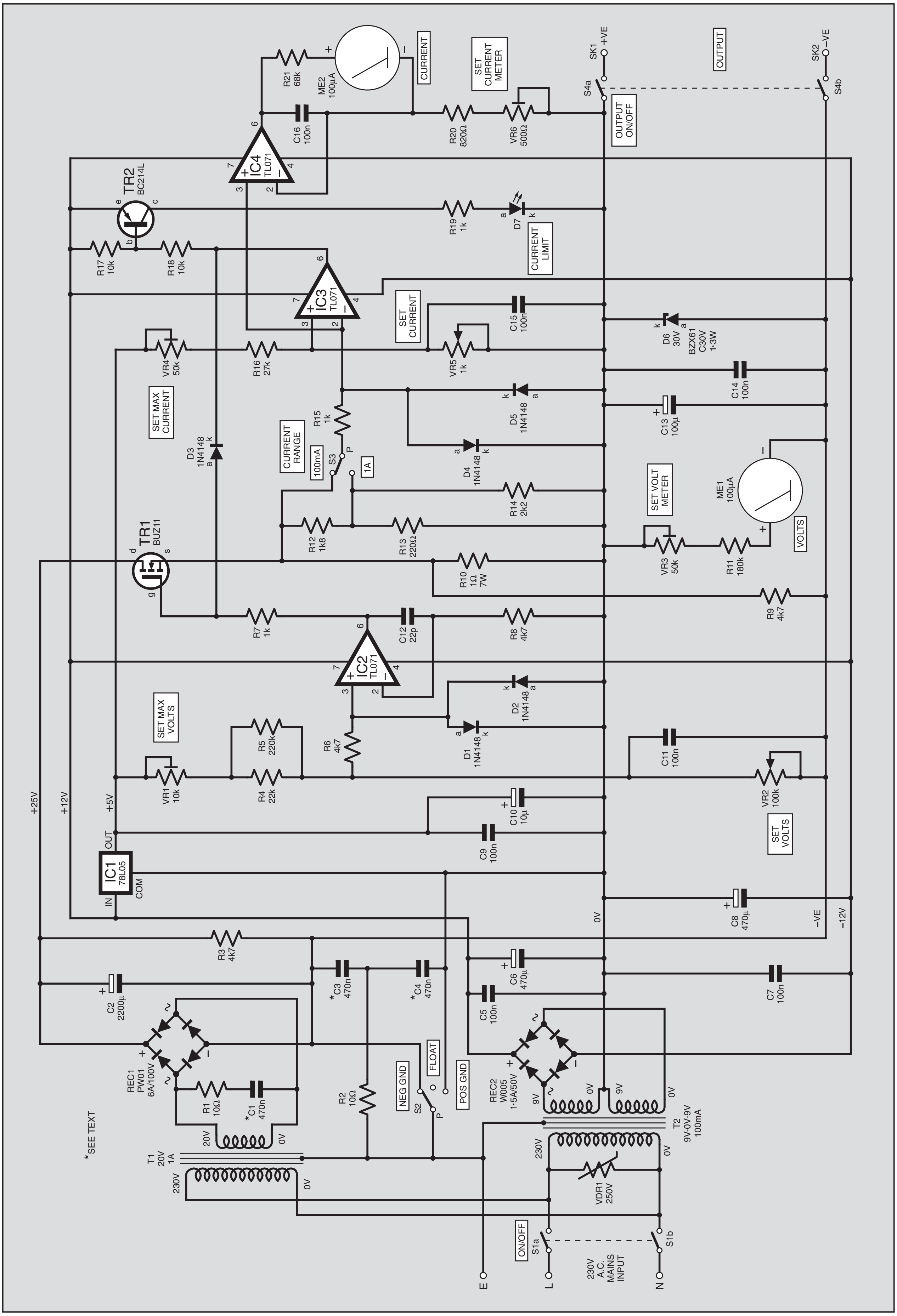
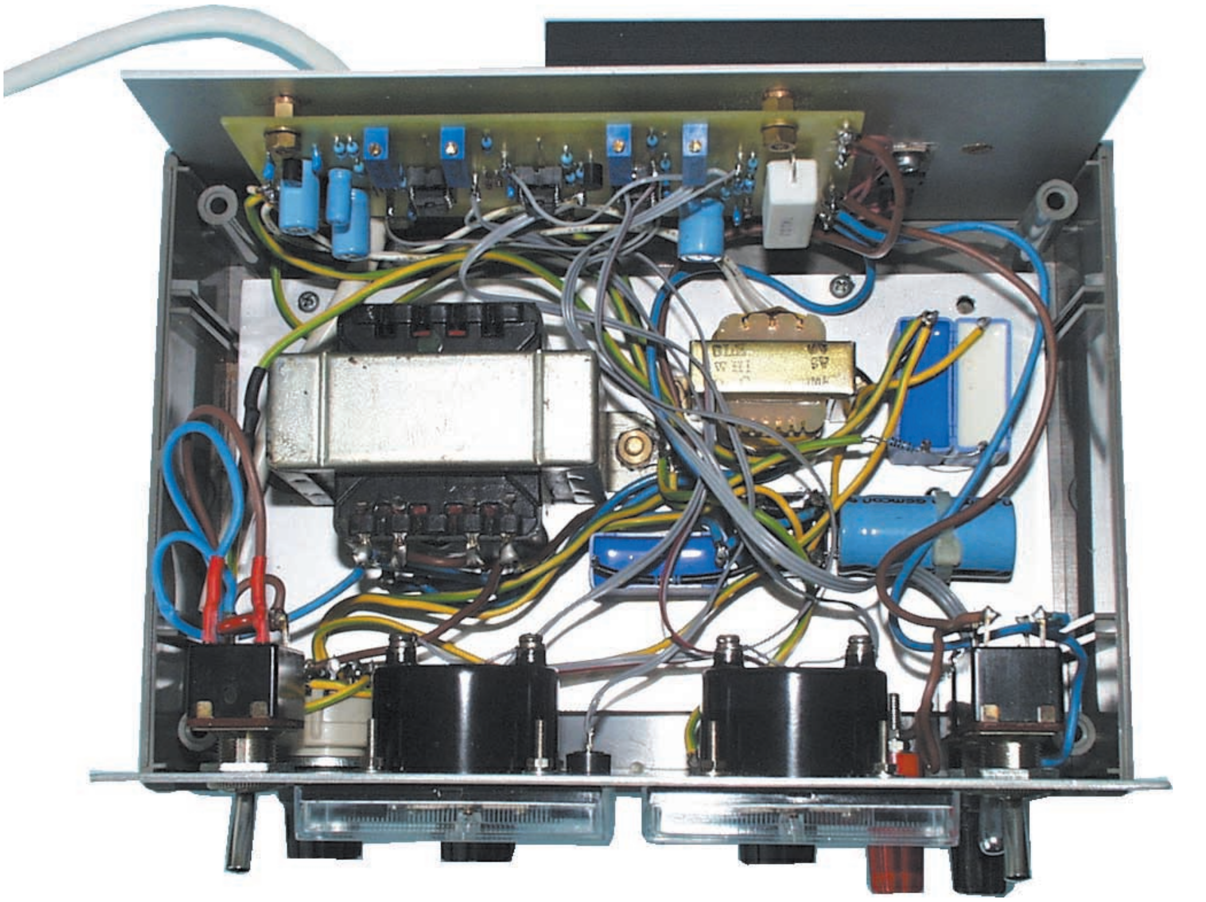


Fig.3. Complete circuit diagram for the Versatile Bench Power Supply.



Internal view of the prototype showing the a.c. supply components.

at most. **For safety, capacitors C3 and C4 must be 250V class X2 suppression types.**

VOLTAGE CONTROL

The voltage controlling part of the circuit is constructed around op.amp IC2 and operates as described earlier. The resistance to which the reference voltage is applied includes the preset VR1 so that the maximum output voltage may be set to exactly 20V.

The input to IC2 has a pair of protection diodes, D1 and D2. Capacitor C12 ensures stability but is small enough to allow a fast response to output load changes. Power MOSFET TR1 handles the full output current. Output voltage is indicated by meter ME1 with VR3 allowing preset adjustment for calibration to 20V full-scale.

Load current is sensed by the one ohm resistor R10. At full output this dissipates a watt of heat, so a 7W type is used to dissipate this safely. A potential divider across R10, consisting of R12 with R13 and R14 in parallel, allows selection of either the full potential across it or one tenth through switch S3, giving the 100mA and 1A current ranges.

The voltage from S3 is compared by op.amp IC3 with an adjustable voltage derived from the reference by divider network VR4, R16 and the current control VR5. When the S3 voltage exceeds this secondary reference voltage, the output of IC3 goes low, pulling the gate voltage of TR1 down through diode D3 to limit the current flow through this transistor.

It also turns on transistor TR2, which illuminates light emitting diode (l.e.d.) D7 to indicate that current limiting is taking place. Preset VR4 allows the current ranges to be set precisely to 100mA and 1A, whilst VR5 gives control from zero to the selected maximum.

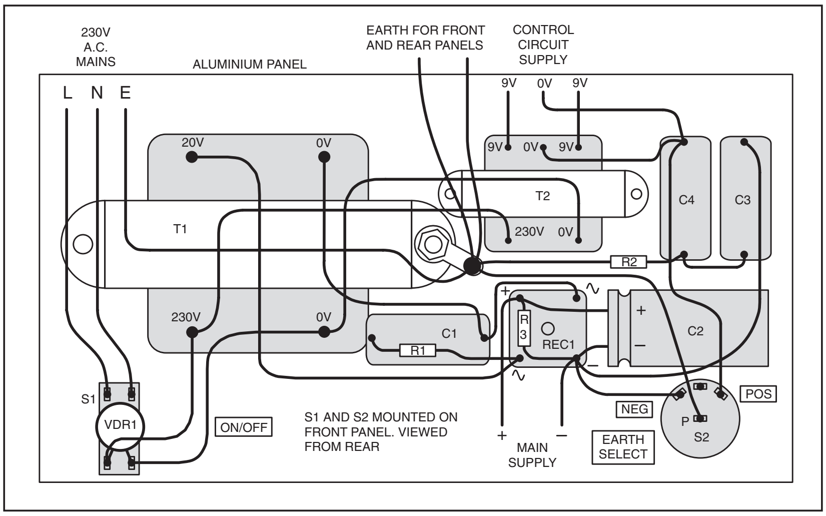


Fig.4. Layout and interwiring of power supply components mounted on an aluminium base plate. The plate also acts as the heatsink for the 6A bridge rectifier REC1. S1 and S2 are mounted on the front panel.

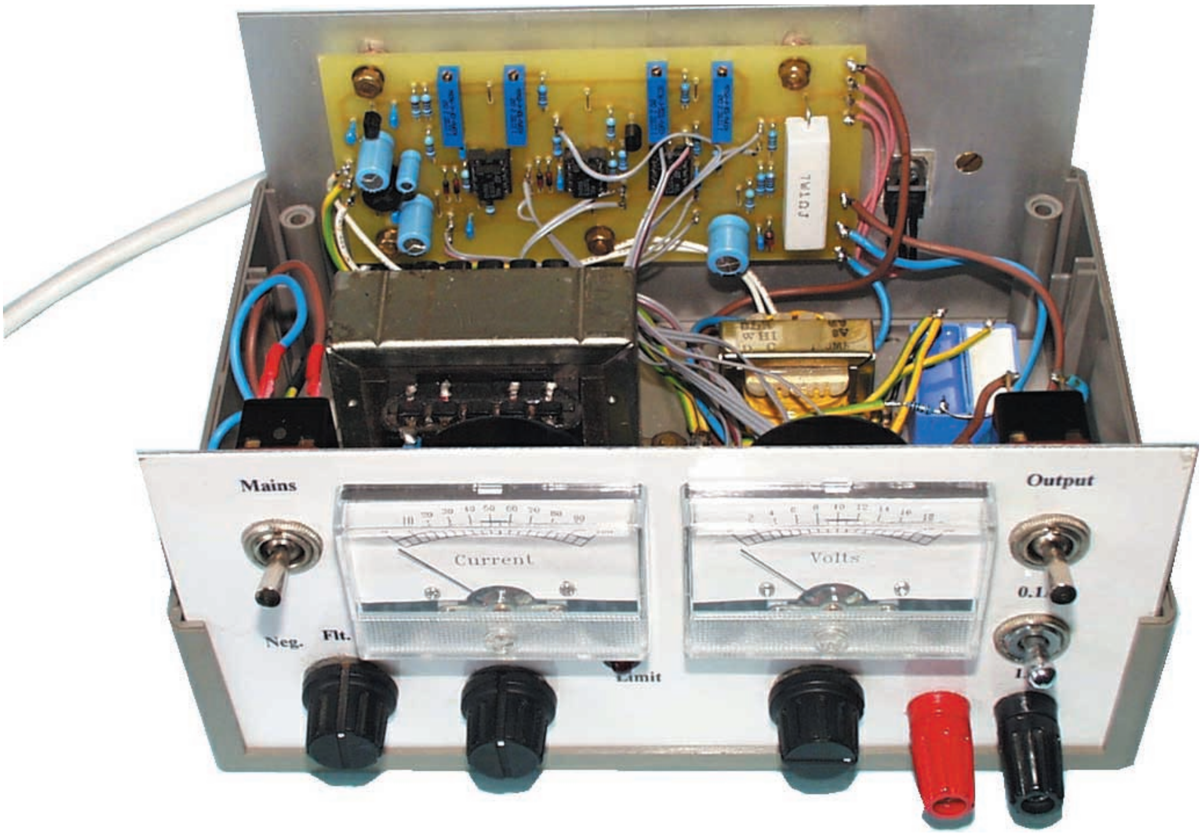
Op.amp IC4 also receives the voltage from S3, and converts it into a 1-100μA drive for the current indication meter ME2. Preset VR6 allows calibration of this meter for full-scale corresponding to the 100mA and 1A signal inputs. The high value of resistor R21 prevents any possibility of meter damage through overdriving.

Double-pole switch S4 allows the output to be switched off independently and also provides instant isolation from the circuit connected to it at any time.

Zener diode D6 protects TR1 from any high voltage pulses arising from the connected load. This can happen with some types of inductive load and, whilst normally tolerant of brief high currents, semiconductors are easily damaged by excessive voltage.

CONSTRUCTION

As this unit is mains powered, its construction should only be carried out by those who are suitably experienced or supervised. All mains connections should be fully insulated using heat-shrink or other suitable materials.



Construction should begin with the transformers, the rectifier REC1 and earthing arrangements. These can be assembled in any manner preferred by the constructor. The layout used in the prototype is shown in Fig.4.

These components are attached to a 190mm × 100mm metal plate drilled to fit the threaded mounting pillars provided in the plastic enclosure. The two transformers and rectifier REC1 are bolted in place so that the plate acts as the heatsink for the rectifier.

The large electrolytic capacitor C2 is fastened with a cable tie passed through holes to each side of it. The three 470nF capacitors, C1, C3 and C4 are glued in place. *It is essential that you ensure that good adhesion occurs. Preferably also use cable ties for these components as well to prevent them from contacting mains connections should they become detached.*

Note the arrangement of the earth wiring, which uses one of the main transformer mounting bolts as a "common" point for all earth connections. *Any other metal parts of the case used, such as front and rear panels, must also be connected to this point.*

This part of the circuit can now be fitted into the case and tested. When connected up and powered, the output of the "main" supply should be about 30V d.c. across capacitor C2 and 9V-0V-9V a.c. should be available from the 100mA transformer. These supplies will be needed for testing the remainder of the circuit.

FRONT PANEL

The front panel should be drilled as shown in Fig.5 and assembled next. The earthing selector switch S2 should be fitted and tested with a continuity testing meter. Mains switch S1 can also be connected up. The mains input is taken to the upper two

Completed power supply with the top-half of the plastic case removed to reveal the circuit board and power MOSFET TR1 bolted to the metal rear panel.

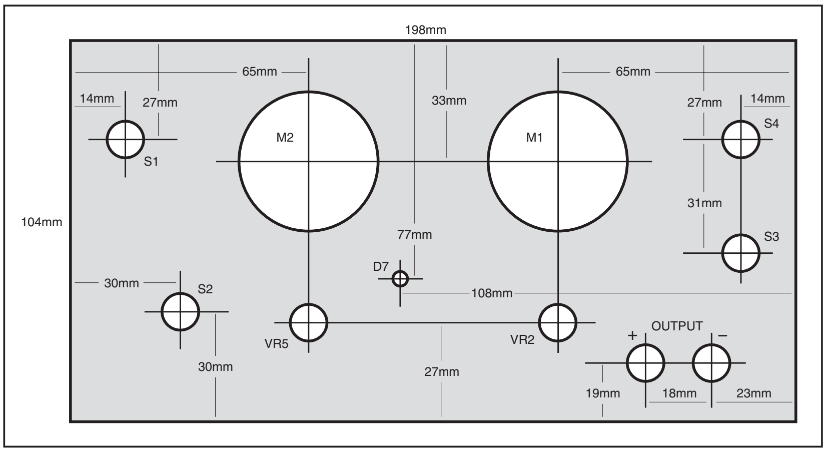


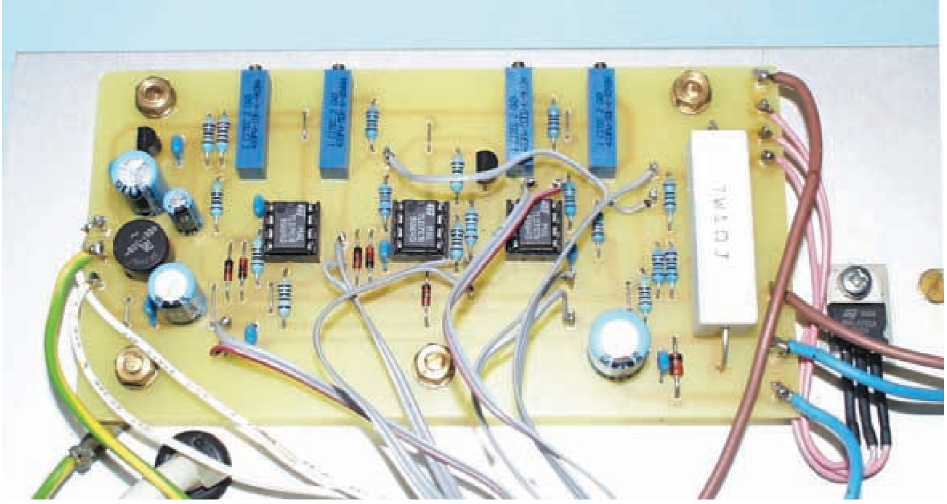
Fig.5. Front panel drilling details and dimensions. The general layout of components and front panel lettering are shown in the photograph below.

connections on this. Transient suppressor VDR1 is fitted directly to the lower two connections on the output side.

The rear metal panel of the case has four mounting bolts for the printed circuit board (p.c.b.) which can be used as a template to mark out for drilling. It also has an external heatsink to aid dissipation of heat from TR1, which is secured to the inside with an insulating mounting washer and a bolt passing right through the heatsink. Four nuts are used as spacers for the p.c.b. when it is fitted.

P.C.B. ASSEMBLY

Most of the rest of the circuit is constructed on the p.c.b. whose details are



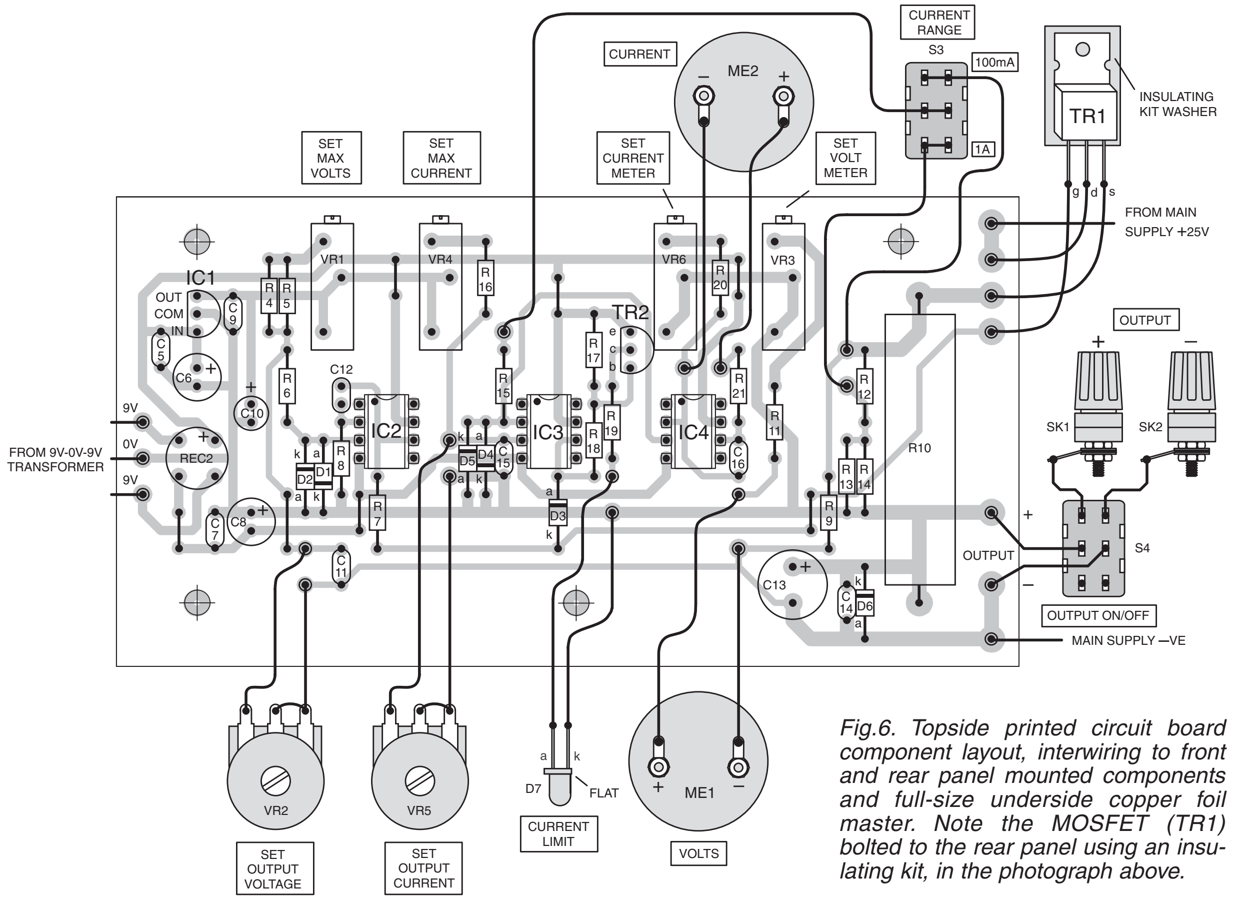
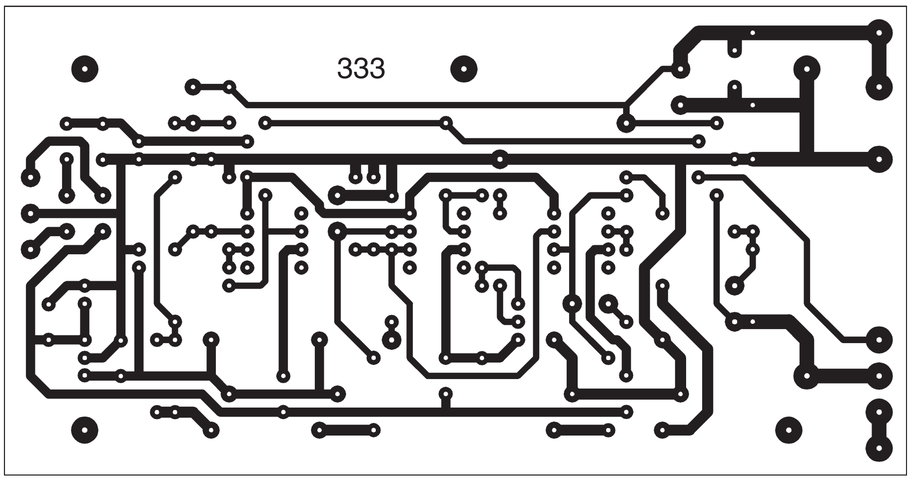


Fig.6. Topside printed circuit board component layout, interwiring to front and rear panel mounted components and full-size underside copper foil master. Note the MOSFET (TR1) bolted to the rear panel using an insulating kit, in the photograph above.

