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NOVEMBER 2000

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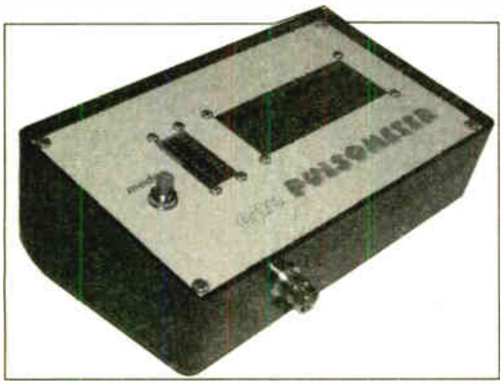

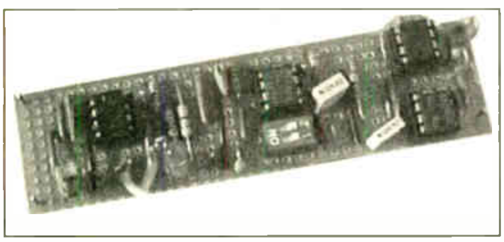

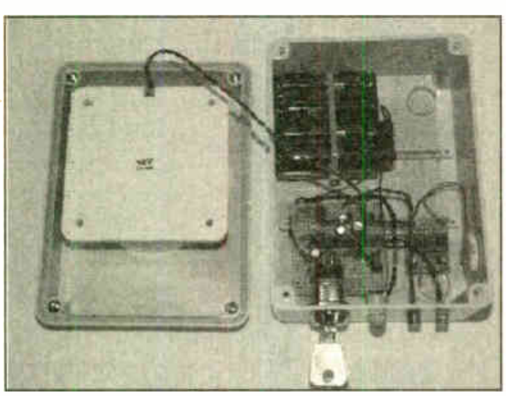

Projects and Circuits

Series and Features

Regulars and Services

NOTE NEW PUBLISHING DATE
December issue on sale
Thursday November 9

Our December 2000 issue will be published on Thursday, 9 November 2000. See page 795 for details

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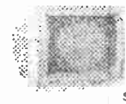

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VGA cable for IBM PC included.
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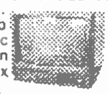

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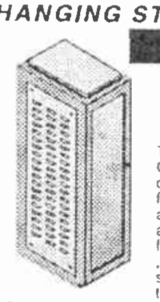

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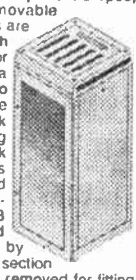

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NEXT MONTH

FREE CHRISTMAS PROJECTS SUPPLEMENT

MAKE IT A FUN-PACKED CHRISTMAS WITH THESE NOVEL PROJECTS

CHRISTMAS TREE LIGHTS

Every electronics hobbyist fantasizes about the festive season – it's the greatest opportunity of the year to show off your talents and prove that you can actually build something useful! The reason? The Christmas Tree Lights Controller, of course! It's your annual chance to dazzle your friends and family with your skills . . . maybe! How about a display that gently fades up and down over a period of time to assist in generating a more relaxed atmosphere?

CHRISTMAS BUBBLE

This project get its name because it looks like a large bubble, repeatedly swelling up and bursting.

PICTOGRAM

A novelty L.E.D. Pattern Generator. Uses a PIC to drive a ring of l.e.d.s to produce an eye-catching display. Could be applied to a belt, headband or to almost any festive decoration.

TWINKLING STAR

A star is the usual symbol of Christmas because, according to the story, the three wise men followed one on their way to Bethlehem and even those for whom Father Christmas and his reindeer or holly and mistletoe or one of the plethora of other "Christmassy" symbols are just as important, still adorn their Christmas Tree with one. If you are tired with the old star which usually decorates your tree and would prefer something more eye catching, then this circuit is for you.

PIC-MONITORED DUAL POWER SUPPLY

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

The full version provides PIC microcontroller monitoring of voltage and current, displaying the data on an intelligent liquid crystal display and sounding a buzzer if preset current limits are exceeded.

It has two channels usable individually or in series, offering two outputs per channel, one switchable for fixed voltages of 5V, 6V, 9V, 12V, 15V or 18V, at up to 1A. The other is fully variable from about 0V up to 1V less than the switch-selected fixed voltage, at up to 350mA.

STATIC FIELD DETECTOR

This ultra-simple device should be of interest to all those who like to experiment with unusual gadgets. It is a form of electroscope, which is a device that detects static electricity. No doubt most readers have seen demonstrations of purely mechanical devices that use electrostatic forces to show the presence of high static voltages. This device uses some simple electronics to detect much smaller potentials, with a twin l.e.d. display showing any increase or decrease in the detected voltage.

It has to be emphasised that this very simple unit is only intended to be a "fun" project, and it is not suitable for serious scientific purposes.

PLUS: FREE VOL. 29 ANNUAL INDEX

NO ONE DOES IT BETTER

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

DECEMBER ISSUE ON SALE THURSDAY, NOVEMBER 9

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SUB MIN TOGGLE SWITCHES. Pack of 3. Order Ref: 214.

HIGH POWER 3in. SPEAKER (11W 8ohm). Order Ref: 246.

MEDIUM WAVE PERMEABILITY TUNER. It's almost a complete radio with circuit. Order Ref: 247.

HEATING ELEMENT. Mains voltage 100W, brass encased. Order Ref: 8.

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HIVAC NUMICATOR TUBE. Hivac ref XN3. Order Ref: 865.

2IN. ROUND LOUDSPEAKERS. 50Ω coil. Pack of 2. Order Ref: 908.

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13A PLUG, fully legal with insulated legs, pack of 3. Order Ref: GR19.

OPTO SWITCH on p.c.b., size 2in. x 1in., pack of 2. Order Ref: GR21.

COMPONENT MOUNTING PANEL, heavy Paxolin 10in. x 2in., 32 pairs of brass pillars for soldering binding components. Order Ref: 7RC26.

PEA LAMPS, only 4mm but 14V at 0·04A, wire ended, pack of 4. Order Ref: 7RC28.

HIGH AMP THYRISTOR, normal 2 contacts from top, heavy threaded fixing underneath, think amperage to be at least 25A, pack of 2. Order Ref: 7FC43.

BRIDGE RECTIFIER, ideal for 12V to 24V charger at 5A, pack of 2. Order Ref: 1070.

TEST PRODS FOR MULTIMETER with 4mm sockets. Good length very flexible lead. Order Ref: D86.

LUMINOUS ROCKER SWITCH, approximately 30mm square, pack of 2. Order Ref: D64.

MES LAMP HOLDERS, slide onto ¼in. tag, pack of 10. Order Ref: 1054.

HALL EFFECT DEVICES, mounted on small heatsink, pack of 2. Order Ref: 1022.

12V POLARISED RELAY, 2 changeover contacts. Order Ref: 1032.

PROJECT CASE, 95mm x 66mm x 23mm with removable lid held by 4 screws, pack of 2. Order Ref: 876.

LARGE MICRO SWITCHES, 20mm x 6mm x 10mm, changeover contacts, pack of 2. Order Ref: 826.

PIEZO ELECTRIC SOUNDER, also operates efficiently as a microphone. Approximately 30mm diameter, easily mountable, 2 for £1. Order Ref: 1084.

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FERRITE RODS, 7in. with coils for long and medium waves, pack of 2. Order Ref: D52.

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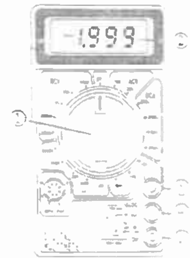

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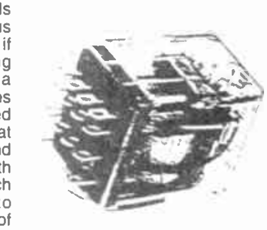

Coil Voltage	Contacts	Price	Order Ref:
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Note – This battery will start a car and is ideal for golf trolleys, etc.

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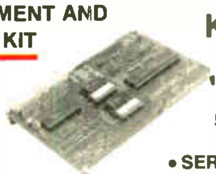

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As featured in *EPE* and now published as Teach-In 7.
All parts are supplied by Magenta.
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Full Mini Lab Kit – £119.95 –
Power supply extra – £22.55
Full Micro Lab Kit – £155.95
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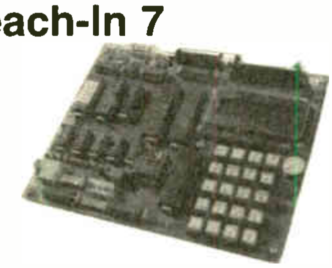

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TOO MUCH

A month or so before Christmas each year we usually publish a "festive" project, be it a tree lights controller, disco lights or some sort of active decoration. Very often contributors will send in projects early in the year in order to get their's accepted for a Christmas issue. These projects have also proved to be very popular with readers – even well after Christmas has passed; presumably some are getting ready for the next festive period well in advance.

All the above has meant that this year we have received a number of differing Christmas projects from a variety of contributors. So, what should we do? Publish one and reject the rest? Publish a couple over two issues and accept the others for next year? Or maybe publish them all so readers can go mad with "flashing" decorations.

We fancied the last option, but to put them all in one issue would have excluded any other projects and that, no doubt, would upset many readers who have no interest in the trivia of "Christmas electronics". So in an effort to please everyone we have decided to put them all into a Special Supplement by adding extra pages to next month's issue. If the mood takes you, you can therefore build them all.

TOO FLASH

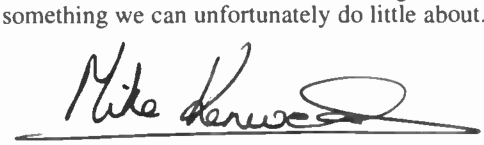
The projects vary from a gently changing cyclic tree lights controller to a PIC-based programmable l.e.d. display, originally used on a top hat but which could be applied to almost any form of dress or tree decoration.

If you want to dazzle family and friends with your skills now is the time. See page 795 for more details.

TO BE SURE

I warned last month of potential supply problems with many specialist magazines, so make sure of your copy of *EPE* next month. To do this you should place an order with your newsagent or take out a subscription. With a bumper issue demand is bound to be high and we cannot guarantee that you will get a copy if you do not order it now!

For those who did not see my Editorial last month, this is all to do with range restriction by some high street newsagents, something we can unfortunately do little about.



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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.

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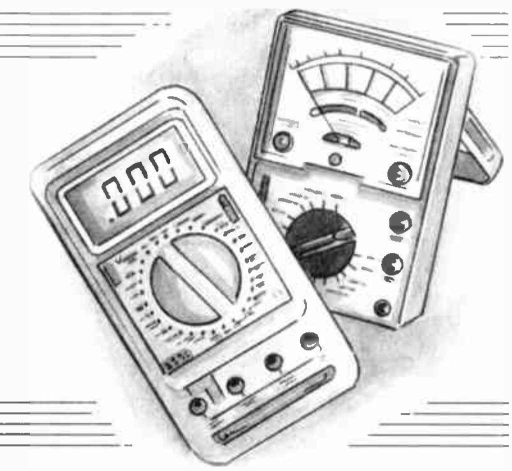
SAMPLE-AND-HOLD



OWEN BISHOP Project 4

This short collection of projects, some useful, some instructive and some amusing, can be made for around the ten pounds mark. The estimated cost does not include an enclosure. All of the projects are built on stripboard, and most have been designed to fit on to boards of standard dimensions. All of the projects are battery-powered, so are safe to build. In a few cases in which, by its nature, the project is to be run for long periods, power may be provided by an inexpensive mains adaptor. Again, the cost of such a unit is not included.

THIS, our fourth Top Tenner project, is an add-on unit for your multimeter, and works equally well if it is an analogue or digital type. As the name suggests, its function is to sample a changing voltage and hold it to give you time to read its value.

Reading a changing voltage can be difficult with a digital meter because the final two or three figures of the reading may be changing too fast to be seen. There is the added complication that a reading of a digital meter is itself a sample-and-hold measurement. The meter samples the input voltage, then holds it while the analogue-to-digital converter in the meter converts the reading to digital form.

Typically, the meter takes several samples per second so it is not possible to read each sample individually. We can only read a value when it is reasonably steady, perhaps varying only in the least significant digit.

An analogue meter is possibly easier to read with a rapidly changing voltage, because the eye can average out the changes over a small interval of time. There is also the inertia of the needle and coil unit to help steady the readings.

Whether you have a digital or analogue meter, there are occasions when you will want to sample and read the voltage at a precise instant, or to sample it and read it at regular intervals of time. This project helps you do just this.

HOW IT WORKS

The principle of the circuit is extremely simple and can be followed by looking at the right-hand half of Fig.1, the full circuit diagram for the Sample-and-Hold project. The voltage is sampled by feeding it to capacitor C4. This has a reasonably low value so that it quickly charges or discharges to attain the same voltage as the "test point" in the circuit under test.

The capacitor is connected to the test point through a switch. We could employ a mechanical switch but it is preferable to use a MOSFET transmission gate, which can be "opened" or "closed" electronically. Here we use a DG419D analogue switch, IC3, which has an "on" resistance of only 35 ohms.

When IC3 is on, current flows from pin 1 to pin 8 or in the reverse direction, depending on whether the existing voltage across capacitor C4 is less than or greater than the present input voltage. There is a control input at pin 6, which closes (connects) the switch when the input is high, and opens (disconnects) the switch when it is low. When the switch is open its resistance is several gigaohms, so it is virtually an open circuit.

When capacitor C4 has been charged, the voltage across it is measured by a meter. To connect the capacitor directly to a meter would make it lose charge rapidly, especially if the meter was the analogue type. It would partly discharge the capacitor before there was time to take the reading.

VOLTAGE FOLLOWER

To prevent this, we use an operational amplifier (op.amp) IC4, wired as a *voltage follower* (buffer). The output voltage of this is equal to its input, the voltage across the capacitor. The reason for using the op.amp is that the input terminal of the op.amp has very high impedance, typi-cally 1 terahohm (10^{12}MΩ) so virtually no current is lost to the op.amp. An op.amp typically has an output impedance of 75 ohms so it can drive the meter, whatever its type, without significant loss of voltage.

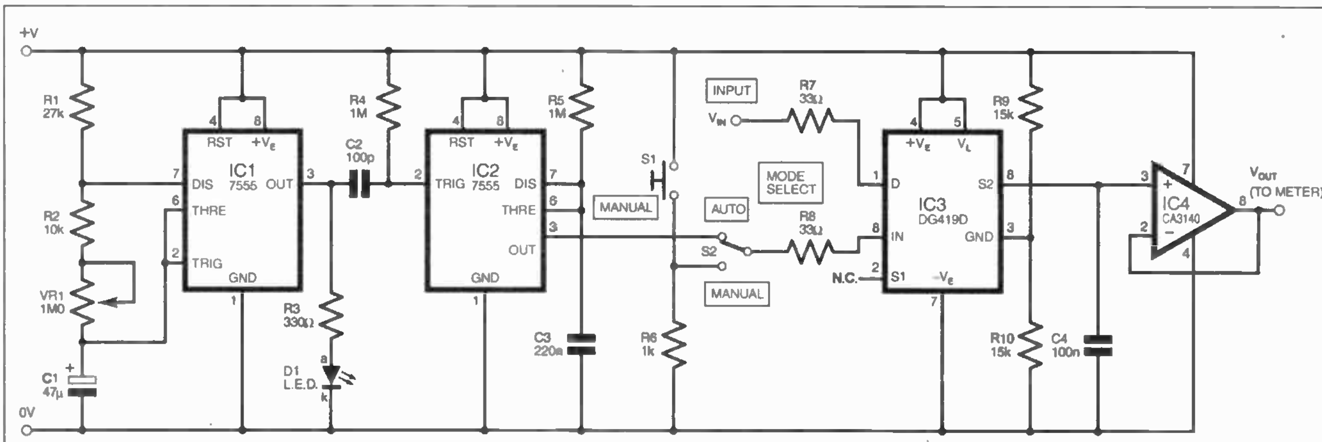


Fig.1. Complete circuit diagram for the Sample-and-Hold. The circuit can be powered from a 6V to 12V supply, see text.

In this kind of circuit, there is always a compromise to be made over the capacitance of C4. It is good for it to be reasonably large. Then any leakage of charge through the switch IC3 or op.amp IC4 makes little difference to the voltage. It stays at the same voltage for several minutes or longer, allowing plenty of time for reading the result. We say that there is little *droop*.

On the other hand, if the capacitance is large, the time constant of the switch resistance and the capacitance is large too. This means that the capacitor takes longer to fully charge or discharge. It cannot follow a rapidly changing input voltage.

The length of time taken for the capacitor to alter its charge from the previous voltage to the present voltage is estimated by calculating the time constant. This is given by:

$$t = RC$$

In this equation, t is the time constant in seconds, R is the resistance in ohms through which current flows to charge or discharge C4, and C is the capacitance of C4, in Farads. In this section of the circuit, R is 35 ohms, the ON resistance of switch IC3, plus 33 ohms due to the current-limiting series resistor R7. This brings R to a total of 68 ohms. C is the capacitance of C4, which is 100nF = 0·1μF. Multiplying one by the other gives t = 6·8μs as the time constant.

It can be shown that it takes five time constants for the voltage on C4 to equilibrate to within one per cent of the new level. This means that it reaches the new level in 34μs, which is certainly fast enough for a simple "sample-and-hold" set-up.

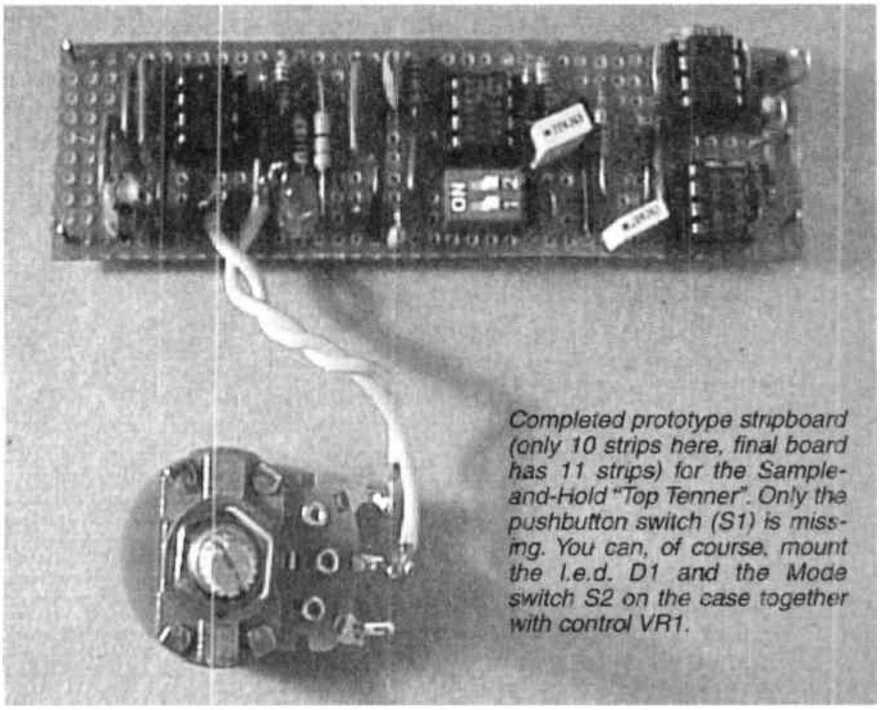
SAMPLING

This Sample-and-Hold circuit provides for manual and automatic sampling. For manual sampling, we set switch S2 to the Manual position. Then resistor R6 holds pin 6 of IC3 low, holding the internal switch of IC3 open. Pressing pushswitch S1, makes pin 6 high connecting pin 1 to pin 8, and closes (connects) the internal switch. The voltage on C4 then follows the input voltage V_{IN}.

To take a sample, we release pushswitch S1, which opens the switch, leaving C4 isolated from the changing input voltage. The attached meter displays the voltage across capacitor C4 at the instant that S1 is released.

Alternatively, the voltage is sampled automatically at regular intervals. There are two CMOS 7555 timer i.c.s, of which IC1 controls the rate of sampling. IC1 is wired as an astable multivibrator, producing a regular series of rectangular output pulses. By adjusting potentiometer VR1, the frequency of the output can be varied from 0·65Hz (just under two samples per second) to 0·015Hz (approximately one sample per minute). The rate of operation of IC1 is indicated by the flashing of l.e.d. D1.

Every time the output of IC1 at pin 3 goes low, it generates a low-going pulse, which passes through capacitor C2 and triggers timer IC2. This is wired as a monostable multivibrator, which produces a single 240ms high pulse when triggered, as set by R5 and C3.



Completed prototype stripboard (only 10 strips here, final board has 11 strips) for the Sample-and-Hold "Top Tenner". Only the pushbutton switch (S1) is missing. You can, of course, mount the l.e.d. D1 and the Mode switch S2 on the case together with control VR1.

The input voltage is sampled as this pulse ends. The pulse length is far longer than five time constants so we can be sure that the charge on capacitor C4 is an accurate sample of the input.

VOLTAGE RANGE

The analogue switch IC3 and op.amp IC4 are powered from the +V and 0V rails. Both can operate on either a single or a double supply. As a single supply, the circuit can be powered from a 6V, 9V or 12V battery. The input voltage must lie within the levels of the power supply rails, so a larger supply voltage is required to cover a larger input voltage range.

The operating range also determines which is the best op.amp to use. It must be one with j.f.e.t. or MOSFET inputs; otherwise, charge will rapidly leak from capacitor C4 through the input of the op.amp. A CMOS op.amp such as the CA3140 is suitable, as it will operate on 4V. Unfortunately, its output will not swing fully to the positive supply rails. Operating on 6V, for example, its output swings from 0V to +4V.

If a wider swing is essential, use the CA3130, which can swing fully to either rail. An alternative is to increase the power supply to 9V or 12V. Incidentally, these op.amps have slew rates of 9V/μs and 10V/μs respectively, so they readily follow rapid changes in input voltage.

Another op.amp that could be used is the TL071, which has a j.f.e.t. input. This has a slew rate of 13V/μs, which is the highest rate achieved by inexpensive op.amps.

However, its output cannot swing fully to either supply rail. For example, with a 6V supply the output swings between 1·35V and 5·5V.

Using this op.amp, the circuit must be operated as if the supply is a dual one. The supply rails are then taken to be plus and minus 3V, 4·5 V or 6V, depending on the battery used. The 0V line is taken from the junction between the appropriate pair of cells, simulated in this instance by the voltage at the junction of the potential divider formed by R9 and R10.

COMPONENTS

See SHOP TALK page

Resistors

R1	27k
R2	10k
R3	330Ω
R4, R5	1M (2 off)
R6	1k
R7, R8	33Ω (2 off)
R9, R10	15k (2 off)

(All 0·25W 1% metal film

Potentiometer

VR1	1M min. rotary carbon, linear

Capacitors

C1	47μF radial elect. 16V
C2	100p, disc ceramic
C3	220n, polyester film
C4	100n, polyester film

Semiconductors

D1	5mm l.e.d., red or green
IC1, IC2	7555 CMOS timer (2 off)
IC3	DG419D, single MOS FET transmission gate
IC4	CA3140 (or CA3130) CMOS op.amp (see text)

Miscellaneous

S1	pushbutton switch, push-to-make
S2	single dual-in-line double-throw style switch (p.c b. linked), or equivalent s.p.d.t. switch.

Stripboard 0·1 inch matrix, size 11 copper strips by 39 holes; 8-pin i.c. socket (4 off); small plastic case, size and style to choice; plugs to fit multimeter (2 off); crocodile clip or probe for input lead; 1mm solder pins (7 off); solder, etc.

Approx. Cost Guidance Only £10
excluding case & batt.

CONSTRUCTION

The Sample-and-Hold circuit is built on a narrow rectangle of stripboard with the idea of fitting it into a handheld enclosure, perhaps with a probe projecting from one end. However, is not essential for the device to be handheld and it can be accommodated in any small plastic enclosure.

The circuit is built up on a piece of 0·1in. matrix stripboard, containing 11 copper strips by 39 holes. The board top-side component layout and details of breaks required in the underside copper tracks are shown in Fig.2. Dual-in-line (d.i.l.) sockets should be used to hold all i.c.s. Note that some resistors are mounted vertically.

The essential off-board components, apart from the battery box, are the potentiometer VR1 and the pushbutton switch S1. Both are mounted on the case and VR1 should be provided with a pointer knob.

You may also decide to mount the l.e.d. D1 and Mode Selector Switch S2 on the enclosure as well. If you do, run leads to them from the corresponding holes on the circuit board. You will also have to decide how you intend to connect the circuit to the "test circuit" and to the meter.

Begin construction by assembling the first timer (IC1). Use the l.e.d. to test that the timer is operating correctly. Also, use the l.e.d. to calibrate the settings of VR1. Mark the position of the knob of VR1 to correspond to useful timings such as 1s, 2s, 5s, 10s, and so on to one minute.

Next, assemble the second timer (IC2). With a voltmeter attached to its output at pin 3, check that a positive pulse is produced every time the l.e.d. turns off. Also, construct the switching circuits (S1 and S2). There are several ways of providing the s.p.d.t. switching action of S2. Check the way your d.i.l. switch operates before soldering it in place and modify the wiring, if necessary.

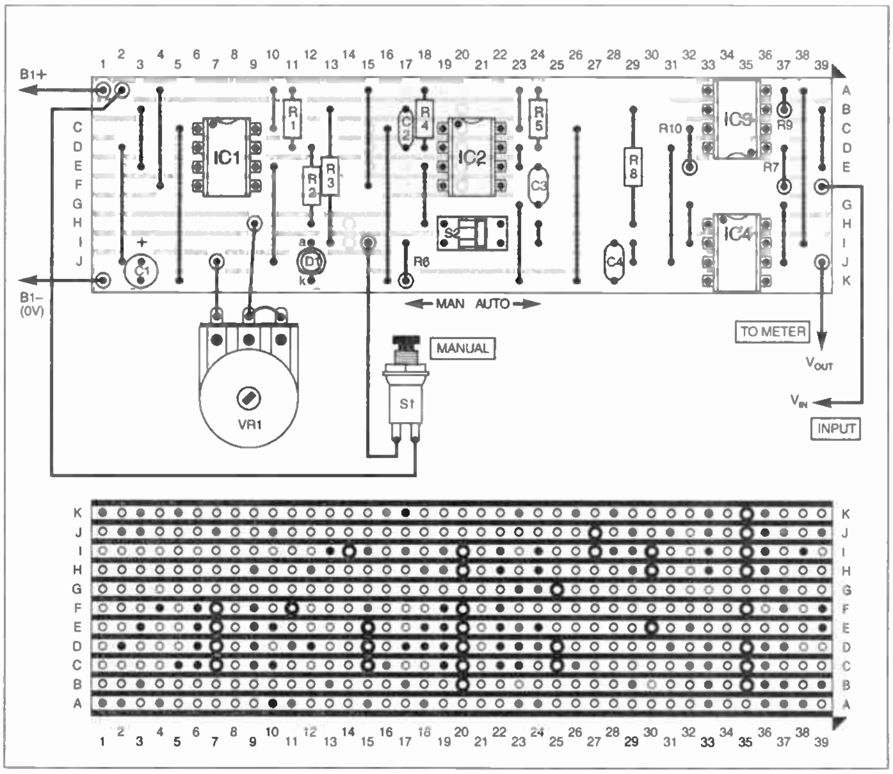


Fig.2. Stripboard component layout, interwiring and details of breaks required in the underside copper tracks.

Finally, assemble the sampling (IC3) and the op.amp (IC4) circuits, noting that IC3 is mounted the other way up, with pin 1 at bottom right. To test the completed circuit board, connect a 10 kilohms potentiometer across the supply rails and run a temporary wire from its wiper terminal to the V_{IN} input, at resistor R7. This provides a full range of input voltages.

Connect your multimeter to V_{OUT} (at IC4 pin 6) and to the 0V rail and then switch the meter on. If you have a spare multimeter, use this to monitor V_{IN} at the same time as V_{OUT}. Select manual control and rotate the potentiometer knob to produce a range of input voltages. Press and release switch S1 as the voltage input is changing and check that V_{OUT} is truly sampled and held. Repeat the tests in automatic mode at various sampling rates. Remove the "test" potentiometer and box-up the board ready for action! ☐

News . . .

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

ANALOGUE FREQUENCY SELL-OFF UNLIKELY

Unlike the sale of 3G networks, vacated analogue TV frequencies may not earn income for the Government. Barry Fox reports.

The UK's Independent Television Commission has bad news for governments hoping to earn easy money, 3G style, from the sale of frequencies released by switching off analogue TV. Its recent *Genesis Project* report warns that even if viewers can be persuaded to buy new digital TVs and VCRs, the released frequencies will be too widely spaced to be of practical use to the mobile radio industry.

Says Gary Tonge, the ITC's Director of Engineering "The released frequencies are peppered throughout the spectrum, so there will be nothing to sell. This is a big problem".

The UK now leads the world in digital terrestrial TV because viewers get free set-top boxes if they pay to view. According to a frequency plan published by the ITC in 1996, and replicated around the world, DTTV services transmit on "taboo" channels which are interleaved with the existing analogue stations.

COMMISSIONED RESEARCH

Recently the ITC commissioned transmitter network operator NTL and the Smith Group of consultants to find out how digital cover could be extended to match analogue's 99.4 per cent cover, and so allow analogue switch-off. The Genesis researchers developed seven scenarios of mind-bending complexity, but none can deliver full digital cover without stealing frequencies currently used for analogue. So there is no hope of simulcasting the same programmes from analogue and digital transmitters while viewers migrate at leisure. At least 10 per cent of the population will face an abrupt change.

Mobile radio operators want large blocks of spectrum which are free across the whole country and in different countries. (A 155MHz slice of spectrum has been earmarked internationally for 3G, third generation mobile phone networks). The released analogue channels are 8MHz wide and straggle over the UHF band, differing from area to area.

Genesis recommends that at least ten channels should be grouped into a contiguous block. But this would involve restructuring the spectrum before switch-off and require international agreement. All viewers would then suffer an "abrupt change" leaving many dark TV screens and useless VCRs unless owners retuned or replaced their equipment.

Mike Short is Cellnet's Director of Network Strategy and sits on the UK government's Spectrum Management Advisory Group. "If there were only a few scattered frequencies available I am sure we could do something with them. But it would cost more and be less efficient.

"Economy of scale is the key issue. Europe's GSM digital cellphone system is a worldwide success because there was international agreement on frequency allocations which allows roaming, with handsets from one country working in others. So handsets get better and cheaper all the time. It's extraordinary for a system only launched in 1992. The US has three different and incompatible digital systems and is backward, like a third world country".

The Genesis report suggests that the cost of a re-plan could be subsidised by the revenue earned from the spectrum auction it enables. But the ITC has growing doubts on the government's hopes for analogue switch-off by year 2010.

There are now 45m TV sets and 20m VCRs in use. Consumers cannot buy a digital VCR even if they want to.

SWITCHING TIME

Says the ITC's Chief Executive Peter Rogers. "It took 20 years to switch off 405-line TV, and digital doesn't have the pulling power of 625-line colour. Sales of integrated digital TV sets have taken a knock from free set-box boxes. I would be surprised and delighted if 50 per cent of the population bought into digital multi-channel pay TV. Even if they do, we still need to find a way to persuade the other 50 per cent to switch. It's a very serious challenge and we are not yet on that course.

"STBs may not be the passing phase we originally thought. I'd love to be surprised and delighted if digital replaced analogue in ten years. Really this is outside the powers of the ITC. We are trying to help but if the DCMS and DTI don't get on top of it, it isn't going to happen".

The ITC's priority is to improve cover for OnDigital's C and D multiplexes. Work by NTL is already under way, and will hopefully be finished by December. NTL is "equalising" the Crystal Palace digital terrestrial TV transmitter, along with four more at Hannington, Oxford, Hemel Hempstead and Sandy Heath. OnDigital's channels on the C and D multiplexes have been transmitting at much lower power than the main free-to-air multiplexes; as low as one kilowatt, compared to 10 kilowatts used for the FTA multiplexes.

By juggling the frequencies and changing the aerial directivity, all the transmitters in the this so-called "CP5" group will now run at the same power, 10 kilowatts. This should dramatically improve reception and reach an extra 750,000 OnDigital viewers in the Home Counties.

Peter Rogers also confirms that the ITC is worried about the continuing delays on SDN's service and the plans to squeeze so many programme channels into the limited airspace that the pictures suffer. "They have real problems" he warns. "Pictures are on the very edge of acceptable quality".

MINI SCANNER

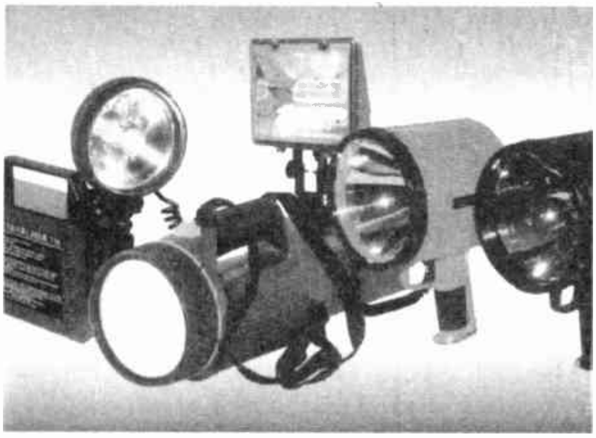
INCASCAN have introduced PennyScan, which they describe as a miniature low cost consumer barcode scanner. With it you can scan web-type barcodes in adverts or other promotional material. PennyScan saves these URLs which can then be used next time you go online, transferring the data via an infrared link.

PennyScan is tear drop shaped and can fit on a key ring. It will read all the major world barcode formats including UPC-EAN, ISBN etc, and holds over 300 barcodes, including time/date stamping. Data transfer is at 19.2Kbps 2-way opto transfer and uses a totally safe low power l.e.d. scan light. Typical battery life is five years.

Apart from scanning, PennyScan can hold and share up to 4K of binary data for encryption, hash functions, key rings, security access, passwords, address links, corporate intranet access and more. Interfacing options include IR, USB, RS232, RS485, and PS2.

For more information contact Incascan, Dept. EPE, 49-51 Rayleigh Avenue, Westcliff On Sea, Essex SS0 7DS. Tel: 01438 718 007. Fax: 01438 718 001.
E-mail: sales@incascan.com. Web: www.pennyscan.com.

NIGHTSEARCHER



NIGHTSEARCHER, the portable rechargeable lighting company, tell us that they are "launching three exciting new products" for the winter 2000/01 market. the Panther, the Focus and the Rechargeable Fluorescent Lantern.

The Panther is a high intensity searchlight giving over one million candlepower of light and a one-mile long beam. It has a virtually unbreakable case and is water resistant.

Operating on either one or two Xenon bulbs with a high and low switch, this powerful search light operates for one and half hours on its main beam, and up to four hours on its secondary beam. It will fully recharge from a mains supply charger as well as from a vehicle's cigar socket, and both types of charger are included. The price is £74.95.

The Focus is a powerful searchlight with a wall mounted charging bracket and a halogen beam. It features a flood beam and an adjustable spot, with adjustable brightness levels and up to eight hours operating time. It costs £43.95.

The Rechargeable Fluorescent Lantern has mains and battery dual power system and uses two 24-inch (61cm) fluorescent tubes. It is ideal for lofts and garages, workshops and the like, and can be mounted on a wall or simply stand by itself. It costs £26.95.

The three units are available direct from Nightsearcher Ltd, Dept EPE. Unit 15, The Wren Centre, Westbourne Road, Westbourne, Emsworth, Hants PO10 7RN. Tel: 01243 370222. Fax: 01243 370666.

E-mail: sorrel@nightsearcher.co.uk. Web: www.nightsearcher.co.uk.

Fluorescent CDs

By Barry Fox

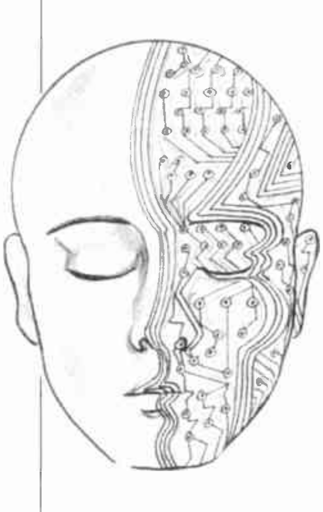
CONSTELLATION 3D, a new company with research facilities in Russia, Israel and Silicon Valley has demonstrated prototypes of FMD, the Fluorescent Multilayer Disc which uses fluorescent dyes to let a laser distinguish between thin tightly sandwiched layers.

Laser light at one wavelength (650nm) hits the dye pits and re-radiates with a slightly different wavelength (680nm). The laser in the player switches focus to read the different layers.

At the recent DVD Summit in Dublin, C3D promised product in April 2001, with discs costing between $1 and $2 to mass-produce and playing on OEM drives which cost between $50 and $70. Write once blanks will be launched in October 2001.

The first discs will have 10 bonded layers, each around 15 microns thick, with a total capacity of 140 Gigabytes. Eventually there will be 100 layers, with terrabyte capacity. Read speed is 25-150MBit/s. The layers are pressed separately, with dye tracks, and then bonded one on top of the others. The Dell computer company is interested. IBM – who tried and failed to make multilayer discs – is impressed. Recordable and re-writeable discs are promised for the future.