5in (127mm)



2·6in (67mm)

shown in Fig.6. This board is available from the *EPE PCB Service*, code 333.

After ensuring that the board will fit on the mounting bolts, the pins for external connections can be fitted, there are 23 of these, and then the links, of which there are seven. Next fit the 0·6W resistors, diodes, dual-in-line (d.i.l.) i.c. sockets, the small ceramic capacitors, presets VR1, VR3, VR4 and VR6 , transistor TR2, regulator IC1, rectifier REC2, the four remaining electrolytic capacitors and 7W resistor R10, preferably in this order for ease of assembly.

Fully check your assembly for correctness of the soldering, component positioning and polarity. The board is then ready for testing.

TESTING

The aim of using separate op.amps for the various functions is partly to make testing and trouble shooting easier, so hopefully this will be the case.

The first test is to connect the 9V-0V-9V transformer as shown in Fig.6. Using 0V (the centre-tap connection) as a reference, the circuit should be powered up and the presence of +12V and –12V checked at pins 7 and 4 respectively of the three d.i.l. sockets.

The presence of +5V from regulator IC1 can also be checked at its output pin. Next, the MOSFET TR1 and VR2, the Voltage control, should be connected, along with the two leads from the main power supply, from REC1 and C2. IC2 should now be inserted into its socket.

Whilst monitoring the output with a voltmeter, the circuit should be powered up, and it should now be possible to vary the output from zero to around 20V with Voltage control VR2. If so, VR2 can be turned right up and the voltage set to exactly 20V with preset VR1. If the voltmeter ME1 is now connected this can be adjusted for an indication of 20V (full scale) with preset VR3.

CURRENT AFFAIRS

Next the current range switch S3 should be connected and set to 100mA, and the current control VR5 should be connected. The current control op.amp IC3 should be inserted into its socket, and a meter set to read a current of about 100mA connected in series with a 100 ohm resistor across the output. The circuit should again be powered and the voltage control turned right up.

Potentiometer VR5 should now control the current, from zero to around 100mA. Preset VR4 can be adjusted for a maximum output of exactly 100mA. The 1A range should automatically be correct following this.

Rear of the completed power supply unit showing the finned heatsink bolted to the rear panel to aid dissipation of heat from the power MOSFET.

The l.e.d. D7 can be connected, this should light whenever current limiting is active.

Finally, the current meter ME2 should be connected, op.amp IC4 inserted, and preset VR6 set for full scale at 100mA. As before, the 1A range should now automatically be correct following this adjustment.

COMPLETION

Once these tests are concluded, the board can be attached to the rear panel to complete the assembly. It might be worthwhile re-checking the adjustments, the presets have been arranged for easy access with the case top half removed to make this simple.

The unit will normally be used to supply a constant voltage to circuits on test, but it may also be operated continuously in constant current mode which is very useful for charging NiCad batteries of various types.

Although the heat-sinking will be adequate for most purposes, the fact should be borne in mind that it could dissipate over 20W and therefore get rather hot. *The supply of low voltages at high currents for long periods is not recommended.* However, most loads of the kind that are likely to be found in the average workshop should present no problems.

If in doubt, just place a hand on the heatsink now and again to check temperature. The prototype has been used continually for weeks on end to power circuits used with electric clocks, and is also the favourite for programming PICs in the workshop, leaving another supply free for operating the PIC-driven circuitry.

CURRENT LIMITATIONS

It should be noted that the current limit takes a finite time to operate so there are some applications where external limiting is needed. The output of IC3 has to come out of saturation and slew through about eight volts before limiting begins, and this will take a microsecond or two!

The limit protects the supply itself against short circuits, and in almost every practical fault situation it is fast enough to prevent damage to faulty circuits on test as these are rarely total short circuits anyway.

However, it should be remembered that the MOSFET output device can handle very high currents and has a large capacitor behind it so, for the brief time it takes for the limit to operate, many amperes can be delivered into a short! An obvious example is the testing of l.e.d.s.

The limit should never be relied upon on its own for this, a suitable series resistor should *always* be used. □

EVERYDAY PRACTICAL ELECTRONICS
INCORPORATING ELECTRONICS TODAY INTERNATIONAL
THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

BACK ISSUES

We can supply back issues of *EPE* by post, most issues from the past three years are available. An *EPE* index for the last five years is also available – see order form. Alternatively, indexes are published in the December issue for that year. Where we are unable to provide a back issue a photostat of any *one article* (or *one part* of a series) can be purchased for the same price. Issues from Jan. 2001 onwards are also available to download from **www.epemag.com**.

DID YOU MISS THESE?

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

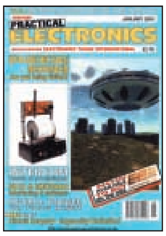
PROJECTS ● Wind-Up Torch ● PIC Dual-Chan Virtual Scope ● Fridge/Freezer Alarm ● EPE Moodloop Field Strength Indicator.
FEATURES ● Teach-In 2000–Part 12 ● Interface ● Ingenuity Unlimited ● New Technology Update ● Circuit Surgery ● Peak Atlas Component Analyser Review ● Net Work – The Internet Page.

NOV '00

PROJECTS ● PIC Pulsometer ● Opto-Alarm System ● Sample-and-Hold ● Handclap Switch.
FEATURES ● The Schmitt Trigger–Part 1 ● Ingenuity Unlimited ● PIC Toolkit Mk2 Update V2.4 ● Circuit Surgery ● New Technology Update ● Net Work – The Internet ● FREE Transistor Data Chart.

DEC '00

PROJECTS ● PIC-Monitored Dual PSU-Part1 ● Static Field Detector ● Motorists' Buzz-Box ● Twinkling Star ● Christmas Bubble ● Festive Fader ● PICtogram.
FEATURES ● The Schmitt Trigger–Part 2 ● Ingenuity Unlimited ● Interface ● Circuit Surgery ● New Technology Update ● Quasar Kits Review ● Net Work – The Internet ● 2000 Annual Index.



JAN '01

PROJECTS ● Versatile Optical Trigger ● UFO Detector and Event Recorder ● Two-Way Intercom ● PIC-Monitored Dual PSU–Part 2.
FEATURES ● Using PICs and Keypads ● The Schmitt Trigger–Part 3 ● New Technology Update ● Circuit Surgery ● Practically Speaking ● Ingenuity Unlimited ● CIRSIM Shareware Review ● Net Work – The Internet.

FEB '01

PROJECTS ● Ice Alert ● Using LM3914-6 Bargraph Drivers ● Simple Metronome ● PC Audio Power Meter.
FEATURES ● The Schmitt Trigger–Part 4 ● Ingenuity Unlimited ● Circuit Surgery ● New Technology Update ● Net Work – The Internet ● *Free* 16-page supplement – How To Use Graphics L.C.D.s With PICs.

MAR '01

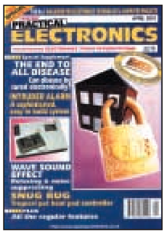
PROJECTS ● Doorbell Extender ● Body Detector ● DIY Tesla Lightning ● Circuit Tester
FEATURES ● Understanding Inductors ● The Schmitt Trigger–Part 5 ● Circuit Surgery ● Interface ● New Technology Update ● Net Work – The Internet Page.

APRIL '01

PROJECTS ● Wave Sound Effect ● Intruder Alarm Control Panel–Part 1 ● Sound Trigger ● EPE Snug-Bug Pet Heating Control Centre.
FEATURES ● The Schmitt Trigger–Part 6 ● Practically Speaking ● Ingenuity Unlimited ● Circuit Surgery ● Net Work – The Internet Page ● *FREE* supplement – An End To All Disease.

MAY '01

PROJECTS ● Camcorder Mixer ● PIC Graphics L.C.D. Scope ● D.C. Motor Controller ● Intruder Alarm Control Panel–Part 2.
FEATURES ● The Schmitt Trigger–Part 7 ● Interface ● Circuit Surgery ● Ingenuity Unlimited ● New Technology Update ● Net Work – The Internet Page.



JUNE '01

PROJECTS ● Hosepipe Controller ● In-Circuit Ohmmeter ● Dummy PIR Detector ● Magfield Monitor.
FEATURES ● Controlling Jodrell Bank ● PIC1687x Extended Memory Use ● Practically Speaking ● Ingenuity Unlimited ● New Technology Update ● Circuit Surgery ● Net Work – The Internet Page.

JULY '01

PROJECTS ● Stereo/Surround Sound Amplifier ● PIC to Printer Interface ● Perpetual Projects 1– Solar-Powered Power Supply and Voltage Regulator ● MSF Signal Repeater and Indicator.
FEATURES ● The World of PLCs ● Ingenuity Unlimited ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page.

AUG '01

PROJECTS ● Digitimer ● Lead-Acid Battery Charger ● Compact Shortwave Loop Aerial ● Perpetual Projects 2 – L.E.D. Flasher – Double Door-Buzzer.
FEATURES ● Controlling Power Generation ● Ingenuity Unlimited ● Interface ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page.

SEPT '01

PROJECTS ● Water Monitor ● L.E.D. Super Torches ● Synchronous Clock Driver ● Perpetual Projects 3 – Loop Burglar Alarm – Touch-Switch Door-Light – Solar-Powered Rain Alarm.
FEATURES ● Controlling Flight ● Ingenuity Unlimited ● Practically Speaking ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page.

OCT '01

PROJECTS ● PIC Toolkit Mk3 ● Camcorder Power Supply ● 2-Valve SW Receiver ● Perpetual Projects 4 – Gate Sentinel – Bird Scarer – In-Out Register.
FEATURES ● Traffic Control ● Ingenuity Unlimited ● New Technology Update ● Circuit Surgery ● Interface ● Net Work – The Internet Page ● *Free* 2 CD-ROMs – Microchip 2001 Tech Library.

NOV '01

PROJECTS ● Capacitance Meter ● Pitch Switch ● Lights Needed Alert ● Teach-In 2002 Power Supply.
FEATURES ● Teach-In 2002 – Part 1 ● Practically Speaking ● Circuit Surgery ● New Technology Update ● Ingenuity Unlimited ● Net Work – The Internet Page ● *Free* 16-page Supplement – PIC Toolkit TK3 For Windows

DEC '01

PROJECTS ● Ghost Buster ● PIC Polywhatsit ● Twinkling Lights ● Mains Failure Alarm.
FEATURES ● Teach-In 2002 – Part 2 ● Marconi – The Father of Radio ● Interface ● Ingenuity Unlimited ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page ● 2001 Annual Index.

BACK ISSUES ONLY £3.30 each inc. UK p&p.
Overseas prices £3.80 each surface mail, £5.25 each airmail.

We can also supply issues from earlier years: 1998 (**except** Jan. to May, July, Nov., Dec.), 1999, 2000 (except Feb., July). Where we do not have an issue a photostat of any ***one article*** or ***one part*** of a series can be provided at the same price.

ORDER FORM – BACK ISSUES – PHOTOSTATS– INDEXES

☐ Send back issues dates . . . .

☐ Send photostats of (article title and issues date) . . . .

☐ Send copies of last five years indexes (£3.30 for five inc. p&p – Overseas £3.80 surface, £5.25 airmail)

Name . . . .

Address . . . .

. . . . Tel: . . . .

☐ I enclose cheque/P.O./bank draft to the value of £ . . . .

☐ Please charge my Visa/Mastercard/Amex/Diners Club/Switch £ . . . . Switch Issue No. . . . .

Card No. . . . . Card Expiry Date . . . .

Note: Minimum order for cards £5.

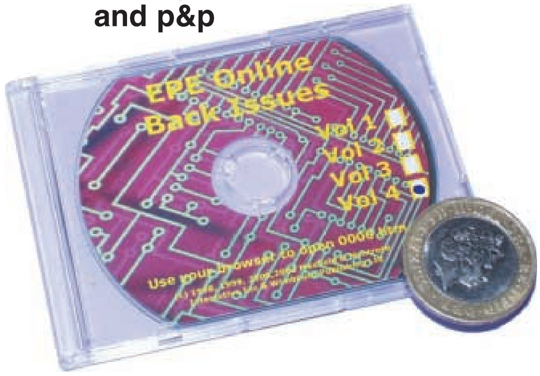
SEND TO: **Everyday Practical Electronics, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND.**
Tel: 01202 873872. Fax: 01202 874562.
E-mail: orders@epemag.wimborne.co.uk **On-line Shop:** www.epemag.wimborne.co.uk/shopdoor.htm
Payments must be in £ sterling – cheque or bank draft drawn on a UK bank. Normally supplied within seven days of receipt of order.
Send a copy of this form, or order by letter if you do not wish to cut your issue.

M01/02

STORE YOUR BACK ISSUES IN YOUR WALLET!

VOL 5 NOW AVAILABLE

ONLY £12.45 each including VAT and p&p



A great way to buy *EPE* Back Issues – our wallet-sized CD-ROMs contain back issues from our *EPE Online* website plus bonus articles, all the relevant PIC software and web links. All this for just £12.45 each including postage and packing.

VOL 1 CONTENTS

BACK ISSUES – November 1998 to June 1999 (all the projects, features, news, IUs etc. from all eight issues). Note: No advertisements or Free Gifts are included. **PIC PROJECT CODES** – All the available codes for the PIC based projects published in these issues.

VOL 2 CONTENTS

BACK ISSUES – July 1999 to December 1999 (all the projects, features, news, IUs, etc. from all six issues). Note: No advertisements or Free Gifts are included. **PIC PROJECT CODES –** All the available codes for the PIC-based projects published in these issues.

VOL 3 CONTENTS

BACK ISSUES – January 2000 to June 2000 (all the projects, features, news, IUs, etc. from all six issues). **PIC PROJECT CODES** – All the available codes for the PIC-based projects published in these issues.

VOL 4 CONTENTS

BACK ISSUES – July 2000 to Dec. 2000 (all the projects, features, news, IUs etc. from all six issues). **PROJECT CODES** – All the available codes for the programmable projects in these issues.

VOL 5 CONTENTS

BACK ISSUES – January 2001 to June 2001 (all the projects, features, news, IUs etc. from all six issues). **PROJECT CODES** – All the available codes for the programmable projects in these issues, including those for *Interface.*

EXTRA ARTICLES – ON ALL VOLUMES

BASIC SOLDERING GUIDE – Alan Winstanley's internationally acclaimed fully illustrated guide.

UNDERSTANDING PASSIVE COMPONENTS – Introduction to the basic principles of passive components.

HOW TO USE INTELLIGENT L.C.Ds, By Julyan Ilett – An utterly practical guide to interfacing and programming intelligent liquid crystal display modules.

PhyzzyB COMPUTERS BONUS ARTICLE 1 – Signed and Unsigned Binary Numbers. By Clive "Max" Maxfield and Alvin Brown.

PhyzzyB COMPUTERS BONUS ARTICLE 2 – Creating an Event Counter. By Clive "Max" Maxfield and Alvin Brown.

INTERGRAPH COMPUTER SYSTEMS 3D GRAPHICS – A chapter from Intergraph's book that explains computer graphics technology in an interesting and understandable way with full colour graphics.

EXTRA ARTICLE ON VOL 1 & 2

THE LIFE & WORKS OF KONRAD ZUSE – a brilliant pioneer in the evolution of computers. A bonus article on his life and work written by his eldest son, including many previously unpublished photographs.

NOTE: These mini CD-ROMs are suitable for use on any PC with a CD-ROM drive. They require Adobe Acrobat Reader (available free from the Internet – **www.adobe.com/acrobat**)

Order on-line from
www.epemag.wimborne.co.uk/shopdoor.htm
or www.epemag.com (USA $ prices)
or by phone, Fax, E-mail or Post

BACK ISSUES CD-ROM ORDER FORM

Please send me .... (quantity) BACK ISSUES CD-ROM **VOL 1**

Please send me .... (quantity) BACK ISSUES CD-ROM **VOL 2**

Please send me .... (quantity) BACK ISSUES CD-ROM **VOL 3**

Please send me .... (quantity) BACK ISSUES CD-ROM **VOL 3**

Please send me .... (quantity) BACK ISSUES CD-ROM **VOL 5**

Price £12.45 each – includes postage to anywhere in the world.

Name . . . .

Address . . . .

. . . .

. . . . Post Code . . . .

☐ I enclose cheque/P.O./bank draft to the value of £ . . . .

☐ Please charge my Visa/Mastercard/Amex/ Diners Club/Switch

£ . . . .

Card No. . . . .

Expiry Date . . . . Switch Issue No. . . . .

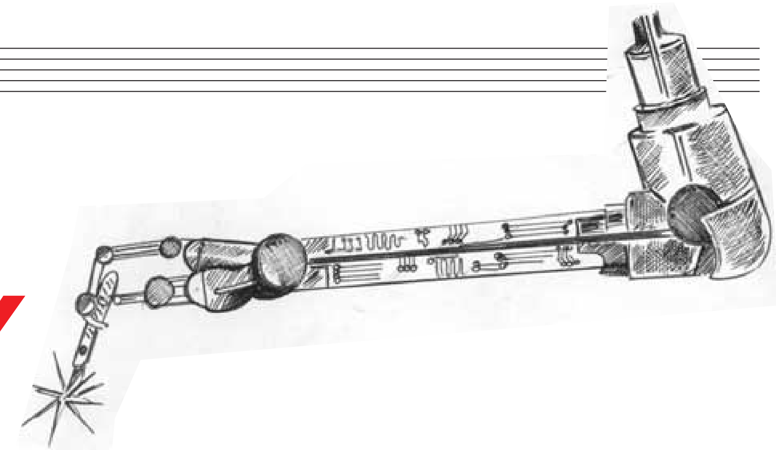
SEND TO: **Everyday Practical Electronics, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND.**
Tel: 01202 873872. Fax: 01202 874562.
E-mail: orders@epemag.wimborne.co.uk

Payments must be by card or in £ Sterling – cheque or bank draft drawn on a UK bank.

Normally supplied within seven days of receipt of order.
Send a copy of this form, or order by letter if you do not wish to cut your issue.

Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY and IAN BELL

This month our Surgeons go back to the classroom to find the answer to a reader's filter problem

Calculated Approach

A query arrived from **Graham Hunter** – who also enquired about the use of transconductance op.amps in last month's *Surgery*. Graham asks:

In designing a notch filter, an equation I am trying to get the hang of is one that I have seen on every filter circuit that I have looked at since embarking on this problem. The first problem is that if resistor R and capacitor C need to be in "base" values, there would be an incredible number of noughts floating around to cause confusion and mistakes. Surely there is a shorthand version to avoid all those noughts!

My second problem is that having an idea of the frequencies that need to be filtered means a re-arrangement of the equation. Could you please go through all the stages, even though some may seem obvious to you. My sincere thanks, ***Graham Hunter.***

All Being Equal

The formula Graham referred to is:

$$f = \frac{1}{2\pi RC}$$

Many readers have a set of formulae to hand which they use to calculate circuit values from time to time – such as calculating the current through a resistor when we know the voltage and resistance values (derived from Ohm's Law *I=V/R*). However, these equations are more fundamental than just calculation instructions, they show the *relationship* between all the items involved and can be rearranged to suit your needs. This all hinges around the equals sign – if we do exactly the same mathematical thing to both sides of the equation then the "equals" will continue to hold true.

For example, if ***a=b+1*** then we can add 1 to both sides of the equals to get *a*+1=*b*+1+1, or more tidily a+1=b+2. This might not seem very useful, but if instead we subtract 1 from both sides then we get *a*–1=*b*+1–1 or ***a*–1=*b*.** We can write this the other way round, as *b*=*a*–1. Thus we have *rearranged* the formula for "calculating *a* if we know *b*" into one in which we can "find *b* if we know *a*".

Basic Rules

A key point in rearranging formulae is a set of basic "algebraic rules". These may seem obvious, but they are very important as they allow us to remove unnecessary items from equations when we are rearranging them (this is known as *cancelling*). For example we just removed the 1–1 from the above because it equals 0, and also *b* plus zero is still equal to *b*.

A value divided by itself is one	$x / x = 1$
A value multiplied by 1 is equal to the value	$1 \times x = x$
A value minus itself is zero	$x - x = 0$
A value plus zero is equal to the value	$x + 0 = x$

Here is another example written in full. If $x = y / z$ we can multiply both sides by z to get $xz = yz / z$, (the multiplication sign is usually left out in equations), but z / z is 1 so we have $xz = y \times 1$, but $y \times 1$ is obviously equal to y, so we finish up with $xz = y$ (or $y = xz$, same thing). We usually leave out these "trivial" cancelling steps when writing out a rearrangement of an equation.

We can rearrange well-known circuit equations in just the same way. For example, consider the formula for the gain (A) of a non-inverting op.amp amplifier:

$$A = V_{out}/V_{in} = R_2/R_1$$

(see *Teach-In 2002* Part 2). If you know the gain you want, and you know the value of R_2, how do you find what value to use for R_1?

Start by subtracting 1 from both sides. Then multiply both sides by R_1 and then divide both sides by (A–1) to get the formula you need. Here's how it's done:

$$A = 1 + \frac{R_2}{R_1} \Rightarrow A - 1 = \frac{R_2}{R_1} \Rightarrow$$

$$R_1(A-1) = R_2 \Rightarrow R_1 = \frac{R_2}{(A-1)}$$

In the above the arrow symbol is used to mean "implies" or "it follows that". It shows the steps in our "mathematical reasoning". Note that when we multiplied A–1 by R_1 we used round brackets, also known as parentheses ( ), around the *A*–1, so we wrote $R_1(A–1)$. The parentheses grouped the *A* and the –1 together as a single item that we could add, multiply, divide by etc. We could write out $R_1(A–1)$ "in full" as $R_1A - R_1$.

Side-by-Side

Using the ideas discussed above, we can also rearrange the filter equation. Start by multiplying both sides of the equation by *R*, which cancels out *R* underneath in the right hand side. You can then divide both sides by *f*, which cancels out *f* in the left hand side leaving *R*. Multiply by *C*, which cancels out *C* in the right-hand side and lastly, divide by *R* leaving the formula for calculating *C*. Thus we can calculate *f*, *R* or *C* as needed. A scientific calculator helps, especially if it is pre-programmed with the value of π.

$$f = \frac{1}{2\pi RC} \Rightarrow fR = \frac{1}{2\pi C} \Rightarrow R = \frac{1}{2\pi fC} \Rightarrow$$

$$RC = \frac{1}{2\pi f} \Rightarrow C = \frac{1}{2\pi fR}$$

We can use a similar approach to form equations relating to quantities expressed other than in the base units (*f* in Hz, *C* in Farads, *R* in Ohms in this case). For example if we want to express *f* in kHz we can multiply the "*f* in Hz" value by 1000 to get the correct formula. We can then divide both sides of the equation by 1000 to get it into a useful form:

$$1{,}000f = \frac{1}{2\pi RC} \Rightarrow f = \frac{1}{2{,}000\pi RC}$$

f in kHz, *R* in Ohms, *C* in Farads

If we want *R* in kilohms as well, we can multiply the R by 1,000 to get

$$f = \frac{1}{2{,}000{,}000\pi RC}$$

f in kHz, *R* in kilohms, *C* in Farads

If we want C in microfarads we can divide the C value by 1,000,000.

$$f = \frac{1}{2{,}000{,}000\pi RC/_{1{,}000{,}000}} = \frac{1}{2\pi RC}$$

f in kHz, *R* in kilohms, *C* in μF

Which after cancellation of the "millions" neatly gets us a manageable formula without lots of zeros in it!

Scientific Notation – no noughts

The above approach of finding new versions of formulae in different units can be useful if you make frequent use of a limited number of them under a limited range of conditions. The problem is you have to remember the correct units combination as well as the formula itself. This may be a worse source of mistakes than getting the zeros wrong! A better solution to the zeros problem is to use *scientific notation* for the large numbers, that way you do not have to write out, or type in, loads of zeros, and your formula will work correctly for any valid range of input values.

Using scientific notation is very straightforward if you use a scientific calculator – you simply use the "enter exponent" (EE) key to set the correct multiple. For example to enter 4·7 kilohms ($4{\cdot}7 \times 10^3$) you would type 4·7 EE 3. For 0·68μF ($0{\cdot}68 \times 10^{-6}$ Farads) you would enter something like 0·68 EE 6±, the last key being the negative/positive key (often labelled +/–). By the way, these values give a frequency of about **50Hz** using the formula. Next we show you how to calculate this manually.

Please note that calculators vary on how keys are labelled and used, so you should consult the instructions on the use of scientific notation. For more information on scientific notation, and multiples and submultiples please look at *Teach In 2002* Part 1 in the November 2001 issue, pages 777 and 781.

In Longhand

If you do not have such a calculator, you still don't need to worry about all these zeros if you utilise scientific notation for the numbers. To multiply $0{\cdot}68 \times 10^{-6}$ by $4{\cdot}7 \times 10^3$ we first do $4{\cdot}7 \times 0{\cdot}68$ to get 3·196. Then **add** the powers of ten $-6 + 3$, which is -3, so the result is $3{\cdot}196 \times 10^{-3}$. Multiplying this by 2π gives the result $20{\cdot}1 \times 10^{-3}$.

We can adjust this back into "proper" scientific notation by shifting the decimal point to the left one place and changing the –3 to –2 (adding 1) to compensate, giving 2.01 x10^{-2} which is more user friendly.

To calculate $1 / (2{\cdot}01 \times 10^{-2})$ we do this actually as: $(1{\cdot}0 \times 10^0) / (2{\cdot}01 \times 10^{-2})$. We do the division 1/2·01 and get 0·498. We **subtract** the power of ten we are dividing by, from the power of ten we are dividing, that's 0 minus –2, which is 2. The overall result is $0{\cdot}498 \times 10^2$. Adjust the scientific notation by moving the decimal point one place to the right, subtracting one from the power of ten to compensate. This gives $4{\cdot}98 \times 10^1$, which is $4{\cdot}98 \times 10$ or **49·8**. (QED).

Summing Up

To summarise, the rules are: **add** the powers of ten when multiplying, **subtract** the powers of ten when dividing; adjust the decimal point so that there is one non-zero digit **before** the decimal point. For each decimal place you move right, subtract one from the power of ten to compensate. Add one for each decimal place shifted left.

Lastly, if you need to add or subtract two numbers expressed in scientific notation, they must have the same power of ten value. Shift the decimal place for one of the numbers to achieve this. For example the calculation $3{\cdot}46 \times 10^{-1} + 7{\cdot}9 \times 10^2$ becomes, after a 3 place shift, $0{\cdot}00346 \times 10^2 + 7{\cdot}9 \times 10^2$ which you can now add together. This gives $7{\cdot}90346 \times 10^2$ or 790·346 as the result. With some practice you will soon get the hang of it. ***I.M.B.***

CIRCUIT THERAPY

Circuit Surgery is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset, BH22 9ND. E-mail (no attachments) **alan@epemag.co.uk**. Please indicate if your query is not for publication. A personal reply cannot be guaranteed but we will try to publish representative answers in this column.

SHOP TALK
with David Barrington

PIC Magick Musick

Most of the parts needed to construct the *PIC Magick Musick* project are RS types and can be ordered through any *bona-fide* stockists, including some of our advertisers. You can order direct (credit card only) from **RS** on ***01536 444079*** or through the web at ***rswww.com***. A post and packing charge will be incurred.

Both the PICs used in this project are identically programmed and it does not matter which of the two is put into which socket assigned to them. If you are unable to program your own PICs, a fully-programmed PIC16F84-4P, *you will need two*, can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £5.90 each (overseas add £1 p&p).

The printed circuit board (code 332) and the software is available from the *EPE PCB Service*, see page 69. The software is available on a 3·5in. PC-compatible disk (*EPE* Disk 5) for the sum of £3 (UK), to cover admin costs (for overseas, see page 69). It is also available *Free* from the *EPE* web site at: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/MagicMusic**.

The 40kHz ultrasonic transducers are listed as a "matched pair" by **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***) code HY12N and they are also available from **Rapid** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***) codes 35-0175 (Tx) and 35-0180 (Rx). The only listing we have found for the TLC7524 8-bit DAC chip is RS (see above), code 650-087. Apart from RS (code 635-167), the L272 dual power op.amp is also stocked by **ESR** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code L272M.

Versatile Bench Power Supply

Most components listed for the *Versatile Bench Power Supply* project should be readily available. The choice of panel meter is left to individual choice and "pocket". The mains rated Class X2 suppression capacitor came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code JR36P. They also supplied the 7W wirewound resistor, code L1R, transient suppressor (VDR1), code HW13P and the 100mA 9V-0V-9V mains transformer, code WB01B. The larger 20VA mains transformer came from **RS** (☎ ***01536 444079*** or ***rswww.com***), code 207-166 or an alternative would be 805-091.

The PW01 6A 100V bridge rectifier seems to be no longer listed. However, a suitable substitute would appear to be listed by **ESR** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code 700-601. They can also supply the BUZ11 power MOSFET.

Readers may find that it is easier to locate and use "double-pole double-throw (d.p.d.t.)" switches rather than those depicted in the prototype photographs. The printed circuit board is available from the *EPE PCB Service*, code 333 (see page 69). The case came from RS (see above), code 267-2714.

Time Delay Touch Switch

It is vitally important that the correct type of capacitor is used for C5 in the *Time Delay Touch Switch* project, and that it must be rated for direct connection across the a.c. mains. Therefore, it is ***essential*** that a Class X2 type be used as these are specially rated for operation up to 275V a.c.

The X2 suppression capacitor used in the prototype was obtained from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), order code JE09K. A similar type is also stocked by **ESR Electronic Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), their code 867-061.

Try as we may, we have been unable to track-down an up-to-date listing for a 2·2 megohms carbon preset potentiometer, they all seem to stop short at 1 megohm. It has been suggested that a 4·7 megohms preset could be used in this circuit, or even possibly a 1 megohm type might be sufficient. A 4·7 megohms preset is listed by **RS** (☎ ***01536 444079*** or ***rswww.com***), code 387-032.

The small printed circuit board is available from the *EPE PCB Service*, code 331 (see page 69). A suitable electrical blanking plate should be stocked by most DIY superstores.

Forever Flasher

Figuratively speaking, one or two points need raising regarding the components for the *Forever Flasher* project.

As the circuit uses the CMOS 4016 bilateral switch i.c. in a relatively unorthodox manner, running it well below its minimum rated supply voltage, it is important to use one of the specific types mentioned in the article. The Philips HEF4016BP is the favoured choice and came from RS Components and can be ordered from any *bona-fide* RS stockist, or directly (credit card only) from **RS** (☎ ***01536 444079*** or ***rswww.com***), code 306-033.

The author's second choice is the Texas CD4016**BE** (*not* the CD4016*BCN*), however, we have been unable to find a listing for the BE version. We understand that this uses more current, so you may need to reduce the value of resistor R3 to around 4·7 megohms.

The 33 megohm resistor (R1) used in the prototype seems to be only available in a ½W rating and was purchased from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***). It is from their "High Voltage" range and should be ordered as: code V33M.

An extreme brightness red l.e.d. (preferably 3000mcd), with a 10 degrees viewing angle, is needed for D3. The author did not indicate which one he used, but two possible candidates appear to be listed in the Ultra-bright AlGaAs range from RS Components (see above). Both are rated at 3000mcd and are coded 564-015 (10° viewing) and 826-701 (7° viewing).

The small printed circuit board is available from the *EPE PCB Service*, code 330 (see page 69).

Teach-In 2002 – Lab Work

Only the capacitive type humidity sensor will be difficult for readers to find locally when shopping for this month's *Teach-In 2002 – Lab Work 3* components. The one in our demonstration set-up came from **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 61-0960, and has a rated capacitance of 122pF ±15% at 25°C, 43%RH, 100kHz.

All of the semiconductor devices should be readily available from our components advertisers. They are certainly listed in the latest **ESR Electronic Components** catalogue (☎ ***0191 251 4363*** or ***www.esr.co.uk***).

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 ★

SO TURN THE YEARS

Dear EPE,

I can't remember quite when I abandoned electronics as a hobby – I guess it waned when I left home to go to university, and finally petered out when I became a home-owner, and swapped Veroboard for Contiboard, 14/.076 for flat twin and earth and my Antex for a blowlamp.

My son seems interested now, and I thought I'd foster that, so I've been busy scheming and planning ways to make it fun, and not "electronics homework". I got to thinking about my last unfinished project, which was a bench power supply, started, if my memory serves me well, because I needed one for the testing and setup stage that I'd reached with "EMMA" (ask Messers Barrington or Kenward . . .).

Wondering whether to finish it, or just buy one, I thought I'd trawl the web to see what they cost, and that led me to Magenta Electronics with their kit, and their site led me to yours.

And what memories the history page brings back – I'm afraid I was never an *EE* reader, but I regularly bought *PE*, and sometimes *ETI* (in fact, I think the bench PSU is an *ETI* design). I'm sure I remember some of those front covers, and I definitely remember some of the adverts, and the suppliers. Home Radio (Components) Ltd – whatever happened to them? I wish I'd kept their catalogue. I think I've still got an old Henry's, but from the look of their website, they're a shadow of their former self. I know that Electrovalue are still going, but were catalogue-free for a while – their website is slowly (very slowly) taking shape. Maplin have gone from strength to strength it seems, and we won't talk about the fact that I remember when another little outfit was known simply as Radiospares . . .

A question for you, if I may – have components got a lot cheaper, in real terms? Obviously I'm no longer on a schoolboy's budget, but even so, the prices of bits do seem to be considerably less onerous than I recall from 25-30 years ago.

Anyway – glad to see the magazine is still going after the cycles of mergers and splits. Available from "good newsagents everywhere" I guess – I shall have to look out for it. Whatever happened to *PW*? And *Wireless World*? And the (tad ambitious) *Practical TV*?

Mike Perry, via the Net

Editor Mike replies:

Welcome back. Yes I remember EMMA Electronic Mime Mobile Animal (I think!) and ZEE which I took to *Tomorrows World* and spent an enjoyable day for it to get about two minutes on TV.

Yes, components are much cheaper in real terms now and of course a number of them are much more complex, possibly one of the reasons there are fewer hobbyist suppliers now – not much profit in components! I still have a Home Radio catalogue – they didn't change with the times and simply faded away.

You will be pleased to hear that *PW* is still going strong and *Wireless World* has become *Electronics World* – mainly deals with software for electronics engineers now. *Practical Television* became *Television* and is still going strong.

Unfortunately with specialist titles it's now more difficult to get into most newsagents but you should find all the above titles, and *EPE*, in a large branch of WHS. *EPE* can also be bought online, via **www.epemag.com**, or ordered from any UK newsagent.

We hope your son will find good use for the digital multimeter you've won on his behalf!

SOLDERING IRON TIPS

Dear EPE,

I intend soldering some very small and sensitive components, and I've been trying to pick out an appropriate iron. I'm considering the Weller W60P-3, a 60 watt iron which is output controlled by the tip you use. Would 60 watts be too much power for fine work?

Rob, via the Net

This query was sent to On-Line Editor Alan, who from his knowledge of soldering replies:

I would speculate that 60 watts is much too high for such intricate work, and the lack of precision temperature control would be a worry. Although you would have plenty of power in reserve – useful for larger joints – you don't need that with small parts. The high "mass" of these irons means they store plenty of heat in reserve. The catalogue says they are suitable for heavy electrical connections and even suitable for sheet metal! I think they will run too hot and overshoot for what you need.

I would use a 45W temperature controlled iron at most, for which you will also need the base station. Or try a cheap 15W mains-powered pencil iron with a fine tip if you don't plan to do much soldering.

I usually use 600°F to 700°F, which I can set on my soldering iron station.

Alan Winstanley

KIWI POWER

Dear EPE,

Are your projects suitable for construction in New Zealand, where we have 230V a.c. mains power?

Simon, via the Net

Indeed they are Simon. We in the UK also have 230V a.c. mains. In fact, though, most projects are battery powered and do not require a mains supply. But even those that do can normally be used anywhere in the world irrespective of the mains a.c. voltage simply by using a suitable mains transformer. The exceptions are the occasional (but rare) projects that use the 50Hz mains frequency for timing purposes. These are only suitable for 50Hz operation and would not work correctly on 60Hz, for example, such as is supplied in the USA.

LIGHTS NEEDED ALERT

Dear EPE,

I have been reading your magazine for a number of years now, and find it very interesting. I have also closely followed your *PIC Tutorial* series, getting quite involved with PIC programming, especially in my A-Level technology project where I eventually obtained an A grade. I have decided to take a gap year in industry, to get some hands on experience of professional electronics in a working environment.

I noticed that a safety precaution for fitting the *Lights Needed Alert* project (Nov '01) was to remove the car battery's *positive* terminal. It is standard procedure to remove the *negative* terminal first and reconnect it last. This is to help prevent causing a short circuit to the car body while either using the tools on the terminal or jewellery such as a metal watch strap, which could accidentally bridge the gap from the terminal to the car body.

A short circuit of an unfused car battery would cause a massive current of many hundreds of amps, welding the points of contact together, with results ranging from a dazzling flash to a nasty burn. The connection/disconnection procedure must be reversed for positive earthed cars, which are very rare these days.

By the way, I thought I'd give the Linux operating system a try after a lot of frustration with Win95, and I have not looked back! I am now using the Debian distribution which has some smart features like the ability to update all software on your system to the latest version on the Debian server by issuing only one command. I am surprised at the stability.

I am running FTP, HTTP, SMB, DNS, NETBIOS, SMTP and POP3 internet services, as well as using it as a secure desk top PC. It has never crashed and has been running for several months and still going strong. I think the most significant thing is that all of this is totally free and available to download via the Internet.

Craig Shelley, via the Net

We are grateful for your comments on car electrical safety, Craig, which we should have picked up on, and for your Linux observations.

BEEB BASIC

Dear EPE,

Readers who have used and programmed using BBC Basic may be interested to know that a new version of BBC Basic has just been released which has been written for Windows. As with previous versions of BBC Basic it includes an assembler which will allow access to PC ports for input and output.

A demo version can be downloaded from **www.rtrussell.co.uk/products/bbcwin/bbcwin.html**, which will allow you to write programs up to 8K in size. The full version allows you to write programs and compile them to create an executable file.

Trevor Cattermole, Colchester, via the Net

Intriguing, Trevor! In fact most readers have moved on now and it seems best that they do. How nostalgic to think that 8K of program memory used to be regarded as big! My Toolkit TK3 *requires around 1·5MB!*

TK3 AND WINZIP

Dear EPE,

Congratulations on an excellent and stimulating project in *Toolkit Mk3* (Oct/Nov '01. I have ordered a p.c.b. and look forward to many hours of enjoyment.

I have downloaded the software from your web site and breadboarded the circuit but get the message "Run time error 53 File not found" when I select the option "Check PCB" the software then crashes. There is no indication as to what file is not found. I would be very grateful if you could tell me how I might be able to get around this problem or if you are planning a fix.

Ralph Llewellyn, via the Net

Well, as Ralph already knows, this took a bit of solving!

I had encountered this message when trying to run TK3 *on Editor Mike's office machine known to have a printer port problem, and thought that was probably the cause.* TK3 *has otherwise correctly run on all the many machines it has been tried with.*

Ralph's identical crash made me look further into the behaviour of Mike's machine. It was obviously a system failure rather than a TK3 *problem, so I inserted intercepts at strategic points in my program and ran it again on Mike's PC.*

Thus I discovered what file it was looking for, which I knew to be there! Except that it wasn't – its filename had been curtailed during the unzipping process, as had other filenames. This turned out to have been caused by Mike's PC having an old version of Winzip (curiously it's ID screen also made reference to PKunzip). Having upgraded to the current version of Winzip, TK3 *ran OK.*

After telling Ralph my findings, he E-mailed back "You hit the nail right on the head. I used PKunzip version 2.04g to unzip the files. I have now unzipped using version 8.0 and the software allows me proper access."

Whilst most TK3 *users should be aware of this situation through notes on our ftp site and through the* Chat Zone*, the first CD-ROM batch did not include info on this (it was not known at that time). Readers unzipping software files for other* EPE *designs should also take care to use a current version of Winzip.*

The latest version of Winzip is available for free download from **www.winzip.com**.

TK3 and PIC16F870

Dear EPE,

I have been to Microchip's web-site and downloaded the programming specifications for the PIC16F870 and found that it is the same as the other PIC16F87x devices you allow for in *TK3*.

Could you add the PIC16F870 to the list of PICs and making its memory size 2K and data EEPROM 64 bytes?

Mark Underwood,
via the Net

Thanks for the comment Mark, yes I can and will if/when I do an update to TK3 *sometime in the future. At that time I shall try to incorporate any practical reader suggestions that could prove useful. One thing I'm gradually doing for my own benefit is to allow keyboard selection of some button functions in the assembly-programming-editing cycle, for example.*

In the meantime, just select the 873 or 874 option but stay within the 2K command limit of the 870.

TK3 INSPIRES BUGS!

Dear EPE,

I have downloaded the new *PIC Toolkit TK3*. Well done John! You seem to have included everything we need, and it's so nice to be able to switch from editing to assembly and then send the program to the PIC. Other nice points are the command listing, the number converter, being able to convert TASM/MPASM etc.

I am using my old *Mk2* board and adding that link was so easy! I was lucky as I used ribbon cable to make up the printer lead, it was only 8-way which gave me two grounds, so a bit of soldering at both ends put it to rights. I am once again into PIC programming and have renewed interest in the buggy I started many months ago.

I am also interested in the *RealRobots* buggy as per the same named magazine, not that it will ever compete with *EPE*! If there are any readers out there who would like to exchange ideas on the subject I would really like to hear from them, by E-mail to **mel.saunders@lineone.net**. My next buggy will have stepper motors for precise movement and control . . . and could even be offered to *EPE*!

Mel Saunders,
Leicester, via the Net

Thanks for the kind comments Mel. It's a long time since we did anything on robotics. We were offered a buggy as a possible design idea sometime ago but the designer never submitted a script. Pity, we had planned on calling it something like "The True Millennium Bug"!

TK3 AND MPASM DECIMAL

Dear EPE,

I recently converted a TASM file to an MPASM file because I wanted to run one of your *PIC Tutorial* programs (TUT15.ASM) on the MPASM's simulator. The program worked well but in the conversion the decimals in TASM became hexadecimals in MPASM.

What I mean is that if the TASM file has a decimal value of 16 (binary 10000), when I convert it to MPASM using *Toolkit TK3*, MPASM reads it as 16 hexadecimal (binary 10110). The two programs are different and the PIC sees it as such. Is there maybe something I am doing wrong here?

Scott Rennie, via the Net

Yes Scott, there is (as of course we've already discussed by E-mail). You had MPASM's Radix Option set to HEX. For the embedded Radix command line inserted during TK3*'s TASM to MPASM conversion to be actioned, MPASM's Radix Option must be set to Default. If you examine your .ERR file created by MPASM you will see a warning message to the effect that the embedded command line has been ignored.*

(Several E-mails between Scott and I were exchanged before we got this sorted out!)

HARDWARE FOR TK3

Dear EPE,

I have just downloaded the *Toolkit TK3* software. Can you recommend what hardware I can use with this program in order to program a PIC. Would your *PICtutor* Deluxe Development kit work with it or are there any other cheaper models that you sell?

Could you also please tell me what the PIC and EEPROM do? Do each run a program or is one only to hold data that is accessed by the other. If you can program a PIC through the hardware that you sell i.e. Development Kits, would they also program an EEPROM, if not what do I need to do this.

Tomas Henry, via the Net

The TK3 *software has been designed only for use with* Toolkit Mk2 *and* Mk3 *boards. It cannot be used with the* PICtutor *board without considerable hardware modification, an act which would invalidate that board's guarantee.*

Your other question has answers that are too complicated to discuss here. In a nutshell, the PIC holds the program that tells the PIC what actions it is to take. Its data EEPROM holds data that can be used by the program to store and/or retrieve additional and changeable values which are preserved even after the power has been switched off. PICtutor*'s software cannot load data directly into the data EEPROM, although* TK3 *can.*

I suggest that you complete your study of PIC programming using PICtutor *and then consider migrating to* TK3 *and its* Mk3 *board when you have more experience.*

TK3 AND WIN 2000

Dear EPE,

I downloaded your TK3 code and went to compile it but it would seem that there is a file missing **inpout32.bas**, although the **dll** is present.

I'm using Windows 2000 and the precompiled version crashes on my system, that's why I'm going for the recompilation. Could you put the file up on the *EPE* ftp?

Tony Wilson, via the Net

Tony, you've raised two major points that need public airing:

First, inpout32.bas *is a freeware file brought to our attention by Robert Penfold through his* Interface *pages. As such it is not part of my suite of source code files supplied with* TK3*. However, it can be downloaded from the* Interface *folder on our ftp site.*

Secondly, TK3 *has not been designed to run under Windows 2000, NT or XP, which have a different architecture to Win95/98/ME. I say in the text that* TK3 *has been designed* specifically *for the latter three. As I do not have machines that run W2000/NT/XP (nor intend to buy any) I regret that I do not propose to upgrade* TK3 *to also run with these other operating systems.*

PIC G-SCOPE

Dear EPE,

I have built the *PIC G-Scope* (May '01) and it is running very nicely except for one problem. When inputting, for example, a 1kHz 5V p-p square wave (bypassing the input op.amp), the display seems to "hesitate" every 1 to 2 seconds (as if the A/D update was too slow for the screen update, although I don't think this is the problem). This is demonstrated by the scope trace going to zero during the hesitation.

Roger Lucas, via the Net

Before I even had a chance to think, Roger follows up with:

I think I have found the reason for the "apparent" intermittent trace reset. The ADC on the '87x is 10-bit. My signal 5V p-p input occasionally exceeded the power supply, i.e. ADC ref, by a smidgen. The 10-bit seems to accept this by rolling over to a 9-bit value, but since the scope only uses 8-bit values, the processing accepts this as a zero value, which was dumped to the l.c.d. as an apparent zero signal. Why do the most perplexing problems generally turn out have the simplest solution?

Incidentally, I love your new *TK3* software with my Magenta version of the earlier *Toolkit Mk2* board, which really speeds chip programming over Picstart, although I use MPlab for assembling and program development because of the assembler directive language.

I was pleased to read your two last paragraphs Roger. Good news on both!

COMPETITION

Dear EPE,

I've been interested in electronics for many years, but the software side has always been my passion. I used to build small 6502 based processor cards, hang off old calculator l.e.d. displays and make the thing produce strange renditions of "Golden Brown" and bits of Beethoven's symphonies.

So, I suggest a challenge. Using your chat group, people form into small groups of two or three. The team then designs and builds a specific project to be set by *EPE* and within a given budget, with the software to be run on a modest PC. *EPE* to judge, and the winners given an all-expenses holiday in Bermuda, or a tour of the *EPE* offices and free lunch in the staff canteen, and perhaps also get their design published.

Joe Farr, via the Net

Nice idea Joe! Unfortunately we have found that design competitions of this type attract a very low entry and have not proved to be worthwhile in the past. So Bermuda's off – and our canteen's yet to be built!

Special CD-ROM Review

ELECTRONIC CIRCUITS & COMPONENTS – V2.0

TERRY de VAUX-BALBIRNIE

"Test driving" the latest version of this popular electronics learning resource.