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 tips, not simply mechanical or electrical ideas. Ideas *must be the reader's own work* and **not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**
Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited,* Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BS21 1PF.
They could earn you some real 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.

Single-Phase Power Regulator – Power Driver

A CIRCUIT diagram of a low cost single-phase mains power regulator is given in Fig. 1. *It is suitable only for experienced and skilled constructors who can assemble mains-voltage circuits competently.*

It is based on a comparator type LM311 (IC1) and two 555 monostable timers (IC2 and IC3). Waveforms at various points in the circuits are shown in Fig.2.

The circuit uses a 3VA step-down transformer T1 for its power and synchronisation. A full-wave rectified (but unsmoothed) voltage V_1 is compared with a d.c. voltage (set by R3/R4) to obtain a square wave. The resulting square wave V_2 is used to trigger IC2.

The triggering time is dependent upon an external control input voltage V_c at pin 5 that may come from potentiometer VR1 as shown, or from a PC through an I/0 card. The duty cycle of IC1 output is a non-linear function of the input voltage.

A second fixed duty cycle monostable, IC3, is triggered by the output (V_3) of the first monostable. The output of the second monostable (V_4) is 50Hz but its delay is dependent upon the external input. It is used to drive an opto-isolated triac type MOD3020 which in

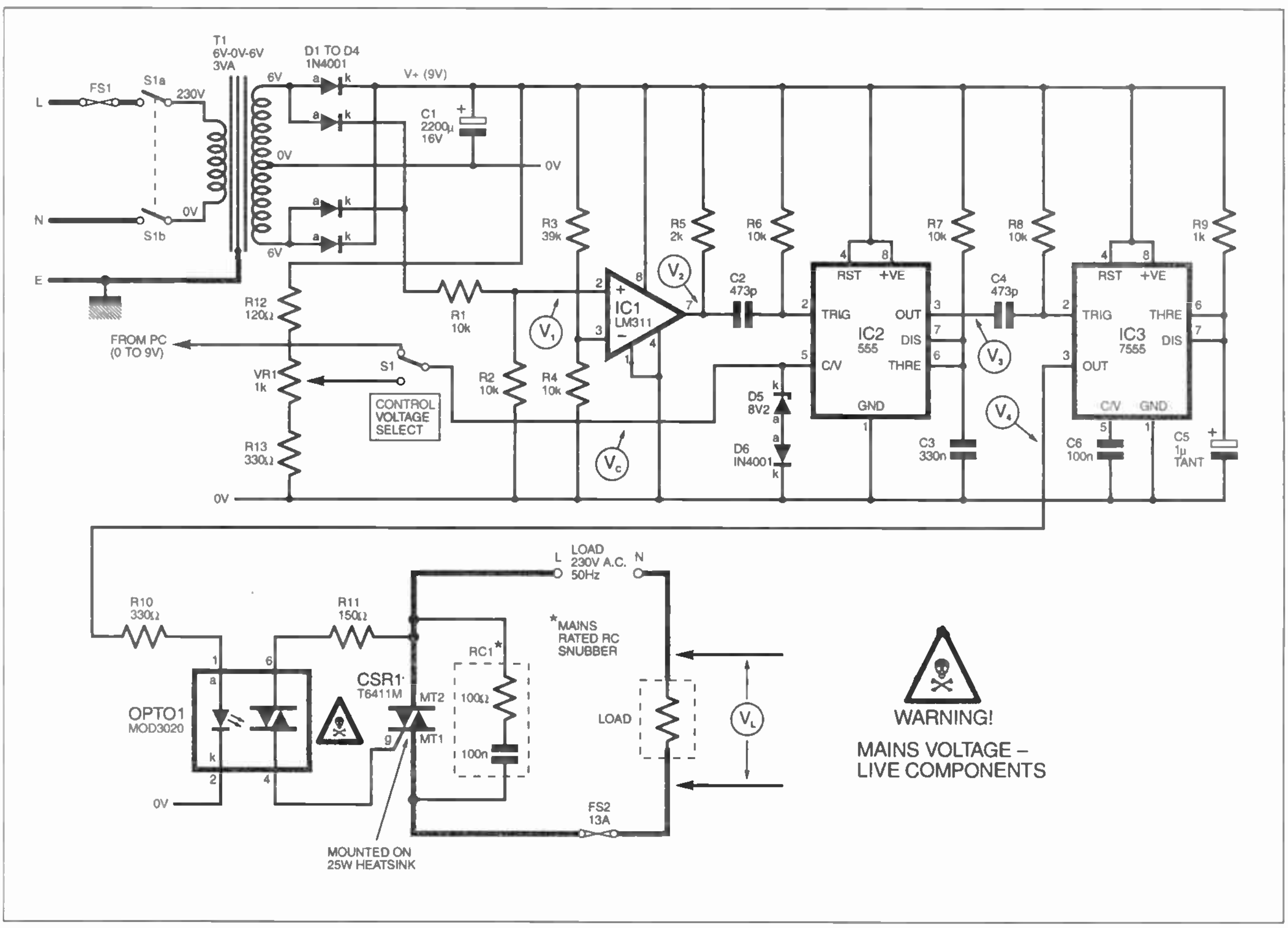


Fig.1. Circuit diagram for a Single-Phase Power Regulator.

Macrovision Blanker – without a PIC

This Macrovision Blanker circuit (Fig.3) was born out of requests from a friend whose ageing UK PAL TV suffered from "Macrovision disease". Also, it presented a nice opportunity for some practical TV circuitry having just endured a BBC Engineering course.

The design requirement was to blank out any Macrovision signals that are present in the first block of lines in a TV picture. Receivers are generally set up so that this area is not seen by viewers, because in a "live" picture it generally carries text and transmission test signals.

The preferred method of blanking out the signal here is to clamp the TV waveform during the Macrovision "active" period and remove the oscillations that cause all the trouble. The field and line synchronisation pulses (syncs) need to be detected to allow the accurate definition of the beginning of each field and line.

Following a simple buffer stage, the first major piece of signal conditioning results in the separation of the mixed syncs from the complete picture signal (point A), then by setting up specific *RC* time constant values, the field and line syncs are isolated. The monostable based around IC3a is triggered at the start of each picture field, and the setting of the 100k potentiometer. VR4 determines for how much of each TV field the monostable will be active – only for about the first ten lines. Once the monostable is triggered, it enables a second monostable IC3b by removing the forced reset at pin 13, with IC4 preventing multiple triggers from spurious line syncs.

The setting of potentiometer VR3 determines how much of any line is clamped. A clamping control signal is derived from pin 10 of IC3b, and transistor TR3 is used to apply it to the picture signal. Control potentiometer VR2 determines the level at which the clamp is made, i.e. it moves the d.c. position of the picture signal with respect to the 0V/clamping level.

A separate 9V split power supply (not shown) is required and the circuit values will require some adjustment if they are to be used with TV systems other than that employed in the UK. However, the structured nature of the circuit allows easy access to each stage of the process, making realignment a straightforward process for an experienced constructor.

Overall, the circuit provides a good insight into the structure of an analogue TV picture, since the blanked area and clamping level can be adjusted to all sorts of values. As such, its building blocks can be the basis of designs for a variety of picture manipulation circuits. And not a PIC microcontroller is in sight!

Steve Dellow,
Warwick.

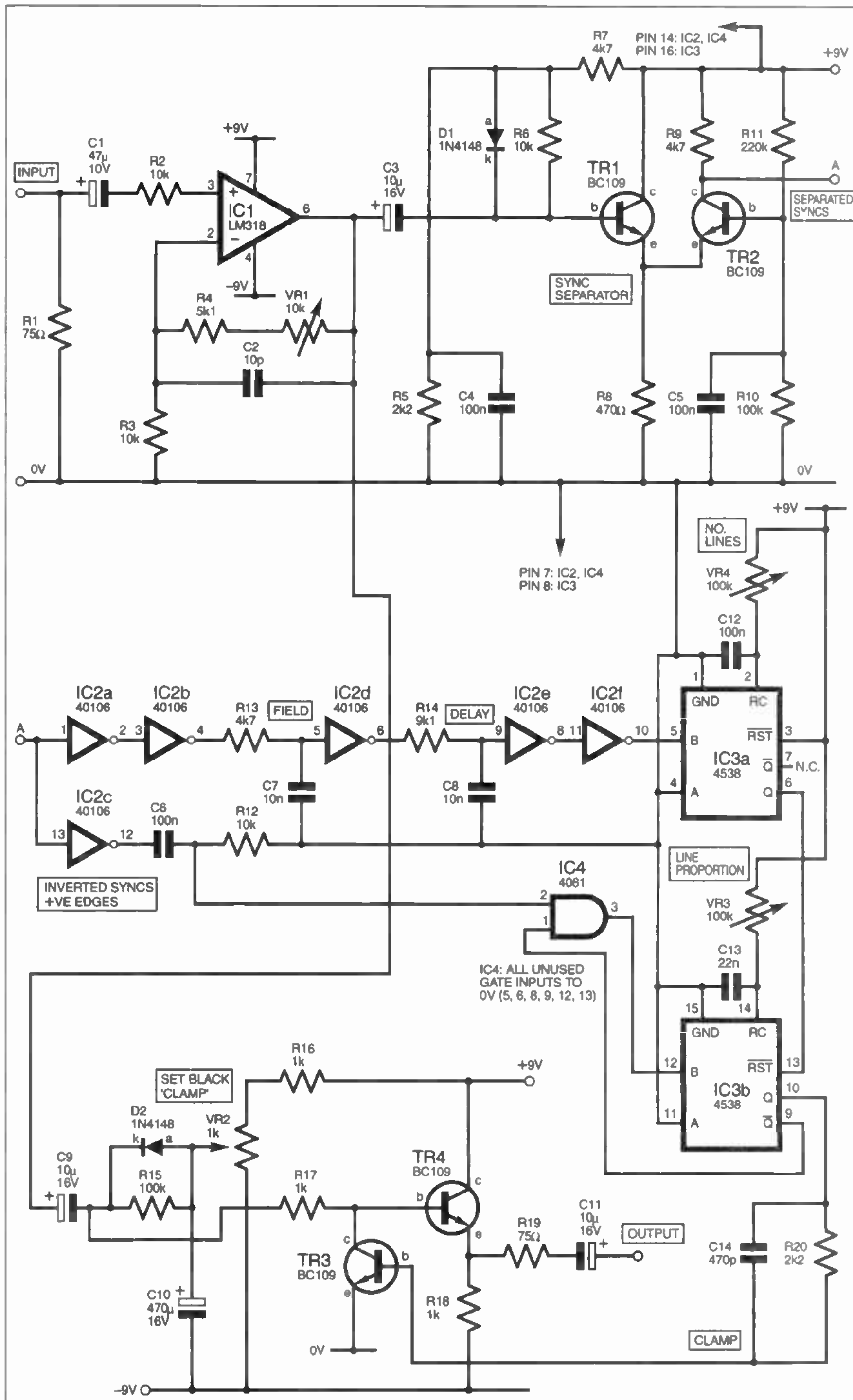


Fig.3. Circuit diagram for the Macrovision Blanker.

turn triggers a high current 30A 600V triac (CSR1) e.g. T6411M fitted to a large heatsink. The waveform across the load (V_L) for a resistive load is also shown in Fig. 2.

This simple single-phase power regulator can be used to drive a heater load or an a.c. commutator motor, noting that the input/output characteristic is non-linear.

(The circuit cannot be used for controlling synchronous or shaded-pole motors as these are frequency-dependent – ARW).

M.T. Iqbal,
Rawalpindi,
Pakistan.

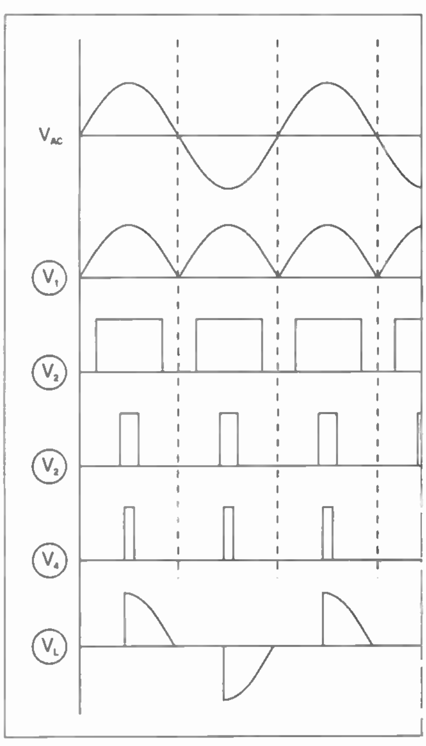


Fig.2. Typical waveforms to be expected at various points in the circuit of Fig.1.

New Technology Update

A new combined dual chipset helps to improve digital image resolution capture. Ian Poole reports.

UNTIL recently digital still cameras could not offer the quality at a price comparable with the more traditional film cameras.

However, now that the technology for electronic digital cameras has advanced, more people are buying and using them. This has resulted in increased sales and further investment. Now developments are beginning to move ahead even more swiftly.

There are, though, still a number of drawbacks. These are generally experienced by the top end professional and semi-professional market. Often this results from the fact that camera manufacturers have had to make some critical trade-offs when designing new cameras.

More Pixels per Photo

For still cameras, the number of pixels per photo has been steadily increasing to improve the picture quality. Even though it is often possible to capture the pixels quickly it then takes some time to process them to adjust the colour, compress the files and to perform the other functions that are needed before the image can be stored. This results in a delay between shots.

Similarly, when video pictures are taken there can be problems with the time involved. In most cases the quality of the pictures is adequate when displayed on a TV screen. Typically between 300,000 and 600,000 pixels are used for each frame that is captured. Whilst this is fine if the image is to be displayed on a TV screen, it is not sufficient if the image is required for printing.

To overcome these problems a company named NuCORE Technology Inc have developed a new chipset that delivers full three-colour quality at a rate of 50 mega pixels a second. The set comprising two chips uses sophisticated algorithms to deliver the high quality video images. By using the chipset, only one CCD sensor is required instead of the three – one for each colour – that would normally be required for high-end applications. In this way cost, size and power consumption are all reduced, making it a very attractive proposition for manufacturers.

Two new chips

There are already chips in existence that perform video image processing. However, one of the keys to the success of the NuCORE set is that they are both from the same manufacturer. As a result they have been able to develop the complete solution, partitioning the features in the optimal way to ensure that performance is not compromised. Usually camera developments take one company's analogue front end and combine it with the digital processing unit from another.

The NuCORE approach uses two chips, one for the analogue processing and the other for the digital processing. To ensure the best performance is obtained, the designers investigated which processing functions were best accomplished using digital or analogue processing. By taking this approach from the outset, some of the restrictions that were previously experienced have been overcome.

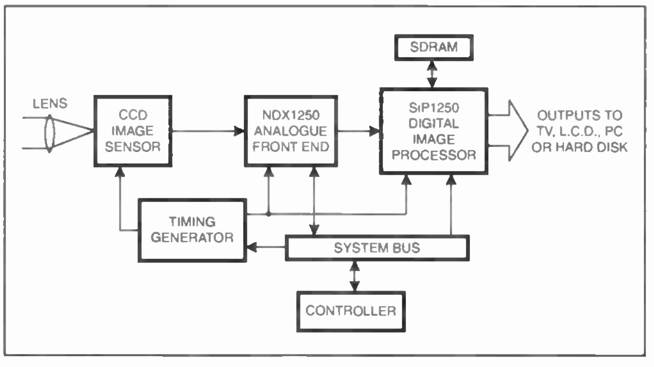


Fig. 1. Camera system using Nu-CORE chipset.

The chipset consists of the NDX1250 analogue chip and the SiP1250 digital processor.

The analogue processor performs all the processing prior to passing the signals to the digital processor. It includes functions such as black level auto calibration, programmable gain amplifier and a twelve bit analogue-to-digital converter (ADC). A further function known as the high speed differential correlated double sampler (CDS) removes spurious low frequency noise from the image sensing CCD by taking two samples from its output. This low frequency noise is a limitation of CCD sensors and one that the NDX1250 successfully overcomes.

The digital processor is the smart digital image processor. It handles the data processing, allowing 30 frames per second performance, mega pixel continuous processing and complete image processing. Unlike other more traditional approaches no external cache memory is required.

Further Developments

One of the major areas of development is the way in which the company has overcome many of the limitations of the CCD image sensor. The first is the dynamic range of the sensor that is considerably less than that of the human eye. With previous designs it has not always been possible to capture both the brightest and darkest parts of a scene. Much of the detail can be hidden in the shadows or extreme brightness.

In single CCD cameras this arises when the camera has to swap between colours. The worst case often arises when the camera has adjusted for the level of green. Because of the way it scans the colours this also includes any yellow. Once it has adjusted for the level of yellow it then needs to change the gain to accommodate the blue. This can show a ten-fold difference in intensity, giving problems when adjusting the level of gain.

Normally, compensation for this takes place in the software after the digital conversion. NuCORE have adopted a different approach, changing the gain pixel by pixel at very high speed: within 20ns for 50 mega pixels per second. This has enabled the dynamic range to be increased to 32dB. This is a significant advantage because the human eye has a much greater dynamic range than single CCD cameras, and it is able to distinguish detail in scenes that have areas in strong sunlight as well as some in shade. Using the new chips it is now possible to successfully capture these scenes.

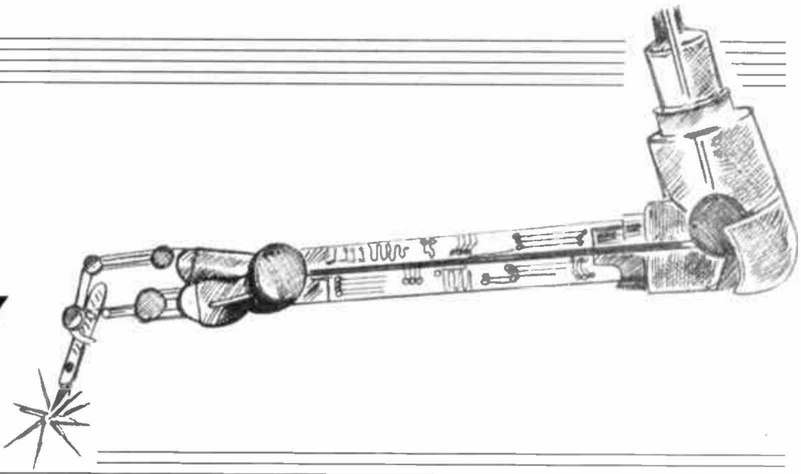
A further improvement has been made by considerably reducing the power consumption. As virtually all the applications for these devices will be in battery powered equipment this is a particularly important consideration.

It is claimed that these new chips consume between a third and a fifth the current of their nearest competitors.

Summary

Whilst the chipset has many features and the two chips are intended for use together, it is still possible to customise their performance so that the final product has its own characteristics that can be set to give it its market "differentiators". This is crucial for successful marketing of a product and showing it is different to the competition.

Regular Clinic



CIRCUIT SURGERY

ALAN WINSTANLEY and IAN BELL

This month our team of surgeons returns to the all-important topic of safeguarding against electrocution with the proper (and improper) use of residual current devices, and investigates p.c.b. track width specifications.

Don't Be Shocked!

Following up our earlier items on Residual Current Devices (RCDs), ***Mr. M. Hopkins*** of London writes:

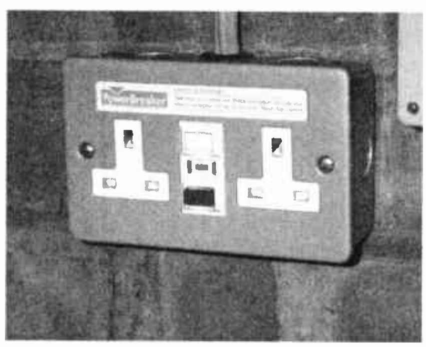
In response to the item "Shocking Stuff" in the September column, I understood that a current flowing through a human individual from hand to foot is nothing like as dangerous as a current flowing from one hand to the other, as in the second case at least some of the current will pass through the heart. I believe that the problem associated with reasonably small currents passing through the human body is that of cardiac arrest; however, larger currents will cause electrolytic destruction of body tissue.

*It was not until later in life that I learned about RCDs: this was when I was rewiring an old house in France, where I discovered that RCDs (*un disjoncteur differentiel*) were a legal requirement in French bathrooms; before then, I believed that fuses provided all the protection required. In light of the* Circuit Surgery *item, I now think that even a fuse and an RCD will not give complete protection as current may flow through an individual from a higher potential to a lower one, and neither trip the RCD nor blow the fuse, unless its current was exceeded. Personally, I would like to know a lot more about electrical safety and I think that a lot more should be taught in schools and colleges about it.*

You are right to say that Residual Current Devices (RCDs) do not provide complete insurance against electrocution. However, they do still protect against the vast majority of common electrical faults that arise, mainly live-to-earth faults. (For the benefit of readers in the USA and Canada, the term GFCI is used instead of RCD, and "live" or phase/line is called hot while "earth" is ground.)

Fuses and ordinary "thermal" miniature circuit breakers or MCBs just protect the appliance's power cord against a fault (e.g. shorting the cores together), or against any internal equipment fault that causes an excessive current to flow (e.g. a direct short to earth), hopefully tripping before the whole lot catches fire or accidentally kills somebody.

An example of a typical plug-in RCD, with test button and warning neon on the front. The reset button is on the back.



A metal-clad RCD suitable for workshop use.

Ordinary fuses or thermal trips offer no protection against progressive insulation breakdown, which could allow a lesser fault current to flow capable of delivering a harmful shock, yet the fuse might never melt.

RCDs operate on the principle that if some of the "live" current flowing out of an RCD fails to arrive back at the neutral terminal, then it assumes that there is an earth leakage fault, perhaps caused by faulty insulation or something more catastrophic, so the imbalance trips the RCD and disconnects the supply. This applies even if using "double-insulated" equipment connected via twin-core mains cable. An earth leakage fault (say, you manage to touch a live mains terminal with wet hands) will trip the RCD in typically 30-40 milliseconds, protecting against lethal shock.

However, for an RCD to work at all, it is imperative that the electricity supply is correctly earthed at the source, to enable a leakage current to flow to earth in the first place! In the event of a fault, if you are fully isolated from earth (e.g. wearing rubber boots), or no earth exists in the installation, then no leakage current will flow and the RCD will not trip. Furthermore, if you accidentally touch both live and neutral at the same time, the RCD will not trip either, unless a sufficient current also leaks to earth. You may suffer a serious and possibly fatal shock as a result.

Teach-In 2000 Part 10 (Aug '00) tabled the effects of electrical shock in relation to current and typical physiological effect (Panel 10.3).

Lest We Get Complacent

The widespread use of double-insulation has reduced the risks considerably, but electrocution still happens, often caused by ignorance, negligence or foolhardiness. A woman was killed instantly when putting up Christmas lights, when she stood on an exposed copper water pipe (a very good earth) and touched a live wire. Fuses offered her no protection but an RCD fuseboard could have saved her.

On the medical aspects, I know that electrocution across the chest is extremely serious. A current through the heart can cause ventricular fibrillation, resulting in a "misfiring" of the heartbeat, followed by the loss of heart muscle action altogether. Death may quickly follow and emergency medical attention is essential. Interesting information published by SureTest (**www.kennedyelectric.com**) states that fibrillation in adults can occur at 52mA, and in children at 23mA (passing through the body).

As if heart failure isn't enough, the loss of muscle control also means that you may be unable to breath properly either. On the up-side, the inability to let go will cause the human grip to tighten, which will increase the current and trip the RCD in the case of live-earth faults. An RCD trips in a tiny fraction of a second, before any real harm can result.

There are several places on the Internet offering more advice. A very good one is managed by the Government of Western Australia which has an interesting on-line resource at **www1.safetyline.wa.gov.au** (search for "RCD"). You can also try **www.codecheck.com/gfci_principal.htm** which explains the mechanics of the RCD. The RCD manufacturer Greenbrook Electrical (**www.greenbrook.co.uk**) has a web site covering domestic and trade RCDs, including an interesting "virtual home". You will find that most regional electricity boards have a web site offering basic consumer safety advice as well.

I think every responsible *EPE* reader has a duty to pass on our knowledge to help prevent accidents arising in the home or workplace. I speak as someone who, when clearing out his fishpond, nearly sliced through a live underwater mains cable thinking that "my word, this lily root is tough, I can't cut it"; then I nearly cut the live mains feed to my pond pump using steel secateurs immersed in 200 gallons of murky water. Luckily, an RCD was installed but its services weren't called upon that time. *ARW.*

Right on Track

If you design your own boards from scratch then there are lots of decisions to make, such as what track widths to use. This is the subject of an E-mail from ***Keith Anderson***, who writes:

"I have recently purchased some p.c.b. design software and I'm unsure what track widths to use. Is there a way to calculate the required width for a given voltage/current?".

The width of p.c.b. tracks (also called traces) becomes critical when they have to carry high currents (say in the order of hundreds of milliamperes or more), otherwise the tracks can generally be quite narrow, particularly if you have to achieve a high density of connections. High currents heat the copper, causing it to detach from the substrate (delamination) or in extreme cases the tracks may burn out altogether.

For typical low current signals in most analogue and digital circuits, track widths in the range 0·25mm to 0·5mm (0·01in to 0·02in) are appropriate, but you can make them wider if you have the space, and smaller if you don't.

Some suggested widths for various currents are given in Table 1. They are reasonably conservative figures, but due to the variability of p.c.b.s and environments we cannot give any guarantee that they are universally applicable.

The minimum width will depend on the type of p.c.b. you are using and the process by which you are making it. Obviously high-tech industrial processes can achieve reliable narrower tracks than home-made boards (be aware of this if you browse commercial p.c.b. production web sites). You may have to experiment to see what the reliable minimum track width you can achieve actually is, so keep your layout files so you can refer back to them. Once you know the minimum track width you can reliably make, you can actually stick with this for most tracks except for the power supply rails and any high current outputs etc.

Table 1. Some suggested track widths for different currents. Based on data from ExpressPCB (**www.expresspcb.com**).

Current Amps	Min. Track Width inches	mm
0·3	0·010	0·25
0·4	0·015	0·40
0·7	0·020	0·50
1·0	0·025	0·65
2·0	0·050	1·3
4·0	0·100	2·5
6·0	0·150	3·8

Table 2. Some suggested track separations for different voltages. Based on data from Designer's Den web site (**www.aracnet.com/~gpatrick**).

Voltage Volts	Min. Track Separation inches	mm
30	0·025	0·65
50	0·060	1·5
100	0·125	3·2
200	0·250	6·4
300-500	0·500	13

Separation

Another issue is track separation. Again there will be a minimum for each type of p.c.b. and production technique. With respect to the circuit, the minimum spacing of particular tracks depends on the voltage between them (either d.c. voltage or peak – not r.m.s. – a.c. voltage). Clearly, too high a voltage for a given separation will result in air or insulator breakdown, causing leakage currents or arcing, especially if environmental conditions affect the board in any way.

For most circuits (i.e. voltages below 30V) spacing of 0·13mm to 0·25mm (0·005in to 0·01in) are OK as far as the voltage goes, but narrower spacing may be difficult to achieve reliably at home. Obviously, larger spacing will reduce the chance of short circuits. For very high voltages (above 500V) allow 0·025mm/V (0·001in per volt).

Table 2 gives some suggested separations for various voltages. It is also worth mentioning that in some designs separation of circuit tracks may also influence factors such as noise due to crosstalk.

We have seen much less conservative figures published in text books, but having given them, we must add that they are only for very general guidance as so many factors play their part in determining minimum track widths and spacing on p.c.b.s.

For example, altitude above sea level (and salts in the atmosphere) influences the minimum separation for a given voltage, and several high current tracks running in a close parallel layout will have to be wider than an isolated track with otherwise the same specification. Minimum track widths also vary with the copper thickness and acceptable temperature rise.

Track Resistivity

To get a better feel of where these figures are coming from, let's look at how we would calculate the minimum track width from scratch (or at least why it is so difficult!). The starting point is to determine what actually sets the limit. The key aspect is the rise in temperature due to the power dissipated in the track as a result of its electrical resistance. This results in the track getting hot and detaching from the board. So we have to specify the maximum acceptable rise in temperature of the track (typically 10°C to 50°C), which will depend on the type of p.c.b. and the application.

To calculate the temperature rise we need to know the electrical resistance of the track. Resistivity (symbol ρ or rho) is something we looked at in *Circuit Surgery* November 1999. The resistance, R, of a conductor of length L, width W, and thickness T is given by:

$$R = \rho L/WT$$

where ρ is the resistivity of the conductor and WT gives the cross-sectional area. For copper it's about $1{\cdot}76\text{cm} \times 10^{-6}\Omega$ cm ($0{\cdot}693 \times 10^{-6}\Omega$ inch), but varies with the type of processing of the copper. There are a number of standard thicknesses for copper on p.c.b.s which are specified by the weight of copper per area of board.

The fact that a real track will have imperfections means that any such calculation will only be an estimate. The situation is complicated by the fact that the resistivity changes with temperature, so as the track heats up the resistance changes. The temperature sensitivity of the resistance also means that the nominal temperature of the p.c.b. when it is used should be known. Calculating the change in temperature due to current flow (known as Joule heating) is difficult, but tables, graphs and empirical formulae are published in industry handbooks and guidelines.

For the electronics industry, two key web sites are Institute for Interconnecting and Packaging Electronic Circuits (IPC) in the USA (**www.ipc.org**) and the PCIF in the UK (**www.pcif.org.uk**) which have links to other industry-related sites. The IPC publishes a *Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies* (IPC-D-275).

There are some sites that contain tables of track widths, spacings, or current/voltage capacities. Examples include p.c.b. track current-carrying trace capacity tables as per Mil. Standard 275 from K&F electronics (**www.circuitboards.com**); ExpressPCB designer tips include suggested track widths for various currents (**www.expresspcb.com**), and George Patrick's Designer's Den PCB Designer's Page (**www.aracnet.com/~gpatrick/**) contain tables based on the IPC-D-27 nomographs.

On the practical side of things, having calculated everything correctly, you can suffer other problems when etching p.c.b.s that might affect circuit reliability. The choice of etchant, and the etching period, can cause etch resist to be undermined, thereby reducing the track width unintentionally. This can be a real problem with fine traces. It's also not a bad idea to reinforce heavy, current carrying tracks with the addition of solder, even soldering tinned copper wire over it if necessary.

Around the power supply area of most boards (notably between bridge rectifiers and large smoothing capacitors), a much heavier current can flow, so it is a good idea to use the widest track possible in this area. Don't forget also that wider tracks equate to more adhesion, which can make for a more reliable board at times. *IMB.*

READOUT

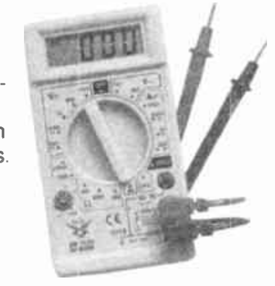
E-mail: editorial@epemag.wimborne.co.uk

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 3½ 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 ★

DECIMAL CHALLENGE

Dear EPE,

Peter Hemsley's excellent solution to the age-old and often messy problem of converting binary information into human perceivable decimal (*Readout* Sept '00) inspired me to develop my own solution.

The following code is the fruit of my labour. A multiply by two with carry is performed on each digit, nested inside a bit counter, each bit determining the state of the carry for the first multiply. This routine takes 1,957 instruction cycles to execute which is a slight improvement on Peter's, which uses 3,086. Both routines maintain a constant execution time. It will be just as easy to change the number of bits converted.

The command "movlw -10, addwf INDF, W" are for the PICs that lack any subtract instructions, the 16c5x for example, "movlw 10, subwf INDF, W" works just the same.

```
BIN2DEC   clrf DEC0              ; Clear decimal output buffer
          clrf DEC1
          clrf DEC2
          clrf DEC3
          clrf DEC4
          clrf DEC5
          clrf DEC6
          clrf DEC7              ; NB, BINn and FSR are trashed after this routine
          movlw 24               ; Initiate bit loop
          movwf BIT_COUNTER
BITLOOP   rlf BIN0, F            ; Every iteration of this loop will copy the next
          rlf BIN1, F            ; bit of the bin value, starting with the MSB,
          rlf BIN2, F            ; to the carry flag
          movlw DEC0
          movwf FSR              ; Initiate DECn pointer and counter
          movlw 8
          movwf DEC_COUNTER      ; The following is executed 8 times per bit
DECLOOP   rlf INDF, F            ; Multiply DECn by two with carry, DECn * 2 + C
          movlw -10              ; See note above - test for DECn > 9
          addwf INDF, W          ; W = DECn -10, if W = positive or zero, C = 1
          btfsc STATUS, C        ; DECn has overflowed (>>9) if carry is set
          movwf INDF             ; If carry is set DECn = DECn – 10
          incf FSR, F            ; Carry is CARRIED over to next multiply
          decfsz DEC-COUNTER, F
          goto DECLOOP           ; Multiply next DECn
          decfsz BIT-COUNTER, F
          goto BITLOOP           ; Do next bit
          retlw 0                ; Could be RETURN on most PICs
     END
```

Steve Teal, Witney, Oxford

Fascinating, Steve, thank you. How long, we wonder, will you now hold the BIN-DEC conversion record? Readers, the gauntlet's down – will you accept the challenge?

E-MAIL CONTACTS

Dear EPE,

I recently read the Editorial in the Feb '00 issue, in which you comment on the UK dragging behind in Internet usage and its high costs.

I must say that it seems to be quite true, because I started writing an E-mail to *Readout* but I couldn't find an E-mail address! Further browsing revealed that there isn't an address for *Circuit Surgery* either, or *Ingenuity Unlimited*, or anything else apart from addresses for Editorial, technical support, ads, subscriptions and orders.

Now, after browsing the *EPE* FTP site, I found an explanation for *IU* not receiving E-mails, but in my opinion even they could receive E-mails just fine, and in the case of a circuit getting published, THEN contact via snail mail to buy the rights to publish it and whatever is required.

The *EPE* web site **www.epemag.wimborne.co.uk** is also sort of non-functional, because it is lacking most of the data in the FTP site. Searching through the FTP site is tedious and unintuitive, while a WWW interface for the projects, PIC programs and especially all the text guides would be a relatively easy and very elegant solution. Shame shame . . . !

So, could you tell me which way to send E-mail to *Readout*?

R. Nissinen, Finland, via the Net

Readout *and all the other pages you refer to come under the Editorial E-mail address, which covers all the Editorial content of the magazine. We have a number of problems with people sending copyright material for IU and have decided that we will only accept IUs by post. That way we have full contact details and a signed disclaimer before we publish.*

Most of what is on the FTP site is special information (not required by every reader) plus software for download. It is not necessary for readers to search it – they know what they want and just click on it.

The Readout *E-mail address is now included above!*

TRANSCENDANT

Dear EPE,

I am trying to repair a Powertran Transcendant 2000 Monosynth as published in *ETI* some years ago. I do not have the circuit diagram and wonder if you have a copy in the archives?

Steven Orr, Cheltenham, Glos

Sorry to disappoint you Steven, but when we took over ETI we did not receive their archive copies from that far back, and Powertran ceased trading many years ago.

However, your local reference library may be able to obtain the National Archives copy of ETI *on loan and we suggest you contact them*

DECIMAL QUERY

Dear EPE,

I was very intrigued with Peter Hemsley's decimalisation code (*Readout* Sept '00) as I had only met previously the powers of ten algorithms to do the binary to decimal conversion, so I tried it out using MPLAB, with a breakpoint at the last RETURN, and a test value in COUNT0-2, but DIGITS1-8 remained obstinately zero.

I cannot see how the code uses COUNT0-2, unless the shift, putting the top bits one at a time into the Carry flag, is the clue, but the flag is not tested anywhere. I would be grateful for your comments.

Harry West, via the Net

We sent Harry's query on to Peter, who responded:

At first I thought that it could be that you have the default radix set to hex whereas the MOVLW 24 is decimal, I prefer having the default radix set to decimal.

Then the light dawned, according to your letter you put a breakpoint at the last RETURN instruction. This would concur with all the DIGITs being zero. The routine does not return from this instruction but from the RETURN immediately before the label SLCNT. If you had let the routine return and put a breakpoint after the call to the routine you would have found that it does indeed work, very well.

Some years ago I wrote a floating point package and got used to the idea of manipulating binary numbers. It's easier than decimal when you get the hang of it and I am no mathematician.

To explain how the routine works let's take a 16-bit binary number, the principle is the same as 24 bits. A 16-bit binary number can be thought of as four hex digits. To convert a hex digit into decimal use the following simple logic, if the hex digit is greater than 9 we add 6 to it and then add 1 (the decimal carry) to the next higher digit.

However, trying to deal with hex digits is not conducive to an easy programming algorithm. Binary multiplication and division are performed by bit shifting and we can use the same technique here. The number to be converted is shifted out of binary COUNT and into the decimal DIGITs, and at each shift checking and adjusting for any decimal overflow.