UNTIL recently, I was a moderator in Electronics for one of the larger School Examination boards. This involved visiting schools and colleges to assess students' course work. It was against this background that I looked forward to reviewing the latest *Electronics Circuits and Components – Version V2.0* CD-ROM by the well-known author, Mike Tooley.

This is one of a series of four CD-ROMS produced by Matrix Multimedia and which, together, comprise an entire course in Electronics up to university level. The other members of the series are: *Analogue Electronics, Digital Electronics* (also by Mike Tooley) and *Electronic Projects* (by Max Horsey). – See the **Electronics CD-ROMs** pages (pages 52 and 53) in this issue.

Electronics Circuits and Components may be used as a teacher-based resource with the aid of a large display. Alternatively, students may work on their own and at their own speed guided by the teacher. Subject to licence, the material may be operated on a network. Most readers will be interested in the low-cost student/home version (which has certain assessment features missing) suitable for self-study at home.

Target Users

The course has been written for more or less anyone wishing to further his or her knowledge of electronics. However, they will require basic mathematics and science skills. They also need to be reasonably proficient in their understanding of English.

At one end of the scale, there will be individuals studying on their own at home for pleasure or employment needs. At the other, there will be students working to GCSE, A-level, GNVQ, BTEC or other pre-University stage.

Making Changes

The original *Electronics Circuits and Components* has been in production since 1996 and Version 2.0 is a thorough revision of this and embodies changes made in response to syllabus up-dates, customer feedback and new technology available.

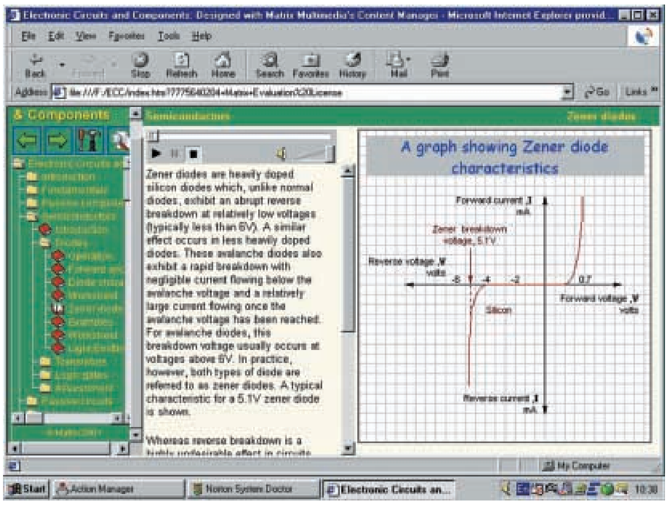
In particular, it is now *browser-based*. In other words, it looks and "feels" like Internet web pages. This is certain to be popular with students who will be familiar with this format. It also enables the material to be processed like any web page and delivered over the Internet for distance learning.

Requirements and Installation

The minimum system requirements are a Pentium-based PC running Windows '95/'98/NT/2000/ME with 32MB RAM and free hard drive space (see below). You also need a Java enabled browser. Microsoft *Internet Explorer V5.0* or Netscape *Navigator V4.5* is the minimum requirement. A sound card and speakers are also needed if the user wishes to make use of the sound commentaries.

Setting-up was found to be reasonably straightforward. However, a *full installation* (to copy all files on to the hard drive) requires 360MB. Those having an older machine fitted with a 1GB (or smaller) drive, may find that they have insufficient space. When using a modern drive having a capacity of, say, 10GB or more there should be no problem unless, of course, it is "junked up" with large sound files and images.

If there is insufficient capacity, space will need to be cleared. Alternatively, a *minimum* installation could be performed requiring only 7MB. Files are then read from the CD-ROM itself. This works well. Although slower than recovering files direct from the hard drive, it is a satisfactory method.



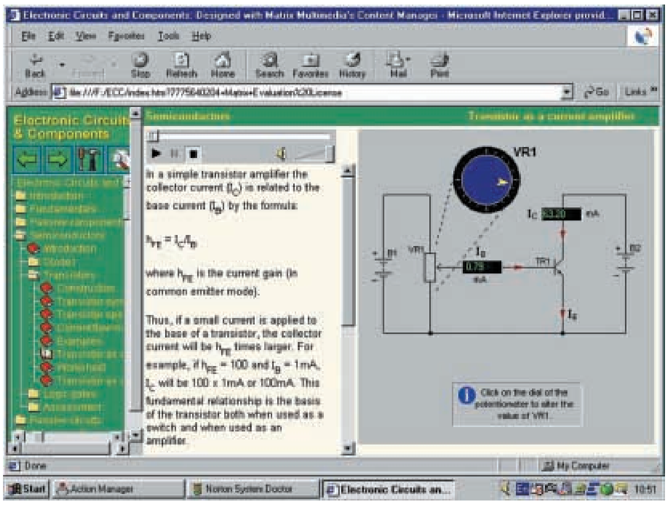
Semiconductors/diodes and Zener diodes have been selected in this screen shot and confirmed by a title bar showing chapter and page.

Up and Running

With the software loaded and running, four *toolbuttons* appear near the top left-hand side of the screen (see photographs). These perform *forwards* and *backwards* (arrows) *system check* (hammer and screwdriver) and *search* (magnifying glass) functions which will be explained at the appropriate point.

Below the toolbuttons is a "tree" (similar to *Windows Explorer*) which displays the entire content. It shows eight broad areas which, when one is clicked on, expands to a set of narrower topics ("chapters"). Clicking on one of these brings pages of detailed information – one page per topic. The user can move through the pages using the *forwards* and *backwards* toolbuttons or by clicking the mouse at the appropriate point.

Selecting a page shows a window. This is typically "split" into an image, explanatory text and, perhaps, a *virtual laboratory* (see later). The text may be played over loudspeakers or headphones plugged into the sound card. This is controlled using the *start, stop, pause* and *volume* controls which appear above the text (see photographs). The commentary is in the form of a clear natural voice which will be understood by those whose first language is not English.



Screen shot of circuit diagram depicting a Transistor as a current amplifier. *It allows the student to adjust the* virtual *potentiometer to control the current entering the base of a transistor and to measure the results with a virtual milliammeter.*

Content

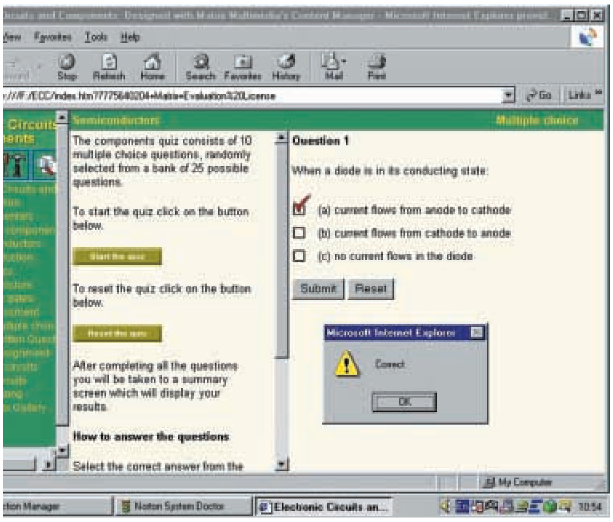
The main topics or chapters are: Introduction, Fundamentals, Passive Components, Semiconductors, Passive Circuits, Active Circuits, Fault-Finding and the Parts Gallery.

The Introduction provides information about other resources available and includes a printable graph-paper grid. There is also a set of Teacher Notes. In this section (and with the *System Check* toolbutton), it is possible to change the style of symbols (European or US) and set UK or US spelling (analogue/analog). I note, however, that "licence" always appears as "license".

The system check will also make sure all parts of the software are in place. Contacts for the manufacturer's web site and Technical Support are given here too.

Virtual Laboratory

In a *virtual laboratory*, students may illustrate specific principles for themselves using on-screen components. They can change certain factors and note the effect. For example, *Transistor as a current amplifier* allows the student to adjust a "potentiometer" to change the current entering the base of a transistor and measure it using a virtual "milliammeter". The collector current may then be measured using another "milliammeter" and a set of results recorded and graphed (see screen photographs).



Multiple choice questions are chosen from a material store and may be reset to call up new ones. Clicking on a box brings up the "correct" window.

Opening up *Semiconductors/Diodes/Light Emitting Diodes* brings up an experiment in which a "variable resistor" may be adjusted to vary the current through an "l.e.d." which becomes brighter as the current is increased.

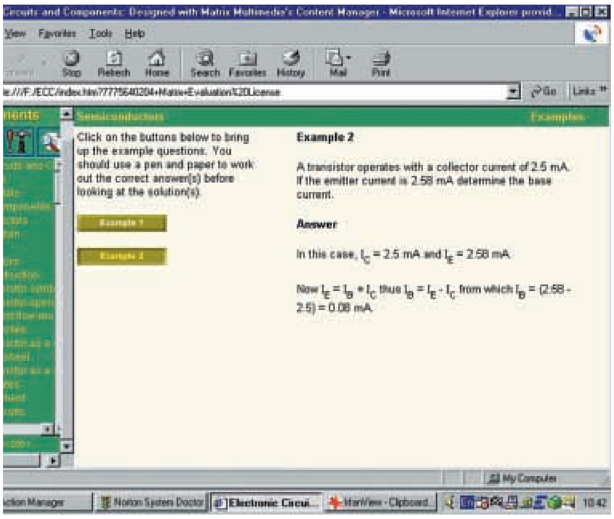
Assessment

At the end of each major section there is an Assessment. This comprises multiple-choice questions, examination-type questions and an assignment (note that the student/home version has only multiple-choice questions). The multiple choice questions are chosen from a bank of material and may be reset to show new ones. Clicking on the appropriate box brings up the "correct" window (see photographs). These questions are designed for self-assessment and motivation rather than formal assessment.

Perhaps of more interest to the teacher are the examination questions and assignments which provide extension work. *Worksheets* also appear at intervals. These involve experiments which may be carried out using real equipment or linked into Electronics Workbench/MultiSIM files. These three elements may be used as a basis for assessment. All except the multiple choice questions may be printed off for distribution.

Sets of *examples* are given throughout the course. These are short numerical questions illustrating a specific point. The answer is written down by the student and checked against the specimen answer. I like the way the answer is explained in terms of the formula needed and the intermediate stages applied to obtain the result.

It is possible to edit the worksheets and examination questions using an HTML editor. More details are given in the *Notes for Teachers.*



A typical "example" question and answer screen display.

Finding Fault

The fault-finding section contains three virtual circuits (Power Supply Unit, Lamp Controller and Audio Amplifier) into which various simple faults may be introduced by pressing the appropriate button. The student then identifies the fault using virtual meters or a virtual oscilloscope.

The instrument leads are simply "dragged" to connect with the chosen components. The results are then revealed and compared with the student's findings.

The Parts Gallery

The Parts Gallery collection provides information about many of the common components used in electronics. This is a useful resource which may be referred to at any time. As before, the "tree" is expanded to give information about a specific member of the group (enamel coated wirewound resistor, multi-pole rotary switch, etc.). For each, there is text, a sound commentary and a detailed close-up image.

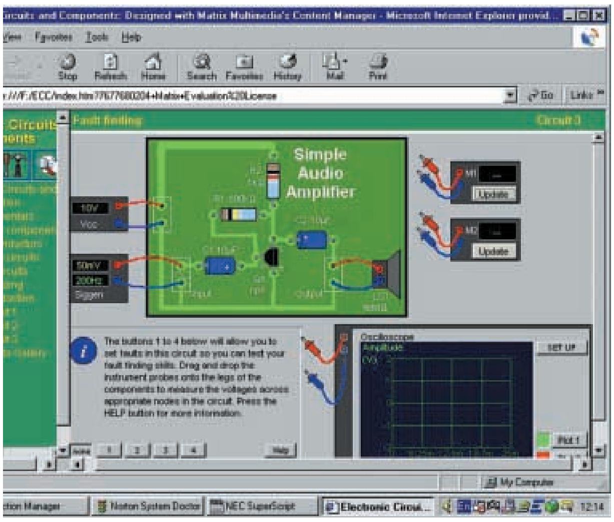
The *Search* feature is another resource which is available all the time. It is activated by clicking on the *magnifying glass* toolbutton. Various options may be set. For example, a keyword or a phrase may be entered. The search may also be narrowed to a specific area if desired.

Due to different system configurations, the search engine does not always work. However, notes are given which should help the user to get it up and running.

Summary

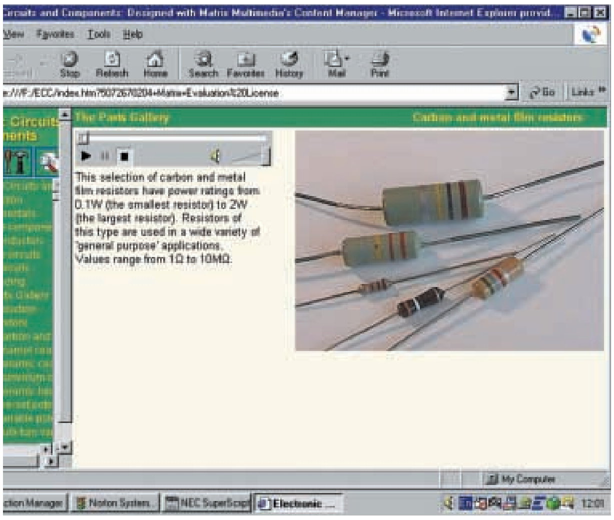
There is an inherent problem writing a course which aims to be "all things to all men". Teachers of those having limited ability will need to be very selective about the parts they use. Some of the material could well discourage a student at the lower end of the ability range. However, this is a job for the teacher or lecturer in the light of the qualification being sought.

Those working on their own will have to do it themselves. They will need to refer to the requirements of their own course and select appropriate work. However, there is plenty of material to satisfy all students and for those at the upper end of the range, there is plenty to challenge them.



Fault-finding display for a simple audio amplifier. Fault conditions are introduced by "pressing" buttons 1 to 4 and the student's task is to investigate them using virtual test equipment, including an oscilloscope.

The course may be conducted entirely without the experience of using real equipment (providing suitable software is available). However, I think it would be a good idea to provide "hands-on" experience with actual instruments and components as often as resources allow.



Typical screen shot from the Parts Gallery showing a group of carbon and film resistors, together with a brief description.

I liked the opportunity for students to record longer answers in written form. I also thought that answers to the numerical examples were well presented. Failure to show *how* a student reaches a numerical answer is a common reason for losing marks.

I would certainly recommend *Electronics Circuits and Components – Version V2.0.* The student/home version, although lacking some assessment material, is sufficiently inexpensive to put it within reach of most people.

Versions

There are three versions depending on the purpose to which it is put. The prices are as follows:

Student/Home use	£45 inc. VAT
Single-user Institution (Schools, Colleges and Industry)	£99 plus VAT
Institutional Site Licence	£499 plus VAT

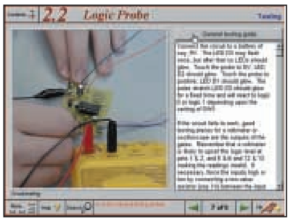
Note that the Student version is *not* licensed for use in institutions or businesses and must only be used by a single student working on his or her own at home.

Technical support is available at **support@matrixmultimedia.co.uk**.

You can purchase the complete "set" of CD-ROMs from our *Electronics CD-ROMs* pages in this issue – see pages 52 and 53.

ELECTRONICS CD-ROMS

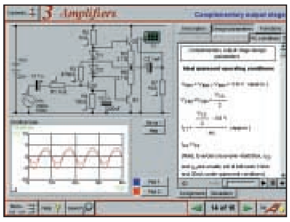
ELECTRONICS PROJECTS



Logic Probe testing

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.

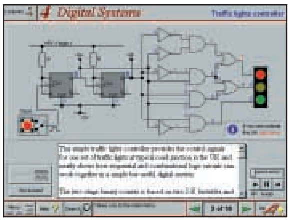
ANALOGUE ELECTRONICS



Complimentary output stage

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.

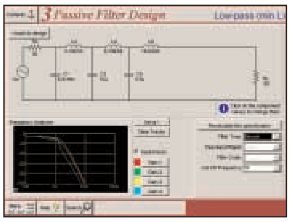
DIGITAL ELECTRONICS



Virtual laboratory – Traffic Lights

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, 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, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units.

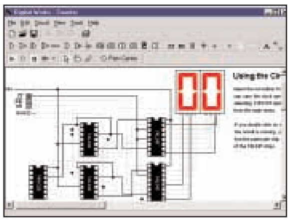
FILTERS



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

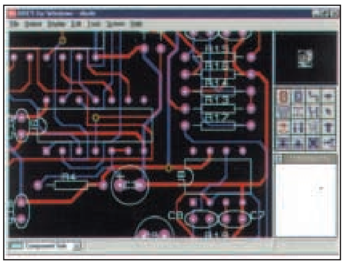


Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability.

- Software for simulating digital logic circuits
- Create your own macros – highly scalable
- Create your own circuits, components, and i.c.s
- Easy-to-use digital interface
- Animation brings circuits to life
- Vast library of logic macros and 74 series i.c.s with data sheets
- Powerful tool for designing and learning

ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots. etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

"C" FOR PICMICRO MICROCONTROLLERS

C for PICmicro Microcontrollers is designed for students and professionals who need to learn how to use C to program embedded microcontrollers. This product contains a complete course in C that makes use of a virtual C PICmicro which allows students to see code execution step-by-step. Tutorials, exercises and practical projects are included to allow students to test their C programming capabilities. Also includes a complete Integrated Development Environment, a full C compiler, Arizona Microchip's MPLAB assembler, and software that will program a PIC16F84 via the parallel printer port on your PC. (Can be used with the *PICtutor* hardware – see opposite.)
Although the course focuses on the use of the PICmicro series of microcontrollers, this product will provide a relevant background in C programming for any microcontroller.

PRICES

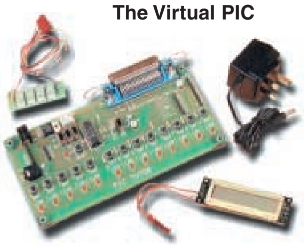
Prices for each of the CD-ROMs above are:

Hobbyist/Student ....£45 inc VAT
Institutional (Schools/HE/FE/Industry).............£99 *plus* VAT
Institutional 10 user (Network Licence) ....£199 *plus* VAT

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

Interested in programming PIC microcontrollers? Learn with PICtutor

The Virtual PIC



Deluxe PICtutor Hardware

This highly acclaimed CD-ROM by John Becker, 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.

Two levels of PICtutor hardware are available – Standard and Deluxe. The **Standard** unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials. The **Deluxe** Development Kit is supplied with a plug-top power supply (the **Export** Version has a battery holder), all switches for both PIC ports plus l.c.d. and 4-digit 7-segment l.e.d. displays. It allows users to program and control all functions and both ports of the PIC. All hardware is supplied **fully built and tested** and includes a PIC16F84.

PICtutor CD-ROM

Hobbyist/Student . . . .£45 inc. VAT
Institutional (Schools/HE/FE Industry) . . .£99 *plus* VAT
Institutional 10 user (Network Licence) .£199 *plus* VAT

HARDWARE

Standard Development Kit . . . .£47 inc. VAT
Deluxe Development Kit . . . . .£99 *plus* VAT
Deluxe Export Version . . . . . .£96 *plus* VAT

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

ELECTRONIC COMPONENTS PHOTOS

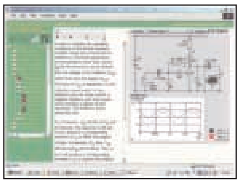
A high quality selection of over 200 JPG images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Also contains a **FREE** 30-day evaluation of Paint Shop Pro 6 – Paint Shop Pro image editing tips and on-line help included!

Price £19.95 inc. VAT

NEW VERSION 2

ELECTRONIC CIRCUITS & COMPONENTS V2.0



Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits. Active Circuits.*** *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams. Selections include: ***Components, Components Quiz, Symbols, Symbols Quiz, Circuit Technology.***

Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

Hobbyist/Student . . . .£45 inc VAT
Institutional (Schools/HE/FE/Industry) . . . .£99 *plus* VAT
Institutional Site Licence . . . .£499 *plus* VAT

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

ELECTRONICS IN CONTROL

NEW

Two colourful animated courses for students on one CD-ROM. These cover Key Stage 3 and GCSE syllabuses. **Key Stage 3:** A pictorial look at the Electronics section featuring animations and video clips. Provides an ideal introduction or revision guide, including multi-choice questions with feedback. **GCSE:** Aimed at the Electronics in many Design & Technology courses, it covers many sections of GCSE Electronics. Provides an ideal revision guide with Homework Questions on each chapter. Worked answers with an access code are provided on a special website.

Single User £29 inc. VAT. Multiple User £39 plus VAT
Student copies (available only with a multiple user copy) £6 plus VAT
(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

MODULAR CIRCUIT DESIGN

NEW VERSION 3

Contains a range of tried and tested analogue and digital circuit modules, together with the knowledge to use and interface them. Thus allowing anyone with a basic understanding of circuit symbols to design and build their own projects. Version 3 includes data and circuit modules for a range of popular PICs; includes PICAXE circuits, the system which enables a PIC to be programmed without a programmer, and without removing it from the circuit. Shows where to obtain free software downloads to enable BASIC programming. Essential information for anyone undertaking GCSE or "A" level electronics or technology and for hobbyists who want to get to grips with project design. Over seventy different Input, Processor and Output modules are illustrated and fully described, together with detailed information on construction, fault finding and components, including circuit symbols, pinouts, power supplies, decoupling etc.

Single User £19.95 inc. VAT. Multiple User £34 *plus* VAT
(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98/NT/2000/ME, mouse, sound card, web browser.

CD-ROM ORDER FORM

B3

Please send me:

- ☐ **Electronic Projects**
- ☐ **Analogue Electronics**
- ☐ **Digital Electronics**
- ☐ **Filters**
- ☐ **Digital Works 3.0**
- ☐ **Electronics CAD Pack**
- ☐ **C For PICmicro Microcontrollers**
- ☐ **PICtutor**
- ☐ **Electronic Circuits & Components V2.0**

Version required:

- ☐ **Hobbyist/Student**
- ☐ **Institutional**
- ☐ **Institutional 10 user**
- ☐ **Institutional site licence**

Note: The software on each version is the same (unless stated otherwise above), only the licence for use varies.

- ☐ **PICtutor Development Kit – Standard**
- ☐ **PICtutor Development Kit – Deluxe**
- ☐ **Deluxe Export**

Note: The CD-ROM is **not** included in the Development Kit prices.

- ☐ **Electronic Components Photos**
- ☐ **Electronics In Control – Single User**
- ☐ **Electronics In Control – Multiple User**
- ☐ **Modular Circuit Design – Single User**
- ☐ **Modular Circuit Design – Multiple User**

Note: The software on each version is the same, only the licence for use varies.

Full name: . . . .

Address: . . . .

. . . .

. . . . .Post code: . . . . .Tel. No: . . . .

Signature: . . . .

☐ I enclose cheque/PO in £ sterling payable to WIMBORNE PUBLISHING LTD for £ . . . .

☐ Please charge my Visa/Mastercard/Amex/Diners Club/Switch: £ . . . . . . .Card expiry date: . . . .

Card No: . . . . Switch Issue No. . . . .

ORDERING

ALL PRICES INCLUDE UK POSTAGE

Student/Single User/Standard Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Institutional, Multiple User and Deluxe Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add 17½% VAT or provide your official VAT registration number).

Send your order to:
Direct Book Service
Wimborne Publishing Ltd
408 Wimborne Road East
Ferndown, Dorset BH22 9ND

To order by phone ring

01202 873872. Fax: 01202 874562

Goods are normally sent within seven days

E-mail: orders@wimborne.co.uk

Online shop:
www.epemag.wimborne.co.uk/shopdoor.htm

ee50b

Constructional Project

FOREVER FLASHER

THOMAS SCARBOROUGH

A novel flashing l.e.d. that could run for over 20 years on a 9V lithium battery or "forever'' using the "free energy'' from a TV aerial or similar.

THIS article describes how a simple micropower l.e.d. flasher circuit may be pulsed off less than 1µA power at 9V. It uses just under 10µW, which, in theory, will enable this circuit to run for many years off a small 9V lithium battery.

Although such a battery has a nominal shelf-life of ten years, it should without trouble be able to power this circuit for twenty or thirty years or more. In some cases, even zinc carbon batteries have been known to last this long.

The proof of the miniscule power consumption lies in resistor R3 (see Fig.1), which has a value of 10M, and is wired in series with the 9V power supply. A simple calculation of V/R shows that it therefore draws less than 1µA at 9V.

FREE ENERGY!

Another conspicuous feature of the Forever Flasher circuit (see Fig.1) is the provision for an aerial and an earth connection. Also, diodes D1, D2, and capacitor C1 should be instantly recognisable as a standard diode pump.

Such a "pump'' circuit is used when a higher d.c. output is required from a lower a.c. input. This is included in the circuit because, due to its miniscule power consumption, the flasher may in some cases be powered off a television aerial, in combination with a ground wire.

It is emphasised that this aspect of the circuit is purely experimental. However, the author found that he was able to power the flasher off various television aerials in various locations.

At first it was supposed that the aerials were picking up pure radio frequency energy. However, after extensive testing, it became clear that the real power source was not only electromagnetic waves at radio frequencies, but a wider range of electromagnetic radiations, including mains wiring and motorised equipment.

With such "free energy" in mind, the Forever Flasher has in fact been designed to operate off a mere 2·5V at 2µA when an *aerial* and a *ground* wire are employed as the power source, battery operation being considered optional.

MINIMAL POWER

A CMOS 4016 quad bilateral switch i.c. (IC1) is employed at the heart of the circuit – see Fig.1. The reason for this is that CMOS devices have minimal power requirements, especially when quiescent. Their quiescent power consumption may not even register on the µA scale of a multimeter.

In addition, the 4016 in particular has no input protection circuitry, which enhances its input sensitivity. It was also found to be free from a problem which commonly affects CMOS i.c.'s in low power circuits. Current consumption frequently rises quite high when input terminals are held at levels close to triggering (typically 50µA to 200µA at 3V), and this would render such i.c.s useless in this application, where IC1 is used as a slow oscillator. This is not the case with the 4016 i.c.

Finally, whenever CMOS i.c.s are pushed to their limits, as is the case here, it is important to choose the i.c. from a specific manufacturer. In this case, the make of i.c. is absolutely critical. Only three specific makes were found to work at these extremes. However, other 4016s may work, but at a higher current consumption. The ones to use are the following:

The HEF4016BP (Philips); the CD4016BE (Texas Instruments), and the HCF4016BE (SGS-Thomson).

The Philips HEF4016BP proved to be the most suitable, and in this case, six individual i.c.s were tested, from two separate batches. Out of these, one failed – however, this may have been due to damage by static discharge.

The CD4016BE (*not* the CD4016BCN) should be the second resort. This uses very slightly more current, so that resistor R3 may be reduced to 4M7 accordingly. The HCF4016BE worked satisfactorily, although it pulsed a little erratically.

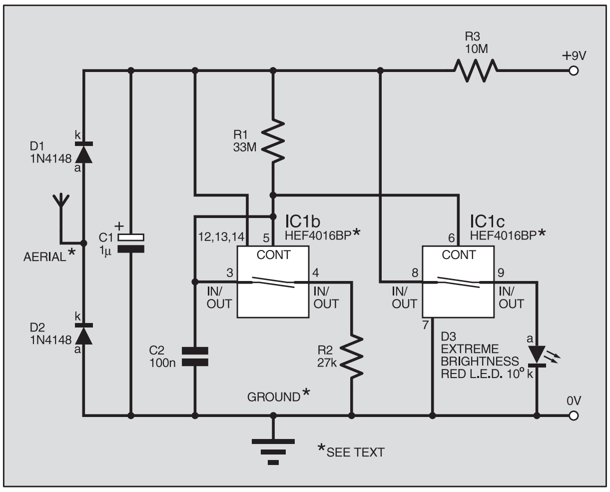


Fig.1. Complete circuit diagram for the Forever Flasher. Both sources of power supply are shown.

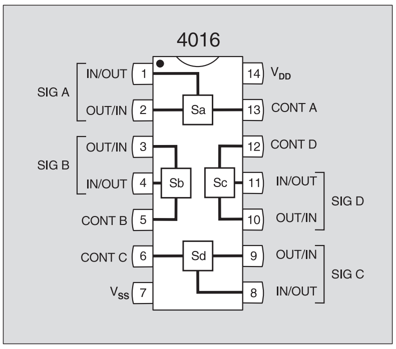


Fig.2. Pinout details for the 4016 quad bilateral switch i.c.

CIRCUIT DESCRIPTION

The full circuit diagram for the Forever Flasher is shown in Fig.1 together with the 4016 pinout details in Fig.2. Being a quad device, the internal "bilateral'' switches are labelled *a* to *d*, but we are only using switches *b* and *c* here as this fits into our printed circuit board (p.c.b.) layout. Hence, the annotations IC1b and IC1c on the circuit diagram. Note that the unused control pins (12 and 13) of switches *a* and *d* are tied to the positive supply (high), this does not affect the functioning of the circuit, but is considered good practice.

The Forever Flasher uses the 4016 (IC1) in an unorthodox manner, running it well below its minimum rated supply voltage. The main purpose of this is to draw as much power as possible from capacitor C1 to illuminate l.e.d. D3. While D3 draws all available current from C1, the voltage of the circuit plummets to about 1·7V – yet the circuit continues to function.

With most CMOS i.c.s, this would present an insurmountable problem. These may dip slightly below their minimum rated voltage (say 10%), but not much more before they fail. This does not apply, however, to the 4016. The only penalty here is that the 4016's "on" resistances gradually rise across the bilateral switches as voltage drops – to about 1kΩ (one kilohm) at 1·5V.

While it would be possible to run this circuit within its "legal" limits (at or above 3V), a theoretically perfect circuit would not make a good circuit in practice.

In this circuit, IC1 is wired as a slow oscillator. Capacitor C2 charges through resistor R1, causing pin 5 to go "high" (two-thirds of supply voltage). This closes switch IC1b, which causes C1 to be discharged through switch IC1b and resistor R2. When pin 5 goes "low" (one-third of supply voltage), switch IC1b opens again, and the charging of C1 begins over again.

At the same time as pin 5 goes "high", so also does pin 6. This causes switch IC1c to close, and so to pulse l.e.d. D3.

In order to conserve power, a very high value is chosen for R1, and a correspondingly low value for C2.

EXTREME BRIGHTNESS

An extreme brightness red l.e.d. (above 1000mcd – preferably around 3000mcd) is used for D3, with a narrow viewing angle (say 10º). Do not use any other l.e.d. in this circuit, as it is unlikely to work. D3 is chosen especially for its very high efficiency, with its extreme brightness converting to high efficiency at low power.

An extreme brightness red l.e.d. requires between 1·7V and 1·9V, depending on the make. It does not matter if D3 is momentarily powered by more than this, as happens in this circuit when capacitor C1 first discharges. L.E.D.s can be powered by far higher than their rated voltage – on condition that this is for a small percentage of their duty cycle.

POWER PUMP

When connected to a standard television aerial and earth, the diode pump (D1, D2 and C1) produces as much as 10V d.c. across capacitor C1 without load. Since all electromagnetic oscillations are a.c., the a.c. voltage for the pump is provided directly by the aerial.

A simple experiment may be performed with D1, D2, and C1. Allow C1 a few seconds to charge (assuming that aerial and ground wire are connected – see below). Then connect an l.e.d. across the terminals of C1, observing the correct polarity. The l.e.d. should flash brightly.

Although they are very common diodes, D1 and D2 have an extraordinarily low reverse current (25nA at 20V), which is essential in this application.

The aerial is a standard television aerial (a roof-top or attic television aerial, connected with coaxial cable), or about 7m of coaxial cable strung up in the air. The ground wire is securely connected to metal water pipes, or to a stake driven into the ground (but not the mains earth, although this does work).

Depending on various factors, the aerial may be shortened to as little as 3m of coaxial cable. In fact, the author found that he was able to power the flasher (under the right conditions – for instance when standing close to electrical equipment) off his own body!

CONSTRUCTION

The Forever Flasher is built on a small single-sided printed circuit board. The topside component layout, wiring and full-size underside copper foil master are shown in Fig.3. This board is available from the *EPE PCB Service*, code 330.

Commence construction by first soldering in position the single link wire, the solder pins, and the 14-pin d.i.l. socket. This should be followed by resistors R1 to R3, then capacitors C1 and C2 and finally diodes D1 to D3. Make sure you observe the correct orientation of polarity-conscious components.

Once you have double-checked component positions, insert IC1 into the d.i.l. socket, being sure to observe anti-static precautions (ideally, do not touch the pins at all) – especially since the 4016 i.c. does not include static protection circuitry on its inputs. This is a very delicate i.c., and if any trouble-shooting is required on completion of the circuit, IC1 should be a prime suspect.

Note that it is possible that an extreme brightness red l.e.d. may have a large anode (instead of cathode) inside its plastic encapsulation, and may seemingly need to be inserted "the wrong way round".

IN USE

If a battery is used (9V), connect it to the supply solder pins provided (positive to the "+" pin, and 0V to the ground pin, being careful to select the right pins). The Forever Flasher should begin to flash at a rate of 0·5Hz to 1Hz.

If an aerial is to be used, connect this to the aerial pin provided (see "Power Pump" crosshead earlier for more details). Next, connect a ground wire. The unit will not work without a ground wire.

All being well, l.e.d. D3 should begin to flash within five seconds, at a slowish rate of about 0·5Hz. This rate may be increased by increasing the value of capacitor C1, or decreasing the value of C2 – although this may lead to a dimmer flash. The flash may also brighten when the aerial wire is touched by moist fingers.

You might wish to work more scientifically. In this case, wire up only diodes D1, D2, and capacitor C1, with the aerial and ground wires connected. Wire a 2M2 resistor across C1. Now use a high impedance voltmeter (a digital multimeter should do) to measure the voltage across C1. This should measure more than 3V, otherwise your aerial and/or ground is inadequate. □

Completed circuit board.

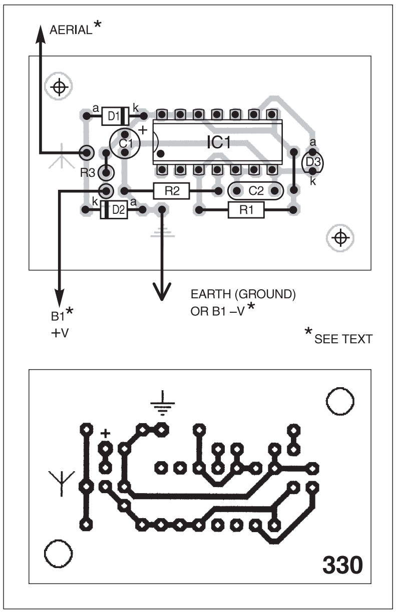


Fig.3. Component layout, wiring and full-size p.c.b. copper foil master.

COMPONENTS

Resistors

R1	33M metal film, 0·5W 5%	
R2	27k carbon film	0·25W 5%
R3	10M carbon film	0·25W 5%

Capacitors

C1	1µ min. radial elect. 63V
C2	100n disc ceramic

See SHOP TALK page

Semiconductors

D1, D2	1N4148 signal diode (2 off)
D3	extreme brightness 3mm red l.e.d. 3000mcd 10° viewing angle
IC1	HEF4016BP CMOS quad bilateral switch (see text)

Miscellaneous

B1	9V lithium battery (PP3), with clips (optional – see text)

Printed circuit board available from the *EPE PCB Service,* code 330; plastic case, type and size to choice; multistrand connecting wire; coaxial cable (see text); solder pins; solder, etc.

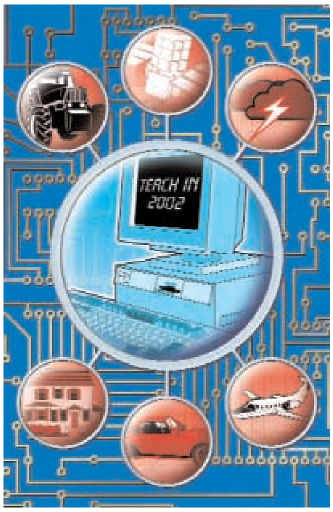
Approx. Cost Guidance Only **£6** ***excl. battery and case***

EPE Tutorial Series

TEACH-IN 2002

Part Three – More on op.amps in sensor circuits, plus humidity sensors

IAN BELL AND DAVE CHESMORE



Making Sense of the Real World: Electronics to Measure the Environment

SENSORS produce variations in different parameters depending on the type of sensor: resistance, voltage, current, capacitance, inductance, frequency, etc.

In the Lab Work for Part 2 last month we made use of the current from a photodiode in a light meter application. In Part 3 we now encounter capacitive sensors for humidity monitoring. First though, we examine more aspects of op.amps in relation to their use in "conditioning" sensor outputs to interface their signals to the outside world.

MORE THAN VOLTAGE

We need different circuits for each type of sensor, but in many cases we end up (if necessary) converting the signal to a voltage or a frequency (or pulse time), both of which can be readily used as the input to a subsequent processing system, such as a computer or microcontroller, for instance.

As we discussed last month, the raw voltage or frequency obtained from the sensor or conversion circuit may need to be scaled or shifted.

We need an analogue-to-digital converter (ADC) (more on these later in the series) to read a voltage into a microcontroller. The ADC may be "on-chip" or an external device.

Frequency can be measured by a microcontroller directly by converting the signal to a square wave at the logic levels of the microcontroller and feeding it to a digital input pin. The software counts the number of pulses occurring in a given period and is therefore able to calculate the frequency.

If the frequency is very high, and therefore too fast for the software, we can scale it down using a frequency divider such as a ripple counter or series of D-type flip-flops. Scaling down a frequency, though, means that the measurement will take longer. For low frequencies it is easier to measure cycle time directly, rather than counting pulses. Frequency can be shifted and scaled up, but this requires sophisticated circuits such as phase-locked loops and will not be discussed here.

Resistance based sensors are commonly used as part of a potential divider, as we did with the thermistor in Lab Work 1. Capacitance based sensors can be made one of the timing components in an oscillator or pulse generator, as we will see later when we look at humidity sensors. Current can be converted to a voltage using an op.amp circuit, as we did in Lab Work 2. We will now look at this circuit in more detail.

CURRENT INPUT

As we saw in last month's Lab Work, an op.amp can be used to convert a current signal from a sensor into a voltage signal, as shown in Fig.3.1.

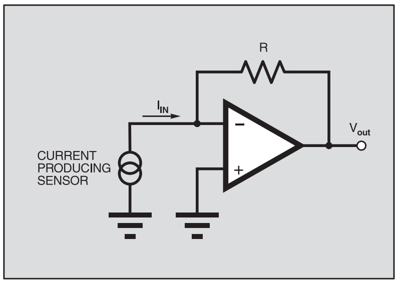


Fig.3.1. Current-to-voltage converter.

The circuit in Fig.3.1. is straightforward to understand if you recall our op.amp discussion in Part 2. The inputs are both at 0V due to the virtual earth and all the current from the sensor flows in resistor R due to the high op.amp input impedance. Thus the voltage at the output is given by

$$V_{out} = -R \times I_{in}$$

Here we have to be careful about the validity of one of our assumptions, namely the input impedance/current of the op.amp being negligible. If the current from the sensor is very small it may be comparable to the bias current required by the op.amp. For example, if the op.amp takes 200nA and the sensor current is 1μA we would get a 20% error.

For the circuit to work as intended (for our assumption to hold) we must choose an op.amp with very high input impedance and very low bias current – a FET input device is appropriate.

OFFSETS AND OP.AMPS

In last month's Lab Work we had a look at measuring the offset voltage of the 741 and OP177 op.amps which we are using in this series. Offsets cause systematic errors in measurements and, to make matters worse, vary over time and with temperature.

They are a particular problem when measuring slowly changing quantities, such as room temperature and humidity. In applications in which only a.c. signals are of interest (e.g. audio signals from a microphone), offsets are less likely to be a problem as they simply cause a shift in operating point and can be blocked using capacitive coupling.

When you work with sensors you are bound to end up having to deal with offsets to get the most from practical circuits. To identify (and ideally avoid) offset problems, it helps to know about the device specifications and basic theory associated with offsets. For op.amps we have to consider both the inherent offset voltage and the offsets due to currents flowing into the op.amp. Let's look at these in turn.

Ideally, with a differential input of zero, the op.amp's output should also be zero, but in real op.amps there will typically be a non-zero output. The **Input Offset Voltage** V_{IO} is defined as the d.c. voltage which must be supplied between the inputs to force the quiescent (zero input signal) open-loop (no feedback resistors) output voltage to zero.

This is illustrated in Fig.3.2 as an "equivalent circuit" – a combination of an ideal op.amp and a voltage source to represent

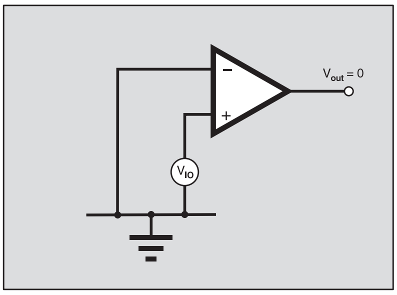


Fig.3.2. Equivalent circuit used to define offset voltage.

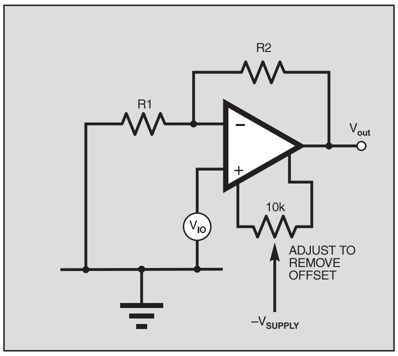


Fig.3.3. Offset Adjustment. The exact arrangement may vary for different op.amps, as will be shown in their datasheets.

the error due to the offset. We do not build this circuit, even to measure offset, it simply serves to clarify the definition.

The input offset voltage is defined with respect to the input. The error in the output voltage due to V_{IO} is equal to the circuit gain times V_{IO} (note *circuit* gain, not *op.amp* gain). So if the datasheet quoted V_{IO} as 2mV maximum and your circuit had a gain of 100 you could get a 0·2V error on the output.

Some op.amps have offset adjustment circuits (see Fig.3.3.) that allow an external trimmer potentiometer, connected to the appropriate pins, to be used to set the output voltage to zero. It is not the only offset adjustment configuration that can be used, so you need to check the datasheet for the op.amp in question.

The problem with manual offset trimming is that offsets can drift with time and are quite temperature sensitive. The **temperature coefficient of input offset voltage** specifies how V_{IO} changes with temperature. The datasheet for an op.amp may also have a graph showing offset variation with temperature. Low offset op.amps must be used in circuits where d.c. accuracy is required.

PANEL 3.1. Negative Feedback

In Part 2 we used the term *feedback* and showed examples of circuits in which it is being used. It is worth considering in a little more detail:

For any op.amp configuration, subtracting a fraction β of the output from the input (termed *negative feedback*) gives:

$$V_{out} = A_v \times (V_{in} - \beta V_{out})$$

where:
A_v is the open loop voltage gain
V_{out} is the output voltage
V_{in} is the input voltage

To find the gain of the circuit with negative feedback applied, that is V_{out} / V_{in}, known as the closed loop gain, A_{CL}, we need to rearrange this equation. This gives:

$$A_{CL} = V_{out} / V_{in} = A_v / (1 + A_v \beta).$$

For high A_v (more specifically βA_v >>1, i.e. βA much greater than 1) the gain of the circuit may usually be approximated to $A_{CL} = 1 / \beta$, which is independent of the gain of the op.amp as long as the high A_v assumption holds.

For A_{CL} to be independent of A_v we need A_{CL} to be much smaller than A_v. This is usually not a problem. For example, if an op.amp has a gain of 500,000 and we require a circuit gain of 20 (ignoring the phase inversion sign) then we need $\beta = 0{\cdot}05$, so $\beta A_v = 25{,}000$ which is obviously much larger than 1 (our criteria for accepting the simplified formula $A_{CL} = 1 / \beta$).

The actual gain of the op.amp if we use the full expression $A_{CL} = A_v / (1 + A_v \beta)$ will be 19·9992 instead of 20, a difference of 0·004% – compare this with typical resistor accuracy, for example five per cent.

What is β for an actual circuit? The easiest configuration to look at is the non-inverting amplifier (see Fig.2.3, centre circuit, in Part 2) as the input and feedback signals are clearly separate. In this circuit R1 and R2 form a potential divider, which provides a portion of the output voltage at the op.amp's negative input. The voltage at the inverting input (V_2) is given by the potential divider formula:

$$V2 = R1 \times V_{out} / (R1 + R2).$$

The voltage at the non-inverting input (V_1) is simply V_{in}, so for this circuit the op.amp's output, which is given by:

$$V_o = A_v(V_2 - V_1) \text{ can be written as:}$$

$$V_o = A_v(V_{in} - R1 \times V_{out} / (R1 + R2))$$

which on comparison with our feedback formula (A_{CL} = etc) indicates that $\beta = R1 / (R1 + R2)$.

This expression for β should not be surprising, as it is simply the proportion of the output provided by the potential divider. If our "high op.amp gain" assumption holds we can write the circuit gain as $1/\beta$, which is $(R1 + R2) / R1$ or $1 + R2 / R1$.

This is an important result because the gain of the circuit is determined by R1 and R2, and is independent of the op.amp's gain so long as the op.amp's gain is high, making circuit design of the amplifier very straightforward.

It is important to make a distinction between op.amp and circuit input and output voltages and gains. The op.amp input voltages in last month's Fig.2.3 are V_1 (non-inverting input) and V_2 (inverting input), its output voltage is V_o and its gain is A_v.

The circuit has a single input voltage V_{in}, an output voltage V_{out} and a gain of A_{CL}. For this circuit it happens that $V_{in} = V_1$ and $V_{out} = V_o$, but this may not always be the case. For the op.amp $V_o = A_v (V_2 - V_1)$ and for the circuit $V_{out} = (1 + R2 / R1) \times V_{in}$ as long as A_v is very large.

BIAS CURRENTS

Bipolar op.amps require bias (base) currents for the transistors connected to their inputs, and op.amps with FET inputs have leakage currents at the inputs. The term **Input Bias Current** I_{IB} is defined as the average current into the op.amp's two inputs with the output at zero volts. This can vary greatly for different types of op.amp, from femtoamps (10^{-15}A) to tens of microamps, with bipolar op.amps having larger input bias currents than FET input op.amps.

Bias currents flow in the external components connected to the op.amp (e.g. the resistors used to set the gain) and in doing so cause voltage drops. If these voltage drops are not equal at the op.amp's two inputs they will be amplified by the op.amp and appear as d.c. errors at the output.

To find the unwanted output voltage, find the difference in resistance at the two inputs and multiply this by the bias current and the circuit gain. This effect can be minimized by adding a resistor to one of the inputs to balance the resistance through which the bias current flows (see Fig.3.4).

In Fig.3.4 the bias current to the inverting input flows through resistors R1 or R2 (in parallel), so making R3 equal to the parallel combination of R1 and R2 will result in the same voltage at the two inputs due to the bias currents (assuming the bias currents are equal).

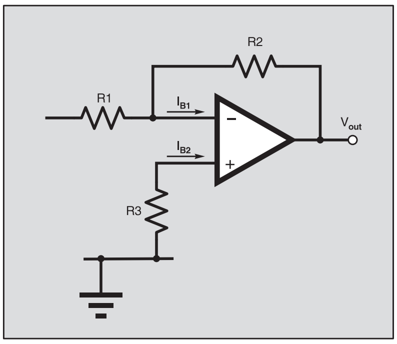


Fig.3.4. Bias Currents.