To go into a little more detail, checking and adjusting is done before the shift left so we need to divide everything by 2. In other words we need to check if the digit is 5 or more. To do this we can add 3 to the digit (which, after shifting left becomes 6, which we need to add for adjustment) and then check if the digit is 8 or more by testing bit 3, and subtracting 3 if adjustment is not required.

We then shift the next bit of the binary into the digits and also deal with any decimal carry caused by the adjustment, i.e. bit 4 is carried into the next higher digit.

It's amazingly simple and if you understand it you will be thinking "Why didn't I think of that?". But then again if we thought of everything there would be nothing left to invent.

Peter Hemsley, via the Net

Thanks Peter, your further explanation is appreciated. Your last comment though, has a certain poignancy to it with regard to the Letter of the Month *from Steve Teal.*

VISUAL BASIC (1)

Dear EPE,

I have just finished reading *Readout* of August '00 and am responding to your request for VB help.

Now retired, I was employed as a computer engineer and later as a communications technician. I don't have a formal background in programming but I can get by in QBasic, although I struggle to understand some of the intricacies of your code.

I am in agreement with David Reid (and others) about the future need to get away from DOS and into Windows programming, so much so that last Winter I purchased a copy of VB 6.0 and decided to do something about it.

Like you, I couldn't make much headway until I came across the following book: *Microsoft Visual Basic 6.0 Professional Step by Step*, Author Michael Halvorson, Price £37-49. It is a Microsoft Press publication, ISBN 1-57231-809-0.

This book is written as a series of 24 lessons that have fully explained code and it is very easy to read. There is also a CD-ROM inside the back cover, which contains all the code in the book, and more . . .

I worked through all the chapters, except those few dealing with the Internet, on my computer and found the experience to be as rewarding as working through your own *PIC Tutorial*.

The only snag with VB is the lack of parallel port I/0, but on page 591 Aug '99 *EPE* there were details of **INPOUT32.BAS** available from **WWW.LVR.COM**. This works fine under VB 6.0, but note that I am using a second port set up as LPT2 that has been removed from the Windows 98 set-up so that it is completely independent of the operating system. This way I can run your *Toolkit V2.3* in a DOS box under Windows. I never have to reboot to the command prompt.

Further to this, I have loosely adapted some of your code and now have a PIC programmer that works in VB 6 under Windows. It is possible to produce some good-looking screens under VB so I urge you to have a go. Incidentally, VB 6 allows you to generate an executable file so programs can then be run stand-alone.

Initially, I spent quite a lot of time tinkering with the properties of the objects that may be placed on forms before I wrote much code. One can do an awful lot and it is quite satisfying to achieve a professional looking result even though one is only an amateur. Go on, have a go!

Colin Birtwistle,
Swanley, Kent

I shall, I shall! Trouble is there are so many things I want to explore before going back to VB, which will have to wait a while. But all the comments being made by readers through these pages are being noted and sooner or later VB will become as familiar as the many other programming languages I've acquired over the years!

VISUAL BASIC (2)

Dear EPE,

Having studied the superb *PIC Tutorials* over the past two years and really enjoyed myself, I have progressed to the point where I want to talk to my PC over a serial link.

I also wanted to do something with the data I received and so I thought it would be a good idea to acquire Visual Basic 6 from Microsoft.

However, *EPE* readers should be cautioned that if they buy the Learning Edition at a cost of around £70 they will find that the program elements required to implement serial communications (**MSCOMM32.OCX**) is NOT supplied – it only comes with the Pro and Enterprise editions, both of which are way outside my price range.

It seems to me that there should be a warning on the box that large chunks of functionality are missing from the program. After all, you wouldn't be allowed to buy a car and then find that the engine was an optional extra.

I am not surprised that Microsoft are being broken up – and based on this example of marketing I for one will stand by and applaud. Of course, it may be that there are ways of communicating with the PC's serial port without using MScom and I would welcome any information from other readers that might help.

Thanks for *EPE*, by the way. I have been reading it in its various names guises since the 70s and a jolly good publication it is too!

Julian Horn, via the Net

Points well noted, thanks Julian, and for your kind comments.

Constructional Project

OPTO-ALARM SYSTEM

STEPHEN SPENCER

Scare the pants off unwanted intruders with this portable, optically balanced, security alarm.

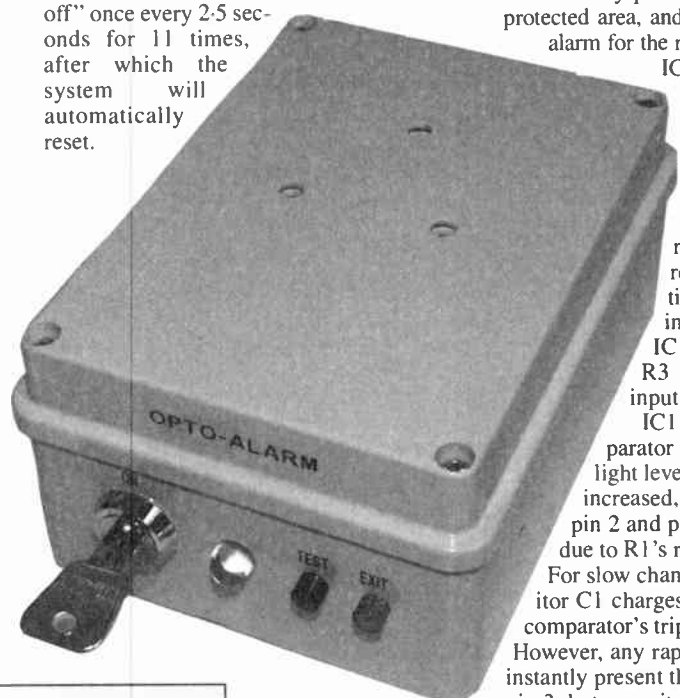
THE Opto-Alarm is an optically balanced light alarm for general purpose security applications. The alarm is triggered by increasing the light level to a light-dependent resistor (l.d.r.), via a focusing lens assembly. This assembly only accepts a narrow field of light to the l.d.r., thus increasing sensitivity, to allow specific object protection and minimise false alarms.

Alarm activation occurs when the light level increases rapidly, varying light levels from cloud movement, 50Hz mains flicker from fluorescent lamps, dusk-to-dawn light changes and total darkness situations, will not cause false alarms.

BASIC SYSTEM

The full system block diagram is shown in Fig.1. The alarm incorporates an Exit delay indicated by a green l.e.d. to allow departure from the protected area, and to allow time to set the system for the required operation. A further red "Test" l.e.d. indicates any triggering whilst setting up. When time-out occurs, the Exit l.e.d. extinguishes and the alarm is now in the "active" mode of operation, further triggering will activate a warning tone, followed by full siren activation for a pre-set period, after which the alarm will fully reset until activated further.

An optional Entry alert facility is also included to give a 30 seconds warning that you must deactivate the system before proceeding any further. A two-tone pulse is produced which sounds for approximately 11 seconds, giving enough time to "cancel" the alarm. If the alarm is not deactivated (reset), the main siren will "sound-off" once every 2·5 seconds for 11 times, after which the system will automatically reset.



CIRCUIT OPERATION

The full circuit diagram for the Opto-Alarm section of the system appears in Fig.2. When power is applied to the circuit, via keyswitch S1, an Exit delay of 1·45 minutes is activated. The NOR gate inputs at IC3a, pin 1 and pin 2 are initially kept high by C4, resulting in the output at pin 3 being kept low preventing IC2 pin 4 (Reset) enabling, thus isolating IC2. This stops the rest of the circuit from operating until capacitor C4 is charged up, through resistor R9 (l.e.d. D3 indicates the Exit delay period is active).

This delay period allows time to exit the protected area, and time to test and set the alarm for the required operation. When IC3a time-out occurs, l.e.d. D3 will extinguish and pin 4 of IC2 will go high, the whole circuit is now in the "Active" mode of operation.

Light-dependent resistor (l.d.r.) R1 and resistor R5 form a potential divider network, biasing the inverting input at IC1 pin 2 through resistor R3 and the non-inverting input (pin 3) through R4.

IC1 is configured as a comparator and when the ambient light level presented to l.d.r. R1 is increased, the voltage present at pin 2 and pin 3 of IC1 will increase due to R1's resistance being lowered. For slow changes in light level, capacitor C1 charges sufficiently fast for the comparator's trip point not to be reached. However, any rapid changes in light level instantly present the voltage change to IC1 pin 3, but capacitor C1 needs to charge up before it can present any changes to pin 2, causing the output at IC1 pin 6 to go high. Resistor R2 helps to prevent any false alarms when the unit is placed in total darkness situations.

The high output at IC1 pin 6 rapidly charges the delay capacitor C3 via diode D1 and the voltage is fed through resistor

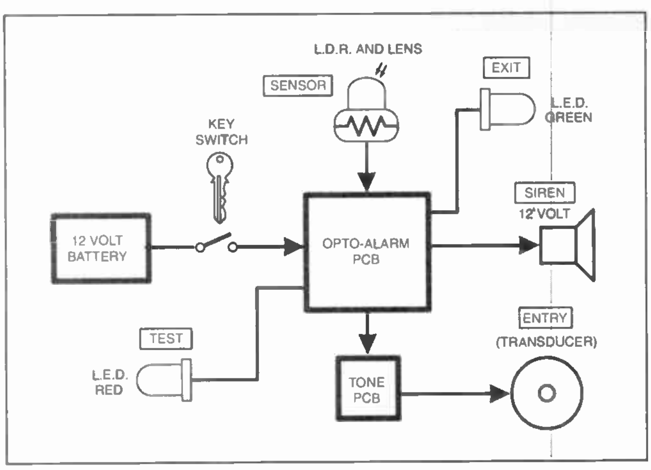
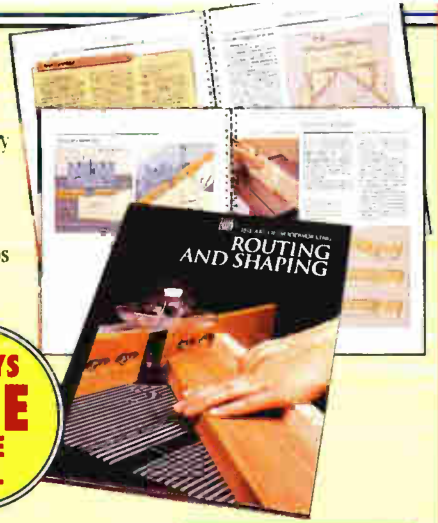


Fig.1. Block diagram for the Opto-Alarm System.

SPECIFICATION . . .

(Subject to component tolerances)
Exit Delay: ***1·45 minutes.*** **Entry Delay:** ***11 seconds.***
Siren: ***Operation 30 seconds. On/Off 11 times. Duration 2·5 seconds.***
Current Consumption (12V): ***12mA – Strong light. 2mA – Darkness. 3mA to 5mA – Normal use.***



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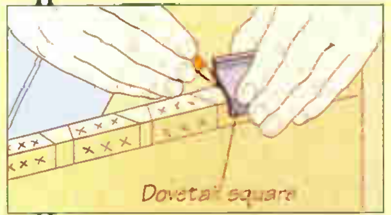

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TIME-LIFE
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CONTEST RULES

1 Entry is FREE and limited to one entry per person.
2 Maximum prize values are: 1st Prize – £157.11; 2nd Prize – 2 x £117.83; 3rd Prize – 3 x £78.55. Prizes are awarded to the first 6 correct entries 'drawn from a hat' on 12th January 2001. If a particular prize is no longer available, a prize of equivalent value is awarded. Cash alternatives are not available.
3 Employees of TIME-LIFE and participating companies, their printers, advertising agencies and families may not take part.
4 Closing date for the contest is 29th December 2000. Judges' decisions are final. No correspondence will be entered into. Entry implies acceptance of the rules.
5 Winners of 1st and 2nd Prizes may be requested to take part in publicity.
6 Winners will be notified by post. Winners' names will be available after 29th January 2001. For a copy send SAE to Art of Woodworking Contest Results, TIME-LIFE, PO Box 419, Uxbridge, Middlesex UB11 1EG.

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R7 to transistor TR1 base (b). The resulting low voltage output from TR1's collector (c) is used to trigger the input of timer IC2, at pin 2. This is indicated by Test l.e.d. D2 via resistor R8.

IC2 is configured as a monostable, whose timing period is determined by capacitor C5 and resistor R10. The positive output at pin 3 is fed to IC3b via resistor R12 and capacitor C6 which cause an 11 seconds delay, after which IC3b's output changes state. The drive to the optional two-tone Entry warning circuit (refer to Fig.3) is also taken from this point.

Input pins 5 and 6 of IC3b go high at "time-out", producing a low output from IC3b pin 4, which in turn triggers an astable oscillator, made up of IC3c/IC3d, at pin 9. Timing components R13, R14 and C7 give an on/off duration of 2·5 seconds, lasting approximately 30 seconds before IC2 time-out occurs.

The astable output is fed, via resistor R15, to the base of Darlington pair TR2/TR3 and finally to a 12V siren WD1. The switching effect enhances the acoustic output from WD1 and conserves battery power. Capacitor C8 helps to prevent any false re-triggering of the circuit, allowing the alarm to fully reset until further activation occurs.

COMPONENTS

Approx. Cost Guidance Only £25 excluding batts.

OPTO-ALARM

Resistors

R1	ORP12, light-dependent resistor (l.d.r.)
R2, R9, R10, R12	1M (4 off)
R3, R4	470k (2 off)
R5, R7, R11, R15	10k (4 off)
R6	20M (2 x 10M soldered in series – see text)
R8	1k
R13, R14	10M (2 off)

All 0·6W 5% carbon film or better

See SHOP TALK page

Capacitors

C1	100n polyester layer, 5mm pitch
C2	47p multi-layer ceramic
C3, C4	100µ radial elect. 16V (2 off)
C5	47µ radial elect. 16V
C6	22µ radial elect. 16V
C7	220n polyester layer, 5mm pitch
C8	220µ radial elect. 16V

Semiconductors

D1	1N4001 rectifier diode
D2	5mm hyper brightness, red l.e.d.
D3	5mm hyper brightness, green l.e.d.
TR1, TR2	BC548C *npn* transistor (2 off)
TR3	TIP41A *npn* power transistor
IC1	CA3140E MOSFET op.amp
IC2	TS555CN low power timer
IC3	4001 quad 2-input NOR gate

Miscellaneous

S1	key-operated On/Off switch
WD1	12V siren, 115dB
B1	12V battery pack (8 x AA cells)

Stripboard 0·1inch matrix, size 21 strips x 20 holes; waterproof plastic box, size 150mm x 110mm x 70mm; 8-pin d.i.l. socket (2 off); 14-pin d.i.l. socket; red Cliplite l.e.d. cover; green Cliplite l.e.d. cover; 10mm clear l.e.d. (for focussing lens – see text); battery clip, PP3 type; multistrand connecting wire; 24 s.w.g. tinned copper wire, for links; 1mm solder pins (12 off); clear epoxy adhesive; solder, etc.

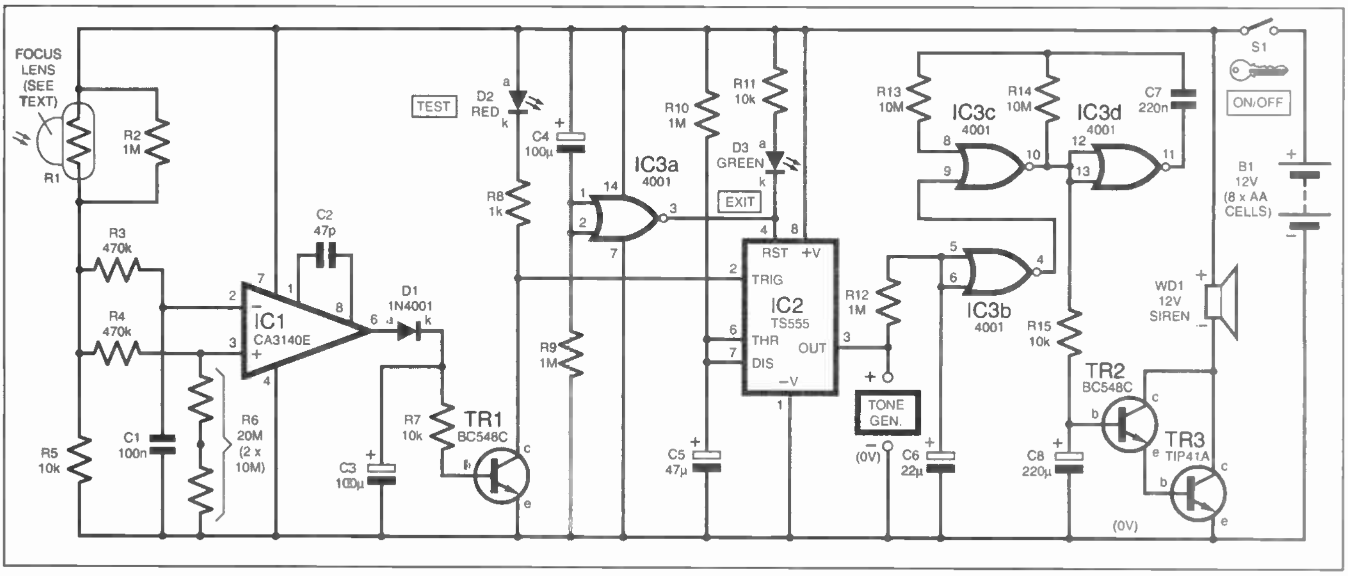


Fig.2. Full circuit diagram for the Opto-Alarm section of the system.

TWO-TONE GENERATOR

The circuit diagram for the optional two-tone warning appears in Fig.3. Operating power is obtained from IC2 pin 3, see Fig.2. The circuit is based around a 556 dual timer, IC4.

The first low frequency oscillator and timing components resistor R16 and capacitor C10 produce an output pulse of about one second duration at pin 5. This output pulse is fed through resistor R17 to the control voltage pin 11 and modulates the second high frequency oscillator. The timing components, resistor R18 and capacitor C11, set the two-tone frequency range. The output at pin 9 is then fed directly to the Entry piezoelectric transducer WD2. This will sound for about 11 seconds before the main siren is triggered. Capacitor C9 is included to decouple the two oscillators, allowing independent operation to be achieved.

CONSTRUCTION

The stripboard component layout and details of breaks required in the underside copper tracks for the Opto-Alarm appear in Fig.4. Begin construction by making the cuts in the copper tracks, inserting all wire links followed by i.c. sockets and solder pins.

Next fit all passive components observing capacitor polarities. Note that capacitor C2 is soldered across IC1 pin 1 and pin 8 on the copper track side. Carefully insert and solder in position diode D1, transistors TR1, TR2 and TR3, taking care over their pin identities and not to overheat the lead-out wires.

Insert all integrated circuits, handle these devices carefully due to the

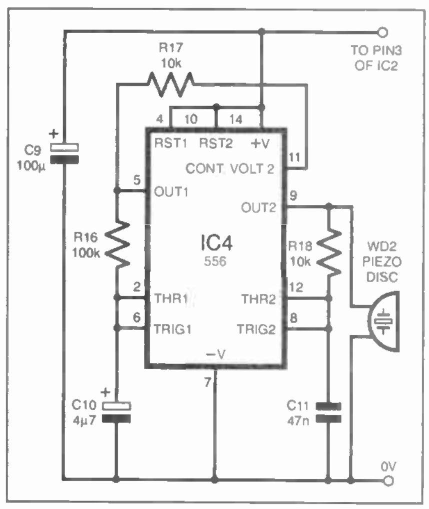


Fig.3. Circuit diagram for the optional Entry "Two-Tone Generator" stage.

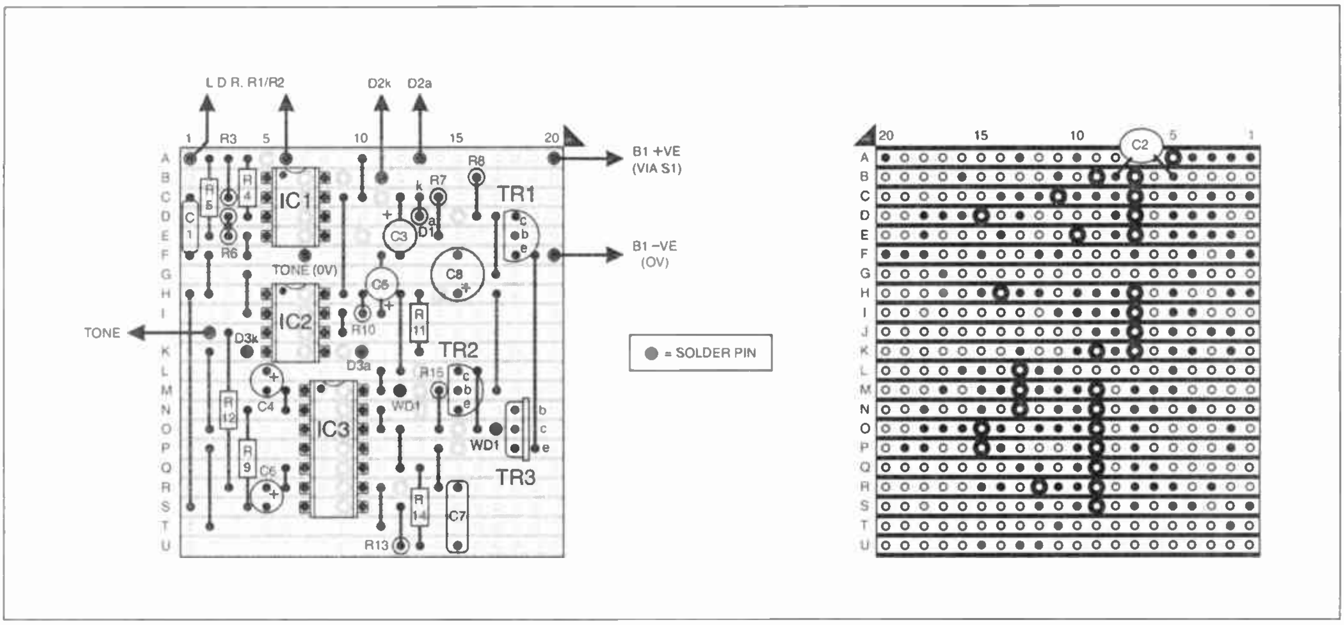
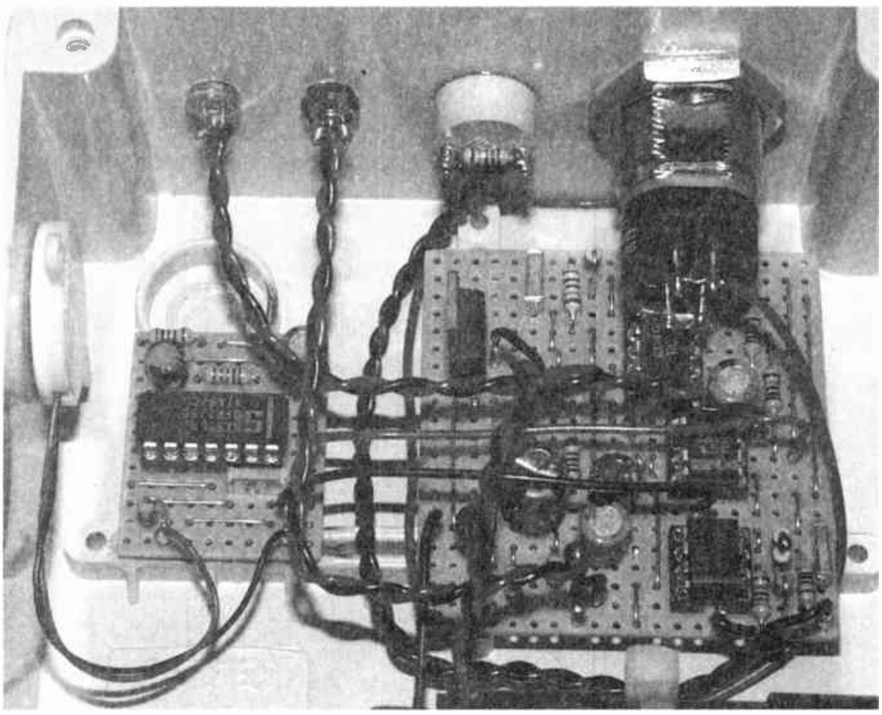


Fig.4. Opto-Alarm stripboard component layout and details of breaks required in the underside copper tracks. Note that capacitor C2 is soldered directly across IC1 pins 1 and 8 on the underside.



Wiring from the off-board components to the two circuit boards.

possibility of static discharges that can destroy CMOS i.c.s. Finally, inspect all solder joints for quality and any possible solder bridges.

Follow the same method for the Two-Tone circuit board construction, again observing polarities. The stripboard component layout and details of breaks required in the underside copper tracks are shown in Fig.5.

FOCUSING LENS

Before commiting the circuit boards and off-board components to the case, it is necessary to consider the make up of the focusing lens. By using a focusing lens in addition to a light-dependent resistor (l.d.r.), there will be a significant increase in sensitivity, and also a narrower acceptance angle, allowing single object protection whilst minimising false alarms from doors opening etc.

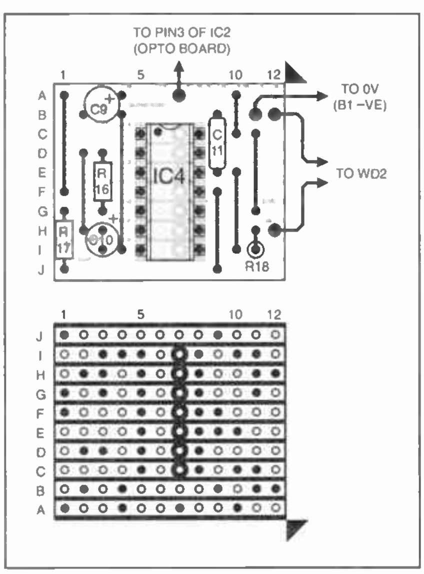


Fig.5 (right). Component layout for the optional "Two-Tone" entry sounder.

The most effective and easiest method of lens construction is to adapt the lens of a 10mm clear l.e.d. Using this method you can choose the l.e.d.'s most acceptable viewing angle, allowing optimised operating conditions (a six degree viewing angle was used on the prototype).

Referring to Fig.6, begin construction of the l.d.r. lens by taking a 10mm clear l.e.d. and holding it in a vice by the lead-out wires, saw off the lens section just above the actual l.e.d. platform, using a junior hacksaw. You now need to sand this end as

COMPONENTS

TWO-TONE GENERATOR

Resistors

R16	100k
R17, R18	10k (2 off)

All 0·6W 5% carbon film

See SHOP TALK page

Capacitors

C9	100µ radial elect. 16V
C10	4µ7 radial elect. 16V
C11	47n polyester layer, 5mm pitch

Semiconductors

IC4	556 dual timer

Miscellaneous

WD2	3V-30V piezo transducer

Stripboard 0·1inch matrix, size 10 strips × 12 holes; 14-pin d.i.l. socket; multistrand connecting wire; 24s.w.g. tinned copper wire, for links; 1mm solder pins (4 off); solder, etc.

Approx. Cost Guidance Only **£3.50**

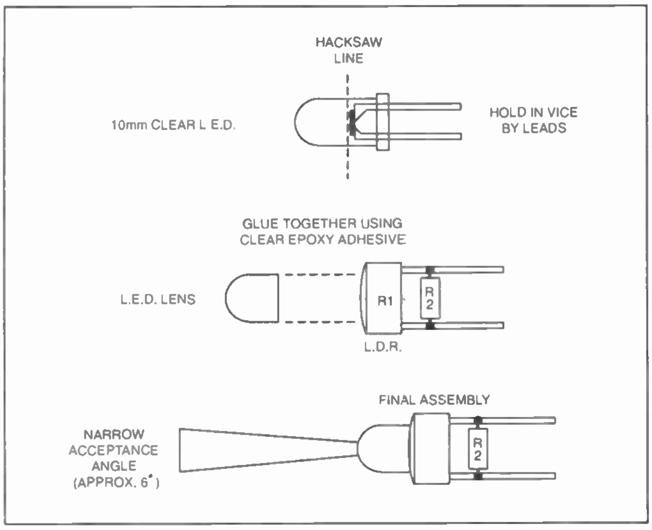


Fig.6. Producing the focussing lens from a 10mm l.e.d. The lens is glued over the "window" of the light dependent resistor (l.d.r.).

flat and smooth as possible using fine grade "wet and dry" paper. The lens will need to be able to transfer collected light as efficiently as possible to the l.d.r., so the face must be finely polished.

Clean the l.d.r. face and use clear epoxy adhesive to glue the l.d.r. and lens together. This completes the focusing lens assembly.

CASING-UP

Attention can now turn to the alarm case and wiring. The author used a plastic waterproof case measuring 150mm × 110mm × 70mm, but the final choice is down to the constructor.

Begin the casing-up process by carefully measuring and marking out where you require the front panel components, and how you wish the interior to be laid out, see Fig.7 and photographs. All the components are mounted in round holes easing construction, and the best way to drill these holes is by first measuring the components against drill bit diameters and choosing a fractionally smaller bit than actual component size.

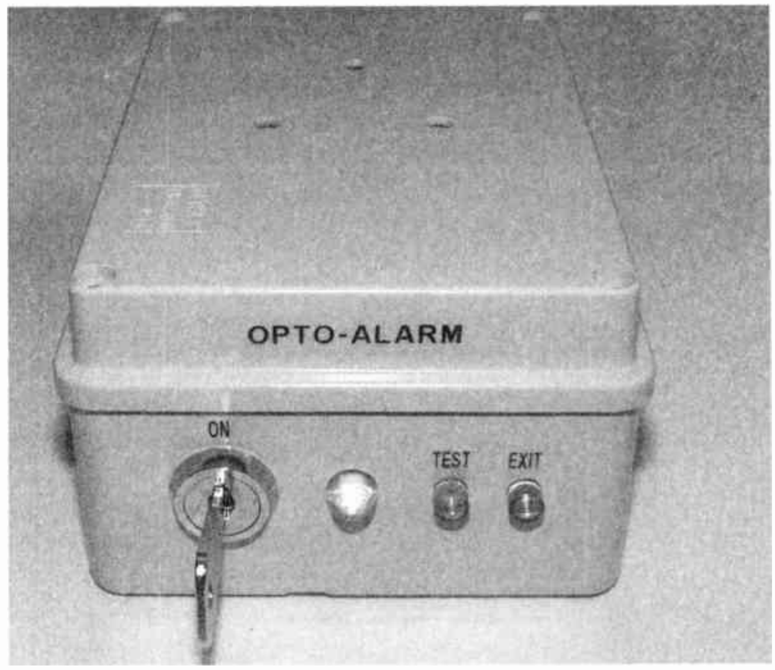
The holes can be enlarged later using a reamer, or needle files. Using a centre punch or bradawl, mark the holes for drilling, begin by using a 2mm diameter bit as a guide hole for producing a clean and accurate final hole.

FINAL ASSEMBLY

Check the fitting of all components and, once satisfied, proceed with the interwiring between the stripboards and all off-board components.

Wire up l.e.d.s D2 and D3, the battery connector, siren, keyswitch S1 and the focusing lens assembly. Remember to solder resistor R2 across the l.d.r. (R1) lead out wires. Finally, wire up the Two-Tone board to the main Opto-Alarm board, as indicated in Fig.7. If using an unwired piezo transducer, take care not to overheat the discs' delicate "white" area when attaching connecting leads.

The two circuit boards were secured to the case using epoxy adhesive, saving on nuts and bolts, allowing a more compact stripboard design and to give additional protection from corrosion. The 12V battery pack was enclosed in a holder made from plastic off-cuts glued in place.



The keyswitch, light sensor and test and exit l.e.d.s mounted on a side panel of the waterproof case.

TESTING

With the two circuit boards now wired up connect the battery supply. At switch on Exit l.e.d. D3 should light for approximately 1·45 minutes. Placing your hand over the focusing lens and then quickly removing it should illuminate Test l.e.d. D2 for around one second. Try moving your hand slowly across the sensor, this should not trigger the Test l.e.d. at all.

When the Exit l.e.d. has extinguished, IC2 now becomes "active" and activating the l.d.r. sensor again should

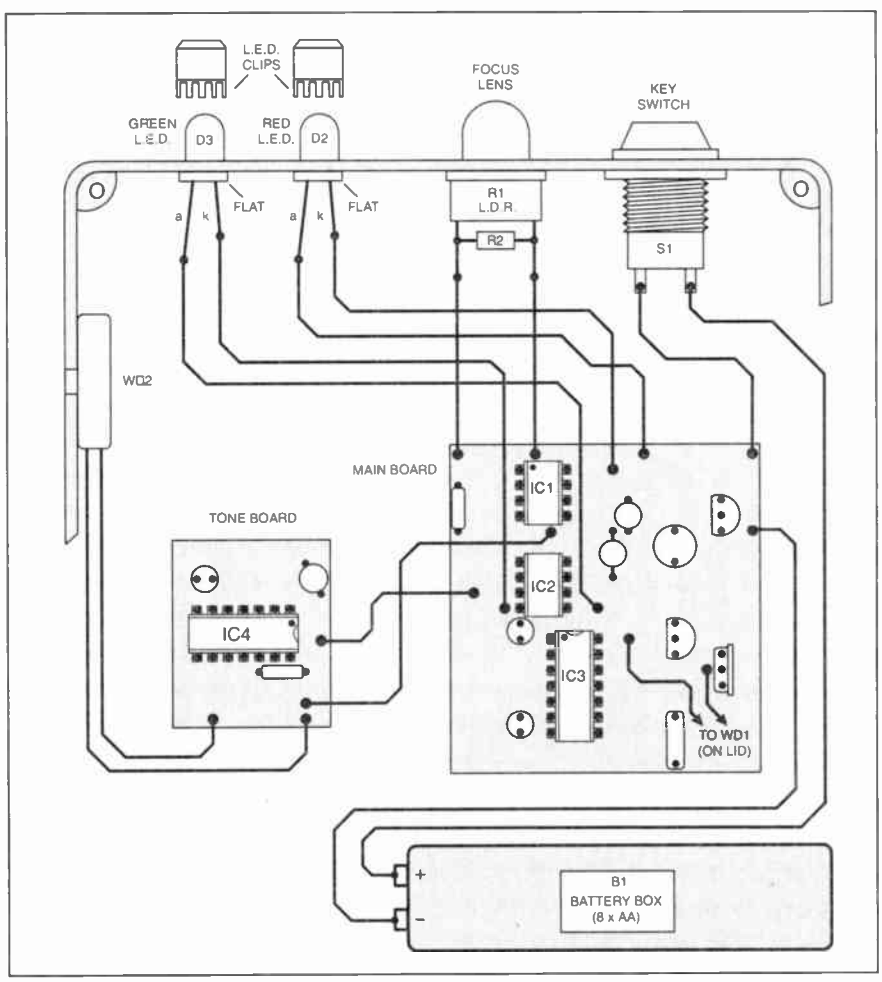
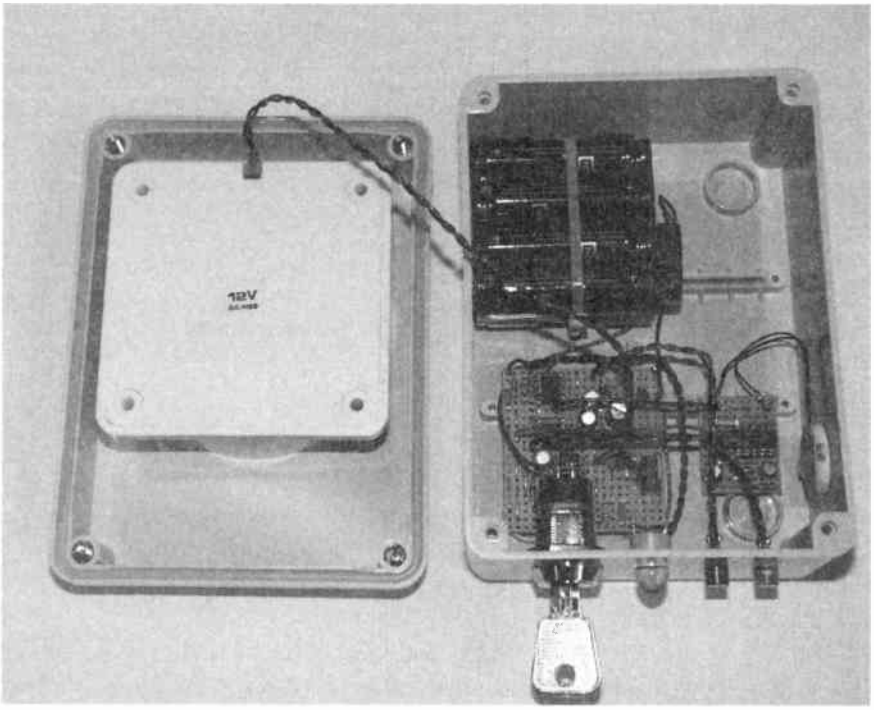


Fig.7. Interwiring from the two circuit boards to all off-board components. The Main siren (WD1) is mounted on the inside rear of the case lid, see photograph on the next page.



Completed Opto-Alarm system showing the main siren in the lid.

produce a two-tone Entry warning for approximately 11 seconds. If the alarm is not reset, via keyswitch S1, within this period the main siren WD1 will sound on/off once every 2·5 seconds for 11 times, after which the alarm should fully reset itself, with no l.e.d.s lit, thus saving battery power. This completes Testing and confirms all circuitry is operating correctly.

Should problems be encountered with the unit switching under bright light conditions, due to the low resistance of the l.d.r., experiment with inserting a low value resistor (e.g. 1kΩ) between the l.d.r. and its positive supply line.

IN USE

The Opto-Alarm will respond instantly to any rapid changes to the ambient light level in the protected area. If the alarm is placed in a well lit area, it will require a fairly high level of introduced light to trigger the unit. However, if the alarm is placed in total darkness or an area of low light level the required amount of light to trigger the unit will be minimal.

The principle of operation does not solely rely on additional light to activate the alarm. If the sensor was aimed at a specific point, for instance, a wall across a room, any person moving rapidly across that point would firstly dim the available surrounding light, and on departure the light level presented to the sensor would instantly increase triggering the alarm. By experimentation you will discover the best set-up for yourself. □

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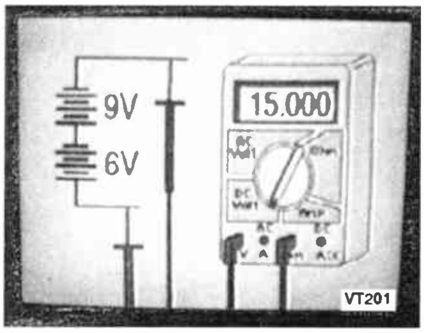

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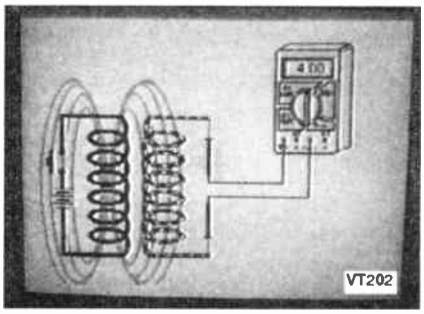

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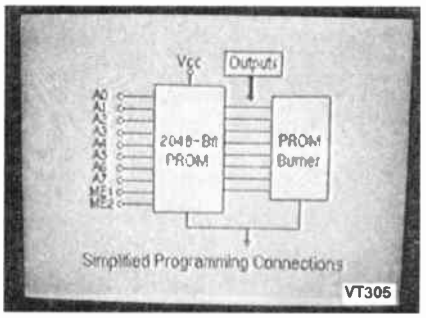

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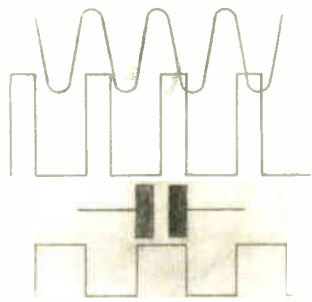
Constructional Project

PIC PULSOMETER



RICHARD HINCKLEY

Accurately measures and displays pulse timings, frequency and capacitance.

THIS project was started because the author had a need to measure sub-microsecond pulses and frequencies in the megahertz range. Along the way it was found that capacitance could be measured at little extra cost – an important feature as the author is the proud owner of several hundred capacitors whose values he has difficulty reading!

FUNDAMENTALS

If a pulse is used to gate an oscillator or clock of known frequency, its duration can be measured by counting the clock pulses. To achieve a high resolution the clock must have a short period, or high frequency, and in this design the clock has a frequency of 40MHz, giving a period of 25ns.

This method can also be used to calculate the frequency of the incoming pulses indirectly from the formula:

Frequency = 1/Period

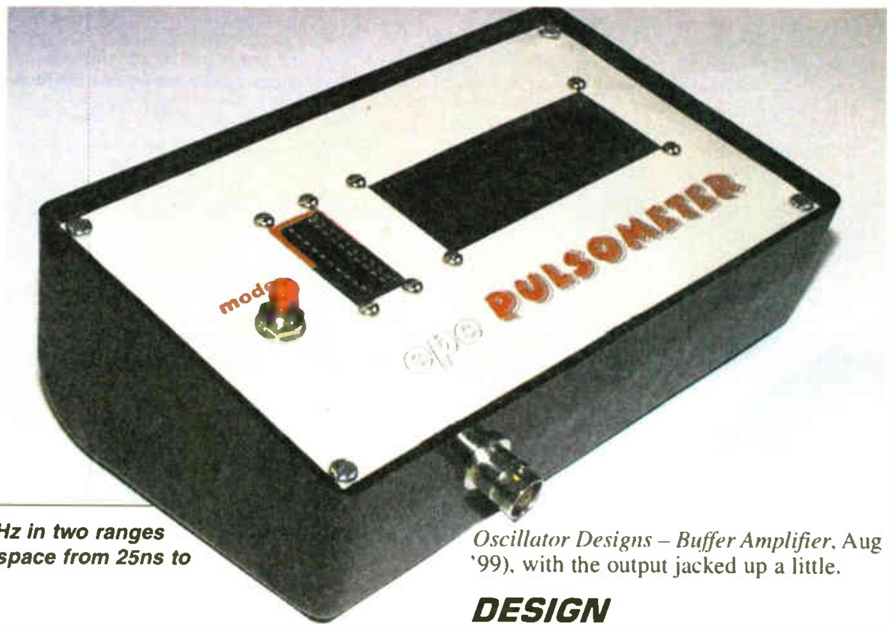
The accuracy of this method is limited at higher frequencies. For example, with a 40MHz clock, a 21MHz input signal would be measured as 40MHz, since only one clock pulse would be counted.

The other method of measuring frequency is to use a pulse of known duration (e.g. one second) to gate the input signal. This direct method has high accuracy at higher frequencies, but poor accuracy at lower ones – e.g. a 10·9Hz signal would be measured as 10Hz. In this design both methods are used.

The absolute accuracy of the Pulsometer is determined by the accuracy of the timing crystals used, as there is no correction mechanism. This gives an accuracy of 100ppm.

The Pulsometer is designed to measure pulses from 74HC/HCT and 4000 series CMOS logic, with a High (logic 1) of 3·25V minimum and a Low (logic 0) of 1V maximum. It will also measure a.c. signals of sufficient amplitude, and TTL signals up to around 10MHz.

For small a.c. signals, a preamplifier will be needed, perhaps based on Raymond Haigh's excellent design (*Practical Oscillator Designs – Buffer Amplifier*, Aug '99), with the output jacked up a little.



SPECIFICATION . . .

Frequency:	***0·00015Hz to 40MHz in two ranges***
Duration:	***Period, mark and space from 25ns to 1.9 hours***
Capacitance:	***1pF to 999μF***
Resolution:	***25ns***
Precision:	***6 most significant digits***
Display:	***16-character 1-line backlit l.c.d.***
Technology:	***PIC16F84 control and 74HC series logic***
Power Supply:	***9V to 12V external supply***

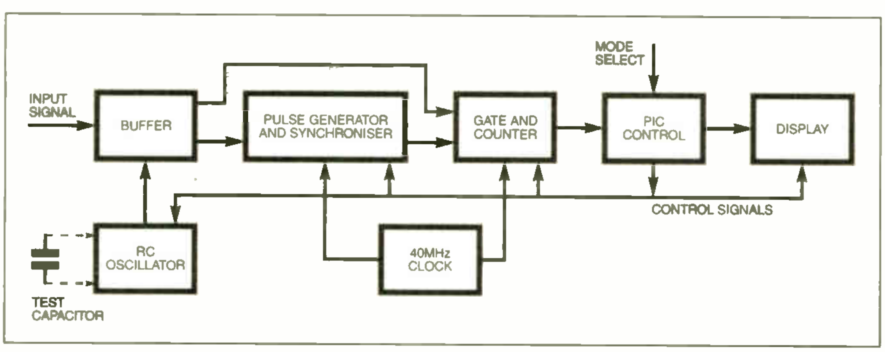


Fig.1. Simplified block diagram for the PIC Pulsometer.

DESIGN

In theory the design of a circuit such as the Pulsometer should be easy. All that has to be done is to feed the gated signal into a PIC, count the pulses, do some simple arithmetic, and display the result.

Unfortunately, a PIC16F84 is not fast enough to count pulses above 250kHz (at an optimistic best), so the input signal has to be scaled down first, but without losing precision.

The design is shown in the simplified block diagram in Fig.1. The mode of operation is decided by the user (push-switch selected) and this causes the PIC to control the rest of the circuit accordingly. This works cyclically in that the input signal is sampled, the result calculated and then displayed, after which the cycle starts again.

The signal is fed in via a buffer to cater for inputs of varying amplitudes. If the time is to be measured, a pulse is generated which represents the period, mark or space of the incoming pulse. This is then synchronised with the 40MHz clock oscillator, the resulting pulse gated with the clock, and the output fed via a counter into the PIC.

At the end of the pulse, any residual count in the counter is "flushed" into the PIC, the appropriate calculations are made, and the result displayed.

For higher frequencies, the input signal is fed straight into the Gate and Counter circuit where it is gated by a one-second pulse generated by the PIC, and counted, calculated and displayed as before.

For capacitance measurement, an RC oscillator is used to generate pulses whose period depends on the capacitance under test. The technique used gives accurate results above 10pF, and creditable ones as low as 1·8pF.

BUFFER

The input circuit diagram for the PIC Pulsometer is shown in Fig.2. The input emitter follower comprising TR1 and R3 gives high input impedance and is preceded by R1, D1 and D2. These clip the input signal to 0V and +5V (within about 0·7V), allowing for input voltages up to (at least) the 15V allowed by 4000 series logic, and for a.c. signals.

Resistor R2 forces the emitter voltage Low in the absence of an input signal, which is important when capacitance is being measured.

The emitter of TR1 feeds IC1a, a Schmitt-trigger NAND gate wired as an inverter, which sharpens up the input. Except when capacitance is being measured, the PIC keeps pin 5 of IC1b Low, and therefore pin 2 of IC1c High.

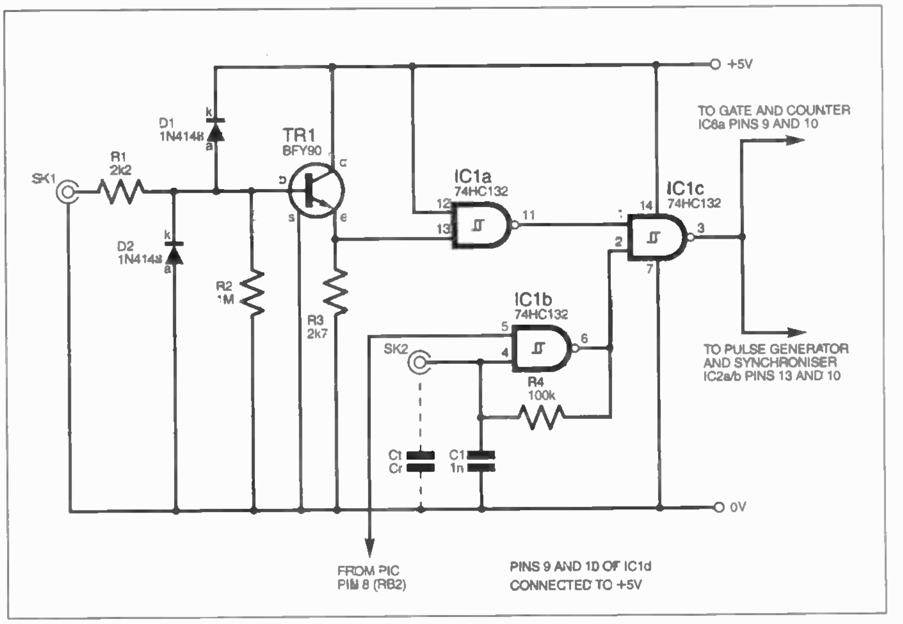


Fig.2. Circuit diagram for the buffer and RC oscillator stages.

The resulting output at pin 3 of IC1c is therefore a sharp pulse train which mirrors the input. This is then fed to the Gate and Counter circuit for high frequency measurement, and to the Pulse Generator and Synchroniser for all other measurements.

It is important to use the BFY90 transistor specified for TR1. This has a very high unity gain frequency. Other transistors – even other RF transistors such as the BF484 – give poor results in this circuit.

The purpose of the RC oscillator built around IC1b is described later. The inputs of the unused gate IC1d (pins 9 and 10) are tied to the +VE rail to prevent spurious operation.

PULSE GENERATOR AND SYNCHRONISER

The Pulse Generator and Synchroniser circuit diagram is shown in Fig.3. The circuit is required to generate a pulse which has the same time as the period of the incoming pulse train, or the same time as either the mark of a single pulse or the space between two pulses.

It relies on the fact that an Exclusive-OR (XOR) gate can be used as a controllable inverter. XOR gates are interesting devices and less-used than perhaps they should be. The usage here is described in the Logic Hints 1 panel.

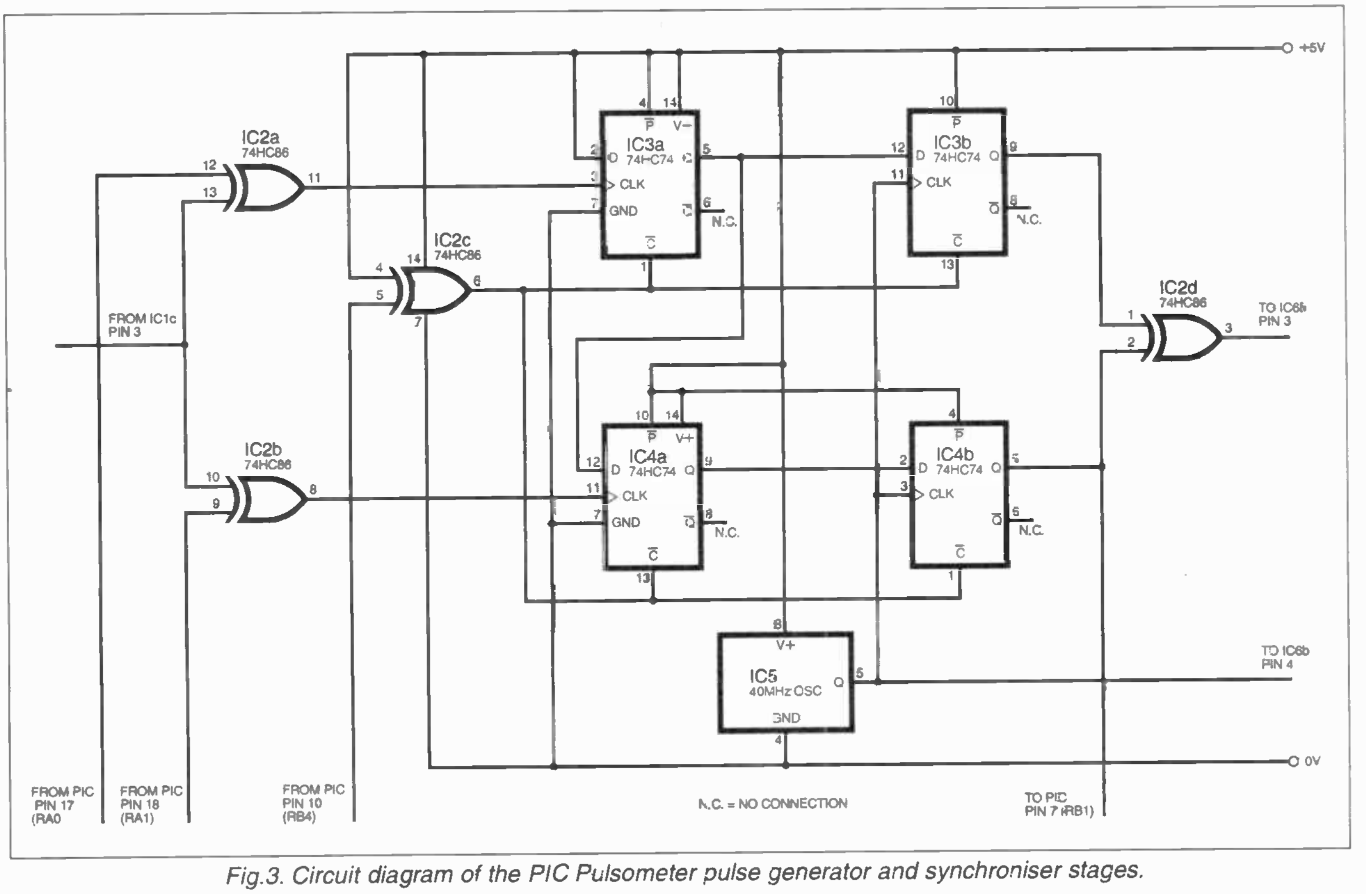


Fig.3. Circuit diagram of the PIC Pulsometer pulse generator and synchroniser stages.

Assume that the mark of a pulse is to be measured. Initially the PIC holds all the 74HC74 D-type flip-flops in a reset state by applying a High to pin 5 of IC2c. This is configured as an inverter, so a Low is present at the Clear pins. The PIC sets pin 12 of IC2a Low, so it does not invert, and pin 9 of IC2b High so that it does.

The PIC releases the reset condition by setting pin 5 of IC2c Low. The next leading edge of the input pulse passes through IC2a uninverted, and arrives at pin 3 of IC3a, the Clock input. Because the Data pin of IC3a is tied High to +5V, this causes IC3a to change state, so that its Q output changes from Low to High.

Until this point, any High at the Clock input of IC4a will have no effect, as the Data pin is connected to the Q pin of IC3a. However, the change of state of IC3a now enables IC4a. So, when the trailing edge of the input pulse arrives at IC4a's Clock input, it has been inverted by IC2b, and goes from Low to High.

This causes IC4a to change state, so its Q output goes High. Further input pulses have no effect on either IC3a or IC4a – they are locked in that state until reset by the PIC.

GLITCHES

The time difference between the Q output of IC3a going High and the Q output of IC4a going High is the same as the input pulse, and this could be used to derive a pulse to gate the 40MHz clock. However, it is not synchronised with the clock, and this can give rise to many "glitches".

This effect is reduced by feeding the Q outputs of both flip-flops into the Data pins of a further pair of D-type flip-flops, IC3b and IC4b, which are clocked by the 40MHz oscillator.

The effect is that the Q output of IC3b will not go High until the leading edge of the first oscillator pulse following the Q output of IC3a going High. Similarly, the Q output of IC4b will not go High until the leading edge of the first oscillator pulse following the Q output of IC4b going High.

The time difference between the Q outputs of IC3b and IC4b going High is now longer than the input pulse, but by no more than the resolution of the Pulsometer, but now the pulse is synchronised with the 40MHz clock.

The outputs of IC3b and IC4b are fed into the XOR gate of IC2d, the output at pin 3 being a positive-going pulse representing the mark of the input pulse. The end of this pulse is detected on the PIC's RB1 pin, which is connected to the Q output of IC4b.

Even with the synchronisation described there is still a little instability in the final display. This is because many signals are unstable at the nanosecond level.

To measure the space between two input pulses, the PIC simply reverses the control signals given to IC2a and IC2b, so that IC3a is triggered by the inverted space, and IC4a is triggered by the uninverted mark. To measure the period of a pulse cycle, the PIC causes neither IC2a nor IC2b to act as inverters, so that IC3a is triggered by the leading edge of the input's mark, and IC4a is triggered by the leading edge of the following mark.

GATE AND COUNTER

The circuit diagram for the Gate and Counter is shown in Fig.4. At the start of the measurement cycle, the PIC holds the 14-bit counter IC7 in reset by applying a High to its Clear pin. The PIC also applies a Low to the 3-input NAND gates at pin 11 of IC6a and pin 5 of IC6b, which causes their outputs at pins 8 and 6 to be High.

The PIC also applies a High to pin 1 of IC6c, and because all three inputs to IC6c are High, the output at pin 12 is Low. This is connected to the Clock input of the counter at pin 10.

If frequency is to be measured directly, the PIC releases the reset on the counter's Clear input and places a High on pin 11 of IC6a for one second. The input signal from the Buffer (IC1c) is now allowed through IC6a and IC6c, and hence clocks the counter.

Counter IC7 is a 74HC4020, which is the 4000 series chip in 74HC technology. This is a 14-bit counter, which overflows on the 16,384th input pulse causing output Q14 to go from High to Low. This is detected by the PIC at its RB0 input, and to do this bit 7 of the PIC's OPTION register must be set to 1, which causes negative-going edges rather than positive-going ones to be recognised.

LOGIC HINT 1
Exclusive-OR (XOR) Gates

TRUTH TABLE

A	B	Y
L	L	L
L	H	H
H	L	H
H	H	L

XOR gates give High outputs when, and only when one input is High and the other is Low. They are very versatile and in this project they are used in several different ways:

a. They can produce an output pulse which equals the time difference between two different signals at the input. IC2d is used like this.

b. When one input is tied High, a signal at the other input is inverted, as in IC2c.

c. If one input is connected to a PIC or other control logic, an input signal can be inverted or not depending on whether the control input is High or Low. IC2a and IC2b are controlled in this way.

The PIC counts these overflows in a multi-byte register, and at the end of the cycle multiplies it by 16,384.

For all frequencies below 16,384Hz, and for all higher frequencies which are not multiples of 16,384Hz, there will be a count left in the counter at the end of the one-second pulse. To flush this out of the counter and into the PIC, pin 1 of IC6c is toggled by the PIC's RB5 pin (with pin 11 of IC6a and pin 5 of IC6b held Low) until the counter overflows.

The PIC counts the number of times it toggled the counter, subtracts it from 16,384, and adds the result to the previous count. The final result is that the PIC now has an accurate count of the pulses received in one second. The total count is scaled to the appropriate units and displayed.

PULSE TIME

To time a pulse, the circuit operates in a similar way. At the start of the cycle the PIC releases the reset on the counter and applies a High to pin 5 of IC6b. When the pulse to be timed is received from the Pulse Generator and Synchroniser at pin 3 of IC6b, it will now gate pulses received from IC5, the 40MHz clock. These are counted in exactly the same way as for frequency measurement. The PIC detects when the pulse has finished via its RB1 pin and the Q pin of IC4b.

For timings, the count is multiplied by 25, which gives the total number of nanoseconds. If frequency is to be calculated, the count is divided into 40,000,000.

The use of the three 3-input NAND gates in IC6 is an example of how to minimise the number of chips used in a design, and the principle is shown in Logic Hint 2.

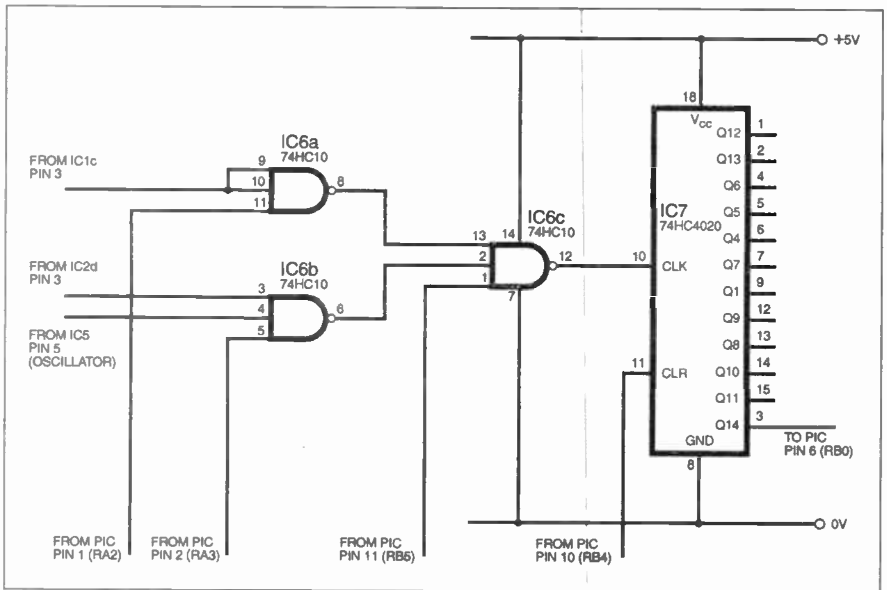


Fig.4. Circuit diagram of the gate and counter sections.

CONTROL AND DISPLAY

The Control and Display circuit diagram is shown in Fig.5. Most of the PIC pins are connected to gates in the other circuits to provide control. The Mode switch S1 is connected to RB7, with R5 as a pull-down resistor. The switch is debounced by the PIC. RA4 has a pull-up resistor (R6), as this is an open-collector output.

You can see from the diagram that the data lines from the PIC (RA0 to RA3) going to the l.c.d.'s pins D4 to D7 also go to other circuits for control purposes. The reason that the l.c.d. does not show junk on its screen is because the l.c.d. only accepts data or commands when its E pin is High.

As the operation of the meter is cyclic, the PIC holds the E pin Low while it is using RA0 to RA3 to control the circuits, and holds the circuits in reset when it is sending information to the l.c.d. and causing it to be displayed with the E pin.

This is a useful trick to use if you are running out of PIC pins, and can be applied to many designs.

Wonderful devices though they are, l.c.d.s do not have particularly good visibility. A couple of extra pounds were spent equipping the Pulsometer with a back-lit type. This requires 5V to be applied to the separate pins 15 and 16. If you don't want to use a back-lit type, omit the pin 15 and 16 connections.

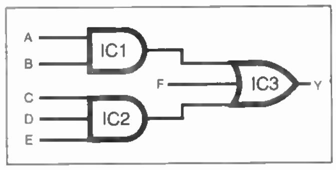
A 16-character by 1-line display was also used, as these have taller and therefore more readable characters. This requires additional programming as each character uses two l.c.d. addresses. A 2-line display can be used, and the code shows the lines that have to be deleted. Finally, VR1 allows the l.c.d. contrast to be adjusted.

RC OSCILLATOR

The RC Oscillator circuit is shown as part of Fig.2. When capacitance is to be measured, the PIC enables IC1b with a High at pin 5. This causes oscillation at a frequency determined by C1 and R4. Providing there is no signal present at socket SK1, transistor TR1 and IC1a enables IC1c at pin 1. This allows the PIC to measure the period of the pulse train using the techniques described above.

LOGIC HINT 2 – Saving Chips

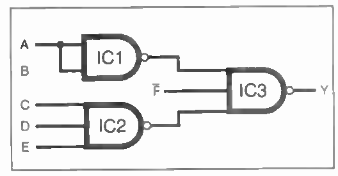
A problem arose with the Gate and Counter circuit logic which needed to function as shown in the following diagram:



The problem is that 2-input AND gates come four to a chip, and 3-input AND and OR gates come three to a chip. So to use this logic as it stands would require three chips, and leave seven gates unused (unless they are needed elsewhere in the project). This adds size and complexity (and a little cost) to the project.

One way to reduce the problem is to use a 3-input AND gate for IC1, tying two inputs together to make a 2-input gate. However, this still needs two chips with four gates unused.

The following circuit provides a more economical solution:



This performs almost the same function as the first circuit, except that the input F must now be inverted. As this is supplied by the PIC this is easy to arrange without using further gates.

This still uses the same number of gates but they are now of the same type, which has reduced the complexity considerably as only one chip is now required, a triple 3-input NAND gate.

Logic design often requires that several inputs are ANDed in groups, and then the groups are ORed together. This technique can be used to advantage in such situations.

A "test" capacitor can be plugged into socket SK2, altering the frequency and therefore the period. The calculation of the value of test capacitors requires a calibration process. Although Schmitt trigger RC oscillators are not very stable, this design is capable of measuring values of a few picofarads and gives good accuracy at 10pF and above.

The RC oscillator is shown with more detail in Fig.6. In a Schmitt trigger RC oscillator, the period T of the pulse train generated is given by the formula:

$$T = K \times R \times C$$

where K is a constant (at least at reasonable frequencies) which depends on the switching points of the Schmitt trigger, which will vary from chip to chip.

In addition, the input capacitance of the Schmitt trigger (Ci) and stray capacitance in the circuit (Cs) will give inaccuracies in trying to measure the value of a test capacitor (Ct) directly using the above formula.

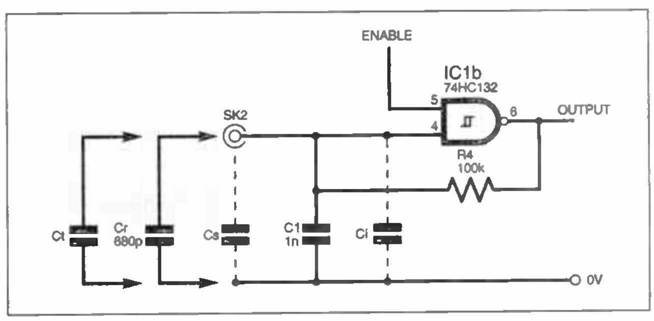


Fig.6. The RC oscillator circuit in more detail.

In the project a calibration step is carried out by inserting a reference capacitor (Cr) into socket SK2. After calibration has been done, a test capacitor can be measured by inserting it into the socket. This gives rise to the following formulae:

$$To = K \times R4 \times (C1 + Cs + Ci)$$
$$Tr = K \times R4 \times (C1 + Cs + Ci + Cr)$$
$$Tt = K \times R4 \times (C1 + Cs + Ci + Ct)$$

From these the following formula can be derived:

$$Ct = Cr \times (Tt - To) / (Tr - To)$$

Since the number of pulses N counted by the PIC is directly proportional to the period T of the pulse being measured, the formula becomes:

$$Ct = Cr \times (Nt - No) / (Nr - No)$$

Like magic, the constant K and the input and stray capacitance have disappeared

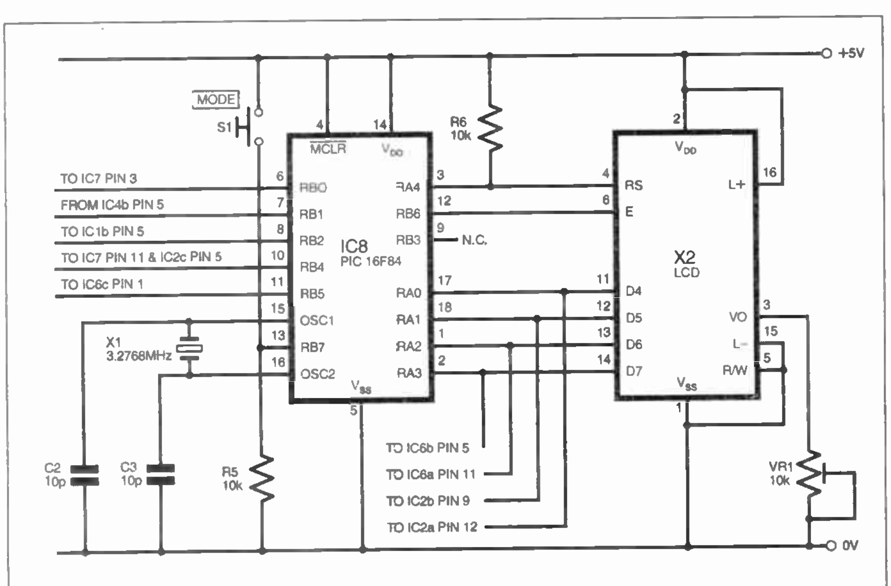


Fig.5. Circuit diagram for the PIC controller and l.c.d. stages.

from the calculation, and the accuracy of the result now seems to depend only on the accuracy of the reference capacitor (Cr).

In the Pulsometer, calibration is not done every time a capacitor is measured, but infrequently, and the values of No and (Nr – No) are stored in the PIC's EEPROM. When a test capacitor is measured, the temperature will probably be different from when the meter was calibrated, and the values of K, R4, C1, Cs and Ci, upon which No and Nr depend, could all be slightly different.

In the prototype high stability items are used for R4, C1 and Cr, and good accuracy and stability are achieved in practice.

According to the theory it doesn't matter what values R4 and C1 have – the ones used were chosen so that the NAND gate would oscillate linearly over the test capacitance range desired, which is from a few pF up to 999µF.

POWER SUPPLY

The power supply is a conventional circuit and is shown in Fig.7. Power is input via socket SK3 and diode D3, the latter guarding against incorrect polarity. With a backlit l.c.d., around 90mA is drawn, and a 1A 7805 voltage regulator was preferred to the 100mA type. If a non-backlit l.c.d. is being used, a 100mA type can be substituted.

Capacitors C4 to C12 provide power stability. 74HC chips have a very fast switching action, which produces big voltage spikes on the positive supply rail.

Decoupling capacitors C7 to C12 are located as close to the Vcc (+VE) pin of each chip as possible, but are shown here rather than in the circuit diagrams for clarity.

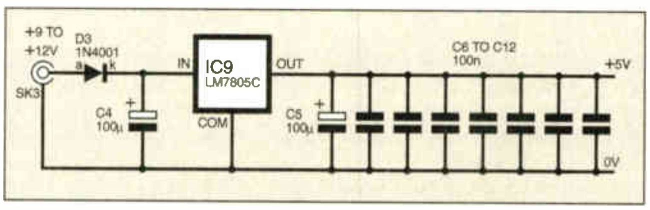


Fig.7. Power supply circuit diagram, including the decoupling capacitors.

CONSTRUCTION

Construction of the PIC Pulsometer is made on stripboard. Stripboard has many advantages for the amateur constructor – no expensive layout software or equipment, no nasty chemicals, and it is easy to modify. On the downside, layouts are physically bigger than with printed circuit boards (p.c.b.s). However, as part of the following construction details, comments are made on how to minimise stripboard layout size.

The prototype uses a console case made of ABS with an aluminium top. It also has an attractive, rounded sloping front, which improves readability, and is no bigger than it need be.

All of which is to say that construction would have been less fiddly if a slightly bigger, regularly shaped case had been chosen! The constructional notes are based on the one used.

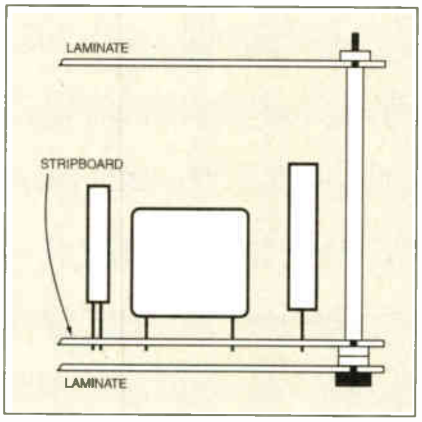


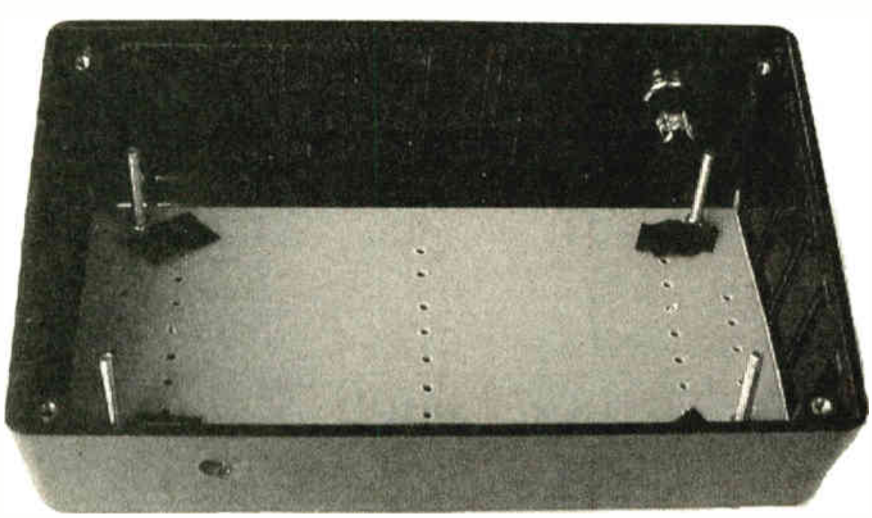
Fig.8. Suggested method of "sandwiching" the stripboard between two pieces of p.c.b. laminate.

The stripboard component layout details and breaks required in the copper tracks are shown in Fig.9.

PREPARATION

First, the stripboard should be prepared by cutting it so that a full 31 rows of 60 holes are available. Stripboard, and the plain p.c.b. laminate also used, may be cut easily by scoring both sides with a sharp knife and then snapping it. Make the corner cutouts required to allow for the case's corner pillars.

The fixing pillars at the bottom of the case are in the wrong place for the stripboard. This is overcome by making a base of single-sided copper p.c.b. laminate, which is screwed to the case using the self-tapping screws supplied. A similar piece of p.c.b. laminate is also used above the stripboard – see Fig.8.


Interior of the case showing the bottom p.c.b. laminate piece (copper-side down) and circuit board mounting bolts. Note the rows of vent holes.

COMPONENTS

See SHOP TALK page

Resistors
R1 2k2
R2 2k7
R3 1M
R4 100k 1% metal film
R5, R6 10k (2 off)
All 0·25W 5% carbon film unless stated.