Resistor R1 in the calibration circuit (Fig.1.5) in Lab Work 1 is used for bias offset reduction and has a value close to the parallel combination of R4 and R5. The same principle can be applied to the current-to-voltage converter discussed earlier (see Fig.3.5).

In practice, the bias currents are not equal so we have **Input Offset Current** (I_{IO}) – the difference between the currents into the two inputs with the output at zero volts, i.e. $I_{B1} - I_{B2}$, where I_{B1} and I_{B2} are the input currents for the two inputs.

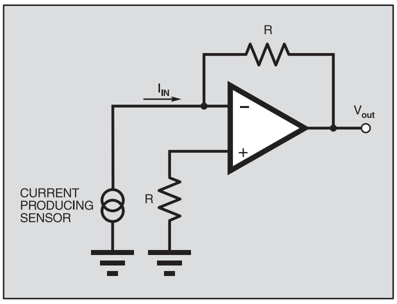


Fig.3.5. Current-to-voltage converter with offset current compensation.

Ideally these currents will be equal, but in practice they are not. The input currents have to flow through the external circuitry and will cause offsets even if the impedances connected to the two inputs are equal (we still want to keep the resistances equal as this is our best shot at keeping the current offsets low).

The only cure for errors due to offset currents, apart from using a better op.amp, is to reduce all the resistance values, but this option is limited by loading and power consumption considerations. Of course, bias current and offset vary with temperature so we have the **temperature coefficient of input offset current** parameter, which specifies how I_{IO} changes with temperature, and graphs on the datasheet to show these changes.

Armed with some more vital information about op.amps and their important d.c. characteristics, let's move on now to looking at another type of sensor.

HUMIDITY SENSING

How moist is the air? We can be very sensitive to high levels of moisture, especially if the air temperature is also high. You will know this if you have visited tropical countries where high humidity can be very uncomfortable.

What *is* humidity? It is a measure of the moisture content of air and is most commonly expressed as the percentage of water vapour in the air relative to the saturation vapour pressure at the same temperature and pressure. In other words, it is the proportion of water vapour compared to the maximum amount the air can hold; this is the *relative humidity* (RH).

Another measure is the *absolute humidity*, which is the mass of water vapour per unit volume of air. The amount of water vapour the air can hold is dependent on air pressure and air temperature, so measuring relative humidity is not particularly easy.

One old and reliable method is to use a single strand of human hair fixed at one end and wrapped around a spindle at the other. The spindle has a pointer attached, changes in humidity cause the hair to change length and move the pointer. The sensors we will be working with are a little more sophisticated and not so fragile!

There are two main forms of humidity sensor – **resistive** and **capacitive**. We shall deal with each type separately. Most humidity sensors have a restricted operating range and will only give accurate results between 25% and 90% humidity.

Some operate between 0% and 100% but they tend to be more expensive. Also, the accuracy is not particularly good, most sensors only being accurate to ±5% or ±10% at low or high humidity.

Calibration is not easy and will be examined later. One other problem with all humidity sensors is that they have a very long time constant, i.e. they take a long time to change value from, say 10% RH to 90% RH. Typical time constants range from two to four minutes.

RESISTIVE HUMIDITY SENSORS

Resistive sensors consist of a layer of material deposited on a substrate. This layer absorbs water vapour and changes its resistance. A number of resistive sensors are available and are relatively low cost. The characteristics of several readily available types are given in Table 3.1.

When designing circuits for humidity sensing, there are a number of points that should be considered:

1. Resistance is related to relative humidity in a logarithmic fashion as shown in the graph of Fig.3.8. For example, the HS15 sensor has a resistance of 10M at 30% RH and about 90kΩ at 90% RH, measured at 5°C. We therefore need to *linearise* the resistance.

2. Resistance changes as a function of temperature, hence the different curves in the graph. At 90% RH, the HS15 resistance changes from 90kΩ at 5°C to 500Ω at 45°C. We therefore need to provide *temperature compensation*.

3. Resistive sensors are damaged by d.c. voltages because the active material becomes polarized and stops working. All circuits must therefore use a.c. signals, hence the inclusion of *measuring frequency* as a parameter in Table 3.1.

If this all seems too complex, don't worry as humidity sensor modules are available which include linearisation and temperature compensation. Whilst they are more expensive, they are very easy to use, requiring only a +5V supply.

PANEL 3.2. Linear and Non Linear Responses

Mathematically, the term *linear* has a precise meaning, usually defined with respect to particular situations, perhaps the most basic being *linear functions*, so it helps to know what a *function* is to define *linear*.

A function is simply a relationship between the values of two or more variables. For example, $y = 2x$ means that the value of y is twice that of x. So, for example, if x is 4, y will be 8. Just as x stands for "any" value when we can write $f(x)$ to mean any function of x. In our example, $f(x)$ is $2x$.

Functions, in the present context, relate to circuits and sensors. For example, if x represents the input to a circuit (e.g. in volts) and y represents the output voltage, then if the circuit function $y = f(x)$ is $y = 10x$, the output voltage is ten times the input voltage, so this could be a voltage amplifier with a gain of 10.

Similarly, we can write mathematical functions which describe how a sensor responds to the parameter it is being used to measure. We saw examples of functions that relate thermistor resistance to temperature in Part 1.

A linear function of x is one of the form $f(x) = ax + b$, in which a and b are constants. For example, the function $f(x) = 60x + 100$ is linear.

The *exponential* function, $f(x) = exp(x)$ (e to the power of x, or e^x) is an example of a non-linear function, and quite often found in sensor responses.

The use of the term *linear* should make sense if you plot graphs of functions – for a linear function you get a straight line, this is illustrated in Fig.3.6 which shows a graph of the two functions just mentioned.

If our sensor response is linear, it is easy to extract the value we want from the sensor output. For instance, if a temperature sensor's output is in the form $y = 0{\cdot}1t + 2$, where t is temperature and y is the current or voltage obtained, we can simply subtract 2 then multiply by 10 to get t – an example of the "shift and scale" operation performed by the calibration circuit in Lab Work 1.

The "subtract 2, divide by 10" technique is an example of what is known as an *inverse function*. If we apply a function to a value and then apply the inverse function to the result we get the original value back.

If our sensor response is non-linear, we can apply the result to a circuit that has a response equivalent to the inverse function of the sensor response function. For an exponential sensor response this would be a *logarithmic* circuit function.

Designing an *inverse function* circuit may not always be easy and a number of other options exist. We can use a circuit function which approximates the inverse function, or we can read the sensor value directly into a microcontroller or PC and "do the maths" in software. More simply (and less accurately) we can use a small range of a non-linear function over which it can be regarded as *approximately* linear.

Referring to Fig.3.6, if you take a small part of the exponential curve it looks quite straight, even though the whole thing is obviously very curved.

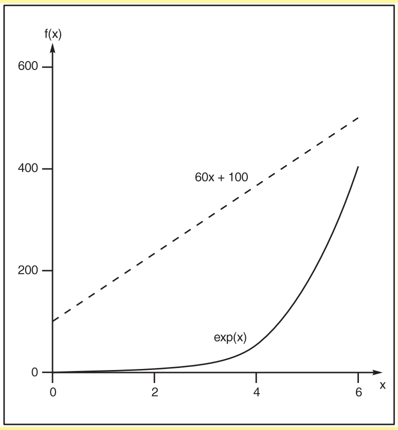


Fig.3.6. Two functions of x, one linear, the other non-linear.

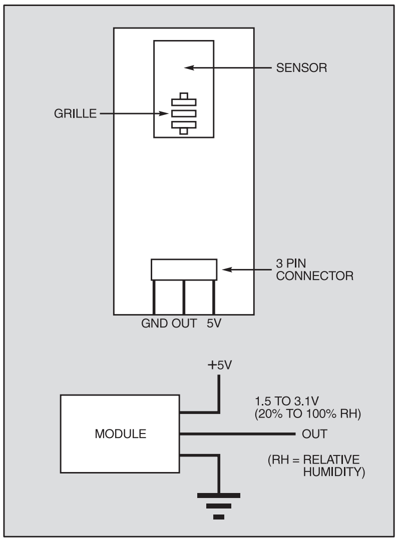


Fig.3.7. Connecting the HU10 Module.

Table 3.1. Characteristics of some Resistive Humidity Sensors

Parameter	*HS15*	*C3-M3*
Humidity Range	20%-100% RH	20%-90% RH
Operating Temperature	0°C-50°C	0°C – 60°C
Accuracy	±5% RH	±5% RH
Impedance at 25°C	60kΩ ±30kΩ @ 50% RH	31kΩ ±30kΩ @ 60% RH
Measuring Frequency	50Hz-1kHz	500Hz-2kHz
Temperature dependence	0·5% RH/°C	0.5% RH/°C
Drive Voltage	1V AC (rms)	1V AC (rms)
Manufacturer	Steatite Group	

Table 3.2 Characteristics of the HU10 Resistive Humidity Module

Supply Voltage	5V ±0·2V
Supply Current	2mA
Operating Temperature	0-50°C
Operating Humidity Range	20% – 100% RH
Measurement Humidity Range	25% – 100% RH
Output Voltage	1·5V @ 25% RH to 3·1V @ 100% RH
Accuracy	±5% RH
Sensor	HS15

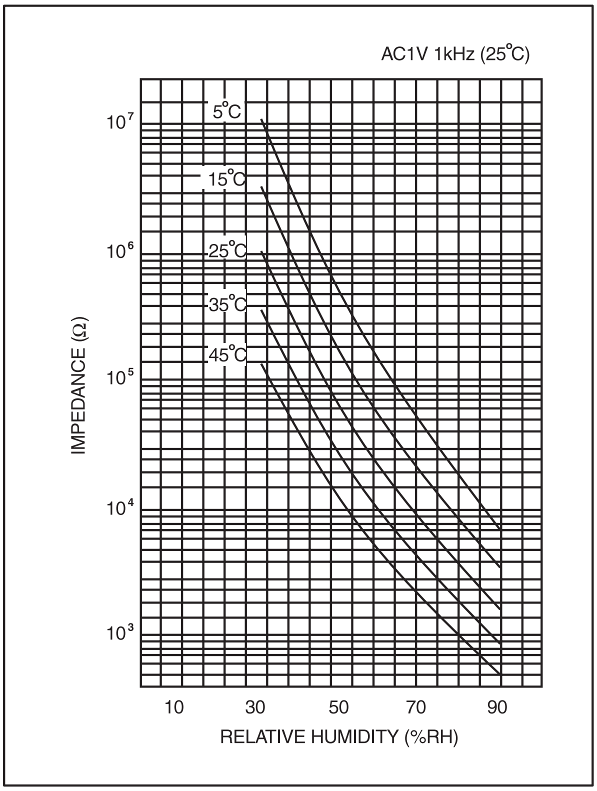
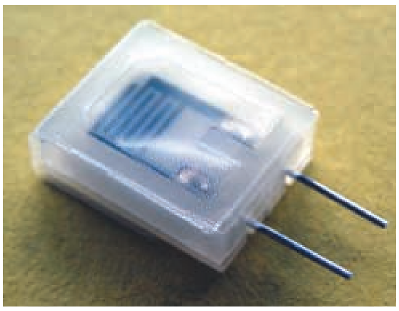


Fig.3.8. Humidity sensing performance of the HS15 sensor.



Resistive humidity sensor.

The diagram in Fig.3.7 shows how to connect an HU10 sensor module. The characteristics of this module are given in Table 3.2. The humidity range is 25% to 100% at 5% accuracy. The module has three pins – 0V, +5V (which must not be exceeded) and the output. You will have noticed that the output voltage ranges from 1·5V at 25% to 3·1V at 100%; this may be changed only by adding a scaling and level shifting circuit.

CAPACITIVE HUMIDITY SENSORS

Capacitive sensors are effectively capacitors that change their capacitance as a function of relative humidity. Fig.3.9 shows the cross-section of a capacitive sensor which consists of a thin layer of non-conducting dielectric material coated with gold on each side. The gold layer is so thin that it allows water molecules to pass through and change the dielectric constant of the non-conducting layer.

Other sensors use platinum instead of gold and often have special coatings that allow water *vapour* to pass but make the sensor immune to *liquid* water (waterproof).

Changes in the dielectric constant alter the capacitance. Table 3.3 gives the characteristics for some capacitive sensors.

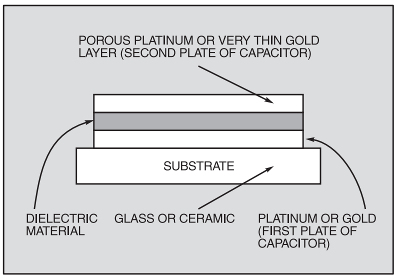


Fig.3.9. Cross-section of a typical capacitive sensor.

These sensors are also readily available. One useful thing to note is that some can operate down to 0%RH.

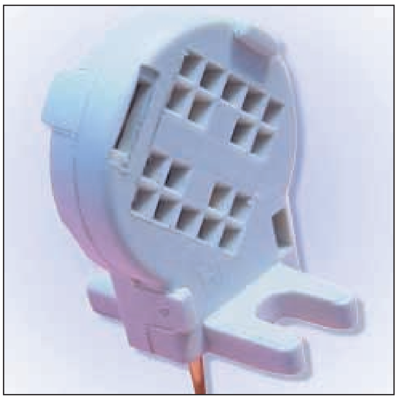
USING CAPACITIVE SENSORS

In order to use a capacitive humidity sensor, we must change the capacitance value to a simpler parameter that can be measured. This can be achieved in several ways. Perhaps the most straightforward is to use the capacitor in an oscillator circuit such as that shown in Fig.3.10.

This circuit consists of a CMOS Schmitt NAND gate connected as an inverter with a resistor (R1) feedback. The capacitive sensor (C1) is connected from the combined inputs to ground.

The circuit oscillates at a rate given by the value of R1 and C1 and the supply voltage. If the capacitor's value changes due to humidity changes, the frequency of oscillation will also change. The circuit thus behaves as a humidity-to-frequency converter and its oscillation frequency can be measured by a frequency counter.

Unfortunately, depending on the sensor used, the variation in capacitance may not be a perfectly linear function of relative humidity. Consequently, we cannot directly relate frequency to relative humidity.



Capacitive humidity sensor.

Table 3.3 Characteristics of some Capacitive Humidity Sensors

Parameter	*H1*	*SMTHS10*	*SMTRH05*
Humidity Range	10% to 90% RH	0% to 100% RH	0% to 100% RH
Operating Temperature	–40°C to 120°C	0°C to 85°C	-40°C to 120°C
Capacitance Range	(0 to 100% RH) 70pF	approx 40pF	40pF±12%
Accuracy	±5% RH (10% to 90%)	±2% RH	±5% RH
Capacitance at 25°C	122pF 15% @ 43% RH	240pF± 20%	300pF @ 0% RH
Measuring Frequency	1kHz to 1MHz	10kHz to 1MHz	80kHz to 900kHz
Temperature dependence	negligible	0·1% RH/°C	–0·15% RH/°C
Maximum Voltage	15V	5V (a.c. only)	5V (a.c. only)
Manufacturer	Philips	Smartec	Smartec

PANEL 3.1. A brief history of the op.amp

The name *operational amplifier* reflects the original use of these circuits – performing mathematical operations in analogue computers. The first op.amps were build using vacuum tube technology. They date from the late 1940s and were based on development work performed for the United States National Defense Research Council.

G. A. Philbrick of George A. Philbrick Researches Inc (GAP/R) and C.A. Lovell of Bell Labs are both credited with designing the first op.amps around 1948. Although analogue computers predated them, op.amps facilitated the design and construction of better computers.

Op.amps can be configured in circuits that perform mathematical operations such as addition, scaling, integration and differentiation. By wiring these operational units together, it is possible to create circuits which represent the mathematics of a complex problem, such as might be encountered in the design of an aircraft.

The early analogue computers that used vacuum tube op.amps, were used mainly for military design work. They were enormous (over 20 cubic metres) and consumed vast amounts of power (30,000 watts).

Vacuum tube op.amps became available as low cost "plug-in" devices such as the K2-W general purpose computing op.amp, which was first introduced in 1952. It was designed by GAP/R and Julie Research Labs Inc, and produced and marketed by GAP/R. Another "computer tube" from GAP/R, the K2-XA, which is a higher output power version of the K2-W, is shown top right.

The development of the transistor brought discrete component semiconductor op.amps in the 1960s from companies such as Burr-Brown and Analog Devices. These in turn were replaced by single chip devices.

The first widely used monolithic semiconductor op.amp (i.e. integrated circuit op.amp) was the μA709. This was designed by Bob Widlar and introduced by Fairchild Semiconductors in 1965. It was followed by the very popular μA741 in the late '60s. This was a lot easier to use than the 709 as it featured output short circuit protection and internal frequency compensation. It quickly became the world's most popular op.amp.

The 741 has since been surpassed in performance by many other devices and there is now a vast range of op.amps to choose from, offering higher speed, lower noise, higher stability, lower offsets, etc. Recent developments have also pushed the power supply voltages and power consumption levels of op.amps progressively lower.

Op.amps are not only found as discrete i.c. packages, but are also found within the circuitry of other i.c.s, including the massively complex "system on a chip" integrated circuits found in modern high-tech electronic products. However, the 741 is still available and its very low cost ensures continued use in applications that do not demand high performance.

We managed to find a datasheet for the K2-XA so we can present a table of comparison for this device with the 741 and OP177 used in the Lab Works, Table 3.4.

Over the years, the primary use of op.amps has changed from analogue computing to signal processing. As you will know, most computing is now done digitally, but one can occasionally come across digitally-controlled analogue-computer-like circuits lurking inside modern i.c.s.

Signal processing is the manipulation of signals from sensors and other sources in order to get them into a form suitable for the "user" or other parts of the system. Signal processing includes things such as amplification, level shifting, mixing and filtering and will be discussed as we progress through this series.

Table 3.4.

	K2-XA	*741*	*OP177*
Max supply voltage	±300V and 6·3V a.c. for heater filaments	±15V	±22V
Typical voltage gain	30,000 (90dB)	50,000 (94dB)	12,000,000 (142dB)
Max power dissipation	14W	85mW	500mW
Input resistance	100MΩ	2MΩ	200GΩ
Input current	100nA	60nA	2nA
Input offset voltage drift	±8mV/day		<2μV/month
Output voltage range	±100V	±12V (±15V supply)	±13V (±15V supply)

It is also possible to add a frequency divider to the output of the oscillator to reduce the frequency to the audio range and to drive a piezo-buzzer directly so that we can hear the changes in frequency.

An example circuit diagram is shown in Fig.3.10, in which a type 4520 dual binary counter is used. The first counter is clocked by the oscillator's output (connected to the input at pin 1). The frequency is divided by 2, 4, 8 or 16 depending on which output is chosen, in this instance pin 1Q3.

Since the oscillator operates at about 64kHz (depending on the capacitance of the sensor chosen), the output at 1Q3 will be 64,000/16 = 4kHz, a frequency that is audible. If you wish to reduce the frequency further, connect the 1Q3 output to the clock input of the second counter (pin 9), as shown in the 4520 to give divisions of 32, 64, 128 or 256, at outputs 2Q0 to 2Q3, respectively.

The second method is to vary the width of a pulse, using an RC (resistor-capacitor) integrator, which will produce a d.c. voltage proportional to the pulse width. Fig.3.11 shows such a circuit.

The conversion is achieved by using a fixed frequency square wave which drives a monostable (see Fig.3.12). The time period of the type 4098 monostable is determined by the RC (resistor R_S and capacitive sensor C_S) time constant, which varies as a function of humidity. The time constant is determined by the equation $0{\cdot}5R_SC_S$.

The monostable is continually retriggered by the square wave and its output is a fixed-frequency variable width pulse train.

The monostable's output is connected to an integrator formed by the long time constant RC network (R_F and C_F) to give a d.c. output. Narrow pulse widths result in a low voltage output, and wide pulse widths produce a higher output voltage.

The oscillator frequency is approximately 18kHz and the pulse width about 10ms for a capacitance of 200pF. The output voltage at point *C* will vary as a function of pulse width and hence humidity, but not by much because the capacitance only changes by a small amount. It may have to

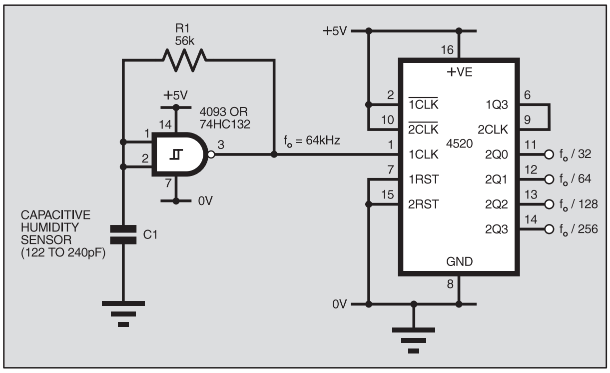


Fig.3.10. Frequency divider to reduce oscillator output to audio frequencies.

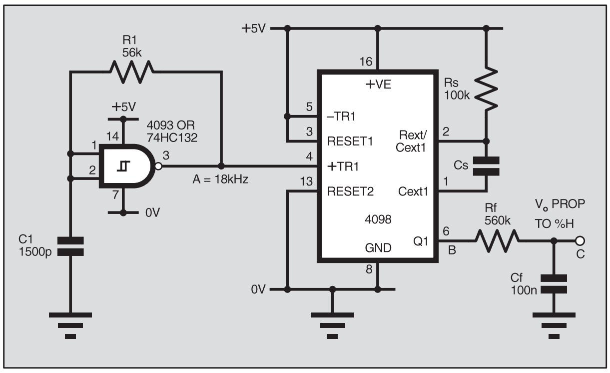


Fig.3.11. Monostable-based capacitance-to-voltage converter.

be scaled. If you want to use this circuit, you may have to change the value of R_S depending on the capacitance range of your sensor.

As you can see, the conversion of capacitance to a voltage is not easy and requires a number of steps. Unfortunately, few sensors are simple to use, as you will see as the series progresses, but our aim in this series is to help you get the best out of them. In Lab 3, we construct both the foregoing circuits

CALIBRATING HUMIDITY SENSORS

Calibration of humidity sensors is quite difficult because we need to generate accurate and known levels of humidity. The scientific way of doing this is to place the sensor above a particular chemical solution at a known temperature in a sealed container. The air above the solution will contain a known amount of water vapour.

To give you an idea, a saturated solution of calcium chloride ($CaCl_2$) at 10°C has a relative humidity of 38%. A saturated solution of potassium bromide (KBr) has a

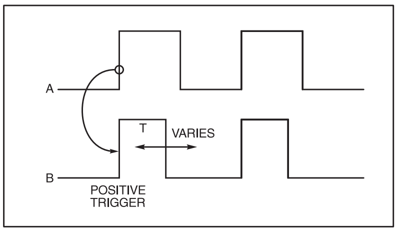


Fig.3.12. Timing diagram for Fig.3.11.

relative humidity of 84% at 20°C. A saturated solution is a solution that cannot dissolve any more solid chemical.

A 0% relative humidity can be obtained more simply by using the silica gel which is found in little bags in boxed electrical and photographic equipment. Silica gel absorbs moisture and will have moisture in it before you use it.

The moisture is driven out by warming it at slightly over 100°C in an oven for a while. Some gel changes colour from pink (or colourless) to blue when it is dry. You can place the dried silica gel into a container with the sensor and seal it. The relative humidity content should reach zero in a short while.

HUMIDITY SENSOR APPLICATIONS

Once you have a humidity sensor, what can it be used for? The obvious application is for monitoring the weather. High humidity indicates possible rain and we all know how high humidity can get in thundery weather!

Other applications could include humidifiers and dehumidifiers, or to detect when the clothes in a tumble dryer have dried. For this application you will need to place the sensor in the air outlet and use a circuit similar to that in the Lab Work light sensing circuit Fig.2.10 in Part 2.

A relay could be used to switch off the dryer when a preset threshold has been reached. A similar application might be to open and close vents in a greenhouse to control humidity levels.

Alan now takes up the story and describes some practical experiments you can perform using an inexpensive humidity sensor.