Potentiometer
VR1 10k carbon preset, min. round

Capacitors
C1 1000p silvered mica
C2, C3 10p ceramic 2·5mm pitch (2 off)
C4, C5 100µ radial elect. 16V (2 off)
C6 to C12 100n polyester 5mm pitch (7 off)
C7 680p silvered mica

Semiconductors
D1, D2 1N4148 signal diode (2 off)
D3 1N4001 rectifier diode
TR1 BFY90 *npn* transistor (see text)
IC1 74HC132 quad 2-input Schmitt NAND gate
IC2 74HC86 quad 2-input XOR gate
IC3, IC4 74HC74 dual D-type flip-flop (2 off)
IC5 40MHz oscillator module, fitting an 8-pin d.i.l.
IC6 74HC10 triple 3-input NAND gate
IC7 74HC4020 14-stage counter
IC8 PIC16F84 microcontroller, pre-programmed
IC9 7805 +5V 1A voltage regulator (see text)

Miscellaneous
SK1 BNC socket
SK2 20-pin d.i.l. socket (stamped pin)
SK3 2.1mm power socket
S1 s.p. pushswitch, break-before-make
X1 3.2768MHz crystal
X2 l.c.d., 16-char × 1-Line backlit l.c.d.

Stripboard, 31 rows × 60 holes; stripboard 16 rows × 8 holes; single-sided p.c.b. laminate (see text); 8-pin d.i.l. socket; 14-pin d.i.l. socket (5 off); 16-pin d.i.l. socket; 18-pin d.i.l. socket (turned pin); BNC plug; 12.5mm metal stand-off (4 off); case to suit; connecting wire; coax cable; 6BA nut (8 off); 6BA 12.5mm bolt (8 off); 3mm nut (12 off); 20mm × 3mm bolt (4 off); solder, etc.

Approx. Cost Guidance Only £38 excl. case

Cut the bottom piece of laminate to the same size as the stripboard, and drill 4mm holes for the self-tapping screws. Check that it will fit into the box, but do not fit in place yet.

The top piece of laminate should be cut slightly smaller than the stripboard along the back and sides. This is to allow the hook up wires to pass.

Clamp the three boards together with the stripboard on top and the laminate boards copper side down, and drill the four 3mm mounting holes.

TABLE 1 Solder Pin Connections

P1 l.c.d. VSS pin 1	P10 l.c.d. D7 pin 14
P2 l.c.d. V0 pin 3	P11 l.c.d. D6 pin 13
P3 l.c.d. VDD pin 2 and switch S1	P12 l.c.d. D5 pin 12
P4 l.c.d. backlight 0V pin 15	P13 l.c.d. D4 pin 11
P5 l.c.d. backlight +VE pin 16	P14 SK2 +VE side
P6 l.c.d. R/W pin 5	P15 SK1 centre pin
P7 l.c.d. E pin 6	P16 SK1 0V (screen) and SK2 0V side
P8 switch S1	P17 SK3 0V } power input (+9V to +12V)
P9 l.c.d. RS pin 4	P18 SK3 +VE } power input (+9V to +12V)

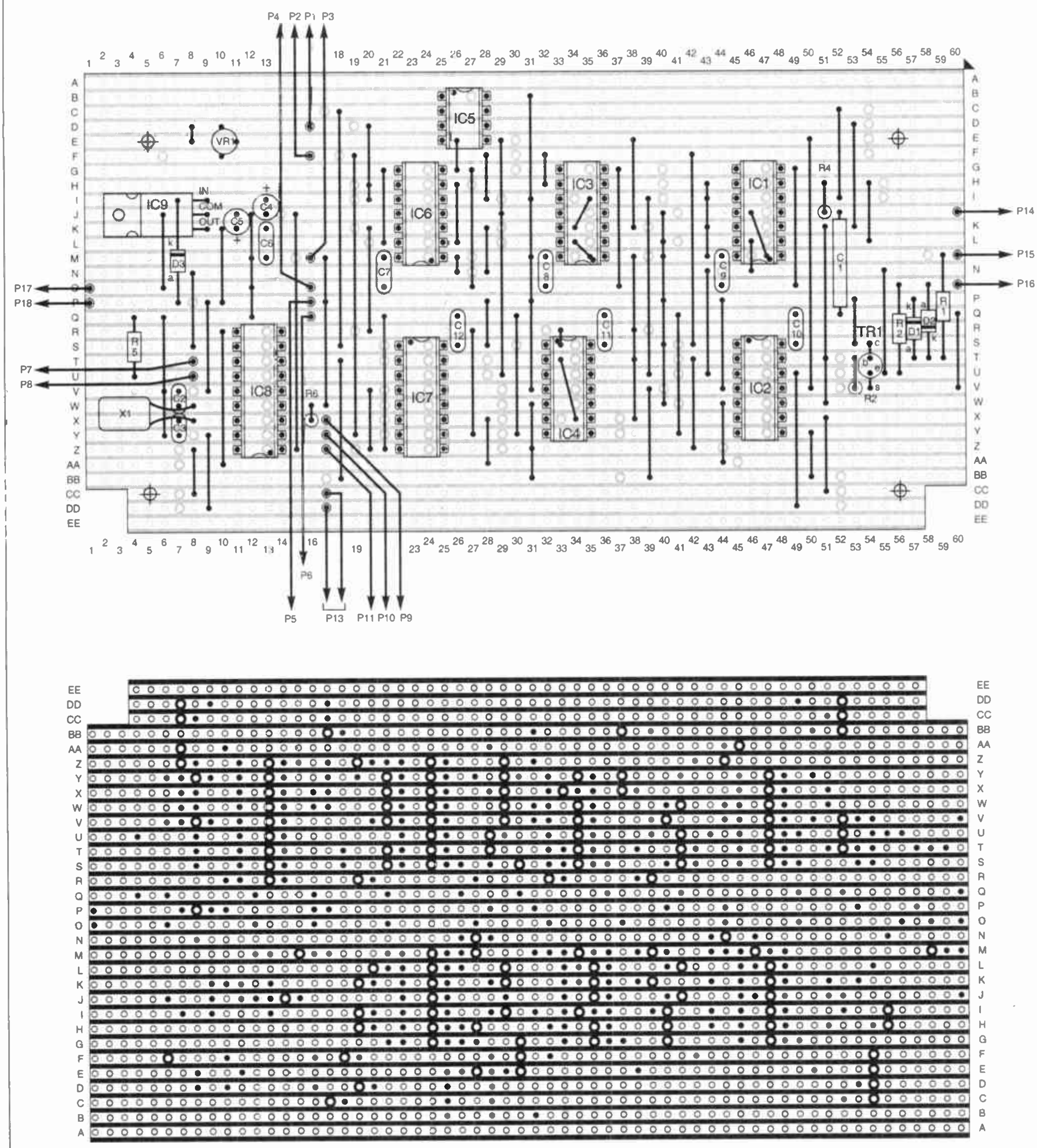


Fig.9. PIC Pulsometer stripboard component layout and details of breaks required in the underside copper tracks. Note some link wires are made from thin 26 s.w.g. or 28 s.w.g. wire to allow two wires to go into the same hole – see text.

Although the circuit does not give out a lot of heat, there is no ventilation, so drill a series of holes through both the top and bottom laminate boards. Make sure there are plenty on the side where the regulator is situated, and on the other side where C1 is placed. Also drill a line of holes along the top of the back of the box, but below the lip where the top sits.

The holes for the BNC socket (SK1) and the power socket (SK3) should be drilled towards the top edges of the box so that they will not foul the top piece of laminate when fitted.

Insert 20mm × 3mm bolts from the copper side of the bottom board, secure them with two nuts each, and screw it into the box, covering the screws with insulating tape.

Using the holes in the laminate as a guide, drill through it to make an identical set in the bottom of the box.

Ream, or drill out the bolt holes in the stripboard and top laminate to be a loose fit over the bolts. Check that you can reasonably easily fit the boards into the box and get them out again!

BOARD NOTES

Another downside of stripboard is creating the layout – it hurts the brain! The author failed to buy a product called Stripboard Magic a few years ago and has regretted it ever since, as the supplier has now gone out of business. It would be interesting to know how it would have got on with this – perhaps any readers out there with a copy would like to give it a go and report the result . . . ?

Although the reverse side of the stripboard is shown, the author prefers to mark the top side of the board with a fine permanent marker where holes in the track underneath have to be cut, and then poke the end of a resistor through to show where the cut has to be made. Not very quick, but very sure!

When cutting the track holes, make sure that no copper edge is left and, after all the holes have been cut, the board should be thoroughly checked, deoxidised and degreased – a p.c.b. polishing block makes a good job of this.

Two techniques are used to reduce the physical size of the layout. The first is the common one of placing links underneath the chips. The second is less common and allows "runs" of connections to use the same "column" of the stripboard – see, for example, the connections made at rows B, I, M, P and V of column 31.

For this to work, thinnish tinned copper wire is needed in order to get two wires into the same hole. The 32swg gauge wire used in the prototype is rather fiddly and 26 or 28swg would be better.

Any attempt to use either insulated wire, or sleeving, will probably drive you completely mad. If the links are reasonably taught then problems are unlikely to occur.

ASSEMBLY

Populate the board with the components (except the i.c.s), starting with the links.

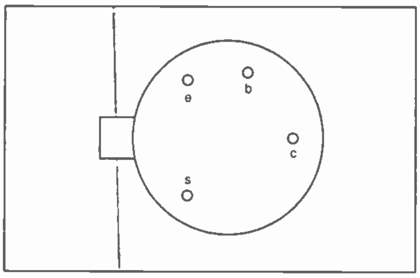
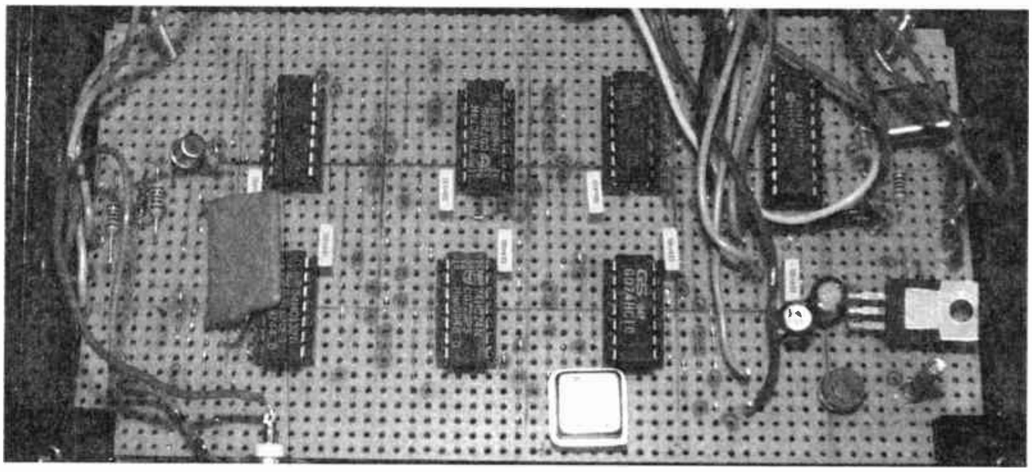


Fig.10. Pinout details (pin view) for the BFY90 transistor. The lead marked S is the screen.

After the links have been soldered in place, check that they all exist and go between the right holes. The remaining components are then mounted in order of increasing height.

Dual-in-line (d.i.l.) sockets should be used for all i.c.s. (including the 40MHz oscillator IC5). Preferably use a turned-pin socket for the PIC, IC8. Make sure the sockets are inserted with the notch pointing the right way.

The leads of crystal X1 and regulator IC9 need to be bent so that the components lie parallel to the surface of the board.



Layout of components on the completed prototype circuit board.

Transistor TR1 has four leads (the fourth being the shield). Its pinout is shown in Fig.10. This is mounted in-line, and so the leads need to be bent carefully to match the holes on the stripboard, taking care they do not short each other.

After soldering, inspect the board through a magnifying glass for solder bridges and splashes. Because the flux that flows into the channels between the tracks can sometimes shine like solder, it helps to clean them out first by running the corner of a small screwdriver blade along the channels.

The requirements are tough for socket SK2, into which capacitors are plugged for measurement. Capacitors come with lead spacings from 2·5mm upwards, and with lead thicknesses of varying sizes. There is probably not an ideal solution, but a reasonable one is to use a 20-pin d.i.l. socket, which must be of the stamped pin variety.

This is mounted on a small piece of stripboard of 16 rows by 8 holes, with wires soldered along the *track side* so that pins 1 to 5 and 16 to 20 are connected together, and pins 6 to 15 are connected together, see Fig.11.

The holes in the corners for the mounting bolts should be isolated from the d.i.l. socket as connecting the top cover to 0V messes up capacitance measurement. Two solder pins mounted from the copper track side of the board provide connections for the hook-up wires.

The d.i.l. sockets have connections that are springy enough to hold thin leads, but will also accept fat ones. After a while the fat leads will destroy the springiness of a particular socket pin, so it is a good idea to reserve pins for particular kinds of leads.

TESTING

Off-board connection points are tabulated in Table 1.

First apply a 9V to 12V supply via solder (terminal) pins P17 and P18. Test the output of the regulator and the Vcc/Vdd (+VE) pins of all d.i.l. sockets for +5V. Do the same for 0V at the GND/Vss pins. Any fault at this stage must be found and corrected.

Remove the supply and attach the l.c.d. to the appropriate solder pins. The usual hook-up wire is a bit thick and the author prefers to use wire stripped from a ribbon cable. Make the wires long enough to reach from the bottom of the case and over the back to the work-table surface.

Insert a pre-programmed PIC16F84 (NOT a PIC16C84) into its socket, making sure the notches line up. If you are programming the PIC yourself, the PIC should be configured for an XT (100kHz to 4MHz) crystal, with the watchdog timer disabled, and the power-up timer enabled.

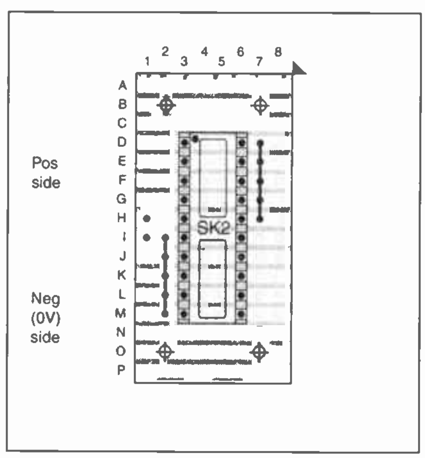


Fig.11. capacitor "test" socket SK2 is mounted on a piece of stripboard, which is bolted to the case lid.

If the power supply is now reconnected, the l.c.d. should look like Fig.12a. It will probably be necessary to adjust the contrast with VR1. With the power removed the remaining chips can now be installed, correctly orientated.

The 40MHz oscillator (IC5) has a spot on the metal case above pin 1, and its leads may need to be trimmed a little so that it fits snugly into its d.i.l. socket.

Except for capacitance measurement, the functions can be tested at this stage by reconnecting the power and applying a suitable signal to the input pins. If you have not got a signal generator, an RC oscillator can be assembled in the same fashion as that around IC1b, using a breadboard and a spare Schmitt trigger chip. The l.c.d. should show a display similar to that in Fig.12b.

If solder pin P8 is connected briefly to solder pin P3, the PIC will change mode each time and displays such as those in Figs.12c to Fig.12f should be obtained. If selected, the capacitance mode may display rubbish at this point, as meter has not yet been calibrated.

TOP PANEL

The top panel is aluminium, not ABS (does anyone like working with ABS?). The rectangular holes for the l.c.d. and 20-pin d.i.l. socket (SK2) are made in the time-honoured way of drilling holes round the edges and filing down.

Drill the hole for switch S1, and the fixing holes for the l.c.d. and SK2 sub-assembly.

If, like the author, you are unable to produce perfectly straight and square edges, then model a template on a computer. Print it out on thin card, make the cutouts with a scalpel, protect the card with a spray coating sold by stationers for this purpose, and fix to the plate with glue.

For best effect the cutouts in the panel need to be very slightly bigger than the card cover. With this technique colouring and lettering from a wide range of fonts can be added, all perfectly aligned.

ASSEMBLY

Assembly is straightforward. First mount the l.c.d., SK2 sub-assembly and switch S1 on to the top panel. Size 6BA nickel-plated bolts give a good appearance, and their full nuts make the d.i.l. socket sit flush with the panel.

Solder the remaining hook-up wires to the solder pins on the stripboard. As there are 18 wires it is best to label them carefully as their connection to the stripboard cannot be seen when it is mounted in the case.

Bend the large capacitor C1 over a little so that nothing on the board rises more than 12·5mm above the surface and mount the stripboard on to the 20mm bolts in the case, with 12·5mm metal spacers on top. These must be metal as one of them forms a 0V link between the two p.c.b. laminates and the stripboard.

Feed all the wires over the back of the case, except those from solder pins 14, 15, 16, 17 and 18, which feed over their respective sides. Gently press them down to follow the contours of the stripboard and case, and fix the top p.c.b. laminate, copper side down, on to the 20mm bolts. The BNC and power sockets can now be fitted.

Fig.12a. Display on power-up.

Fig.12b. High frequency measure-

Fig.12c. Low frequency measurement.

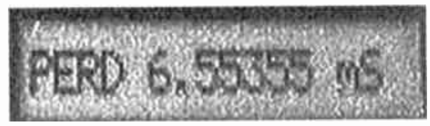


Fig.12d. Period measurement.

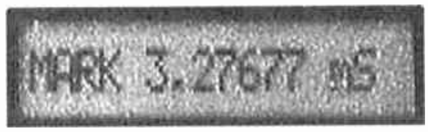


Fig.12e. Period measurement.

Fig.12f. Period measurement.

Finally, trim the remaining hook-up wires to length and solder to the sockets and switch S1.

An oscilloscope probe can be used with the Pulsometer or, failing that, make one up from a BNC plug, coax cable and probes or crocodile clips at the other end.

OPERATION

The meter does not have an on/off switch – it starts working when plugged in. Any 9V to 12V d.c. mains adaptor supply should be suitable. Nor is there a reset button. It is a brave programmer who claims not to have any bugs in their code, but the author has not found any since completing the project. However, if the PIC gets confused, reset by interrupting the power supply.

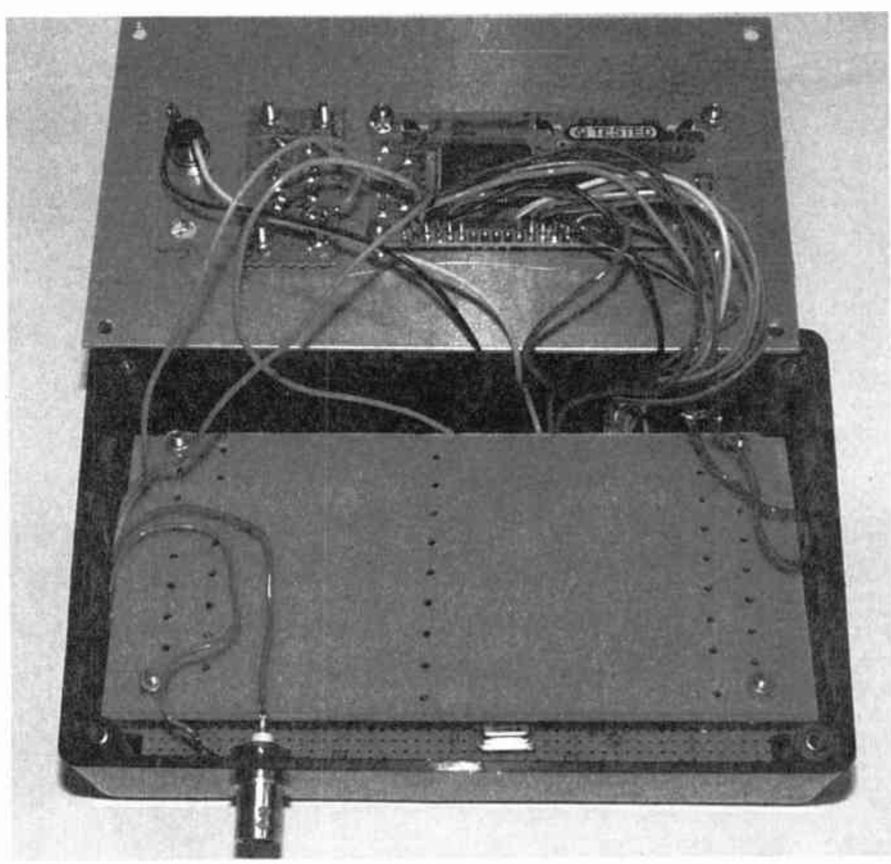
You have probably played with the meter during the testing stage, but the following is a complete description of its functions.

At first power-up the screen in Fig.12a is displayed, stating that the meter is in the higher frequency mode, F(H). This measures frequency to the nearest Hertz, rounded down.

The display removes leading zeros but not trailing ones, and is scaled to the appropriate units. The display is refreshed every second. Try the meter out at higher and lower frequencies.

Mode is selected by using the pushbutton switch S1. The first push brings the lower frequency mode. When no signal is present on first use of the mode the measurement and units area will remain blank. This is not an error – the meter is waiting to be triggered by the leading edge of an input pulse. Try it out on the same frequencies as before and notice the difference.

It will be seen that if the input signal is removed, the last measurement made will continue to be displayed until either a new signal is input, or the mode is switched.



Completed unit showing wiring to the Mode switch, "test" socket and l.c.d. module bolted to the rear of the case lid.

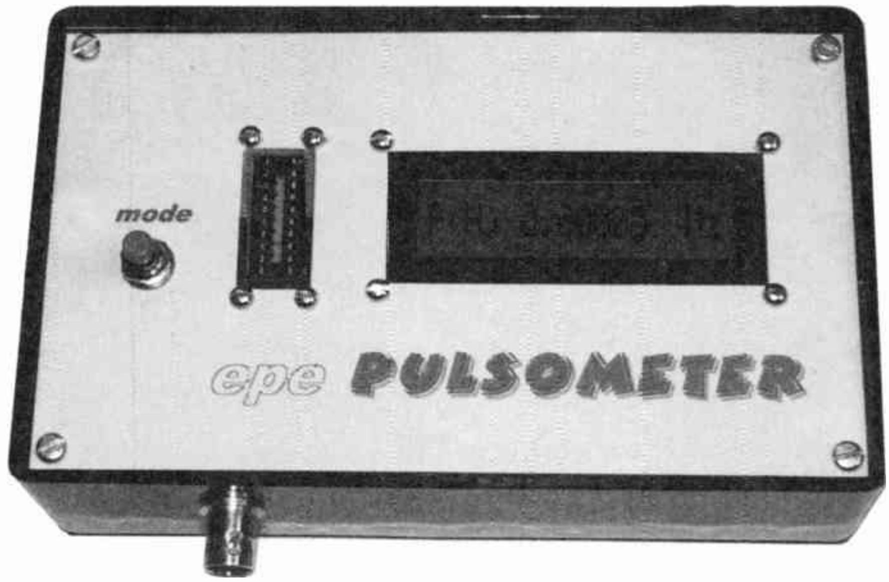
The point where one mode is more accurate than the other is approximately 6324Hz – this being the square root of the 40MHz clock frequency.

Further pushing of the switch brings the Period, Mark and Space modes. These have the same characteristics as the lower frequency mode. The maximum time that can be measured is just over 1·9 hours (which is shown in seconds).

Should this time be exceeded the letter "O" (meaning overflow) will appear in the next available character on the screen. No reset is necessary – it will disappear of its own accord when the next input below this limit is measured.

The time taken to display the result depends on the time of the Period, Mark or Space being measured, but the meter is slugged so that the display is never updated more frequently than about once a second.

The Pulsometer's clock has a period of 25ns, which means that Period, Mark and Space (and lower frequency) measurement become increasingly accurate as the pulse time gets longer or the frequency lower.



Finished PIC Pulsemeter showing front panel display cutout and the 20-way d.i.l. socket for testing capacitors. The top half of the socket has been painted red to identify the "positive" side.

CALIBRATION

A final push of the switch will bring up the capacitance measurement mode. Until calibration has been done, the display may show zero or any random value.

For accuracy, the Pulsometer should be allowed to reach normal working temperature by leaving it switched on for 10 minutes or so, before either measurement or calibration is performed. No signal should be present at the input BNC socket during either calibration or capacitance measurement, as this will confuse the meter.

Calibration mode can be entered from any other mode by pressing and holding the pushswitch for several seconds, and then releasing it as soon as the message appears (see Fig.13a). This cryptic message is the downside of using a 1-line display!

A precision, low temperature coefficient 680pF capacitor should now be plugged into the 20-pin "test" socket SK2, with one lead going to the top half, and the other to the bottom half. A silvered mica one per cent type with the leads trimmed short was used for the prototype.

The switch is then pushed, when the capacitance display will appear, as in Fig.13b. This should show a value very close to 680pF, and the display may vary every second by up to 1pF either way.

CAPACITORS

Capacitors may now be measured by plugging them into SK2. Measurement is very accurate for capacitors of 100pF upwards, when tested with one per cent capacitors. Readings between 10pF and 99pF appear to be accurate, although they were tested using only 10 per cent capacitors. Useful indications are given as low as 1·8pF. See Fig.13c to Fig.13e.

Measurement is disabled above 999uF – these take around two minutes to measure, which seems long enough. Electrolytics and tantalums must be inserted into the d.i.l. socket (SK2) with the correct polarity.

If the capacitance to be measured does not plug into the socket, stick a couple of wires, with clips or probes at one end, into the d.i.l. socket. This will affect the calibration, which can be compensated for by measuring the offset given by the 680pF capacitor, or by recalibrating.

It is not necessary to recalibrate if power is removed from the meter, as the calibration values are stored in the PIC's (non-volatile) EEPROM. Calibration can be checked at any time simply by measuring the 680pF capacitor.

Variations of a few pF will be because of temperature differences, so if precise measurement, or measurement of small capacitors is required, the meter should be allowed to reach working temperature and the ambient temperature should be similar to that when the meter was calibrated. If the reading for the 680pF capacitor is not close to that value, then recalibrate.

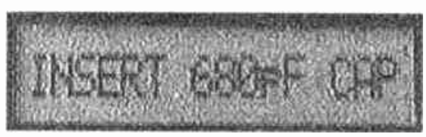


Fig.13a. Calibration message.

Fig.13b. After calibration.

Fig.13c. Display for a 1·8pF 10 per cent capacitor.

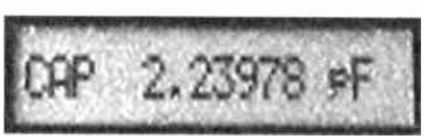


Fig.13d. Display for a 2·2pF 10 per cent capacitor.

Fig.13e. Display for a 100nF 10 per cent capacitor.

POWERING OFF

No "brown-out" detection is included in this design, and so the meter should not be powered down in calibration mode. If this is done and a brown-out occurs, the calibration values in the EEPROM may be incorrect. If this happens, simply recalibrate.

PROGRAM

The program occupies almost the whole of the code area, and it is not appropriate to describe it in detail here. The software is available on 3·5-inch disk from the Editorial office (a small handling charge applies), or *free* from the *EPE* web site. See this month's *Shoptalk* page for more details.

The code is by no means perfect in that some code space could be saved by greater use of subroutines in some instances. Working on the principle that "if it ain't broke don't fix it", the author decided not to make these cosmetic alterations.

The Pulsometer uses some multi-byte registers to do its arithmetic – three 5-byte ones for binary working and two 13-byte ones for BCD. The PIC's instruction set has some limitations which make handling such registers tedious (no store-to-store instructions, and only one indirect addressing register). The Pulsometer's source code illustrates some useful techniques.

In calculating lower frequencies, and for the capacitance calculations, adding and subtracting big integers in long registers is required, as is multiplication and division of fractions. The latter use a form of floating point arithmetic, although the division subroutine is slightly less accurate than the best. This was done for space reasons, and is accurate enough for the project.

Finally, there are subroutines for converting big numbers from binary to BCD. □

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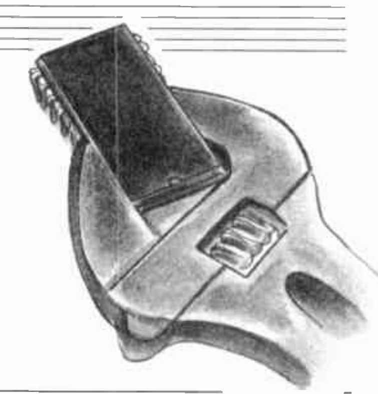
PIC TOOLKIT MK2 UPDATE V2.4



JOHN BECKER

More facilities are added to this versatile PIC programmer.

FOLLOWING suggestions from readers, and in the light of the author's own experience, *PIC Toolkit Mk2* has had several features added in version V2.4.

To enlighten readers who may not be familiar with *Toolkit Mk2* (May/June '99), it is *EPE*'s own programmer for use with PIC microcontrollers type PIC16x84 and PIC16F87x. It supports programming dialects TASM and MPASM, and can translate between the two.

EDIT FILE SELECTION

The main menu now allows "cursor-controlled" selection of which text-based Default File, as shown on the right of the screen, is selected for viewing through the Edit facility. Text-based files include .ASM, .HEX and .MSG. They do not include .OBJ files, which are binary-based.

The <UP> and <DOWN> keyboard arrows shift the "cursor", which consists of the word EDIT plus a right-facing arrow. The selected (active) file name is confirmed by also being placed alongside the Edit Text File option. Pressing key <E> or <ENTER> calls the Edit facility with the named file loaded for viewing and amendment.

A screen line reminds that this selection facility exists.

When the main functions provided through keys <1> to <9>, plus <S>, <R> and <A> are selected, the active Edit file name changes to suit, along with the Edit cursor position. The latter is stored for automatic recall next time the program is run, even after the computer has been switched off.

The way in which the default file names are allocated to different options has been rationalised, hopefully avoiding one or two "anomalies" which became apparent.

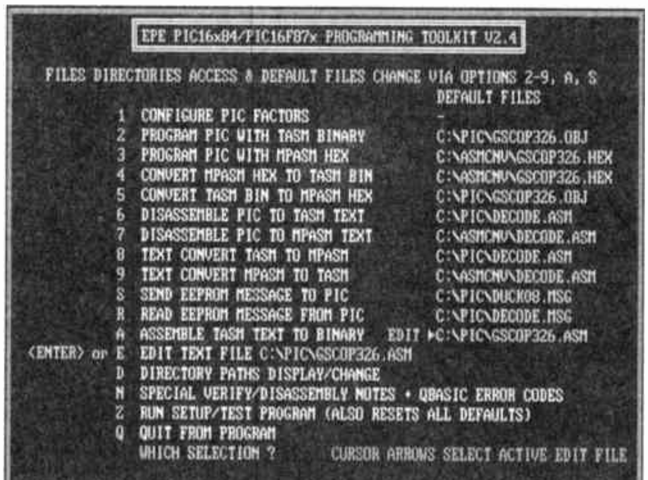
QBASIC ERROR CODES

Alongside the Special Verify/Disassembly Notes option, the statement "+ QBasic Error Codes" has been added. Readers have occasionally experienced the program finding difficulties with the software they are attempting to run with it. In such cases a default screen has appeared quoting an error code number, but without a definition of that number.

The full list of QBasic error codes (previously referred to as DOS error codes) is now screened in the event of unexpected errors. This same file can also be viewed via the main menu. Pressing <N> for the Verify Notes option first displays that screen, and also provides access to the QBasic codes by pressing <C> (as stated on screen).

The error-trapping routines in *Toolkit*'s programs now intercept for the known errors that readers have reported, preventing a "crash" from occurring.

Should an unexpected error occur, the error code list offers a guide to what might be the problem. If you cannot deduce its nature, contact the Editorial office, giving details.



Main menu screen for PIC Toolkit Mk2 V2.4.

POST-PROCESS ROUTING

Following assembly of a .ASM source code file to a .OBJ object code file, options have been added to select which exit route is then taken from this sub-routine.

If there are no assembly errors reported (i.e. no "literal" code bugs you've not spotted!), three options are offered:

To press <ENTER> for entering directly to the .OBJ sending routine (main menu option 2). To press <E> if you want to go straight to the Editing facility to examine the source code file. To press any other key to return to the main menu.

If bug errors have been found, you are offered the option to view a listing of the errors on screen "right now", by pressing <ENTER>. Alternatively, pressing <E> puts you into the Editing facility to examine the source code. Pressing any other key returns you to the main menu.

On pressing <ENTER> to view the errors, the screen changes and the disk file holding the list of errors (TKTEMP.ERR) is opened and its contents displayed in order of detection by the assembly routine, together with line numbers.

You now have the option to press <E> to return to Edit, or to press <P> to print the errors list to your printer (which must be in a ready condition), followed by a return to Edit. Pressing any other key selects the main menu.

TEMP FILES

In previous versions, intermediate .ERR and .LST (error and list) files are created using the name of the base source code file selected. On occasions, the author (who changes a suffix number on the source code file name for each significant change in coding development), found that a lot of files could be generated before he actively deleted them.

The program has been modified to only generate two general-purpose intermediate files, TKTEMP.ERR and TKTEMP.LST. As said a moment ago, the option to view the .ERR file is offered when first generated. Both files may also be viewed through the Edit facility, although they need to be loaded via Edit's own Load option.

INCLUDE FACILITY

The option to use INCLUDE files with source codes has been added. Command forms of $INCLUDE and .INCLUDE are recognised. Whilst the extension of .ASM is preferable, other extensions, such as .TXT or .INC, may be used in the associated file names.

Header files to be processed via the INCLUDE command must only contain EQUATES and #DEFINES, and be placed at the start of the source code.

Program files to be INCLUDEd may be placed anywhere within the main program, but must not include equates or definitions.

For each INCLUDE code command, the TKTEMP.LST file places a <+> symbol alongside the cumulative line numbers generated at the start of each .LST line. A statement that an INCLUDE file has been started or ended is inserted appropriately.

DIRECTORY GROUPS

A useful addition to the Directory files display has been made. Sub-categories can be selectively displayed as before, using the familiar "wild-card" symbols of <?> and <*>.

However, the sub-category identifiers are now stored for automatic recall on next entering the particular directory route, of which there are four, each displaying files having a specific dot-extension (.ASM, .OBJ, .HEX, .MSG). The sub-selection can be changed as required.

Incidentally, the annoying fact that newly created file names do not necessarily appear as the last name on the directory list has nothing to do with *Toolkit*. It is something of which both QBasic and QuickBASIC are "guilty". Even performing a DEFRAG does not prevent this occurring. Would that it were not so!

The author has deliberately not added an automatic SORT option to the file names, since there are frequent occasions when it is the date/time order of creation/updating that is important, rather than an alphanumeric order.

INSTALLATION

The software revision is available free via the *EPE* web site, or on disk from the Editorial office for a nominal charge to cover admin costs. See the *EPE PCB Service* page for ordering details.

Having unzipped your *Toolkit* disk or web-accessed software, copy the files into the folder named "C:\PIC\" (which you will have to create if you are new to *Toolkit* or do not have one already created).

The installation automatically overwrites any existing "TK-prefixed" file having the same name. If at any stage you are asked if you wish to overwrite, answer yes to all. This is likely to occur when files having .EXE and .BAS extensions are being copied.

Then run the "batch file" sub-program "TK.BAT" which will launch you into the full *Toolkit* software. Do not try to enter *Toolkit* by any other route. The automatic access to the Editing facility will not work if you do.

If *Toolkit* has not been previously installed, you will be launched into a preliminary Setup routine, as described in the original published text. If you are simply updating to version V2.4, on entry to the main menu press <Z> to route through to the Setup routine.

It is essential the Setup is run since it generates a lot more "TK" prefixed files, some of which are newly added through V2.4. Failure to do so will result in errors which even the in-built error-trapping might not intercept!

OTHER CHANGES

Minor cosmetic changes in *Toolkit*'s program may be spotted, but nothing worth highlighting.

Special thanks to Andy Flind for his help with regard to INCLUDE files.

If you would like to suggest further improvements to this software, let us know at Editorial (the author might even add them – one rainy day!)

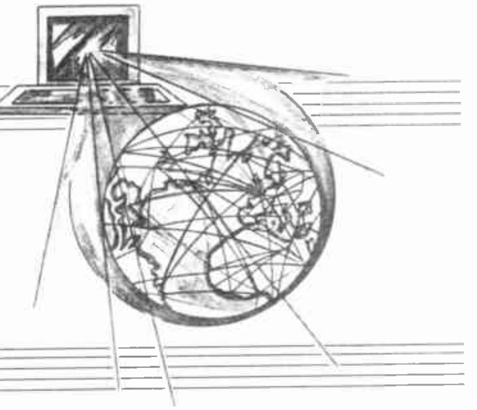
REMINDER

When sending a .OBJ file to a PIC, *Toolkit* (and its predecessors) automatically places GOTO 5 in location 0 (the Reset vector), followed by NOP into locations 1, 2 and 3. This action is specified by PTASM$ in source code file TKMAIN02.BAS, in which "CHR$(40) + CHR$(5)" specifies the jump to location 5.

Location 4 holds the Interrupt vector, which is specified by the user in the PIC source code (.ASM). It is the first .ORG that the code is allowed to specify and must always be stated as .ORG 4. Location 5 is that at which the program itself commences, as previously stated by the GOTO 5 command in location 0.

The logic behind this format is historical, mandatory and originally instigated in the *Simple PIC16C84 Programmer* of Feb '96. It has been highlighted on several occasions since then. □

SURFING THE INTERNET



NET WORK

ALAN WINSTANLEY

AltaVista Cashes Out

In early March 2000, AltaVista shook the UK Internet dial-up market by announcing its intention to offer a fixed price unmetered access for home users, as reported in May 2000 *Net Work*. In order to ensure that the service wouldn't be over-subscribed, AltaVista's intention was to roll out at a rate of 90,000 users per month.

This was a surprising and ill-conceived move, given that other ISPs had tried and failed to offer an unmetered service, often blaming over-subscription or over-use by consumers. However, AltaVista did succeed in wrong-footing cable operator ntl to offer its own unmetered service, and BT too was forced onto the defensive. There have been numerous complaints concerning ntl's failure to cope with the demand, resulting in delays of months for some subscribers.

Several companies including LineOne and CallNet0800 have since scrapped unmetered access because it is commercially unsustainable. The free service 08004U also folded, its owners EZESURF reportedly blaming its supplier, Planet Online, for billing errors that resulted in Planet Online (now Energis Squared) bankrupting EZESURF with an unexpected bill for call charges totalling £1.7 million.

The countdown to the launch of AltaVista UK's unmetered service soon began. Their upbeat on-line FAQs talked about providing "starter kits" to Windows users, also stating that AV was introducing this new service to "remove the uncertainty of open-ended access call charges". They were "on track" to launch sometime in June.

On August 3, AltaVista E-mailed interested subscribers to announce that on June 30 it had indeed launched its new service which "is currently being rolled out to our list of pre-registered customers" and to prevent over-subscription this would happen "in a controlled manner." This would, in the event, mean "in your dreams."

Things started to smell fishy when at the same time AltaVista launched two additional subscriber services called *Net on Demand* and *Freetime 20*. Meantime, a nationwide appeal by the UK press failed to produce any users of AltaVista's new unmetered service at all.

The rest is history – there never actually *was* an unmetered service from AltaVista UK. British Telecom accused them of turning reality on its head and Andy Mitchell, AltaVista's UK Managing Director resigned in disgrace over the affair. AltaVista could never have made their unmetered service work, and it is for a good reason that AltaVista FreeAccess in the USA and Canada (see **www.microav.com**) is actually supported by on-line advertising delivered to your desktop.

Sense of déjà vu

There is a sense of *déjà vu* about unmetered access. As a rule, people will often stay online and consume bandwidth for no reason at all, except that it is cheap. Way back in the early 1990's London-based Demon Internet offered dial-up Internet access through a number of points of presence (PoPs) dotted across the UK. You dialled the nearest one in order to obtain local rate calls, and getting through within ten or twenty attempts was akin to winning the lottery.

A small number of canny users in the city of Hull, which enjoys its own independent telephone service including cheap all-day local calls, soon found that they could dial into the Internet using Demon's Hull PoP, and by hogging the line they could enjoy a leased line to the Internet for just a few pence a day. Needless to say, the Hull PoP was soon relocated out of the city.

Always-on Internet access is still something of a luxury in this country. Cable company ntl will automatically cut off subscribers every two hours regardless, and will time out after five minutes of inactivity. Always-on access would be nice to have, but how many people seriously need it? It eats precious bandwidth and opens your vulnerable system to the possibility of hacking or nuking, so you face the prospect of configuring firewall software such as Norton Internet Security, Nukenabber or the highly regarded ZoneAlarm software.

Always-on broadband services (ADSL) are on the way to enabling consumers to download material at 512Kbps or more, which judging by BT's Openworld data seems to be good for adding a streaming video content to your Internet experience and not much more: in reality, rare is the time most people need massive bandwidth to download huge multi-megabyte files. BT Openworld supports most Internet protocols but there are exceptions, including H.323-based applications, Microsoft Netmeeting and ICQ. It's time to fire up the modem again.

Not everyone will be able to receive ADSL due to their location or availability from the local exchange, and most people will not want to pay £39.99 per month ($58) and £150 ($217) installation for it either. Reader Per Gradal in Sweden tells me that ADSL provided via Telia costs SKr. 200 per month (say £15 or $22) and SKr. 1200 (£90 or $130) installation, with unlimited download, and you can quit within a month. BT ADSL easily costs more than double this. The Swedish Government, Per says, hopes to give the entire population broadband access before 2004.

V.92 Modems

One advantage of ISDN2e is the near immediacy of connecting to the Internet, typically within four seconds or so. Coupled with the provision of two digital and two analogue ports (use any two at a time) and the faster download speeds, ISDN2e starts to sound more appealing.

If, like myself, you waste a total of three hours a month waiting for your modem to connect, and you are teetering on the brink of installing ISDN, then just when you think there is no life after V.90 (56K) modems, along comes another standard to give you hope. The new V.92 modem standard agreed by the ITU in July 2000 doesn't increase the download speed beyond the existing 56K (V.90) rate, but it does increase the **upload** rate to the Internet from 33·6Kbps to about 48Kbps maximum.

More importantly (for me, anyway), V.92 promises to vastly reduce the negotiation time needed when connecting to the Internet – as little as ten seconds – and ISPs will benefit from freeing up the bandwidth to the modem racks.

What will be the best news of all for many users, V.92 also offers a new feature dubbed "modem on hold". If your modem is on-line and that same telephone line should happen to receive an incoming phone call, then instead of the modem causing an engaged tone, it will put the Internet call on hold for a period determined by the ISP, and allow the incoming call to be handled by the user.

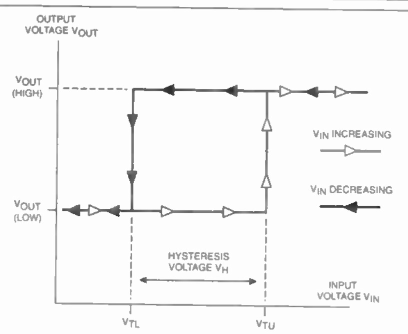
Modem software may possibly issue a warning when the time-out period is approaching, but even if you lose the call, you benefit from fast re-dial periods afterwards. V.92 could be a genuine money-saver: some consumers may be able to cancel Call Waiting service costs on that line, or even cancel the rental on a second line altogether.

Don't get too excited just yet though. As always, the improved standard depends on ISPs updating their modem racks and software. Watch out for a whole slew of new V.92 modems appearing by the end of the year, and also be sure to check modem web sites to see whether your flash-upgradeable modem can be upgraded. The telephone line and analogue modem will be with us for many years to come yet.

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

Special Series

THE SCHMITT TRIGGER



ANTHONY H. SMITH

Part 1

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

Discrete Schmitt triggers based on bipolar transistors

IN 1938, the *Journal of Scientific Instruments* published details of a comparator circuit that converted a slowly varying input signal into an abrupt change in output voltage. Based on cross-coupled thermionic valves, the circuit was developed by one O. H. Schmitt, and since then the term ***"Schmitt trigger"*** has been used to describe a particular type of circuit in which *positive feedback* is used to enhance the switching action of a comparator.

In this series of articles, we'll investigate the Schmitt trigger's operation, and examine different ways of implementing the function using transistors, operational amplifiers (op.amps) and digital gates. Also, we will look at ways in which the circuit can be improved and adapted to create other functions such as oscillators and pulse width modulators.

Thresholds and Hysteresis

Essentially, the Schmitt trigger can be considered as a voltage comparator with two distinct thresholds, an "upper" threshold and a "lower" threshold, where the value of each threshold is determined by positive feedback from the output. The voltage difference between thresholds is termed the ***"hysteresis"***. (See panel *What is Hysteresis?*).

A simple differential amplifier consisting of bipolar transistors TR1 and TR2 connected as a "long-tailed pair', where the emitter resistor R2, common to both devices, forms the "tail", is shown in Fig.1.1. For the moment, assume that resistor R4 is disconnected from TR1's collector (c) and instead is connected to the positive supply rail, V_{CC}, such that TR2's base (b) is held at a constant voltage, V_{B2}, determined by the potential divider effect of resistors R4 and R5.

If TR1's base voltage, V_{B1}, is lower than V_{B2}, TR1 will be "off" and TR2 will be conducting, such that the emitter potential, V_E, common to both transistors, will equal $V_{B2} - V_{BE2}$, where V_{BE2} is the base-emitter potential of TR2. Since TR1 is "off', no current flows through resistor R1, and TR1's collector voltage, V_{C1}, equals V_{CC}. However, since transistor TR2 is conducting, its collector current, I_{C2}, will cause a voltage drop across resistor R3 such that its collector potential, V_{C2}, will be lower than V_{CC}. The actual value of V_{C2} will depend on the relative values of resistors R2 and R3, and on TR2's base voltage, V_{B2}.

If we now increase V_{B1} by applying a linearly increasing input voltage, V_{IN}, the point will come where V_{B1} equals V_{B2}: this is shown in the graph of Fig.1.2a. If the transistors are matched (i.e., if they have identical characteristics), the base-emitter junction of TR1 will now be sufficiently forward biased to enable it to conduct, and its collector potential will fall due to current I_{C1} now flowing through resistor R1.

Further small increases in V_{B1} cause corresponding increases in the emitter potential, V_E, and, since V_{B2} is fixed at a constant level, V_{BE2} starts to decrease and TR2 turns "off'. Transistor TR1 is now responsible for all the emitter current, I_E, flowing in resistor R2, and since TR2's collector current is zero there is no voltage drop across resistor R3 and V_{C2} rises to V_{CC}. Note how V_{B2} effectively forms a reference level, or threshold: once V_{B1} crosses this threshold, the circuit "changes state" as shown by the transition in V_{C2}. The circuit behaves as a *comparator*, where V_{B1} is "compared" to the V_{B2} reference level.

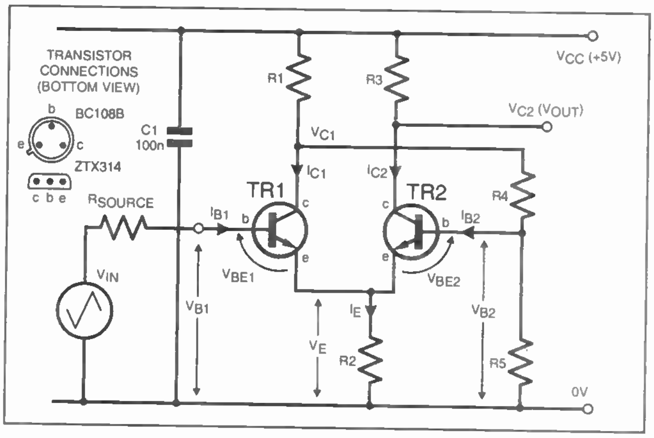


Fig.1.1. Simple two-transistor Schmitt trigger circuit based on a differential "long-tailed" pair set-up.

An ideal case where V_{B1} is completely free of any "noise', such that V_{C2} makes a clean transition as transistors TR1 and TR2 turn on and off, respectively is shown in Fig.1.2a. In practice, however, all real-world signals are "corrupted" by some degree of noise as shown in Fig.1.2b, where the noise on TR1's base voltage causes the signal to cross the V_{B2} threshold not once, but *three* times, resulting in an unwanted "pulse" in TR2's collector signal. If the comparator were being used as the input stage of, say, a digital counter, each of these pulses would result in an extra "count" – clearly an erroneous and unacceptable condition.

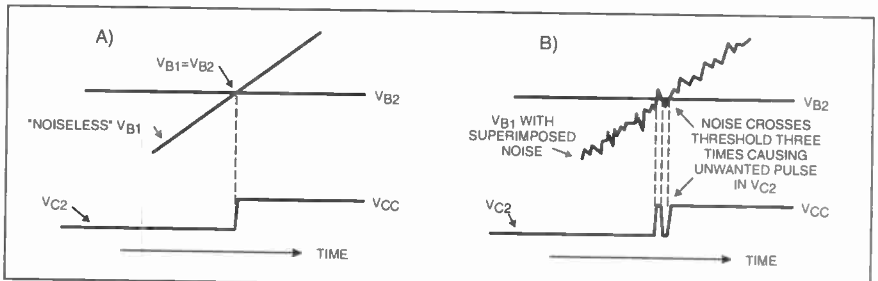


Fig.1.2. The performance of a simple comparator is degraded by noise.

Positive Thinking

How, then, do we eliminate the effects of noise? One solution is to remove, or filter out, the noise before it reaches transistor TR1's base. However, if the noise content is relatively large, or if it is similar in frequency to the wanted signal, the degree of filtering required may be impractical. Furthermore, all filters introduce a "phase delay" to the signal which may be unacceptable in certain applications. The solution is to introduce a specific amount of *positive feedback*.

Let us now disconnect resistor R4 from V_{CC} and reconnect it to TR1's collector as shown in Fig.1.1. If we assume that V_{B1} is small such that TR1 is off, TR2's base potential, V_{B2} will be set by the potential divider formed by resistors R1, R4 and R5. Since TR1 is off, I_{C1} is zero and has no effect on V_{B2}.

As the input voltage V_{IN} increases, we arrive at the point where V_{B1} just exceeds V_{B2} and, as before, transistor TR1 now starts to conduct, and as its collector voltage starts to fall it "pulls down" V_{B2} to a lower level. This, in turn, lowers the common emitter potential, V_L, which increases TR1's base-emitter potential, V_{BE1}, and causes it to conduct even harder.

This *regenerative* process has two beneficial effects. First, it causes the transistors to switch on and off much more rapidly than for the case of the simple comparator. Second, it imparts a significant amount of *noise immunity* to the comparator action.

This can be seen in the graph of Fig.1.6, where V_{B2} is initially at its higher level, denoted V_{TU} for "upper threshold". When V_{B1} crosses this threshold, transistor TR1 turns on and, if resistor R1 is several times larger than R2, TR1 will saturate causing V_{B2} to fall to a lower, constant level denoted V_{TL} for "lower threshold".

The difference between V_{TU} and V_{TL} is the *hysteresis voltage*, V_H. Provided V_H is large enough, the noise superimposed on V_{B1}

WHAT IS HYSTERESIS?

Whilst using a garden tap the other day, it was noticed that it needed quite a few turns before the water started to flow. However, in order to stop the flow, at least four clockwise turns were needed before the water stopped. The difference between "flow" and "no flow" – in this case four turns – is an example of ***hysteresis***.

In this example, the hysteresis served no useful purpose, but in other "on-off" control applications, hysteresis is essential to avoid the over-frequent cycling of pumps, motors, heaters, and so on. Perhaps the most obvious example is the thermostatic control used in domestic central heating systems.

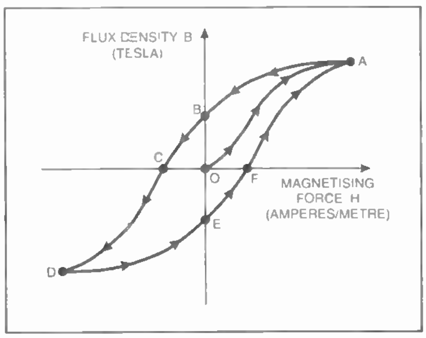


Fig.1.3. Typical BH-curve for mild steel.

If the room thermostat is set to, say, 20°C, the heating will remain on until the room temperature rises to around 22°C where it turns off. However, if the room temperature falls a fraction of a degree below 22°C, the heating does not come back on again but remains off until the temperature drops to 20°C.

The difference, or hysteresis, of 2°C provides a "time lag" during which the room gradually heats up and cools down. Without the hysteresis, the heating would continually cycle on and off as the temperature varied a fraction below and above the set point.

Hysteresis is also found naturally, a good example being the so-called "BH curve" of a magnetic material, which defines the relationship between the Magnetising Force, H, applied to the material and the resulting Flux Density, B.

A typical BH curve for mild steel is shown in Fig.1.3. Gradually increasing the magnetising force from zero causes the curve to move up the path from O to A, at which point the flux density reaches a maximum. If the magnetising force is now reduced to zero, the curve does not retrace its original path, but instead moves from A to B, where the material exhibits a non-zero, "residual" flux density. In order to reduce the flux density to zero, the magnetising force must be decreased to a negative value at point C.

Any further negative excursions of H cause the curve to follow the path from C to D, but if the magnetising force is now returned to zero the curve follows path D to E where the material displays a negative residual flux density. An increase in magnetising force then causes the curve to follow path E to F and then F to A.

The resulting symmetrical curve shows how the flux density always "lags behind" the magnetising force: the Collins *English Dictionary* defines hysteresis as "the time lag of magnetism behind the magnetising force", where hysteresis is derived from the Greek word *hysterein* meaning "to lag behind".

Schmitt trigger circuits like the ones described in this article also exhibit hysteresis, but this time the relationship is between input voltage and output voltage. Fig.1.4 shows the hysteresis curve for the *non-inverting* Schmitt triggers of Fig.1.1 and Fig.1.10. Initially, when input V_{IN} is a minimum, the output voltage is at its minimum level, $V_{OUT(LOW)}$, and remains there until V_{IN} has increased to the upper threshold voltage, V_{TU}, at which point V_{OUT} makes a rapid transition to its maximum level, $V_{OUT(HIGH)}$. Any further increase in V_{IN} has no effect on V_{OUT}.

As V_{IN} is reduced, V_{OUT} remains at its maximum level until V_{IN} falls to the lower threshold voltage, V_{TL}, where V_{OUT} rapidly falls back to its minimum level, $V_{OUT(LOW)}$. The "width" of the loop is the hysteresis voltage, V_H, which is simply the difference between V_{TU} and V_{TL}, that is:

$V_H = V_{TU} - V_{TL}$. Notice how the curve follows an "anti-clockwise" path around the loop.

An example of a "clockwise" hysteresis loop is shown in Fig.1.5 which represents the input-output relationship for *inverting* Schmitt triggers like those shown in Fig.1.13 and Fig.1.14. The only difference between this curve and that of Fig.1.4 is that the output voltage is initially at its maximum level and remains there until V_{IN} exceeds the upper threshold voltage, V_{TU}.

The hysteresis inherent in the Schmitt trigger is its most powerful attribute and results in a high degree of noise immunity, an essential feature for circuits like zero-crossing detectors working on noisy mains-derived signals. However, as we shall see later in this series, the Schmitt trigger's versatility lends it to many other applications.

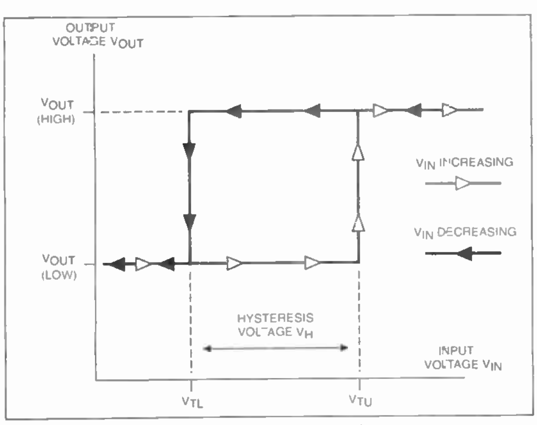


Fig.1.4. Input/Output relationship for the non-inverting Schmitt trigger.

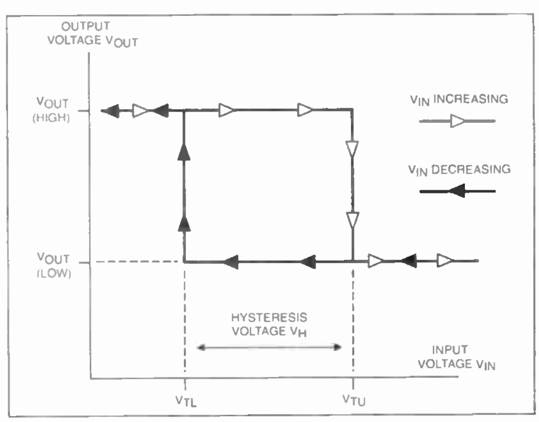


Fig.1.5. Input/Output relationship for the inverting Schmitt trigger.

has no effect on the switching function: V_{C2} changes state only once as V_{B1} crosses the upper threshold and does not change state again until V_{B1} has fallen low enough to cross the lower threshold.

The introduction of positive feedback converts the simple comparator into a Schmitt trigger. This is an important concept which can be restated as follows. Negative feedback tends to keep an amplifier within its *linear* region; positive feedback tends to force it into *saturation*.

The Schmitt trigger is a *bistable* device, i.e., it has two stable states and can remain in either state indefinitely until the input signal crosses a threshold and changes the state. In this respect, it behaves as a memory element, and with a little modification, the two-transistor version shown in Fig.1.1 can form a logic-level bistable device, similar to the type used as a single-bit memory element in early computer systems.

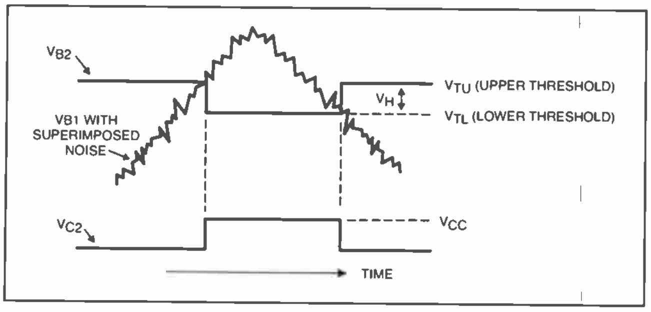


Fig.1.6. Adding hysteresis to a comparator eliminates the effect of noise.

Determining Thresholds

For the single-rail Schmitt trigger of Fig.1.1, the thresholds are defined by the following equations:

Lower threshold voltage,

$$V_{TL} = \frac{R5 \times ((R2 \times V_{CC}) + (R1 \times V_{BE2}))}{(R1 \times R5) + (R2 \times (R1 + R4 + R5))} \quad \text{(volts)}$$

where V_{BE2} is the forward-biased base-emitter voltage of TR2.

Upper threshold voltage,

$$V_{TU} = \frac{R5 \times ((R2 \times h_{FE2} \times V_{CC}) + ((R1 + R4) \times V_{BE2}))}{(R2 \times h_{FE2}) \times (R1 + R4 + R5) + (R5 \times (R1 + R4))} \quad \text{(volts)}$$

Fortunately, these somewhat unwieldy expressions can be simplified. For example, if we make R1 = R2, the expression for V_{TL} becomes:

Lower threshold voltage,

$$V_{TL} = \frac{R5 \times (V_{CC} + V_{BE2})}{R1 + R4 + (2 \times R5)} \quad \text{(volts)}$$

Also, if we assume that h_{FE2}, the common-emitter current gain of TR2, is large (in the order of 100 or more), and if R2 and R5 are similar in magnitude, the expression for V_{TU} reduces to:

Upper threshold voltage,

$$V_{TU} = \frac{R5 \times V_{CC}}{R1 + R4 + R5} \quad \text{(volts)}$$

Clearly, the accuracy and stability of each threshold will depend on the tolerance and stability of the resistors used, and also on the supply voltage, V_{CC}. For example, it is not uncommon for a "regulated" +5V supply to vary by as much as ±5% from its nominal value, and since each threshold is directly proportional to V_{CC} they, too, will vary by this amount. Furthermore, V_{TL} is also dependent on V_{BE2}, which may vary considerably with factors such as base current, collector-emitter voltage, temperature, etc.

To check the accuracy of the expressions for V_{TL} and V_{TU}, the circuit was built using 10kΩ (ten kilohms) resistors for R1, R2, R3 and R4, and 20kΩ for R5. Also, V_{CC} was set to precisely 5·00V, and a value of 520mV was used for V_{BE2} (determined by in-circuit measurements). Transistor type BC108B was chosen for TR1 and TR2, although any other *npn* with an h_{FE} of at least 100 would suffice. The simple equations yield values of V_{TL} = 1·84V and V_{TU} = 2·5V.

To test the circuit, a 500Hz triangle wave input voltage, set to swing from 0·5V to 4·5V was used; the source resistance, R_{SOURCE}, was zero. A triangle wave is the ideal input signal shape for testing Schmitt triggers: by observing the triangle at the base of transistor TR1 on a carefully zeroed oscilloscope trace and by overlapping the output waveform (in this case, V_{C2}) using a second trace, the points at which the output signal's transitions cut the triangle wave indicate the precise values of the thresholds. In this case, they measured V_{TL} = 1·90V and V_{TU} = 2·35V; reasonably close to the design values stated.

Speed and Frequency Response

So far, we've only considered the low-frequency response of the Schmitt trigger; the high-frequency response is limited primarily by the transistors, which take a finite time to turn on and off. These switching times are influenced by internal junction capacitances, which must be charged and discharged every time the device makes a transition from non-conducting to conducting, and back again.

A thorough analysis of the switching behaviour of bipolar transistors is beyond the scope of this article; a good rule of thumb, however, is that the more current there is available to charge and discharge the internal capacitances, the faster the transistor can switch. Therefore, achieving good high-frequency response in *all* transistor circuits, whether discrete or integrated, tends to require the use of relatively low impedances (this is why the current consumption of high-frequency devices such as wideband op.amps is usually much greater than that of their low-frequency counterparts).

To illustrate the effect of impedance levels on switching speed, two versions of the circuit of Fig.1.1 were built, each using BC108B transistors, but with different resistor values. For the first circuit, large values were selected: R1, R2, R3 and R4 = 100kΩ and R5 = 200kΩ; for the second, using the same *ratio* of resistances, but a hundred times smaller: R1, R2, R3 and R4 = 1kΩ and R5 = 2kΩ. An 80kHz triangle wave was fed to the input of each Schmitt trigger and the output waveform at the collector of TR2 was observed.

The resulting waveforms shown in the oscillograph of Fig.1.7 illustrate the dramatic performance difference between the two circuits. The middle trace is the output waveform of the circuit using high resistances: clearly, the collector signal is grossly distorted. The bottom waveform, on the other hand, is the collector signal of the circuit using low resistances: note how the rectangular waveshape is well-formed and makes rapid transitions (less than 200ns) from one state to the other.

Fast Devices

At very high frequencies, general purpose transistors like the BC108B are often inadequate for fast switching, even when low resistances are used in the circuit. It then becomes necessary to use special transistors, specifically designed for fast-switching applications.

To demonstrate the improvements in switching speed available from these fast devices, two further versions of the Schmitt trigger of Fig.1.1 were built. Each used the same low resistance values (R1, R2, R3 and R4 = 1kΩ and R5 = 2kΩ), but one was built using BC108B transistors, the other using Zetex ZTX314 high-speed switching transistors.

The response of each circuit to a 1MHz triangle wave input is shown in Fig.1.8. The middle trace shows the response of the BC108B circuit, where TR2's collector waveform starts to rise about 40ns after V_{IN} has crossed the 2·5V upper threshold. The performance of the ZTX314 circuit is shown in the lower trace, where the ZTX314 starts to turn off almost at the instant V_{IN} crosses the upper threshold, and its collector voltage has reached its high level (V_{CC}) some 40ns before the BC108B.

The major difference, however, is in the transistors' turn-on time. In the lower trace, the ZTX314 begins to turn on almost as soon as V_{IN} has crossed the lower threshold, whereas the BC108B takes around 200ns before it begins to conduct sufficiently for the collector waveform to fall from V_{CC} to its low level. Not only do these switching delays limit the maximum frequency response of the BC108B circuit, they also cause a shift in the effective threshold values.

Looking again at the middle trace, TR2's high to low transition occurs when V_{IN} has reached a minimum, such that the effective lower threshold is zero. The ZTX314, on the other hand, makes the transition when V_{IN} is very close to the nominal lower threshold value of 1·84V.

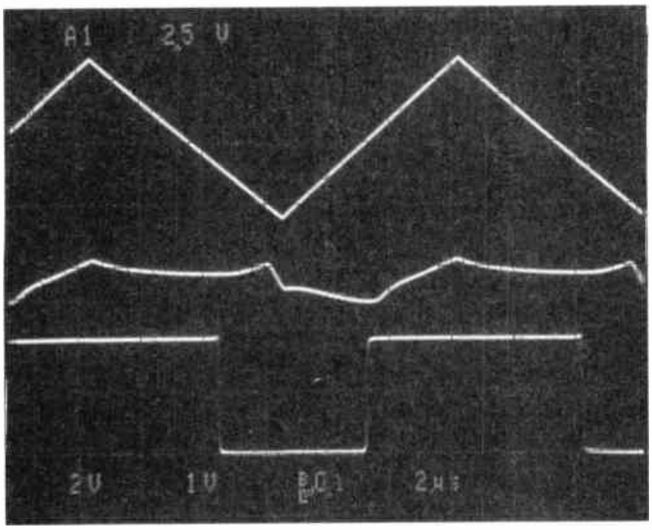


Fig.1.7. Resistor values have a marked effect on high-frequency performance. Top trace: V_{IN} (2V/div.). Middle trace: Output waveform using high resistance values (1V/div.). Bottom trace: Output waveform using low resistance values (1V/div.). Timebase: 2μs/div.

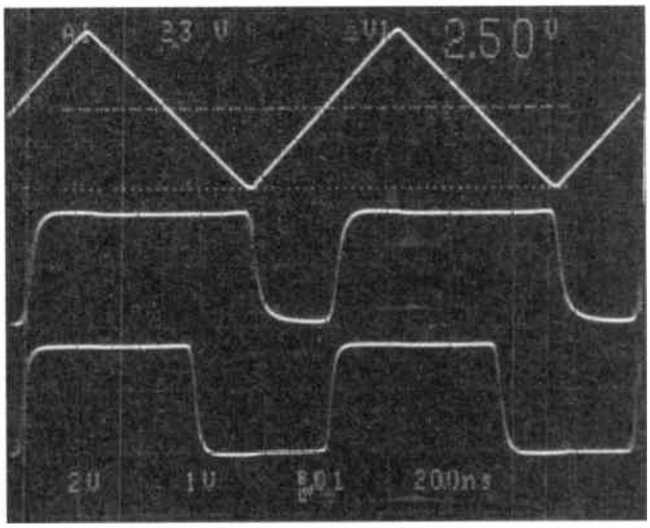


Fig.1.8. Fast-switching transistors provide improved high-frequency performance. Top trace: V_{IN} (2V/div.). Middle trace: Output waveform using BC108B devices (1V/div.). Bottom trace: Output waveform using ZTX314 devices (1V/div.). Timebase: 200ns/div.

There are, however, disadvantages to using high speed devices like the ZTX314. One is price: the ZTX314 tends to cost a few pence more than the BC108B. Also, the process of tailoring a transistor for high speed applications may require other parameters to be sacrificed: for example, the h_{FE} of the BC108B is in the region 200 to 450; that of the ZTX314, on the other hand, is only 30 to 120.

Input Impedance

The inputs to most active devices like amplifiers, comparators, ADCs, and so on, can be modelled by the circuit of Fig.1.9, where R_{SOURCE} represents the internal resistance (sometimes termed "output resistance') of the voltage source, and V_T represents the *terminal* voltage appearing at the output of the voltage source. (For the case of the Schmitt trigger in Fig.1.1, V_T would equal V_{B1}). R_{IN} and C_{IN} represent the resistance and capacitance seen "looking into" the input terminals of the circuit or device, and I_B represents a bias current which may flow into or out of the circuit.

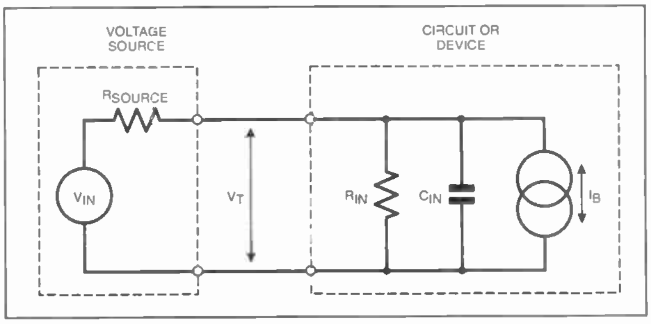


Fig.1.9. Simple model for input parameters of circuit or device.

For the circuit of Fig.1.1 operating at low frequencies, we are primarily concerned with I_{B1}, the base current flowing into transistor TR1, although at higher frequencies the effects of C_{IN} (TR1's base capacitance plus any stray capacitances) must also be considered.

The effect of I_{B1} is to cause a voltage drop across R_{SOURCE} making the voltage at TR1's base less than the input voltage V_{IN}. This has the effect of increasing the *apparent* threshold voltages: although the *actual* thresholds measured at TR1's base remain fixed, the voltage drop across R_{SOURCE} means that V_{IN} has to rise to a higher voltage in order for V_{B1} to cross the thresholds.

For example, with resistors R1 to R4 = 1kΩ, R5 = 2kΩ, and using BC108Bs, it was found that increasing R_{SOURCE} from zero to 100kΩ caused the apparent values of V_{TU} and V_{TL} to increase by 260mV and 700mV, respectively, relative to their nominal values.

We'll examine the effects of input impedance in more detail later in this series, when we look at Schmitt triggers based on op.amps, comparators and digital gates.

Four Better Than Two

The two-transistor Schmitt trigger circuit of Fig.1.1 is simple, inexpensive, and can be very effective in undemanding applications such as "squaring up" a sinewave or removing interference from a noisy signal. However, it does have two significant disadvantages.

First, referring to the equations for V_{TU} and V_{TL}, we see that the thresholds are highly interdependent: changing any resistor value to vary one threshold will also vary the other. Therefore, selecting appropriate values to define specific thresholds can be extremely difficult.

The second disadvantage is that the output signal at TR2's collector has a limited output swing. Referring to the bottom trace of Fig.1.7, we see that the output signal amplitude is less than 2V; whilst this may be adequate for certain applications, it would hardly be sufficient to satisfy the logic levels of a digital gate operating on the same 5V supply.

Both of these disadvantages can be eliminated by introducing two more transistors as shown in the circuit diagram Fig.1.10, where positive feedback is again applied to the base of TR2, but this time via TR3 and TR4. (Note transistor TR4 is a *pnp* type.) The circuit works as follows.

Assume V_{B1} is zero such that transistor TR1 is off and provides no base current for TR4. Since TR4 is off, TR3 also receives no base drive and it, too, is off. Consequently, resistors R3, R4 and R5 form a potential divider which sets TR2's base voltage (V_{B2}) to a fraction of the supply voltage; if we assume TR1 and TR2 are matched, the value of V_{B2} equals the upper threshold voltage, V_{TU}. If resistor R2 is similar in magnitude to R3, R4 and R5, and if TR2's h_{FE} is large, the upper threshold is given by:

Upper threshold voltage,

$$V_{TU} = \frac{(R4 + R5) \times V_{CC}}{R3 + R4 + R5} \quad \text{(volts)}$$

When V_{B1} exceeds V_{TU}, transistor TR1 begins to conduct and biases TR4 on, which in turn provides base drive for TR3. Provided resistors R6 and R7 are correctly sized, TR3 will be biased fully on and, if we assume its collector-emitter saturation voltage $V_{CE3(sat)}$ is zero, R5 is effectively shorted out. The effect is to "pull down" TR2's base, which in turn reduces the emitter voltage V_E causing TR1 to turn on even harder.

On Balance

Again, we have a regenerative action which causes TR1 and TR2 to change state rapidly. TR2's lower base voltage now constitutes the lower threshold voltage:

Lower threshold voltage,

$$V_{TL} = \frac{R4 \times V_{CC}}{R3 + R4} \quad \text{(volts)}$$

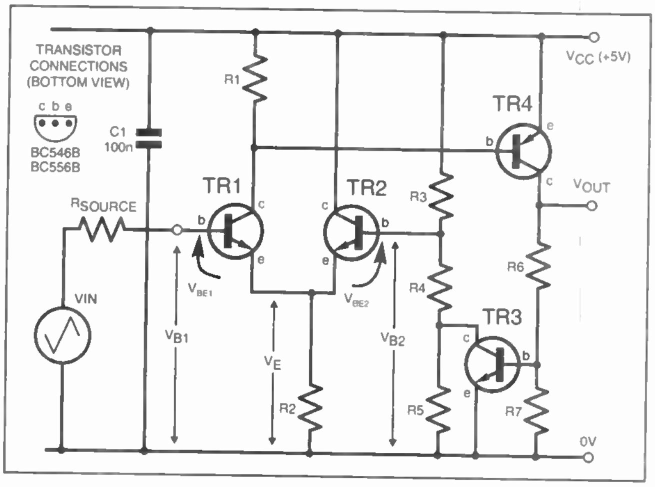


Fig.1.10. A four-transistor Schmitt trigger offers improved performance. Note: Here transistors TR1 to TR3 are BC546s and TR4 is a BC556.

Note that this equation does not contain R5, thus allowing V_{TU} to be set independently of V_{TL}. For given values of V_{CC} and V_{TL}, R3 and R4 can be found from:

$$R3 = \frac{R4 \times (V_{CC} - V_{TL})}{V_{TL}} \quad \text{(ohms)}$$

Knowing V_{TU}, it is then a simple matter to calculate R5:

$$R5 = \frac{V_{TU} \times (R3 + R4) - (V_{CC} \times R4)}{V_{CC} - V_{TU}} \quad \text{(ohms)}$$

In practice, the thresholds are affected slightly by the values of resistors R1 and R2, and, to some extent, by R6 and R7. For fast response, R6 and R7 must be fairly small (a few kilohms) to ensure transistor TR3 can be turned on and off quickly.