TEACH-IN 2002 – Lab Work 3

ALAN WINSTANLEY

Humidity Sensors and Test Equipment Limitations

FOLLOWING on from this month's Tutorial section, in Lab Work 3 we now perform some practical experiments with humidity sensors and expose a few facts about test equipment and its limitations.

Lab 3.1: Know the limits!

This Lab demonstrates some of the practical limitations that exist with most forms of test equipment, including the PC-based Picoscope ADC-40 used in *Teach-In 2002*.

The humidity sensor circuit in Fig.3.10 (see Tutorial section) is a simple CMOS oscillator using one Schmitt NAND gate running at roughly 64kHz. This generates a square wave which is coupled to one half of a 4520 dual binary up-counter, so the counter's output frequency is divided by sixteen, which can be observed at pin 6.

The resultant frequency can be divided further by a factor of 2, 4, 8 or 16, by cascading and clocking the 4520's second counter, whose input is at pin 9. Using both counters this way means that the original signal can be divided by a factor of 32, 64, 128 or even 256. You would therefore expect to measure these frequencies at the counter's outputs 2Q0 to 2Q3.

The pinouts of both i.c.s are given in Fig.3.13 and you should now construct Fig.3.10 on a solderless breadboard. You can use either a 4093 or a 74HC132 for IC1, but note that they have different pinouts. Note also that unused CMOS input pins should be grounded to 0V as usual, and that the +5V supply of the *Teach-In Power Supply* is required.

An ordinary fixed capacitor can be used in place of the capacitive humidity sensor for the time being. We used a 100pF ceramic capacitor with a 100k resistor for R1 in the *RC* oscillator. This means that whilst we will not necessarily expect a 64kHz signal we should still see something of that order of magnitude.

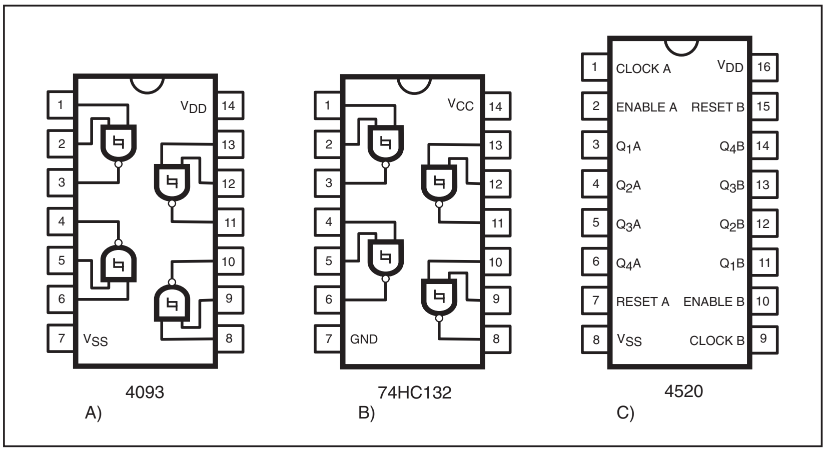


Fig.3.13. Pinouts for the 4093, 74HC132 and 4520 devices.

PICOSCOPING

The Picoscope screenshot we obtained at the 4520 2Q2 output is shown in Fig.3.14.

By measuring the time period of the square wave (using on-screen rulers) if we wish, we can predict what the input frequency should be (use frequency in Hz = 1 / period). For example, the $f_o/128$ output (pin 13) shows a period of 1·4ms, implying an input frequency of approximately 91kHz.

Lab 3.2: Aliasing Effects

Now check the clock input (pin 1) of the 4520. Using the Picoscope ADC-40 to examine the clock signal results in some very strange and interesting waveforms, which illustrate a principle known as *aliasing*. Even after setting the Picoscope to its fastest setting (go File/Setup/Scope and enter say 20,000 samples per scope trace), instead of a nice square wave, you will get a noisy, small signal that bears no resemblance to the one we predicted!

Additionally, if you connect a frequency divider and look at each output in turn, you will not get accurate results until the signal has been divided by at least 8 (i.e. an output of 8kHz).

We will be covering the full explanation of this effect later but here is a brief summary:

The Picoscope's maximum sampling rate is 20,000 samples per second and according to the *Nyquist Sampling Criterion* the maximum input frequency that can be "seen" correctly is half of the sampling frequency, 10kHz in this case. If any signals with frequencies greater than 10kHz are input, then the result will be a lower frequency than 10kHz.

In the extreme case of the input being exactly equal to the sampling frequency then the output result will appear to be d.c.! Of course we could use other Picoscope models with higher sampling rates but they would be more expensive.

Lab 3.3: Relative Humidity to Frequency Converter

Now replace the timing capacitor with a capacitive-type humidity sensor. Our own model was a 122pF at 25°C/43% relative humidity (RH) device. Our timing resistor was 100k which produced a clock frequency

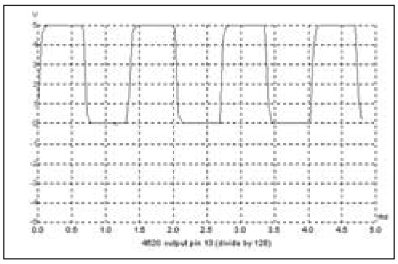
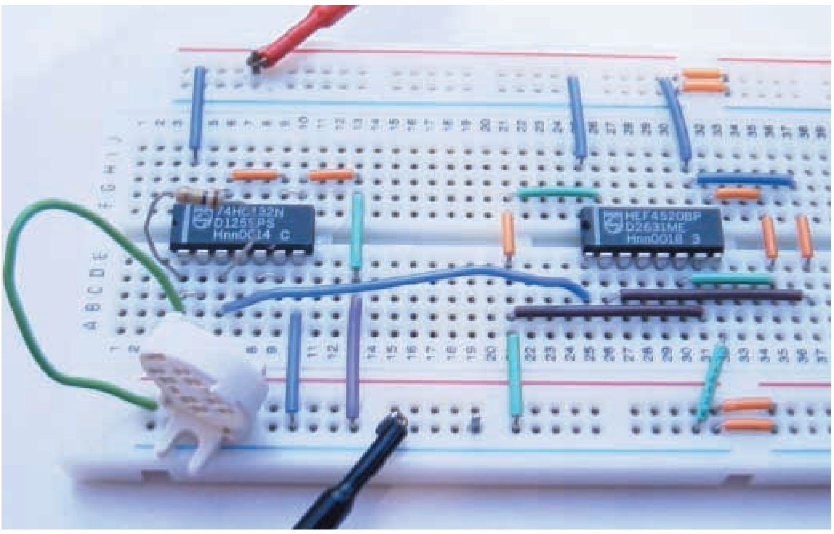


Fig.3.14. Picoscope screen display of the pin 13 output from the 4520 device in Lab 3.1.



Breadboard layout for Lab 3.2.

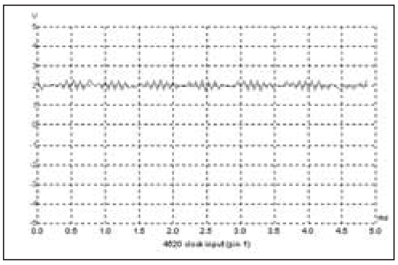


Fig.3.15. Picoscope display showing the effect of aliasing when sampling high frequencies at too slow a rate.

of about 75kHz as measured on a digital oscilloscope.

For a 240pF device, use a 56k resistor instead. A note of caution: insert the humidity sensor into the breadboard sympathetically so as to avoid bending its pins, or consider soldering a pair of leads to the sensor instead.

The output frequencies of the 4520 depend on the humidity detected by the sensor and these can be measured directly using the Picoscope as before. You can also try hooking a piezo disc to the outputs and by breathing on the humidity sensor, the

COMPONENTS

N.B. Some components are repeated between Lab Works

See SHOP TALK page

Lab 3.1

Resistor
R1 56k for 240p sensor, or 100k for 122p sensor
All resistors 0.25W 5% carbon film or better

Capacitor
C1 100p ceramic

Semiconductors
IC1 4093 or 74HC132 quad Schmitt NAND gate
IC2 4520 dual binary up counter

(No extra parts for Lab 3.2)

Lab 3.3
Capacitive humidity sensor 122p or 240p (see text)
Piezo disc sounder element (optional)

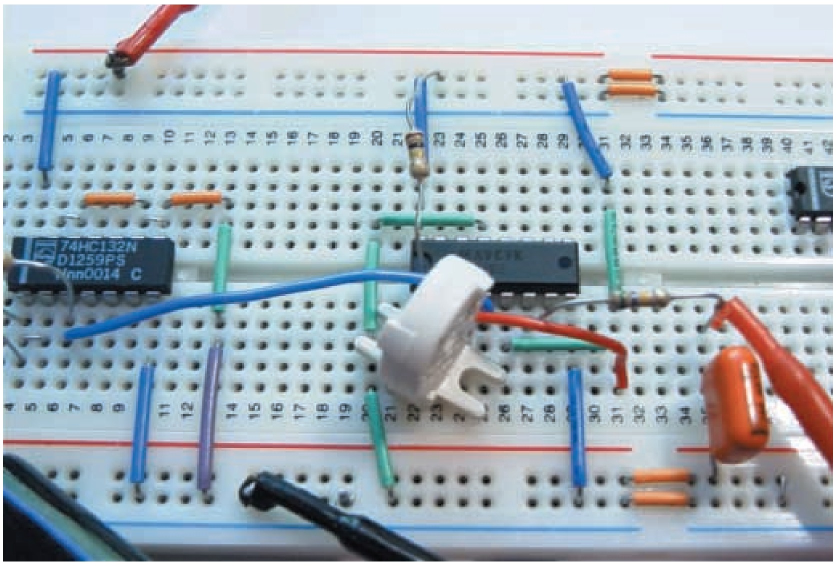
Lab 3.4

Resistors
R1 56k
R_s 100k
R_f 560k

Capacitors
C1 1500p ceramic
C_s 122p or 240p humidity sensor
C_f 100n polyester

Semiconductors
IC1 4093 or 74HC132 quad Schmitt NAND gate
IC2 4098 dual monostable

Approx. Cost Guidance Only **£14**



Breadboard layout for Lab 3.4.

audio tone from the disc will rise slightly. The resulting square wave can be connected to further processing systems to enable some detection and monitoring of humidity levels to be made.

Lab 3.4: RH to Voltage Converter

Lab 3.4 is an optional experiment. The circuit in Fig.3.11 (see Tutorial section) shows a technique for producing a voltage which is dependent on relative humidity. A fixed frequency oscillator is formed of discrete components using a NAND Schmitt gate, and a capacitive humidity sensor is used as the timing capacitor in a 4098 dual monostable multivibrator. Thus the oscillator triggers one of the monostable timers, the period of which is controlled by a humidity sensor.

The period of waveform at point B is determined roughly by 0·5 R_S.C_S, therefore time is proportional to the percentage of relative humidity. A low-pass filter, R_f and C_f, produces a d.c. voltage which is proportional both to the time period and the %RH as well. Note that the change in voltage will be small as the change in capacitance is in itself small.

In practice, it is only really possible to demonstrate the changing square wave with a high quality oscilloscope due to the higher frequencies involved. Nevertheless, some meaningful waveforms can be measured with the Picoscope. The circuit was constructed on solderless breadboard and we measured a voltage of about 745mV on the filter output (point C). By breathing on the humidity sensor the voltage rose to 790mV.

Next month: We offer some novel ideas related to the use of strain gauges and we take a look at some possible ways in which vibration can be detected.

CORRECTIONS

We regret that in Part 2 incorrect drawings were published for Figs.2.5 and 2.7. The correct ones are printed below.

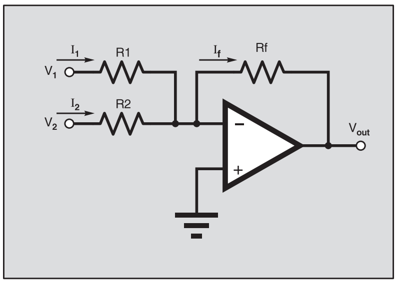


Fig.2.5. Two input adder circuit.

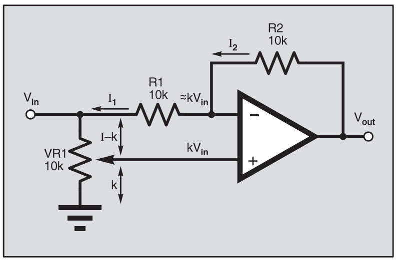
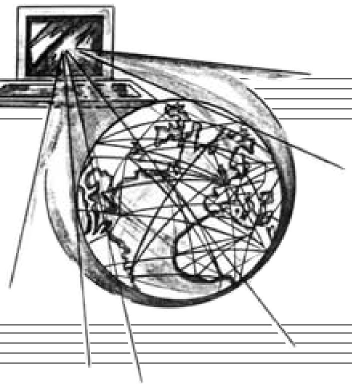


Fig.2.7. Circuit with variable gain from –1 to +1.

SURFING THE INTERNET

NET WORK

ALAN WINSTANLEY



On the Broadband Wagon

IT'S TIME once again for my yearly spell of navel-gazing as we reflect on the state of the British Internet market, looking at what is really happening, as opposed to what might actually have been.

In this respect, as a barometer of the state of the nation I have decided to nominate the wooden telegraph pole stuck in the pavement just outside my home. It carries my three telephone lines, and it seems to embody neatly the challenge of trying to get a fast and dependable Internet service delivered to British homes at a reasonable rate.

Every three or four years the lines have to be repaired because the wind and rain eventually damages the terminations through wear and tear. The pole also carries bare electricity wires: in Summer 2001 along came the local electricity board who decided to move the cables onto taller poles – so a second, larger wooden pole was planted next to the old one, and the live mains wires were moved higher up out of harm's way.

This left my three phone lines draped like hammock strings from the older pole nearby. Just to remind me how dangerously low the phone lines actually are, a courier's truck then sheared through the whole lot when making a delivery to neighbouring premises. Thankfully a laptop and an infrared mobile phone kept me going for several days until the phone wires were "temporarily" repaired. Four months later though, there is no sign of them being migrated onto the new poles, and even less sign of the old poles being taken away. I await the dreaded day when a BT workman suddenly appears, shins up the telegraph pole and cuts my wires for the day without any warning.

It's a Cop-out

Which brings me to the pavement (sidewalk) down below: all the villages in the region are connected by a foot-wide strip of tarmac levelled into the pavement, interspersed by metal access covers stamped with "CATV". Underneath lies the makings of a very good cable network. In fact the cable was laid over three years ago, the only problem being that NTL has never switched it on, and furthermore they have no plans to "enable" it in the foreseeable future. Whenever I ask, no-one at NTL has ever been able to say anything remotely encouraging about a switch-on date.

Today NTL is far more interested in earning more money out of its existing customers than it is in attracting new ones. I often gaze at that neat tarmac strip and dream about what could have been, wondering why I should struggle with archaic dial-up access when a cable modem could have brought many benefits to the locality.

Meantime, British Telecom continues to keep a tight grip on that critical bit of the network, namely the stretch of copper wire that connects most homes to the telephone system. This length of wire – known as the "local loop" – has probably been bought many times over by BT's customers, but earlier hopes of forcing BT to relinquish its vice-like hold in a process known as LLU, or local loop unbundling, have gradually faded away. The idea was then to allow other "telcos" to install their own equipment alongside BT's racks in the telephone exchanges, which would open up the market to better competition, but many telecoms companies withdrew from the process due to a combination of escalating costs, their widely reported frustrations of dealing with BT, and perhaps a degree of attrition setting in.

We are now into the 21st Century and all that BT has to offer is a number of miserly "Surftime" monthly tariffs littered with small print and get-out clauses. Even its "Anytime" package, which lets you "surf the net whenever you want" will throw you off the Internet after no more than two hours of continued use – just the thing when downloading large software upgrades. And should you ever leave your connection unattended, BT may withdraw the tariff from you altogether. I await satellite Internet access, if only so that I can snub NTL sales reps. when they finally call at my door.

Open Season

Mention "Openworld" and seasoned Internet users immediately think of BT's ADSL broadband service and all the problems it has created. ISPs including AOL and Freeserve want to get on the (broad) bandwagon but BT gave itself a headstart on ADSL (asymmetric digital subscriber line) through its Openworld division (known by many of its hard-bitten customers as Openwoe or Openwound). BT then re-sells the ADSL service to other ISPs.

Newsgroups are full of complaints from unhappy Openworld ADSL customers relating to installation problems, poor service, technical headaches and slow speeds. Surprisingly, BT Internet has ditched its name in favour of the Openworld brand and so you will soon start to see adverts for ordinary dial-up Internet access services from BT Openworld instead.

One ADSL user found out when trying to upgrade his 500k ADSL link to a faster and even more expensive 2MB, that his cable quality was not adequate enough to handle the higher speed reliably, so now he is effectively stuck with the handbrake half on. The possibility of having ADSL all depends on the distance from the 'phone exchange to the customer's premises, and the technology also relies heavily on the quality of the connection.

Users' expectations are very high but the fact is that DSL is a highly-strung technology and it seems to be pot luck whether it can be made to work for you. Even if a phone line passes basic DSL compatibility tests, there is no guarantee that it can handle higher speeds later on. My old wooden telegraph pole(s) with dodgy phone lines that crackle in the rain, appear to have no hope of seeing anything faster than good old 56k V.90 rattling by, and a cable modem will be just a dream for years.

Shopping Caught

Last month I mentioned a few shopping carts worth checking out, including RS Components (**http://rswww.com**) which is an advanced and powerful catalogue system. Not to be left out, competitor Farnell Components has its own system available at **www.farnell.com**. It must be said that none of us at *EPE* have ever thought very much to the Farnell CD-ROM catalogue, so how would their online version fare? To find out, I placed my first order, and what a disappointment I found the experience to be.

It took several attempts at creating a user profile before the penny dropped that actually, it had created it all along, the system just hadn't told me: it refreshes details without confirmation. And it was some time before I realised that the order codes used online are different from catalogue order codes – there is no hyphen (and no mention of this anywhere). As a new user I found the basic navigation to be poor and unintuitive: for example, why is the "Add 5 (blank) lines to your order" the third option along when you have to start there first?

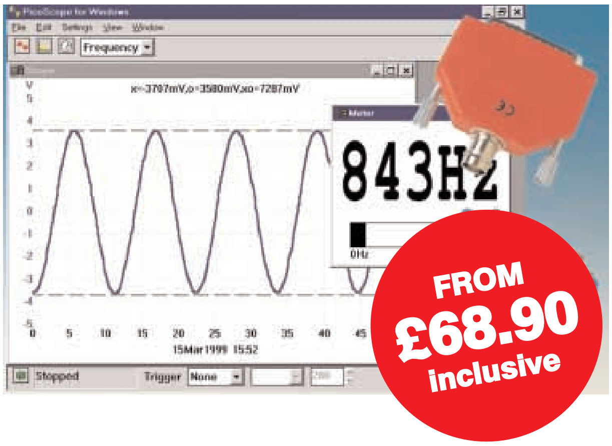
However, undeterred, I pressed on and eventually placed an order for £75 worth of parts. Perhaps I must have missed something else during the long-winded, unintuitive process, because having submitted the order I have to report that my order never arrived. It is hard to know what went wrong, but a Farnell sales agent could offer no reason for the order not appearing on the system so my order was re-entered the old fashioned way. I found the Farnell system to be unrewarding and slow to use. At this rate who needs broadband anyway?

Time for the writer to head over to the *Teach-In 2002* labs, so wherever you are around the world, I would like to thank all those who follow *Net Work*, for their feedback and encouragement, and I wish you all a safe and prosperous New Year. See you in 2002!

You can contact the writer at **alan@epemag.co.uk**.

PICO ADC-40
SPECIAL *TEACH-IN 2002* OFFER
LOW COST SINGLE CHANNEL PC-BASED OSCILLOSCOPE

EPE SPECIAL OFFER



- ★ **Save over £12 on the normal price**
- ★ **Oscilloscope and data logging software**
- ★ **Uses PC monitor for large display**
- ★ **No power supply required**
- ★ **Compact design (55mm x 55mm x 15mm)**
- ★ **No complex set-up procedures**
- ★ **Shows: frequency, DC voltage, AC voltage, peak-to-peak, risetime etc.**
- ★ **Windows 3.x, 95/98/ME, NT/2000 compatible**
- ★ **Two-year guarantee**

This easy to use low cost PC-based oscilloscope has been chosen for use with our *Teach-In 2002* series. We have been able to arrange a special offer on the Pico ADC-40 for readers. Just fill in the coupon below and send it in with your remittance or credit card details. You can order the ADC-40 on its own or together with a x1/x10 oscilloscope probe and two metre parallel port extension lead to connect to your PC.

Post the coupon below to: PICO/*EPE* SPECIAL OFFER, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND.

You can also order by phone, fax or via the web. Tel 01202 873872. Fax 01202 874562.
www.epemag.wimborne.co.uk/shopdoor.htm

OFFER ENDS JANUARY 28, 2002

SPECIFICATION

Resolution	8 bits
Channels	1 x BNC
Voltage ranges	±5V
Overload protection	±30V
Input impedance	1MΩ
Sampling rate	20kS/s
Accuracy	±1%
Scope timebases	500µs/div to 50s/div
Spectrum ranges	0 to 10kHz
Dynamic range	50dB
Analogue bandwidth	10kHz

Orders normally sent within 7 days but please allow up to 28 days for delivery – more for overseas orders

PICO/*EPE* SPECIAL OFFER ORDER FORM

Please supply .... (quantity) ADC-40 + software

.... (quantity) ADC-40 + software + probe + lead

Name . . . .

Address . . . .

. . . .

. . . .

Post Code . . . . .Tel: . . . .

I enclose a cheque to the value of £........... Make cheques payable to *Everyday Practical Electronics*

Please charge my card – Visa, Mastercard, Amex, Diners Club or Switch

Card No. . . . .

Expiry Date . . . . Switch Issue No . . . .

UK PRICES

ADC-40 + software	**£68.90**
ADC-40 + software + x1/x10 probe + parallel port extension cable	**£87.90**

Both prices include VAT and postage

OVERSEAS PRICES

To European Union Countries (other than UK):

ADC-40 + software	**£71.90**
ADC-40 + software + probe + lead	**£90.90**

Both prices include VAT and postage

To all countries outside of the European Union

ADC-40 + software	**£64.60**
ADC-40 + software + probe + lead	**£83.40**

***Note** these countries do not have to pay VAT*
Both prices include postage

OFFER ENDS JANUARY 28, 2002

If you do not wish to cut your issue send a copy of the coupon or order by letter

EPE TEACH-IN 2000 CD-ROM

The whole of the 12-part *Teach-In 2000* series by John Becker (published in *EPE* Nov '99 to Oct 2000) is now available on CD-ROM. Plus the *Teach-In 2000* interactive software covering all aspects of the series and Alan Winstanley's *Basic Soldering Guide* (including illustrations and Desoldering).

Teach-In 2000 covers all the basic principles of electronics from Ohm's Law to Displays, including Op.Amps, Logic Gates etc. Each part has its own section on the interactive software where you can also change component values in the various on-screen demonstration circuits.

The series gives a hands-on approach to electronics with numerous breadboard circuits to try out, plus a simple computer interface which allows a PC to be used as a basic oscilloscope.

ONLY **£12.45** including VAT and p&p

Order code Teach-In CD-ROM

DIRECT BOOK SERVICE

NOTE: ALL PRICES INCLUDE UK POSTAGE

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.

For a further selection of books see the next two issues of *EPE*.

Robotics

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. Then 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.

Details building and programming instructions provided, including numerous step-by-step photographs.

288 pages – large format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision Command System

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using Lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

298 pages **Order code BP902** **£14.99**

ANDROIDS, ROBOTS AND ANIMATRONS
John Lovine

Build your own working robot or android using both off-the-shelf and workshop constructed materials and devices. Computer control gives these robots and androids two types of artificial intelligence (an expert system and a neural network). A lifelike android hand can be built and programmed to function doing repetitive tasks. A fully animated robot or android can also be built and programmed to perform a wide variety of functions.