However, the resulting current required from TR4's collector places demands on TR1's collector current which must supply TR4's base drive. Consequently, resistor R1 should be fairly large such that all of TR1's collector current is available to TR4's base; however, for fast response, R1 should be small enough to "suck" stored charge out of TR4's base region, such that it turns off quickly.

The current available to TR4's base also depends on resistor R2, which sets an upper limit on TR1's collector current. For a given V_{TU}, making R2 small will maximise TR1's collector current; however, if R2 is too small, the increased base current taken by TR2 (when V_{B1} is below V_{TU}) tends to "load" the R3-R4-R5 network, causing V_{TU} to be lower than the value predicted by the equation above.

All these conflicting requirements demand a careful balance of resistor values for proper operation. Generally, if all the resistors are of similar magnitude, and if V_{TU} and V_{TL} are set within the range 1·25V to 4V (assuming V_{CC} = 5V), the actual thresholds will be fairly close to their nominal values.

Note that the output is taken from transistor TR4's collector rather than TR2 (TR2's collector resistor is no longer required). When the input voltage rises above V_{TU}, the voltage output V_{OUT} rises to V_{CC} as TR4 turns on; when V_{IN} falls below V_{TL}, the output is pulled down toward 0V by resistors R6 and R7. Thus, like the simple two-transistor Schmitt trigger, the output is "in phase" with the input, but with a much greater swing, typically 0 to 5V when the output is lightly loaded.

Input Signal Range

Transistor TR1's base voltage should not be allowed to go too far negative, otherwise its base-emitter junction could break down. Devices like the BC108B and BC546B have a maximum reverse-biased base-emitter voltage of around 5V; if this is exceeded, the junction can "avalanche" and conduct excessive current. Thus, if V_{TL} is set to, say, 2·5V such that the emitter potential is around 2V, V_{B1} should not be permitted to go more negative than –3V.

So far, we've been working with a supply voltage of 5V, but there's no reason why this should not be increased, provided the resistors are rated accordingly and the maximum collector-emitter voltage, $V_{CEO(max)}$, of the transistors is not exceeded. For transistors like the BC546 and BC556 (see below), $V_{CEO(max)}$ is around 60V; however, for the BC108 it is only 25V, and for devices like the ZTX314 it can be as low as 15V, so it is necessary to limit V_{CC} accordingly.

When V_{B1} exceeds V_{TU} and transistor TR1 turns on, its collector voltage is effectively clamped at one diode-drop below V_{CC} by TR4's base-emitter junction. However, as TR1's base voltage rises so, too, does its emitter voltage. Eventually, when V_{B1} is roughly equal to V_{CC}, TR1 saturates, and any further increase in V_{B1} causes the voltage across resistor R1 to decrease below the diode-drop needed to bias TR4 on.

The result is that TR4 switches off, and V_{OUT} makes a sudden transition from V_{CC} to 0V. Thus, for correct operation, input V_{IN} should not be permitted to rise to within, say, half a volt of V_{CC}.

Actual Performance

To check the circuit performance of Fig.1.10, BC546B *npn* transistors were used for TR1 to TR3, and a BC556B *pnp* for TR4 (these are general purpose, medium-gain devices). With V_{CC} = 5·00V and R6 = 3·3kΩ and R7 = 1·5kΩ, values of 1kΩ for R1, R2; 2kΩ for R3; 510Ω for R4 and 7·5kΩ for R5 were chosen to provide nominal thresholds of V_{TL} = 1·02V and V_{TU} = 4·00V.

By inputting a 150Hz triangle wave (R_{SOURCE} = 0), the actual thresholds were measured as V_{TL} = 1·30V and V_{TU} = 3·98V. Although the upper threshold was almost "spot on", V_{TL} was about 0·3V higher than its design value. Why?

When transistor TR1 is on, its collector current is roughly equal to its emitter current. Therefore, since the value of R1 is the same as R2 in this example, the voltage across each resistor will be the same. To keep transistor TR4 fully on, we need at least 0·65V across R1 – and, hence, across R2 – to provide sufficient voltage to forward bias TR4's base-emitter junction.

Now, the voltage across R2, $V_E = V_{B1} - V_{BE1}$, so if we take V_{BE1} = 0·65V, it follows that V_E will drop below 0·65V when V_{B1} falls below 1·3V. Thus, TR4 starts to turn off when input V_{IN} falls to 1·3V, resulting in V_{TL} being 300mV higher than its design value.

The simple solution to this problem is to increase the value of R1 to make more voltage available to TR4's base when V_E is low. With R1 increased to 10kΩ, V_{TL} measured 1·02V – exactly equal to the design value!

Want More Speed? Get Clamped!

Like the two-transistor Schmitt, the resistance values of the four-transistor version should be kept low for good high-frequency response. However, this alone is sometimes not enough.

When a bipolar transistor saturates (i.e., when $V_{CE} \approx 0$), an excess of minority charge carriers gets stored in the base region. Therefore, to ensure the transistor can turn off quickly requires either that it is not allowed to saturate, or that the stored charge must be removed rapidly from the base. For the Schmitt trigger, failure to ensure rapid transistor turn off can cause significant errors in the apparent threshold values at high frequencies.

For example, values of 1kΩ for R1, R2, R4 and R5, and 2kΩ for R3 were chosen to give nominal threshold values of V_{TL} = 1·67V, V_{TU} = 2·5V at V_{CC} = 5·00V. With resistor R6 set to 2·2kΩ and 22kΩ selected for R7, the actual low-frequency thresholds (measured at 150Hz) were 1·72V (V_{TL}) and 2·48V (V_{TU}), and the corresponding voltage levels at TR2's base were 1·70V and 2.48V. So far, so good.

However, with the input frequency increased to 150kHz, the thresholds had merged into one, and TR2's base voltage was a *constant* 1·70V, even though TR4 was switching on and off. Closer inspection revealed that transistor TR3 had turned on, but could not turn off because resistor R7 was too large to provide the low-resistance path necessary to remove the charge stored in its base region.

Reducing the value of resistor R7 to 470 ohms corrected the problem, allowing TR3 to turn off properly: TR2's base voltages were now 1·70V and 2·50V, roughly the same as the low-frequency values. However, the actual thresholds were now 1·24V (V_{TL}) and 2·58V (V_{TU}). Clearly, TR1 and TR4 were switching on quickly, such that V_{TU} was roughly the same as its low-frequency value; however, TR4 was switching off relatively slowly, resulting in the effective value of V_{TL} being significantly less than its low-frequency value (1·72V).

Reducing R1 to 680 ohms helped to turn off TR4 more quickly by removing more of the stored charge from its saturated base. However, this measure only succeeded in raising V_{TL} to 1·37V, still some 300mV short of its design value.

Although changing transistor TR4 to a faster device would certainly help, an alternative solution is to *prevent* TR4 from saturating. This is achieved by adding two diodes, D1 and D2, as shown in the circuit diagram Fig.1.11. This arrangement, known as a "Baker Clamp", works as follows.

When transistor TR1 turns on, its collector is clamped at two diode drops below V_{CC} (there is one diode drop across TR4's base-emitter junction, and another across D1). Transistor TR4 now turns on and its collector rises toward V_{CC}, forward biasing diode D2.

Since D2 is the same diode type as D1, it will exhibit a similar voltage drop, such that its anode (a) will rise to the same potential as D1's anode. The result is that TR4's collector cannot rise any higher than its base, such that its collector-emitter voltage will be the same as its base-emitter voltage, preventing it from saturating.

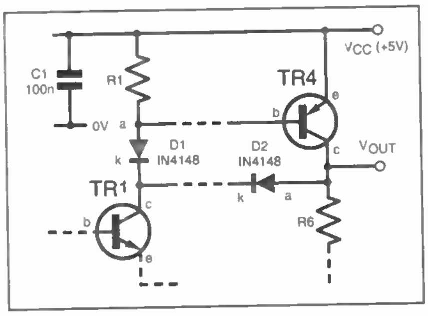


Fig.1.11. The addition of a "Baker Clamp" improves switching speed.

The waveforms shown in Fig.1.12 illustrate the performance of the Baker Clamp, where the upper trace is the input triangle wave at 150kHz. The bottom trace shows the output response *without* diodes D1 and D2; the middle trace shows V_{OUT} with D1 and D2 fitted as shown in Fig.1.11.

Notice how the clamp makes TR4 turn off some 460ns more quickly than it does without the clamp. As a result, the high-frequency response was much improved: with the clamp in place, V_{TL} was 1·64V, almost equal to its ideal, design value (1·67V). Also, notice that the amplitude of the middle trace is only about 4·4V; the presence of the clamp means that V_{OUT} can only swing from 0V to one diode drop below V_{CC}.

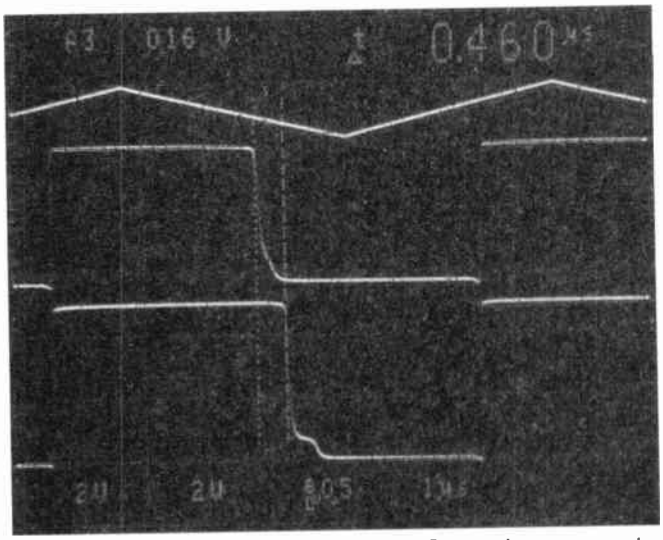


Fig.1.12. Waveforms showing Baker Clamp improvements. Top trace: V_{IN} (5V/div.). Middle trace: Output waveform with Baker Clamp fitted (2V/div.). Bottom trace: Output waveform without Baker Clamp (2V/div.). Timebase: 1µs/div.

Complementary Schmitt

The differential pair common to both the two- and four-transistor Schmitt triggers is a powerful topology used extensively in many circuits, both discrete and integrated. However, before concluding our look at discrete circuits, it's worth considering two Schmitt triggers that use a *complementary* arrangement.

In the circuit diagram of Fig.1.13, complementary transistors TR1 and TR2 are both cut off when input V_{IN}, and hence V_{B1}, is zero. Under these conditions, TR2's base voltage is set by V_{CC} and the potential divider R1–R2–R3:

$$\text{TR2 base voltage, } V_{B2} = \frac{R3 \times V_{CC}}{R1 + R2 + R3} \quad \text{(volts)}$$

In order to forward bias TR1 and TR2, V_{B1} must rise to $V_{BE1} + V_{BE2} + V_{B2}$, so the upper threshold voltage relative to TR1's base is:

Upper threshold voltage,

$$V_{TU} = V_{BE1} + V_{BE2} + \frac{(R3 \times V_{CC})}{R1 + R2 + R3} \quad \text{(volts)}$$

When transistors TR1 and TR2 turn on, TR1's collector voltage falls to a lower value, thereby "pulling down" TR2's base; again, we see positive feedback causing a regenerative action which causes both devices to turn on harder. Assuming TR2's base current is negligibly small, its base voltage is now:

$$\text{TR2 base voltage, } V_{B2} = (V_{CE1} + V_{BE2}) \times \frac{R3}{R2} \quad \text{(volts)}$$

Transistor TR1 will turn off when V_{B1} falls below $V_{BE1} + V_{BE2} + V_{B2}$; therefore, assuming TR1 is saturated when "on", such that V_{CE1} (= $V_{CE1(sat)}$) is much less than V_{BE2}, the lower threshold relative to TR1's base is:

Lower threshold voltage,

$$V_{TL} = V_{BE1} + V_{BE2} \times (1 + R3/R2) \quad \text{(volts)}$$

Notice that this circuit is an "inverting" Schmitt trigger, in that the output voltage at TR1's collector *falls* when V_{IN} rises above V_{TU}. Although relatively simple, the circuit has several drawbacks; in particular, the thresholds are highly dependent on V_{BE1} and V_{BE2}, which change with temperature and exhibit part-to-part variations.

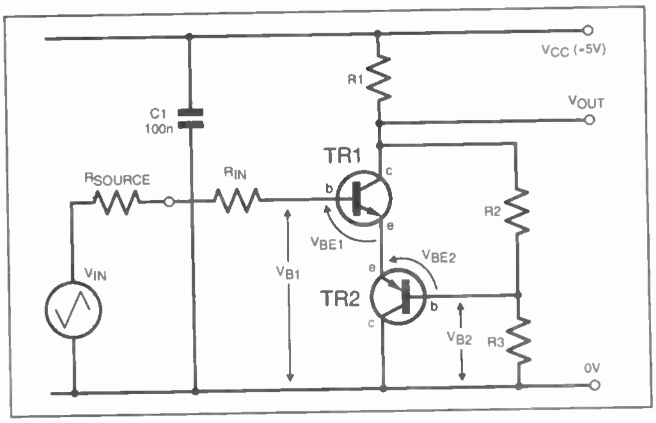


Fig.1.13. Circuit diagram for a Schmitt trigger using complementary transistors.

Also, V_{OUT} does not swing from 0V to V_{CC}, but covers only a fraction of this range and is influenced considerably by the values selected for the thresholds. A sufficiently large input resistance, R_{IN}, is required, otherwise, when TR1 turns on, its collector voltage gets "pulled up" as V_{IN} rises, thereby distorting the output signal (although R_{IN} may be omitted if R_{SOURCE} is large enough).

Variation on a Theme

A variation on the complementary theme is shown in the circuit diagram Fig.1.14. When V_{IN} is low, TR1 and TR2 are both off, and resistors R2 and R3 set TR1's base voltage to $V_{B1} = V_{CC} \times R3/(R2+R3)$. As V_{IN} rises and the voltage at TR1's emitter reaches $V_{B1}+V_{BE1}$, TR1 starts to conduct.

If both devices have large h_{FE}, we can ignore their base currents and assume that all of TR1's emitter current flows through resistor R1 to 0V. The voltage on R1 increases until it equals V_{BE2}, TR2's base-emitter forward-bias voltage.

Transistor TR2 now starts to conduct and provides more base current for TR1, which in turn provides more base drive for TR2 and the familiar regenerative process continues until both devices are fully on. TR1's base voltage, which is also the output voltage $V_{OUT(1)}$, falls from its initial value given above, to a very low value defined by TR2's saturation voltage, $V_{CE2(sat)}$.

The upper threshold voltage relative to V_{IN} is given by:

Upper threshold voltage,

$$V_{TU} = V_{B1} + V_{BE1} + \frac{(R_{SOURCE} + R_{IN}) \times V_{BE2}}{R1} \quad \text{(volts)}$$

and so:

$$V_{TU} = \frac{V_{CC} \times R3}{(R2 + R3)} + V_{BE1} + \frac{(R_{SOURCE} + R_{IN}) \times V_{BE2}}{R1} \quad \text{(volts)}$$

As V_{IN} falls, TR1 and TR2 will start to turn off when TR1's emitter voltage, V_{E1} falls below $V_{BE2} + V_{CE1(sat)}$ (assuming TR1 is saturated when conducting).

However, $V_{E1} = V_{IN} - I_{E1} \times (R_{SOURCE} + R_{IN})$, and since $I_{E1} \approx I_{C1} = V_{BE2}/R1$, the transistors will start to turn off when:

$$V_{IN} - \frac{(R_{SOURCE} + R_{IN}) \times V_{BE2}}{R1} = V_{BE2} + V_{CE1(sat)} \quad \text{(volts)}$$

Rearranging and putting $V_{IN} = V_{TL}$ gives:
Lower threshold voltage,

$$V_{TL} = V_{CE1(sat)} + V_{BE2} \times (1 + (R_{IN} + R_{SOURCE})/R1) \quad \text{(volts)}$$

Like the previous circuit, R_{IN} (required to limit the input current) can be omitted if R_{SOURCE} is large enough. Again, the thresholds are highly dependent on transistor parameters like V_{BE} and $V_{CE(sat)}$. Output voltage $V_{OUT(1)}$ swings from near zero to a high level defined by resistors R2 and R3; this limited range can be improved by adding resistor R4, transistor TR3 and R_L (R_L can be a simple pull-up resistor, or could be a load such as a relay or l.e.d.). The additional stage provides a second output voltage, $V_{OUT(2)}$, with a range of approximately zero to V_{CC}. Note, however, that R4 and TR3 must be considered in parallel with R3 when determining the threshold values; also, $V_{OUT(2)}$ is inverted with respect to $V_{OUT(1)}$.

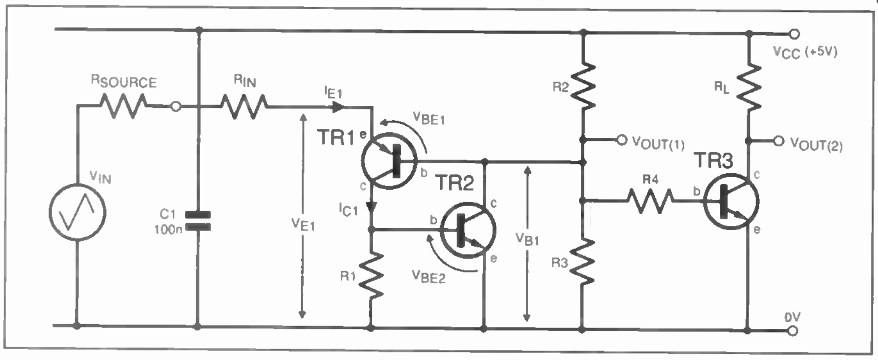


Fig.1.14. Alternative complementary-transistor Schmitt trigger circuit.

Looking Ahead

For non-demanding applications, the discrete Schmitt triggers we've examined can sometimes provide a simple, cheap solution. However, achieving a degree of precision demands careful attention to factors such as transistor matching, resistor values and biasing levels, particularly for high-frequency applications. Life would be much simpler if we could combine the differential pair with some extra gain stages and a wide-range output stage and enclose the whole lot inside a "black box".

Fortunately, devices like the operational amplifier (op.amp) and the comparator do just that. Next month, we shall see in Part Two how the op.amp frees us from most of the design work associated with discrete circuits, and instead allows us to focus on the Schmitt trigger as an interesting and versatile circuit "element".

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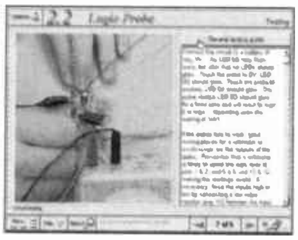

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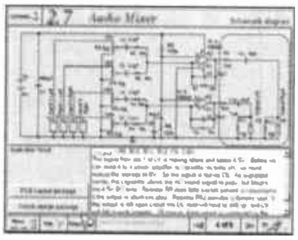

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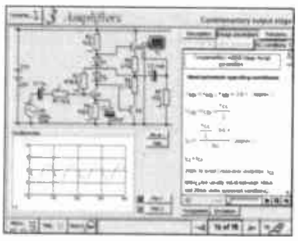

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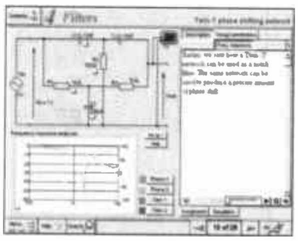

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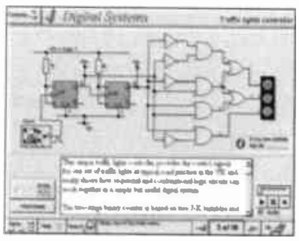

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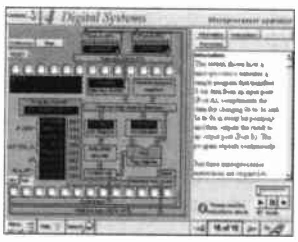

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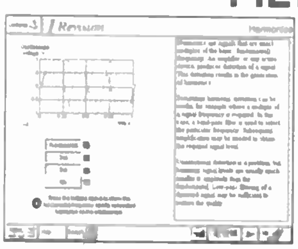

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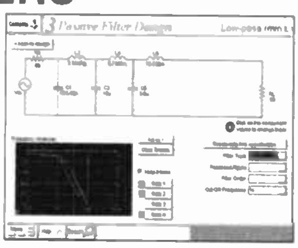

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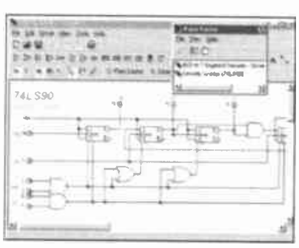

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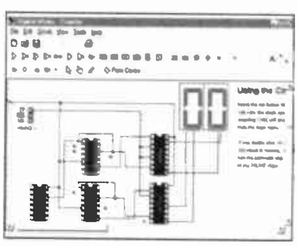

Counter project

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.

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Prices for each of the CD-ROMs above are:

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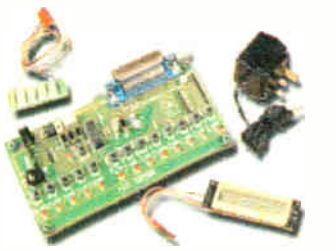
The Virtual PIC



Deluxe PICtutor Hardware

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

Nearly 40 Tutorials cover virtually every aspect of PIC programming in an easy to follow logical sequence.

HARDWARE

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

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

HARDWARE

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SHOP TALK
with David Barrington

PIC Pulsometer

The 40MHz crystal timing module used in the *PIC Pulsometer* project is a 4-pin device which plugs directly into an 8-pin d.i.l. socket. It is an RS type and was ordered through **Electromail** (☎ ***01536 304555*** or ***http://rswww.com***), their mail order outlet. They advertise two devices, codes 268-032 and 249-3779, and either will be OK in this circuit.

Regarding the 16-character 1-line, back-lit, l.c.d. module, this was obtained from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code NT55K. They also supplied the ABS, sloping front case, code LH63T.

For those readers unable to program their own PICs, a ready-programmed PIC16F84 can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £5.90 (overseas readers add £1 for p&p). For those who wish to program their own PICs, the software is available from the Editorial offices on a 3·5in. PC-compatible disk, see *PCB Service* page 868. It is also available *free* via the *EPE* website: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/pulsometer**.

Handclap Switch

One or two components may cause buying problems when shopping for parts for the *Handclap Switch* project. Fortunately, they appear to be fairly standard items and our component advertisers should be able to offer devices with almost identical characteristics.

The choice of a 12V relay will obviously depend on the appliance being "controlled" and the relay contacts must be rated accordingly. The one in the prototype was ordered from **Rapid Electronics** (☎ ***01206 751166***) and is a miniature 12V coil type, with 16A s.p.d.t. contacts, code 60-1015. We see that **Display Electronics** (☎ ***0208 653 3333***) say they have "200,000 from stock". Check their web at: **www.distel.co.uk**.

For the prototype, a 9V-0V-9V 100mA mains transformer, with "flying" leads, was chosen and also came from Rapid Electronics, code 888-0105. A higher current transformer may be used if preferred and your usual component supplier should be able to offer one at a reasonable price.

As far as miniature electret microphone inserts go, these are generally listed and carried by such advertisers as **ESR Components** (☎ ***0191 251 4363***), **Cricklewood** (☎ ***0181 452 0161***) and **Maplin** (☎ ***0870 264 6000***).

The small printed circuit board is available from the *EPE PCB Service*, code 270 (see page 868). Finally, please don't forget to uprate the mains carrying cables if you intend switching high current appliances.

Sample-and-Hold

Our latest "Top Tenner" project is a simple *Sample-and-Hold* add-on for your analogue/digital multimeter and most of the components should be readily available from our components advertisers.

The only exception is likely to be the DG419DJ TTL/CMOS compatible analogue switch chip. Any readers who do experience problems with this device, should note that it is currently listed by **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code AX47B and **Electromail** (☎ ***01536 304555*** or ***http://rswww.com***), code 656-574.

If you intend running from a 6V supply, you can use the CA3140 CMOS op.amp, however, as stated in the article, its output cannot swing fully to the positive supply rail; at 6V its output swings from 0V to +4V. If a wider swing is needed, try the CA3130. Alternatively, increase the power supply to 9V or 12V.

Opto-Alarm System

The neat looking case used in the Opto-Alarm System project came from the **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***) "waterproof box" range and is their medium size one, code YM91Y. They also supplied the multi-tone 12V main siren, code JH25C.

Most of our components advertisers should be able to provide the ubiquitous ORP12 light dependent resistor (l.d.r.) or its derivative. Depending on the characteristics of the l.d.r. purchased, you may need to adjust the value of resistor R5 as outlined in the article.

It may pay readers to shop around for the key-operated switch as prices seem to vary quite considerably.

PLEASE TAKE NOTE

PIC Dual-Chan Virtual Scope *Oct '00*

Since going to press with the *PIC Dual-Chan Virtual Scope*, the device specified for IC3, TC55257DPL (and its alternative TC55257DPI), has become obsolete.

The author has proved that the NEC device µPD43256BCZ-70LL is a satisfactory replacement and is available from Electromail (the mail order division of RS Components) as code 265-465.

Do *not* attempt to use any other variant of the TC55257 since it may have a different pin configuration.

Interface (Temperature PC Interface) *Oct '00*

All source code files (including "forms") are now available via our FTP site and on the newly introduced "Interface Disk 1", see page 868.

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PROJECTS • Flash Slave • Garage Link • Micro-PICscope • High Performance Regenerative Receiver–2.
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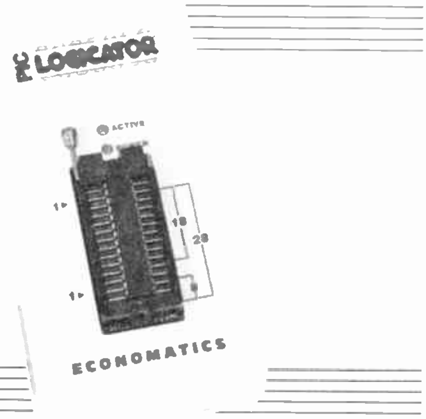
Special Review

PIC LOGICATOR

ROBERT PENFOLD



Learning to program PICs in a very different way, in which flowcharts provide the method.

MICROCONTROLLERS such as the PIC series of processors have huge advantages in many practical applications, but getting started with these components can be a bit daunting. Many of the problems are probably perceived rather than actual, and producing gadgets based on microcontrollers is not really that difficult.

The Logicator is a PIC programmer that aims to make the introduction to the PIC range of processors as painless as possible. To be more precise, it is the software supplied with the programmer that makes life easier for newcomers. The system does include a program that enables the hardware to operate as a conventional PIC programmer, but the main software provides an easy introduction by avoiding the use of any conventional programming language.

Instead, the user produces a flowchart, and then the software converts this into PIC code that can be downloaded to a chip in the programmer. Fine in theory, but how does it perform in practice?

Getting Started

Unusually, the main software is supplied on just a single high-density floppy disk, but two further disks are required for the software that enables the hardware to function as a conventional PIC programmer. The installation process follows along normal Windows lines and it is quite quick and simple.

The main program will run under Windows 95, 98, or 2000, but not Windows 3.1 or NT. The ordinary programmer software will run under Windows 9X or 3.1. No minimum hardware requirements are specified, but the software does not seem to be very demanding in this respect. However, a spare serial port is essential to provide the link to the hardware.

The hardware consists of a neat programmer unit in a plastic case with a 28-pin ZIF socket for the processors on the top. Markings show the correct positions and orientations for 8-, 18-, and 28-pin chips. There are also two l.e.d.s on the top panel of the box, and these are power and activity indicators.

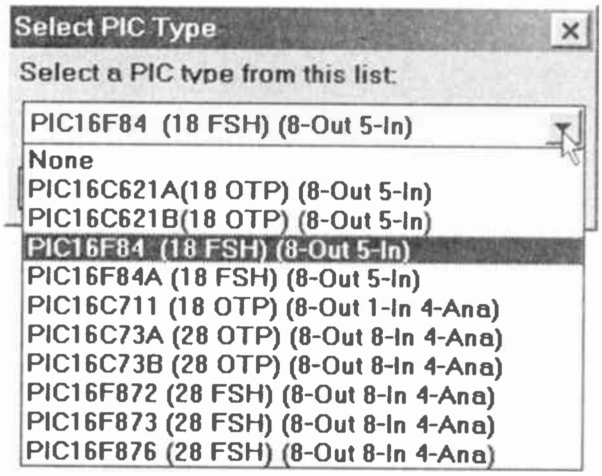


Fig.1. The first task is to select a processor from the list of supported chips.

The programmer connects to a serial port of the PC via the supplied 9-pin serial lead. An adapter (not included in the outfit) is needed for an old style 25-pin serial port. Power is obtained from the mains adapter supplied with the outfit. Getting the hardware set up is very simple and straightforward.

Easy Flowing

The program has a fairly conventional Windows look with a menu bar at the top and a row of icons just below this to provide shortcuts to the frequently used commands. The Options menu is the first port of call when creating a new flowchart. The PIC Type option brings up a window that provides a list of compatible PIC processors (Fig.1). The right-hand section of the screen has a palette of the basic building elements for the flowcharts. These are simply dragged to the required positions on the main drawing area, which takes up the vast majority of the screen.

Initially, there are no flowchart elements in the palette, but a pop-up window enables elements to be added and removed as desired (Fig.2). Double clicking on a cell in the flowchart brings up a small dialogue box that enables the label to be extended. For example, instead of "OUT" you could have something more helpful such as "OUT LED1".

Editing flowcharts is very easy. Once in position, a cell can simply be dragged to a new position if you change your mind. Groups of cells can be selected by drawing a box around them, or cells can be picked individually by holding down the Shift key and left clicking on them. Once selected a group can be dragged around the screen to any desired position.

Single cells or groups can be deleted by selecting the appropriate cell or cells and pressing the Delete key. The Edit

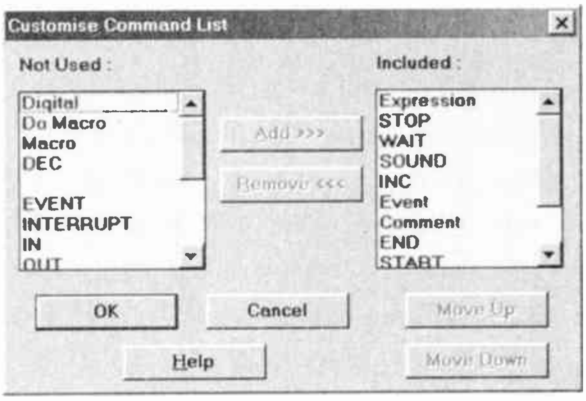


Fig.2. Elements can be added to or removed from the command list at the right-hand side of the screen.

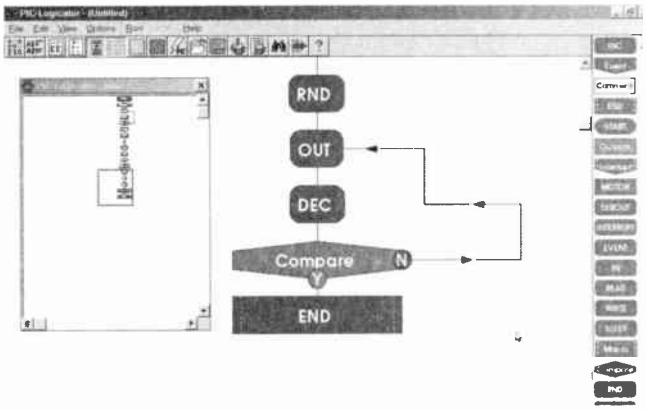


Fig.3. It is easy to navigate around a drawing using the Map facility.

menu provides the usual cut, copy, paste, and delete functions, which will work with individual elements or groups of them.

Routes (the lines between cells) are drawn by holding down the right mouse button and then dragging the lines from one cell to another. The drawing area can be viewed at a wide range of zoom levels, and a map facility (Fig.3) makes it easy to navigate around charts when using high zoom levels. The drawing area can be used with or without guidelines to help with the placement of the elements.

Programming

The process of drawing and editing flow charts is easy enough, but producing charts that actually get a PIC processor to do something worthwhile is inevitably a bit more difficult. With most of the cells in a chart it is necessary to provide more information in order to get exactly the required function.

For example, an Outputs block controls an output port, but the programmer must indicate the required state of each bit of the port. Where appropriate, double clicking on a cell brings up a small dialogue box that enables its characteristics to be controlled. Fig.4 shows the Cell Details window for an output port.

Left clicking enables each bit to be cycled through logic 0, logic 1, or no change (indicated by a dot in the control panel). Each type of cell has its own characteristics. With a Wait cell the delay in seconds can be specified, with a Sound cell the pitch and duration of the signal are set, and so on.

This system enables programs to be produced very easily, but it inevitably involves some compromises. The PIC processors can have each pin of a port individually set as an input or an output, but the Logicator software only supports one preset port configuration for most chips. With a few there are two port options to choose from.

This means that you have to settle for something quite basic, such as one five-bit input port and one eight-bit output type with the PIC16F84 for instance. Some analogue inputs are provided for chips that have a built-in analogue to digital converter.

Of course, the Logicator software is not intended as an alternative to conventional PIC programming, and is designed to be an easy introduction to using these devices. Having exhausted the possibilities of the Logicator software the user can move on to conventional assembly language programming and the standard programming software provided with the system.

Anyone making the transition from the Logicator software to conventional assembly language will have a lot to learn, but Logicator programs have the normal programming elements. There are loops, conditional commands, variables so that a loop can be performed a certain number of times, macros(subroutines), etc. Events and interrupts are catered for, as is a timed SLEEP mode.

Flowchart methods of programming can become unwieldy, but the Logicator software provides a good compromise between straightforward operation on one hand and functionality on the other.

Testing Time

Having completed a flow chart it can be tested using the emulation mode. The block currently being processed is highlighted, and there are optional windows that can be brought up to monitor the contents of the EEPROM, variables, and the ports.

The screen in Fig.4 shows a simple l.e.d. flashing program being tested, with the Digital Panel being used to show the states of the input and output lines. A variable delay can be used between cells to slow things down to the point where the action of the program can be followed properly.

The emulation mode should bring to light any major bugs so that they can be fixed prior to downloading programs to PIC chips.

Once you are completely satisfied that the software is working properly it is downloaded to the processor by selecting Program PIC from the Options menu. Downloading is done as a single operation with no separate compilation process. If everything is set up correctly the software will be immediately downloaded to the chip, and the whole process is very quick and easy. The chip is then ready for the "acid test".

The conventional programmer software (Fig.5) has the usual pushbutton controls, etc. that make it easy to select the required options and download the software. Only a limited range of processors are supported at present, but hopefully more will soon be accommodated. This program can be used to download HEX files generated by the Logicator program.

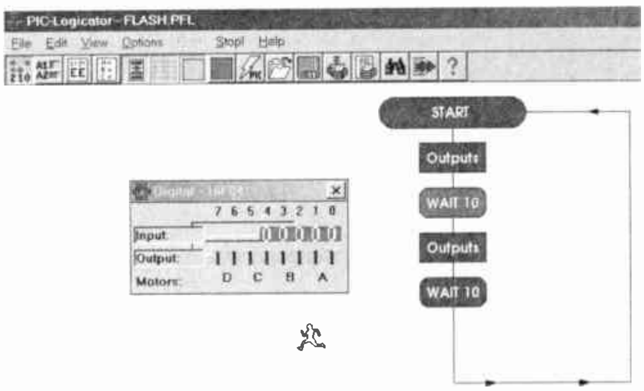


Fig.4. The Digital Panel shows the states of the input and output lines while an emulation is running.

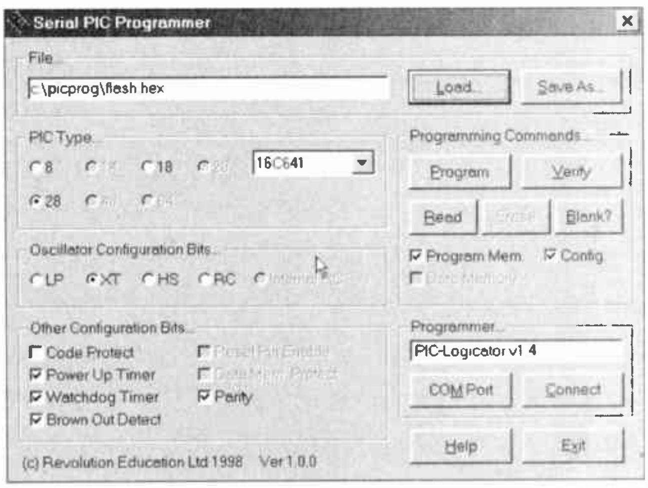
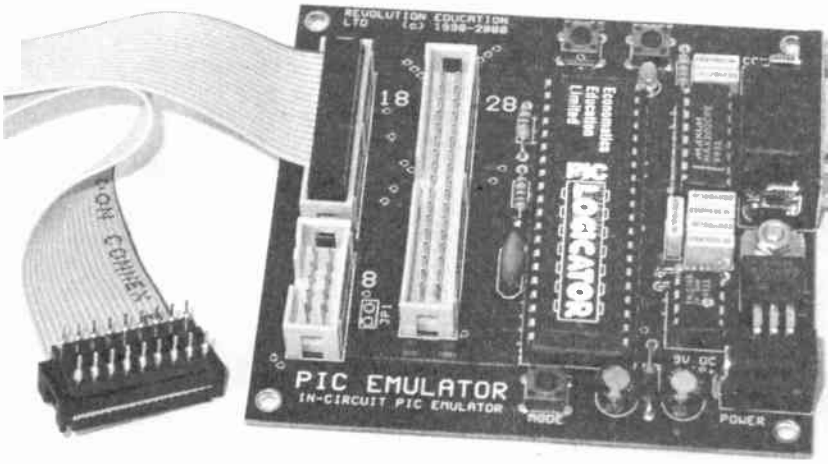


Fig.5. The conventional programmer software is easy to set up and operate.