The contents include an Overview of State-of-the-Art Robots; Robotic Locomotion; Motors and Power Controllers; All Types of Sensors; Tilt; Bump; Road and Wall Detection; Light; Speech and Sound Recognition; Robotic Intelligence (Expert Type) Using a Single-Board Computer Programmed in BASIC; Robotic Intelligence (Neutral Type) Using Simple Neural Networks (Insect Intelligence); Making a Lifelike Android Hand; A Computer-Controlled Robotic Insect Programmed in BASIC; Telepresence Robots With Actual Arcade and Virtual Reality Applications; A Computer-Controlled Robotic Arm; Animated Robots and Androids; Real-World Robotic Applications.

224 pages **Temporarily out of print**

Radio

BASIC RADIO PRINCIPLES AND TECHNOLOGY
Ian Poole

Radio technology is becoming increasingly important in today's high technology society. There are the traditional uses of radio which include broadcasting and point to point radio as well as the new technologies of satellites and cellular phones. All of these developments mean there is a growing need for radio engineers at all levels.

Assuming a basic knowledge of electronics, this book provides an easy to understand grounding in the topic.

Chapters in the book: Radio Today, Yesterday, and Tomorrow; Radio Waves and Propagation; Capacitors, Inductors, and Filters; Modulation; Receivers; Transmitters; Antenna Systems; Broadcasting; Satellites; Personal Communications; Appendix – Basic Calculations.

263 pages **Order code NE30** **£15.99**

PROJECTS FOR RADIO AMATEURS AND S.W.L.S.
R. A. Penfold

This book describes a number of electronic circuits, most of which are quite simple, which can be used to enhance the performance of most short wave radio systems.

The circuits covered include: An aerial tuning unit; A simple active aerial; An add-on b.f.o. for portable sets; A wavetrap to combat signals on spurious responses; An audio notch filter; A parametric equaliser; C.W. and S.S.B. audio filters; Simple noise limiters; A speech processor; A volume expander.

Other useful circuits include a crystal oscillator, and RTTY/C.W. tone decoder, and a RTTY serial to parallel converter. A full range of interesting and useful circuits for short wave enthusiasts.

92 pages **Order code BP304** **£4.45**

AN INTRODUCTION TO AMATEUR RADIO
I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the century. This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.

150 pages **Order code BP257** **£5.49**

VALVE RADIO AND AUDIO REPAIR HANDBOOK
Chas Miller

This book is not only an essential read for every professional working with antique radio and gramophone equipment, but also dealers, collectors and valve technology enthusiasts the world over. The emphasis is firmly on the practicalities of repairing and restoring, so technical content is kept to a minimum, and always explained in a way that can be followed by readers with no background in electronics. Those who have a good grounding in electronics, but wish to learn more about the practical aspects, will benefit from the emphasis given to hands-on repair work, covering mechanical as well as electrical aspects of servicing. Repair techniques are also illustrated throughout.

A large reference section provides a range of information compiled from many contemporary sources, and includes specialist dealers for valves, components and complete receivers.

288 pages **Order code NE34** **£20.50**

Computers and Computing

MULTIMEDIA ON THE PC
Ian R. Sinclair

In this book, you'll find out what a CD ROM is, how it works, and why it is such a perfect add-on for a PC, allowing you to buy programmes, text, graphics and sound on a CD. It also describes the installation of a CD ROM drive and a sound card, pointing out the common problems that arise, and then shows how to use them to create a complete multimedia presentation that contains text, photos, a soundtrack with your own voice recorded as a commentary, even animation and edited video footage.

184 pages **Order code PC112** **£12.95**

HOW TO BUILD YOUR OWN PC
Morris Rosenthal

More and more people are building the own PCs. They get more value for their money, they create exactly the machine they want, and the work is highly satisfying and actually fun. That is, if they have a unique beginner's guide like this one, which visually demonstrates how to construct a state-of-the-art computer from start to finish.

Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. For non-specialists, there's even a graphical glossary that clearly illustrates technical terms. The author goes "under the hood" and shows step-by-step how to create a socket 7 (Pentium and non-intel chipsets) and a Slot 1 (Pentium II) computer, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows 98. The few existing books on this subject, although badly outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are eagerly looking for.

224 pages – large format **Order code MGH2** **£21.99**

PIC YOUR PERSONAL INTRODUCTORY COURSE SECOND EDITION John Morton **NEW**

Discover the potential of the PIC micro-controller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PIC's capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised second edition covers the popular reprogrammable EEPROM PICs: P16C84/16F84 as well as the P54 and P71 families.

270 pages **Order code NE36** **£13.99**

UNDERSTANDING PC SPECIFICATIONS
R. A. Penfold (Revised Edition)

If you require a microcomputer for business applications, or a high quality home computer, an IBM PC or compatible is often the obvious choice. They are competitively priced, and are backed up by an enormous range of applications programs, hardware add-ons, etc. The main difficulty for the uninitiated is deciding on the specification that will best suit his or her needs. PCs range from simple systems of limited capabilities up to complex systems that can happily run applications that would have been considered beyond the abilities of a microcomputer not so long ago. It would be very easy to choose a PC system that is inadequate to run your applications efficiently, or one which goes beyond your needs and consequently represents poor value for money.

This book explains PC specifications in detail, and the subjects covered include the following: Differences between types of PC (XT, AT, 80386, etc); Maths co-processors; Input devices (keyboards, mice, and digitisers); Memory, including both expanded (EMS) and extended RAM; RAM disks and disk caches; Floppy disk drive formats and compatibility; Hard disk drives (including interleave factors and access times); Display adaptors, including all standard PC types (CGA, Hercules, Super VGA, etc); Contains everything you need to know if you can't tell your EMS from your EGA!

128 pages **Order code BP282** **£5.45**

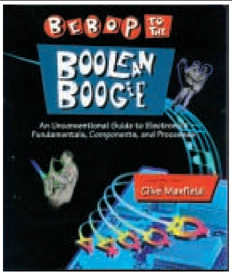
Theory and Reference

Bebop To The Boolean Boogie

By Clive (call me Max) Maxfield

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. . . .

470 pgs – large format **Order code BEB1** **£26.95**

DIGITAL ELECTRONICS – A PRACTICAL APPROACH **FREE SOFTWARE**
With FREE Software: Number One Systems – EASY-PC Professional XM and Pulsar (Limited Functionality)
Richard Monk

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchronous and synchronous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer aided design including the FREE software.

There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

Those who prefer the 'Teach-In' approach or would rather experiment with some simple circuits should find the book's final chapters on printed circuit board production and project ideas especially useful.

250 pages (large format) **Order code NE28** **£17.99**

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.

199 pages **Order code NE23** **£13.99**

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** **£21.99**

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.

96 pages **Order code BP239** **£3.45**

DIGITAL GATES AND FLIP-FLOPS
Ian R. SInclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.

No background 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** **£9.95**

Music, Audio and Video

QUICK GUIDE TO ANALOGUE SYNTHESIS NEW
Ian Waugh

Even though music production has moved into the digital domain, modern synthesisers invariably use analogue synthesis techniques. The reason is simple – analogue synthesis is flexible and versatile, and it's relatively easy for us to understand. The basics are the same for all analogue synths, and you'll quickly be able to adapt the principles to any instrument, to edit existing sounds and create exciting new ones. This book describes: How analogue synthesis works; The essential modules every synthesiser has; The three steps to synthesis; How to create phat bass sounds; How to generate filter sweeps; Advanced synth modules; How to create simple and complex synth patches; Where to find soft synths on the Web.

If you want to take your synthesiser – of the hardware or software variety – past the presets, and program your own sounds and effects, this practical and well-illustrated book tells you what you need to know.

60 pages **Order code PC118** **£7.45**

QUICK GUIDE TO MP3 AND DIGITAL MUSIC NEW
Ian Waugh

MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?

All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.

Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

60 pages **Order code PC119** **£7.45**

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 **Temporarily out of print**

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 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.

124 pages **Order code PC116** **£10.95**

THE INVENTOR OF STEREO – THE LIFE AND WORKS OF ALAN DOWER BLUMLEIN
Robert Charles Alexander

This book is the definitive study of the life and works of one of Britain's most important inventors who, due to a cruel set of circumstances, has all but been overlooked by history.

Alan Dower Blumlein led an extraordinary life in which his inventive output rate easily surpassed that of Edison, but whose early death during the darkest days of World War Two led to a shroud of secrecy which has covered his life and achievements ever since.

His 1931 Patent for a Binaural Recording System was so revolutionary that most of his contemporaries regarded it as more than 20 years ahead of its time. Even years after his death, the full magnitude of its detail had not been fully utilized. Among his 128 patents are the principal electronic circuits critical to the development of the world's first elecronic television system. During his short working life, Blumlein produced patent after patent breaking entirely new ground in electronic and audio engineering.

During the Second World War, Alan Blumlein was deeply engaged in the very secret work of radar development and contributed enormously to the system eventually to become 'H25' – blind-bombing radar. Tragically, during an experimental H2S flight in June 1942, the Halifax bomber in which Blumlein and several colleagues were flying, crashed and all aboard were killed. He was just days short of his thirty-ninth birthday.

420 pages **Order code NE32** **£15.99**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

124 pages **Order code PC115** **£10.95**

PC MUSIC – THE EASY GUIDE NEW
Robin Vincent

How do I make music on my PC? Can I record music onto my PC? What's a sequencer? How can I get my PC to print a music score? What sort of soundcard do I need? What hardware and software do I need? How do I connect a keyboard to my PC?:

Just a few of the questions you've probably asked. Well, you'll find the answers to all these questions, and many more, in this book. It will show you what can be done, what it all means, and what you will need to start creating your own music on your PC. It's an easy read, it's fully illustrated and it will help you understand how a computer can be used as a creative music tool.

It covers soundcards, sequencers, hard disk digital audio recording and editing, plug-ins, printing scores with notation software, using your PC as a synthesiser, getting music onto and off the Internet, using Windows, sample PC music setups, FAQs, a glossary, advice on hardware and software, and a list of industry contacts.

116 pages **Order code PC117** **£11.95**

HIGH POWER AUDIO AMPLIFIER CONSTRUCTION
R. A. Penfold

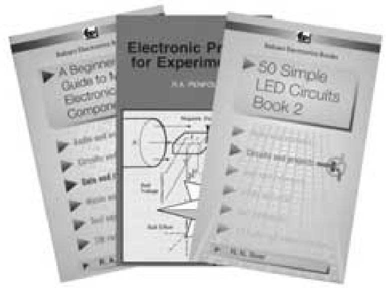
Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs.

96 pages **Order code BP277** **£4.49**

Circuits, Data and Design

PRACTICAL ELECTRONIC FILTERS
Owen Bishop
This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.
The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rythm sequencer and a multi-voiced electronic organ.
Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.
88 pages **Order code BP299** **£5.49**

ELECTRONIC HOBBYISTS DATA BOOK
R. A. Penfold
This book should tell you everything you are ever likely to want to know about hobby electronics, but did not know where to ask or refer. Comprehensive contents pages makes it easy to quickly locate the data you require.
The subjects covered include: Common circuits, and related data (including helpful graphs and tables of values); Colour codes for resistors, capacitors and inductors; Pinout details for a wide range of CMOS and TTL devices, plus basic data on the various logic families; Pinout details and basic data for a wide range of operational amplifiers; Data and leadout information for a wide range of transistors, FETs, power FETs, triacs, thyristors, diodes, etc; General data including MIDI message coding, radio data, ASCII/Baudot coding, decibel ratios, etc.
242 pages **Temporarily out of print**



50 SIMPLE LED CIRCUITS
R. N. Soar
Contains 50 interesting and useful circuits and applications, covering many different branches of electronics, using one of the most inexpensive and freely available components – the light-emitting diode (LED). Also includes circuits for the 707 common anode display.
64 pages **Order code BP42** **£2.99**

CIRCUIT SOURCE BOOK 1
R. A. Penfold
Written to help you create and experiment with your own electronic designs by combining and using the various standard "building block" circuits provided. Where applicable, advice on how to alter the circuit parameters is given.
The circuits covered in this book are mainly concerned with analogue signal processing and include: Audio amplifiers (op.amp and bipolar transistors); audio power amplifiers; d.c. amplifiers; highpass, lowpass, bandpass and notch filters; tone controls; voltage controlled amplifiers and filters; triggers and voltage comparators; gates and electronic switching; bargraphs; mixers; phase shifters, current mirrors, hold circuits, etc.
Over 150 circuits are provided, which it is hoped will be useful to all those involved in circuit design and application, be they professionals, students or hobbyists.
182 pages **Temporarily out of print**

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** **£5.45**

HOW TO USE OP.AMPS
E. A. Parr
This book has been written as a designer's guide covering many operational amplifiers, serving both as a source book of circuits and a reference book for design calculations. The approach has been made as non-mathematical as possible.
160 pages **Order code BP88** **£4.49**

CIRCUIT SOURCE BOOK 2
R. A. Penfold
This book will help you to create and experiment with your own electronic designs by combining and using the various standard "building blocks" circuits provided. Where applicable, advice on how to alter the circuit parameters is provided.
The circuits covered are mainly concerned with signal generation, power supplies, and digital electronics.
The topics covered in this book include: 555 oscillators; sinewave oscillators; function generators; CMOS oscillators; voltage controlled oscillators; radio frequency oscillators; 555 monostables; CMOS monostables; TTL monostables; precision long timers; power supply and regulator circuits; negative supply generators and voltage boosters; digital dividers; decoders, etc; counters and display drivers; D/A and A/D converters; opto-isolators, flip/flops, noise generators, tone decoders, etc.
Over 170 circuits are provided, which it is hoped will be useful to all those involved in circuit design and application, be they professionals, students or hobbyists.
192 pages **Order code BP322** **£5.45**

Project Building & Testing

ELECTRONIC PROJECTS FOR EXPERIMENTERS
R. A. Penfold
Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different. No doubt many of the projects featured here have practical applications, but they are all worth a try for their interest value alone.
The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.
138 pages **Order code BP371** **£5.45**

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.
132 pages **Order code BP374** **£5.45**

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 the following topics:
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.
135 pages **Order code BP392** **£5.49**

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.
166 pages **Temporarily out of print**

HOW TO USE OSCILLOSCOPES AND OTHER TEST EQUIPMENT
R. A. Penfold
This book explains the basic function of an oscilloscope, gives a detailed explanation of all the standard controls, and provides advice on buying. A separate chapter deals with using an oscilloscope for fault finding on linear and logic circuits, plenty of example waveforms help to illustrate the control functions and the effects of various fault conditions. The function and use of various other pieces of test equipment are also covered, including signal generators, logic probes, logic pulsers, and crystal calibrators.
104 pages **Order code BP267** **£4.00**

BOOK ORDERING DETAILS

All prices include UK postage. For postage to Europe (air) and the rest of the world (surface) please add £1 per book. For the rest of the world airmail add £2 per book. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard, Amex, Diners Club or Switch – minimum card order is £5 – to:
DIRECT BOOK SERVICE, WIMBORNE PUBLISHING LTD.,
408 WIMBORNE ROAD EAST, FERNDOWN, DORSET BH22 9ND.
Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*
For a further selection of books see the next two issues of *EPE*.
Tel 01202 873872 Fax 01202 874562. E-mail: dbs@epemag.wimborne.co.uk
Order from our online shop at: www.epemag.wimborne.co.uk/shopdoor.htm

BOOK ORDER FORM

Full name: ....

Address: ....

....

....

.... Post code: .... Telephone No: ....

Signature: ....

☐ I enclose cheque/PO payable to DIRECT BOOK SERVICE for £ ....

☐ Please charge my card £ .... Card expiry date...................

Card Number .... Switch Issue No....................

Please send book order codes: ....

....

Please continue on separate sheet of paper if necessary
If you do not wish to cut your magazine, send a letter or copy of this form

PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the PCB Service, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £1 per board for *airmail* outside of Europe. Remittances should be sent to **The PCB Service, *Everyday Practical Electronics*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND. Tel: 01202 873872; Fax 01202 874562; E-mail: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.wimborne.co.uk/shopdoor.htm.** Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only).**

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.

PROJECT TITLE		Order Code	Cost
★EPE Mood PICker	JULY '99	233	£6.78
12V Battery Tester		234	£6.72
Intruder Deterrent		235	£7.10
L.E.D. Stroboscope (Multi-project PCB)		932	£3.00
Ultrasonic Puncture Finder	AUG '99	236	£5.00
★8-Channel Analogue Data Logger		237	£8.88
Buffer Amplifier (Oscillators Pt 2)		238	£6.96
Magnetic Field Detective		239	£6.77
Sound Activated Switch		240	£6.53
Freezer Alarm (Multi-project PCB)		932	£3.00
Child Guard	SEPT '99	241	£7.51
Variable Dual Power Supply		242	£7.64
Micro Power Supply	OCT '99	243	£3.50
★Interior Lamp Delay		244	£7.88
Mains Cable Locator (Multi-project PCB)		932	£3.00
Vibralarm	NOV '99	230	£6.93
Demister One-Shot		245	£6.78
★Ginormous Stopwatch – Part 1		246	£7.82
★Ginormous Stopwatch – Part 2	DEC '99		
Giant Display		247	£7.85
Serial Port Converter		248	£3.96
Loft Guard		249	£4.44
Scratch Blanker	JAN '00	250	£4.83
Flashing Snowman (Multi-project PCB)		932	£3.00
★Video Cleaner	FEB '00	251	£5.63
Find It		252	£4.20
★Teach-In 2000 – Part 4		253	£4.52
High Performance Regenerative Receiver	MAR '00	254, 255, 256 }	£5.49 Set
★*EPE* Icebreaker – PCB257, programmed PIC16F877 and floppy disc		Set only	£22.99
Parking Warning System		258	£5.08
★Micro-PICscope	APR '00	259	£4.99
Garage Link – Transmitter / Receiver		261, 262 } Set	£5.87
Versatile Mic/Audio Preamplifier	MAY '00	260	£3.33
PIR Light Checker		263	£3.17
★Multi-Channel Transmission System – Transmitter / Receiver / Interface		264, 265, 266 } Set	£6.34
★Canute Tide Predictor	JUNE '00	267	£3.05
★PIC-Gen Frequency Generator/Counter	JULY '00	268	£5.07
g-Meter		269	£4.36
★EPE Moodloop	AUG '00	271	£5.47
Quiz Game Indicator		272	£4.52
Handy-Amp		273	£4.52
Active Ferrite Loop Aerial	SEPT '00	274	£4.67
★Remote Control IR Decoder **Software only**		–	–
★PIC Dual-Channel Virtual Scope	OCT '00	275	£5.15
Handclap Switch	NOV '00	270	£3.96
★PIC Pulsometer **Software only**		–	–
Twinkling Star	DEC '00	276	£4.28
Festive Fader		277	£5.71
Motorists' Buzz-Box		278	£5.39
★PICtogram		279	£4.91
★PIC-Monitored Dual PSU–1 PSU		280	£4.75
Monitor Unit		281	£5.23
Static Field Detector (Multi-project PCB)		932	£3.00
Two-Way Intercom	JAN '01	282	£4.76
UFO Detector and Event Recorder			
Magnetic Anomaly Detector / Event Recorder / Audio Alarm		283, 284, 285 } Set	£6.19
★Using PICs and Keypads **Software only**		–	–
Ice Alarm	FEB '01	287	£4.60
★Graphics L.C.D. Display with PICs (Supp)		288	£5.23
Using the LM3914-6 L.E.D. Bargraph Drivers			
Multi-purpose Main p.c.b. / Relay Control / L.E.D. Display		289, 290, 291 } Set	£7.14
★PC Audio Power Meter **Software only**		–	–
Doorbell Extender: Transmitter	MAR '01	292	£4.20
Receiver		293	£4.60
Trans/Remote		294	£4.28
Rec./Relay		295	£4.92
EPE Snug-bug Heat Control for Pets	APR '01	296	£6.50
Intruder Alarm Control Panel			
Main Board		297	£6.97
External Bell Unit		298	£4.76

PROJECT TITLE		Order Code	Cost
Camcorder Mixer	MAY '01	299	£6.34
★PIC Graphics L.C.D. Scope		300	£5.07
Hosepipe Controller	JUNE '01	301	£5.14
Magfield Monitor (Sensor Board)		302	£4.91
Dummy PIR Detector		303	£4.36
★PIC16F87x Extended Memory **Software only**		–	–
Stereo/Surround Sound Amplifier	JULY '01	304	£4.75
Perpetual Projects Uniboard–1 Solar-Powered Power Supply & Voltage Reg.		305	£3.00
MSF Signal Repeater and Indicator			
Repeater Board		306	£4.75
Meter Board		307	£4.44
★PIC to Printer Interface		308	£5.39
Lead/Acid Battery Charger	AUG '01	309	£4.99
Shortwave Loop Aerial		310	£5.07
★Digitimer – Main Board		311	£6.50
– R.F. Board		312	£4.36
Perpetual Projects Uniboard–2			
L.E.D. Flasher — Double Door-Buzzer		305	£3.00
Perpetual Projects Uniboard–3 Loop Burglar Alarm, Touch-Switch Door-Light and Solar-Powered Rain Alarm	SEPT 01	305	£3.00
L.E.D. Super Torches – Red Main / – Display Red		313, 314 } Set	£6.10
– White L.E.D.		315	£4.28
★Sync Clock Driver		316	£5.94
★Water Monitor		317	£4.91
Camcorder Power Supply	OCT '01	318	£5.94
PIC Toolkit Mk3		319	£8.24
Perpetual Projects Uniboard–4 Gate Sentinel, Solar-powered Bird Scarer and Solar-Powered Register		305	£3.00
Teach-In 2002 Power Supply	NOV '01	320	£4.28
Lights Needed Alert		321	£5.39
Pitch Switch		322	£5.87
Capacitance Meter – Main Board (double-sided) / – Display Board (double-sided)		323, 324 } Set	£12.00
★★PIC Toolkit TK3 – **Software only**		–	–
4-Channel Twinkling Lights	DEC '01	325	£6.82
Ghost Buster – Mic / – Main		326, 327 } Set	£5.78
★PIC Polywhatsit – Digital / – Analogue		328, 329 } Set	£7.61
Forever Flasher	JAN '02	330	£4.44
Time Delay Touch Switch		331	£4.60
★PIC Magick Musick		332	£5.87
Versatile Bench Power Supply		333	£5.71

EPE SOFTWARE

Software programs for *EPE* projects marked with a single asterisk ★ are available on 3.5 inch PC-compatible disks or ***free*** from our Internet site. The following disks are available: **PIC Tutorial** (Mar-May '98); **PIC Toolkit Mk2 V2·4d** (May-Jun '99); ***EPE* Disk 1** (Apr '95-Dec '98); ***EPE* Disk 2** (1999); ***EPE* Disk 3** (2000); ***EPE* Disk 4** (2001); ***EPE* Disk 5** (Jan 2002 issue to current cover date); ***EPE* Teach-In 2000; *EPE* Interface Disk 1** (October '00 issue to current cover date). **★★PIC Toolkit TK3** software (Nov '01) is on CD-ROM. The 3·5 inch disks are £3.00 each (UK), the CD-ROM is £6.95 (UK). Add 50p each for overseas surface mail, and £1 each for airmail. All are available from the *EPE PCB Service*. All files can be downloaded *free* from our Internet FTP site: **ftp://ftp.epemag.wimborne.co.uk.**

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code   Project   Quantity   Price

....

Name ....

Address ....

....

Tel. No. ....

I enclose payment of £................ (cheque/PO in **£ sterling only**) to:

Everyday Practical Electronics

MasterCard, Amex, Diners Club, Visa or Switch

Minimum order for cards £5   Switch Issue No. . . . .

Card No. . . . .

Signature..................................... Card Exp. Date................

NOTE: You can also order p.c.b.s by phone, Fax, E-mail or via our Internet site on a secure server:

http://www.epemag.wimborne.co.uk/shopdoor.htm