The A4 ring bound instruction manual is not particularly long at 56 pages, but it covers a fair amount of ground. In addition to getting everything set up correctly and building flowcharts, it also covers basic circuits for the various PIC chips that can be used with the system. These provide supply connections, reset circuits, clock circuit (a 4MHz ceramic resonator must be used), and connections to devices such as l.e.d.s, lamps, counters, and sounders. The manual is clear, well written, and easy to follow.

Ice

Economatics produce a PIC emulator for use with the Logicator system. When using the emulator things are handled in the normal way up to the point where the software is downloaded to the PIC chip. Instead of using the programmer, the emulator is connected to the serial port. The emulator uses the same lead and power supply unit as the programmer. The emulator has 8-, 18-, and 28-way sockets that connect to the prototype circuit via a cable and header plug. The header plug takes the place of the PIC processor in the prototype circuit. Only an 18-way cable and header plug is provided with the emulator.



The PIC Emulator used with the Logicator system.

There are two operating modes available. In the direct mode the input and output ports of the emulator hardware are controlled and read directly by the Logicator software. If the remote run mode is used the program is downloaded to the emulator's EEPROM memory, and the emulator then operates as a stand alone unit that requires no further control from the host PC.

The emulator is in the form of an uncased board that has a power/status l.e.d. plus reset, pause, and mode controls provided by miniature pushbutton switches. The status l.e.d. goes from red to green when the unit is switched into the remote run mode.

The emulator does not provide power to the test circuit, which must therefore have its own power supply where appropriate. The emulator does not use any clock circuit in the test circuit, but instead uses its own 4MHz clock generator. In order to run a simulation in direct mode you simply select the Run option from the main menu. The program is then emulated on screen and in the test circuit.

Downloading a program to the emulator is handled in exactly the same way as downloading a program to a chip in the programmer. Once downloaded, the emulator automatically switches to the remote run mode and runs the program. Using the emulator and a solderless breadboard it is possible to thoroughly check designs before downloading the software to a PIC processor. For educational purposes and experimenting it is possible to dispense with the PIC chips altogether, with the emulator being used as an alternative.

Conclusion

During the brief test period the software proved to be entirely stable, and the hardware did what it was supposed to do. The hardware seems to be well made and quite tough, which it needs to be, as the PIC-Logicator system is used extensively in UK schools to teach Design and Technology.

This system is not really suitable for developing complex equipment based on PIC processors, but it is not intended for this role. It has been designed as an easy introduction to using PIC processors, and it fulfils this role very well. Having exhausted the possibilities of the flowchart method of programming, the user can move on to the "real thing" by using a PIC assembler to produce HEX files that can be downloaded to the PIC chips, using the programmer and the supplied software. No assembler is supplied with the system, but free PIC assemblers are readily available from web sites.

Neither the Logicator system nor the emulator is particularly cheap, but the prices are quite reasonable. Although aimed primarily at educational establishments, the Logicator system and the emulator are also well suited to electronic hobbyists requiring an easy way of getting to grips with PIC processors. With no obvious drawbacks and plenty going for it, the Logicator can certainly be recommended for both educational and hobbyist use.

The PIC-Logicator system costs £149.95. The Emulator costs £119.95. Both prices include VAT and UK carriage. For further information contact Economatics, Dept EPE, Epic House, Darnall Road, Sheffield S9 5AA, UK. Tel:0114 281 3311. Fax: 0114 243 9306. There is also a web site devoted to the PIC-Logicator system and providing an interactive software demo at **www.pic-logicator.com**.

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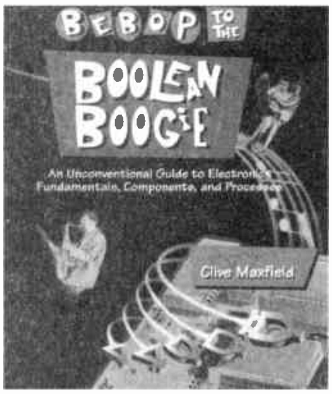

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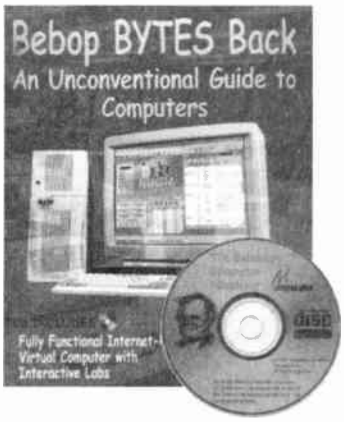

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Constructional Project

HANDCLAP SWITCH

TOM WEBB

Let there be light – quick as the clappers!

THIS circuit has been designed to give you an easy life. No need to bend down to turn on awkwardly positioned switches, just clap your hands and the controlled appliance will be turned on for you.

The block diagram in Fig.1 shows how the circuit is split up into separate sections. The sound made by a handclap is picked up by an electret microphone, amplified by an op.amp, half-wave rectified and then cleaned up by a Schmitt trigger.

There is then a switched choice of either using the Timer circuit, which turns on a relay for a predetermined time set by a potentiometer, or using the Latching circuit, which turns on the relay until another handclap is received to turn it off.

CIRCUIT DIAGRAM

The circuit diagram for the Handclap Switch is shown in Fig.2.

The electret microphone is shown as MIC1 and is powered via resistor R1. Incoming sounds are a.c. coupled by C1 and fed to the non-inverting input (pin 3) of op.amp IC1. This input is d.c. biased at half the supply voltage by the potential divider formed by resistors R2 and R3.

The op.amp's gain is set at about 471, as determined by the values of resistors R4 and R5, i.e. (R4/R5) + 1. Capacitor C2 provides d.c. stability of the feedback path. The amplified output signal at IC1 pin 6 is a.c. coupled by C3 and fed to the preset amplitude control VR1.

From the wiper of VR1. the signal is rectified by the diode pump circuit comprising C4 and diodes D1 and D2. The resulting output voltage from D2 is smoothed by the *CR* network formed by C5 and R6.

From C5, the rectified voltage is fed to the Schmitt trigger circuit formed around NOR gates IC2a and IC2b. This circuit "cleans-up" the amplitude changes from C5 so that well-shaped logic level changes are output from IC2b pin 4.

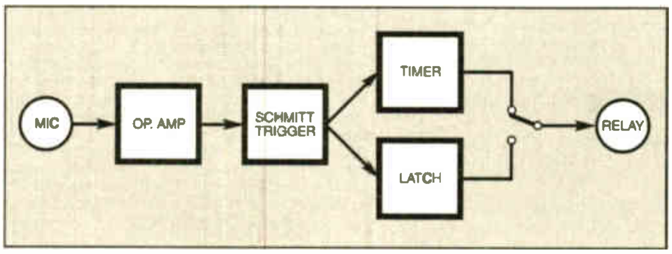


Fig.1. Block diagram for the Handclap Switch.

The voltage input to IC2a via R7 has to rise to well over half of the supply voltage before the output at IC2b will switch to logic 1. The output will only revert to logic 0 when the input falls to well under half the supply voltage. This helps to prevent false triggering of the circuit.

The latching part of the circuit is based on a D-type bistable, IC3a, which is configured as a T-type (toggle), by tying pin 2 to pin 5. This enables its output Q to latch high when a high-going trigger pulse from IC2b is received at pin 3. It then latches low again when it receives the next pulse. After which the next pulse toggles the output high again, and so on.

TIMING CIRCUIT

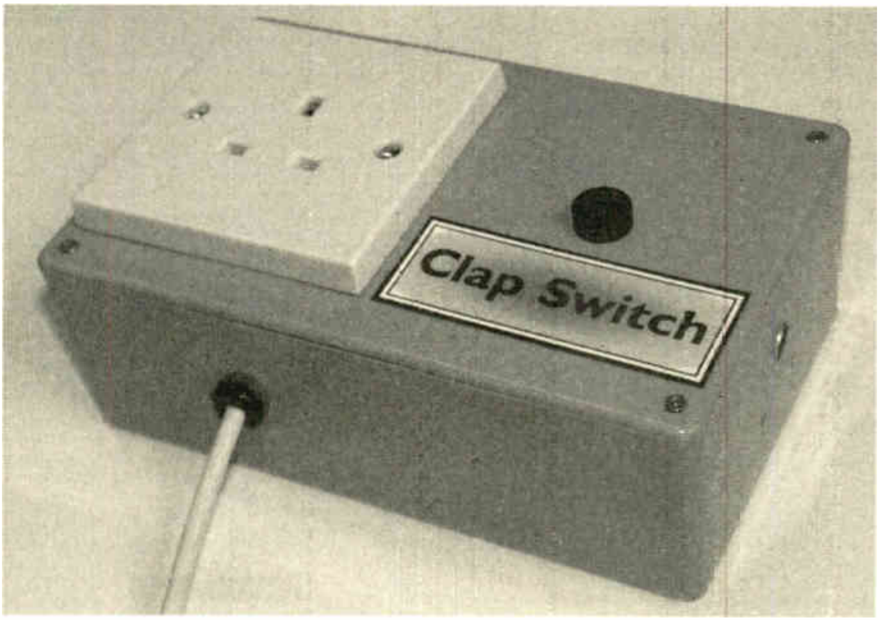
The Timing circuit is based around NOR gates IC2c and IC2d, configured as a monostable. The circuit's time constant (the time that its output stays high once triggered) is set by the value of capacitor C7 and the total resistance through preset VR2 and resistor R9.

The timing formula is T = 0·7 × R × C, where T is the time for which the circuit remains triggered, in seconds, R is the resistance in Ohms and C is the capacitance in Farads.

This circuit uses values of R = 1M + 15k = 1015000 ohms, and C = 100μF = 0·0001F. In theory, therefore, the maximum time the circuit can remain on is: 0·7 × 1015000 × 0·0001 = 71·05 seconds. In practice, component tolerances will produce somewhat different timings, but the formula provides a guide to expectations.

If a longer time is required then a larger capacitor can be used, but it should not exceed 2200µF as timings will begin to be unpredictable, due to current leakage through the capacitor. The fixed resistor R9 ensures that the total resistance can never be zero, even if VR2 is set to zero resistance. The value for R9 was chosen so that the minimum timing period is approximately one second.

Switch S1 selects whether the latching or timed circuit is used, the chosen output feeding via resistor R10 to transistor TR1. When the output is high, the transistor is turned on, so activating the relay, RLA. Diode D3 prevents back-e.m.f. (voltage spikes) from being generated at the moment that the relay is turned off.



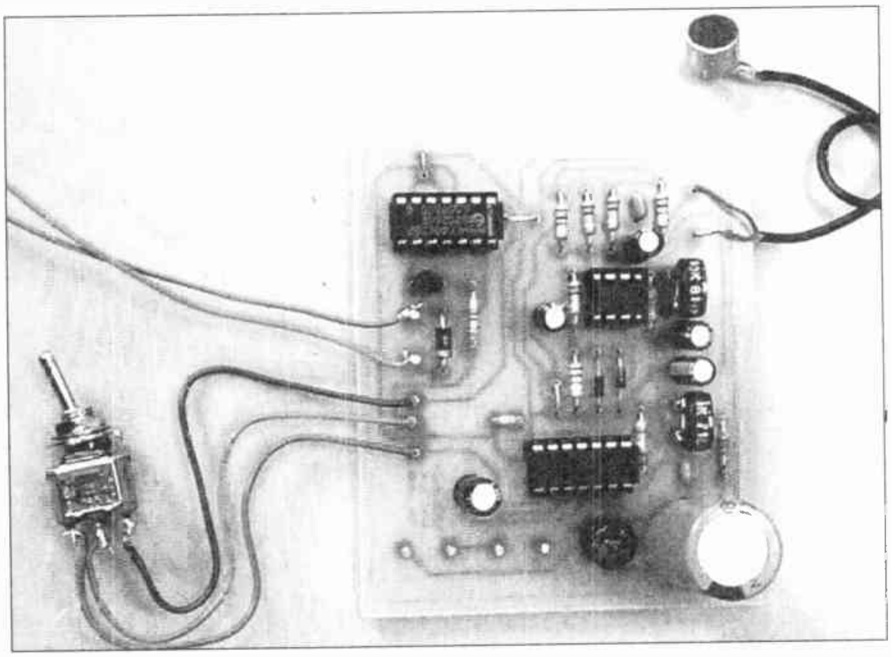
POWER SUPPLY

The power supply circuit is also shown in Fig.2. Power is derived from the a.c. mains and transformer T1 provides an isolated output voltage of 9V a.c., at up to about 100mA. A higher-current transformer may be used if preferred. The 9V a.c. supply is bridge-rectified by REC1 and smoothed by capacitor C9, producing a d.c. supply of about 12V.

Fuse FS1 is included in the 9V a.c. supply line and should be rated to suit the maximum current that is permitted to be drawn from the transformer.

Although not included in the prototype, a fuse should also be included in the mains a.c. live supply line before the connection to the relay and transformer. This should be rated to suit the maximum load that the relay is required to switch, plus about 1A margin for the current through the primary winding of the transformer.

A neon lamp, LP1, is wired across the mains supply, following fuse FS2, indicating when mains power is connected.



CONSTRUCTION

Since this unit contains mains voltage, great care should be exercised in its construction. If in any doubt about construction consult a qualified electrician. Mains voltage can be lethal if abused.

Apart from the electret microphone, switch, relay and transformer, all the components are contained on a single printed circuit board (p.c.b.). The topside component layout and the full size underside copper foil track master are shown in Fig.3. This board is available from the *EPE PCB Service*, code 270.

Begin construction by soldering in the resistors and wire links. Ensure that the electrolytic capacitors, transistor, diodes and bridge rectifier are connected the right way round. Use sockets for the three i.c.s, but do not insert the i.c.s until construction has been completed (ensure their correct orientation when they are fitted).

If you choose not to use the timer circuit, VR2, R9, C6 and C7 can be omitted and a wire link inserted to join IC3 pin1 to R10. If you choose to omit the latching circuit, IC3 and C6 can be omitted and a wire link inserted to join IC2d pin11 to R10. In both cases S1 is omitted.

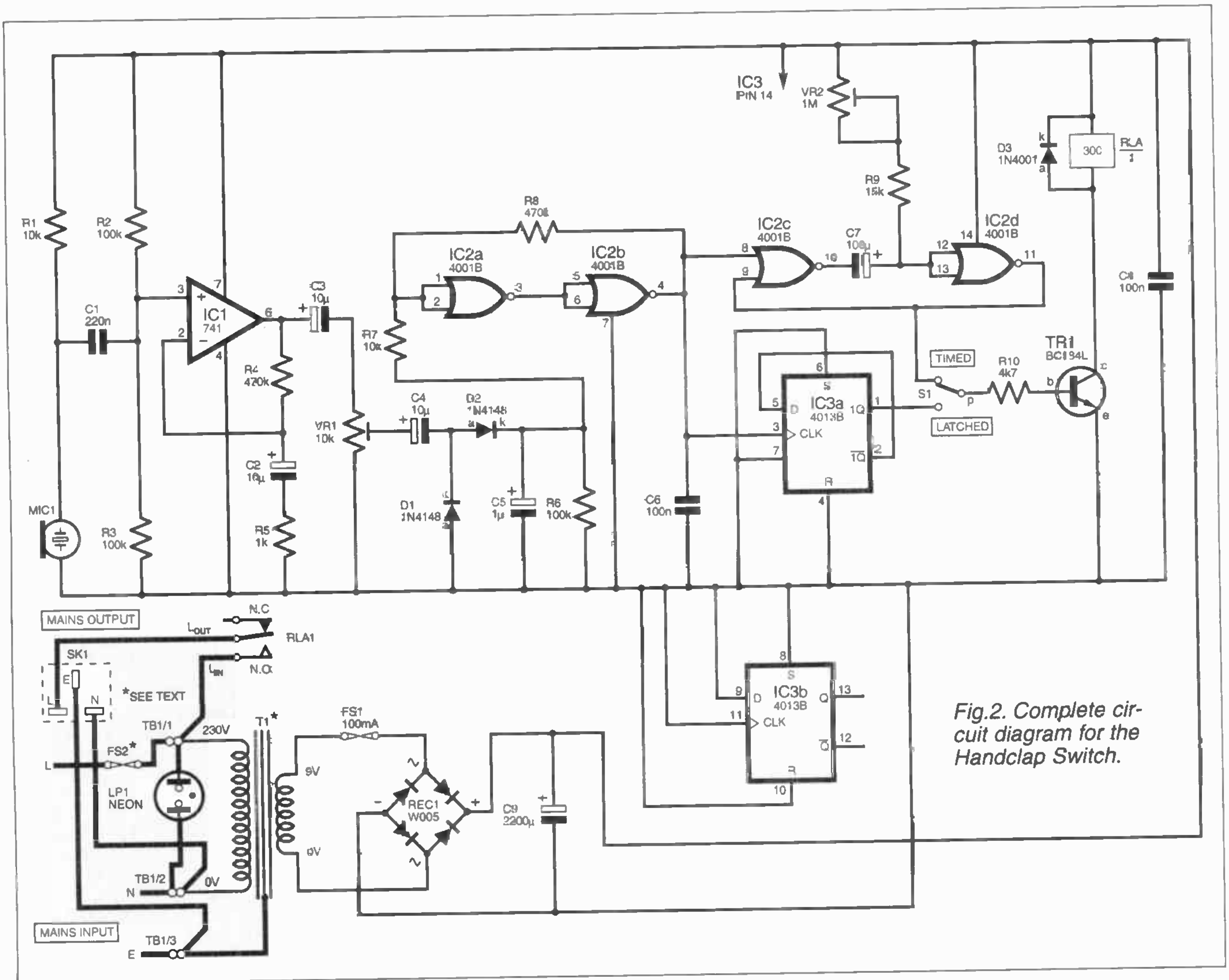


Fig.2. Complete circuit diagram for the Handclap Switch.

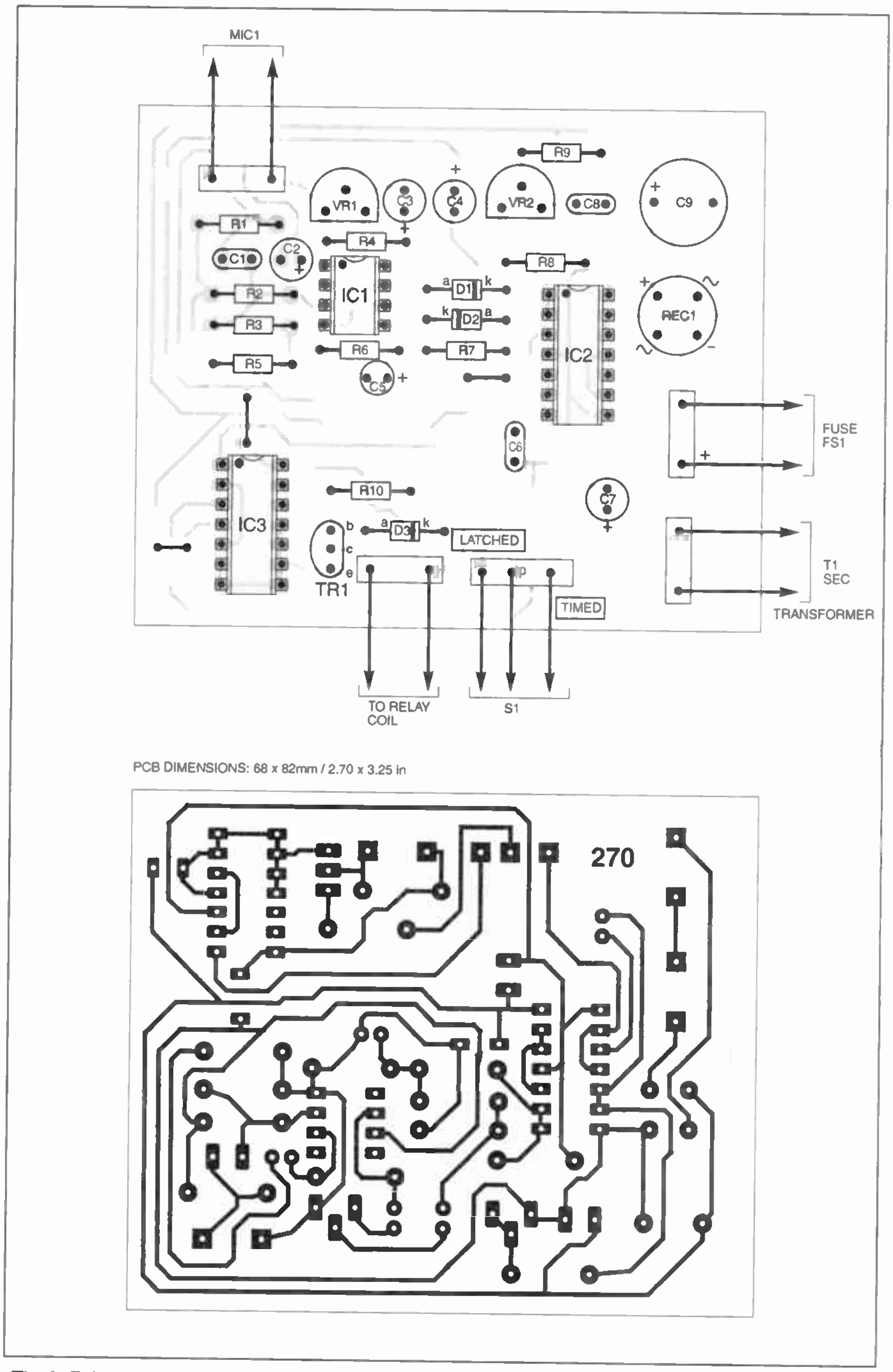


Fig.3. Printed circuit board component layout and full size copper foil track master pattern.

CASING

The mains voltage section of this unit should be kept in a separate compartment of the box to ensure that it is completely isolated from the low voltage circuit.

This is done by inserting a plastic partition inside the case. A small slot should be made at the bottom of it, allowing the *low voltage* wires from the relay and transformer to come through. The partition should be cut so that it fits securely in the slots provided in the side of the case.

The transformer should be firmly bolted to this partition. The relay is glued to it, using good quality adhesive that is suited to the plastic of the partition and of the relay's cover. *It is essential that the relay can never break its bond with the partition.*

Drill holes in side of the case to suit the positions of the electret microphone, switch S1, mains input cable grommet, neon and fuse FS2. In the lid, drill a hole for fuse FS1 and make a cut-out into which the 13A output socket will fit snugly, drilling holes for its mounting bolts as well.

Additionally, two holes are required to allow adjustment access to the two preset potentiometers using a small screwdriver.

The mains input cable used in the prototype is rated at 3A, which is fine for a low current item such as a desk lamp, for example. However, if you wish to switch higher current appliances, like an electric fire, then mains cable rated at **13A must** be used. (The relay must be capable of switching the voltage and current of the appliance to be controlled, i.e. 230V a.c. 13A.) A clamping grommet must be used with the mains input cable to prevent it being pulled out.

A set of three terminal blocks is used to connect up the mains to the wires for the transformer, relay and neon. This should be bolted securely to the base of the case, through holes drilled in a suitable position.

The mains wires connecting between the relay and the output socket must have the same rating as the mains input cable. They are soldered to the relay terminals.

COMPONENTS

See SHOP TALK page

Resistors

R1, R7	10k (2 off)
R2, R3, R6	100k (3 off)
R4, R8	470k (2 off)
R5	1k
R9	15k
R10	4k7

All 0.25W 5% carbon film.

Potentiometers

VR1	10k min. preset, vertical mounting
VR2	1M min. preset, vertical mounting

Capacitors

C1	220n ceramic disc
C2 to C4	10μF elect. radial, 25V (3 off)
C5	1μ elect. radial 25V
C6, C8	100n ceramic disc (2 off)
C7	100μ elect. radial, 25V
C9	2200μ elect. radial, 25V

Semiconductors

D1, D2	1N4148 signal diode (2 off)
D3	1N4001 rectifier diode
TR1	BC184L, or other gen. purpose *npn* transistor
REC1	W005 50V 1A bridge rectifier
IC1	741 op.amp
IC2	4001B quad 2-input NOR gate
IC3	4013B dual bistable (flip-flop)

Miscellaneous

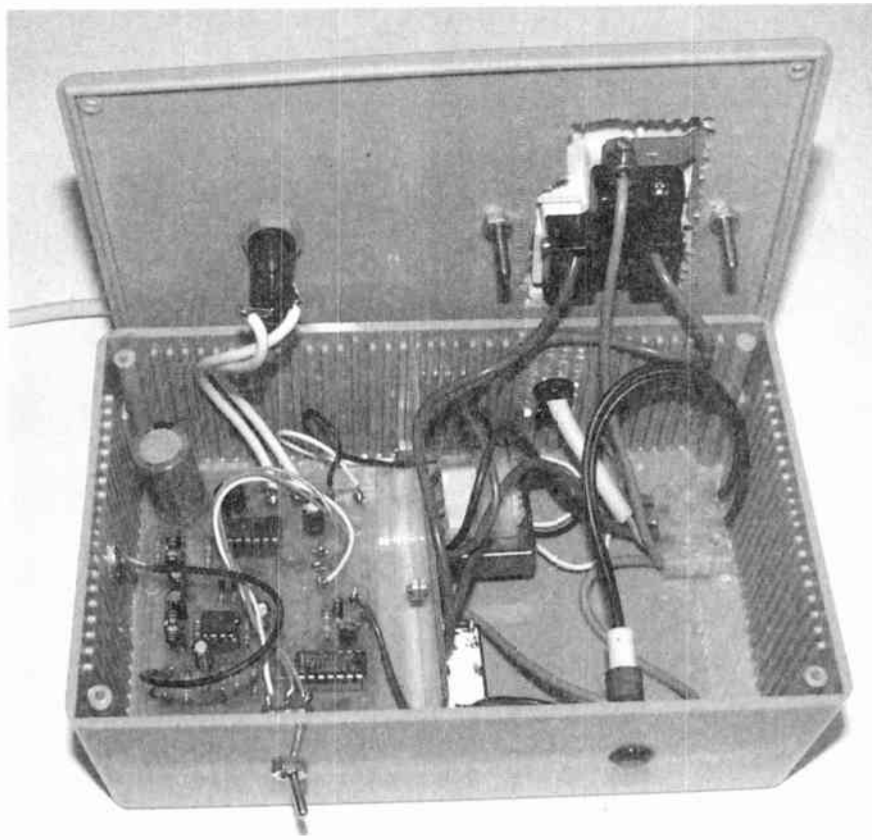
LP1	mains neon, panel mounting
MIC1	electret microphone insert
RLA	min. 12V s.p.s.t. relay, contact rating to suit powered appliance
S1	s.p.d.t. toggle switch
T1	mains transformer, 9V a.c. 100mA secondary
FS1	100mA fuse, 20mm
FS2	mains rated fuse, value to suit powered appliance (see text)

Printed circuit board, available from the *EPE PCB service*, code 270; plastic case, 185mm × 115mm × 65mm; plastic insert to suit case (see text); fuseholder, panel mounting, 20mm (2 off); cable grommet, locking, panel mounting; 8-pin d.i.l. socket; 14-pin d.i.l. socket (2 off); 3-way mains rated terminal block, screw terminals, bolt mounting; nuts and bolts to suit; p.c.b. supports, self-adhesive (4 off); mains rated cable (see text); 13A mains socket, flush mounting; earthing solder tag; connecting wire; solder, etc.

Approx. Cost Guidance Only £23 excluding case and mains socket

TESTING

Once the p.c.b. has been assembled, fully check for any mistakes, and the quality of soldering.



Interior of the assembled Handclap Switch. Note that the mains connections are well isolated from the low voltage circuit and that the central partition fully separates the two sides of the box. This prototype does not include the mains fuse FS2.

In the prototype, the p.c.b. is secured to the base of the case using self-adhesive p.c.b. supports. However, it is advisable not to fully secure the p.c.b. until testing is complete.

The first thing to check is that the d.c. output from the rectifier circuit is the correct voltage, of around 12V. If it is not, immediately disconnect the circuit from the mains and check that the transformer, bridge rectifier and capacitors have been connected correctly.

To start testing, adjust preset VR2 for its minimum resistance in series with resistor R9. To adjust preset VR1 to its correct setting, first adjust it for maximum signal output at its wiper, then turn it back about ten degrees.

These two settings should give you a sensible level in respect of the amplified electret microphone signal, and also a time delay of one second for the timer circuit.

COMMON PROBLEMS

Typical constructional mistakes include dry solder joints and adjacent p.c.b. track pads accidentally bridged together with solder. Other problems include failure to insert wire links.

Also check that the components are correctly placed, and the correct way round.

FAULT FINDING

To assist in fault finding, temporarily disconnect the wires between the p.c.b. and the relay coil. Connect a light emitting diode (l.e.d.), with a 1kΩ ballast resistor in series, to the p.c.b. terminals provided for the relay coil connection. The l.e.d. will provide you with a way of knowing if the circuit is working.

Testing can be done using a multimeter but it is preferable to use an oscilloscope as the signal sometimes fluctuates. Start by again testing the power supply, which should still be around 12V. Next connect the oscilloscope to the positive side of the electret microphone (junction with resistor R1) to see if sounds are being received when you clap hands.

After that, check that the voltage at pin 6 of IC1 is at 6V when no sound is occurring, and that the sound signal is amplified when it is present. If a suitably amplified signal is present, check that the voltage at IC2a pins 1 and 2 is above 6V. If this is not so, check that diodes D1, D2 and capacitors C4, C5 are connected the correct way round, and that VR1 is not set to minimum gain.

If all is well the output at IC2b pin 4 should be 12V when a sound signal is present.

Connect a meter to switch S1 pin 1 then to S1 pin 3. Pin 3 should remain high until you clap your hands again, which should cause it to go low.

Pin 1 of switch S1 should remain high for the period set by VR2, R9 and C7 and then go low. If it does not, check that C7 is connected the correct way round.

SETTING UP

Both presets, VR1 and VR2, can be adjusted to suit the user's particular needs. The following is a summary of their functions:

VR1: Sets the sensitivity of the circuit to sound.

VR2: Only used if the timer circuit has been selected by switch S1. It sets the time for which the timer remains active. Reducing the resistance reduces the timing period.

IN USE

This design can be used to turn on any normal mains powered domestic appliance, within the limits of the cabling and value of fuse FS2.

Plug the appliance into unit's output socket, clap hands or shout and it will turn on, either:

1) for a timed period up to about 70 seconds, or

2) until you clap or shout again.

These options can be chosen with the selection switch S1. □

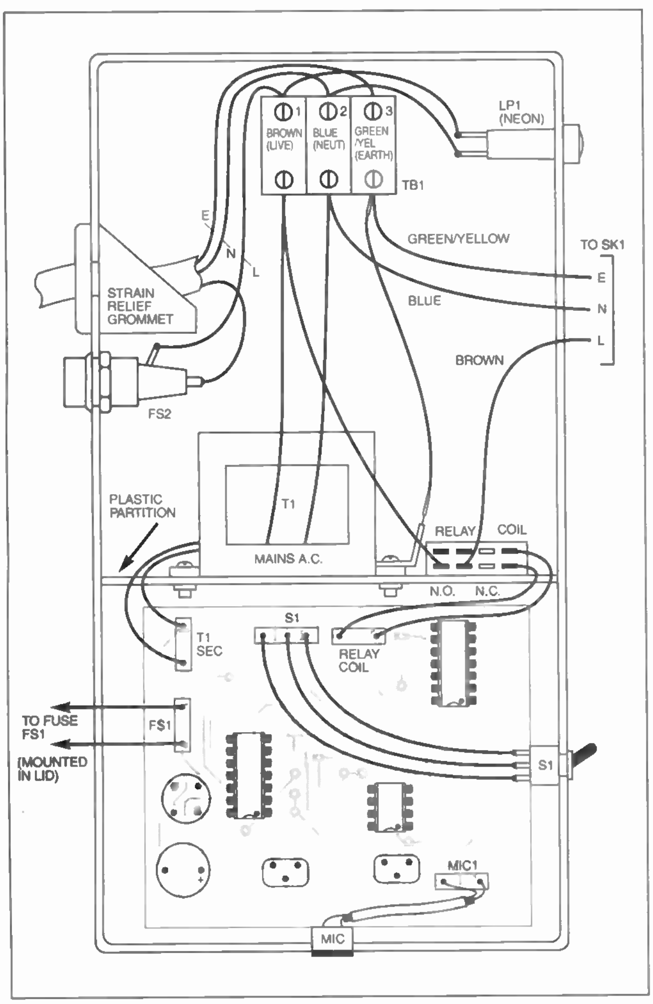


Fig.4. Interwiring between the two partitioned areas and the off-board components.

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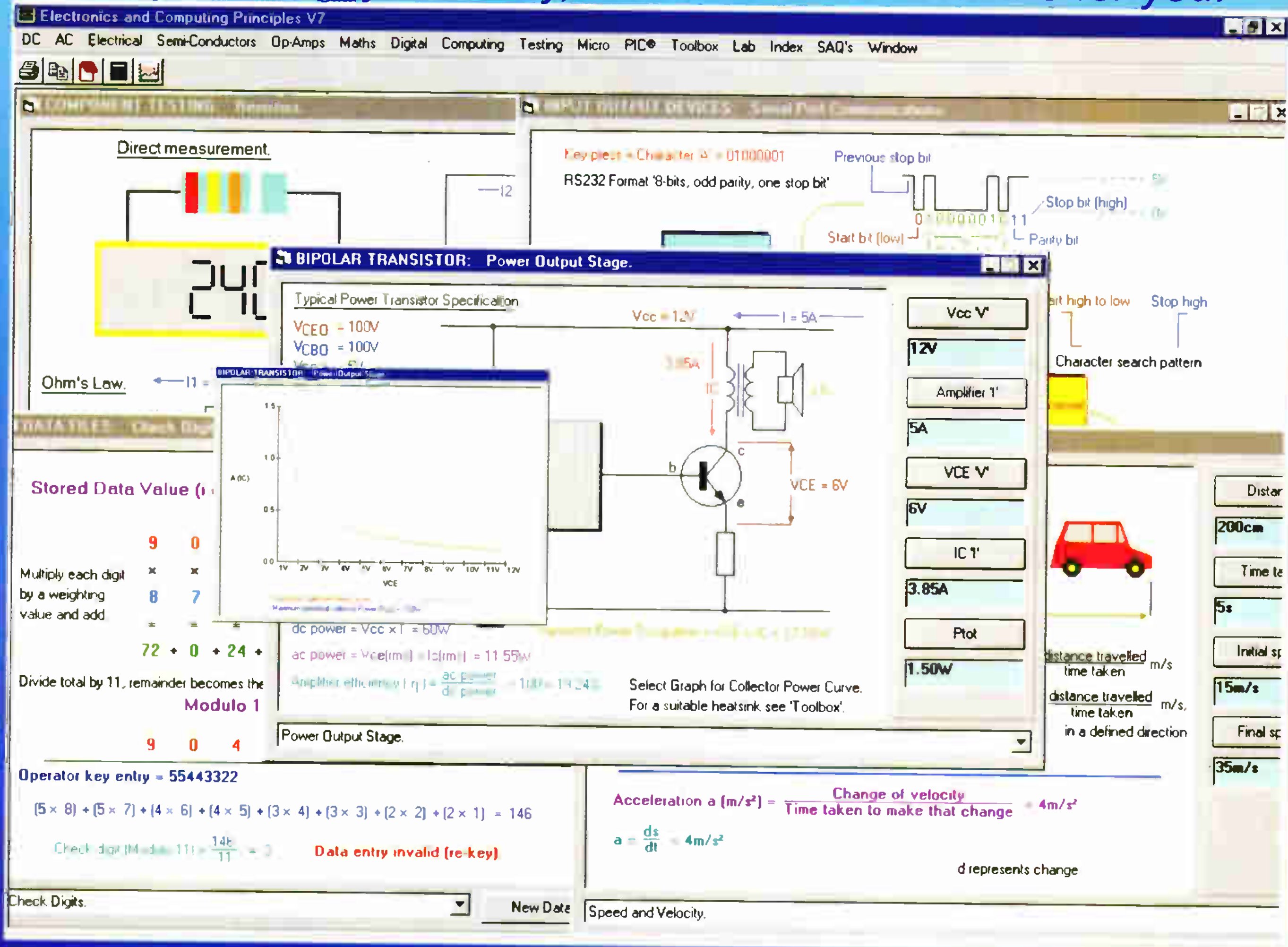

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