THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY

PRACTICAL ELECTRONICS

Vol.33 No.8

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VOL. 33. No. 8 AUGUST 2004
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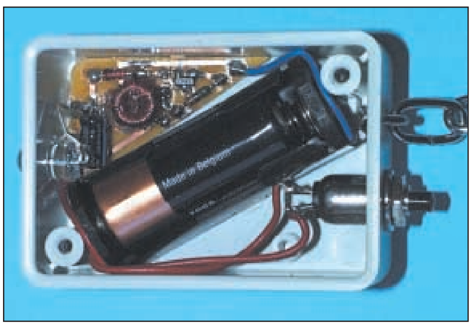

Series and Features

Regulars and Services

Our September 2004 issue will be published on Thursday, 12 August 2004. See page 519 for details

NEXT MONTH

RADIO CONTROL FAILSAFE

This failsafe unit was developed for use in radio control (RC) models, originally for combat robots, but it can be applied to any land-based RC model. There is a statutory requirement for such a failsafe device, in particular with the rules associated with the use of fighting robots. The safety aspect is, of course, of paramount importance.

In RC systems, especially when there is a fault, such as in the case of the loss of transmitter signal at the receiver, the effect could be to send the robot or model into uncontrollable action and cause damage to property, the model itself, or indeed to bystanders.

This unit is designed to sense the moment of failure of the RC system and put the robot or model into a safe condition, rendering it motionless. It is "transparent" during normal operation, but during a fail situation it provides the servo or speed controller with a reliable and steady train of pulses.

When the unit is used with a speed controller, on a model boat for instance, the latter's supply can be switched off via a relay during failsafe, and the controller put into neutral – a belt and braces approach maybe, but it is better to err on the side of caution!

ALPHAMOUSE GAME

Do you remember those childhood toys which comprised a square frame enclosing 15 or more letters that you slid around to arrange into different orders? Perhaps even your children have one now. In their day they were the forerunners of Rubic's Cube, before both became ousted by PlayStation and the like.

Recently, the author was considering how best to illustrate in a simple fashion the way in which a PC's mouse could be put to alternative good use, following on from his article PIC to PS/2 Mouse and Keyboard Interfacing *(Aug '04). Somehow, these letter frames came to mind, and sparked off a series of high-speed bashings at the keyboard to write the code for a modern equivalent.*

The result of just a few hours coding and programming is this AlphaMouse Game, in which a 2-line 16-characters (per line) alphanumeric liquid crystal display replaces the lettered frame, and a PC's PS/2 mouse controls the movements of 31 letters around the 32-position area.

WART ZAPPER

As improbable as it may seem, the common wart may be destroyed with a simple circuit that uses a tiny keyfob battery delivering a boosted 24V to the skin. Taking into account the resistance of the skin, this translates to just 100μA or so passing through the wart internally.

Four successive prototypes were tested on several volunteers, as well as two prototypes being tested by doctors. The final prototype achieved close to a 100% success rate with the common wart (a brown or skin-coloured, rough wart), and 100% success with plain warts (a very flat wart).

The Wart Zapper's high success rate does not, of course, guarantee that it will work in very case, but it is certainly worth a try. A simple, inexpensive project using around a dozen components.

NEW SERIES

LIGHT EMITTING DIODES

Operation and Applications

This short series of articles examines the features, construction and behaviour of l.e.d.s. It looks at the electrical characteristics of different l.e.d. types and examines various ways of biasing them. In particular, it contrasts the merits of different l.e.d. driver circuits, and examines some of the many special-purpose l.e.d. driver i.c.s that are currently available. The series concludes by looking at some of the more unusual applications for l.e.d.s, and discovering how light emitting diodes have not just one, but four *different uses.*

Two allied constructional projects will also be described: a Volt Checker and a Logic Probe.

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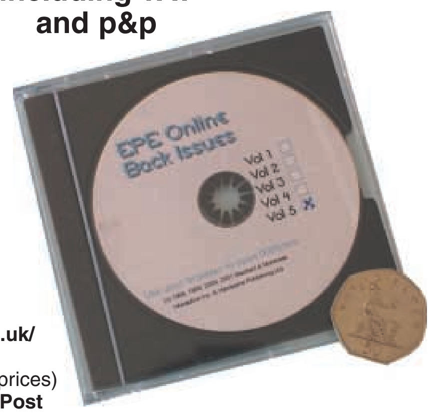

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All volumes include the *EPE Online* editorial content of every listed issue, plus all the available **PIC Project Codes** for the PIC projects published in those issues.

Note: Some supplements etc. can be downloaded free from the Library on the *EPE Online* website at **www.epemag.com**.
No advertisements are included in Volumes 1 and 2; from Volume 5 onwards the available relevant software for *Interface* articles is also included.

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To help to overcome the problem we have set up a Special Subscription Offer for new UK subscribers – see page 561 for full details. (Overseas subscribers please see the last magazine page for subscription details.) This offer runs until the end of August 2004 and is applicable to all new UK subscriptions, so you can order using the form provided or via our web site at **www.epemag.wimborne.co.uk** – click on "Subscribe Now"; the web site does not show the Special Offer gifts but everyone in the UK who takes out a new subscription before August 31 2004 will be sent the relevant free gifts.

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Mike Kenward

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All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in *EPE* employ voltages than can be lethal. **You should not build, test, modify or renovate any item of mains powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.**

COMPONENT SUPPLIES

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Constructional Project

EPE Scorer

David Coward

Score with the technological solution for quizmasters and sportsmasters!

A LETTER from *EPE* reader John Reynolds in the April 2003 edition prompted the design of this Scorer. It is a versatile PIC-microcontrolled aid for all quizmasters, providing independently adjustable scores for two teams, a countdown stopwatch timer ("You have two minutes on . . .") and "Fingers on the button" functionality.

Three score pushbutton switches are provided for each team so that scores can be increased by one, two and four points for each press. There are also buttons to "undo" the last score and take a point off for corrections and penalties.

As well as quizzes, the design could be used to keep track of both time and scores in rugby, football, hockey or other similar sports.

An optional extra is a remote slave unit (or units) so that each team can have its own local display if needed.

Master Circuit

The circuit diagram of the Master Unit is shown in Fig.1. A PIC16F877-20 microcontroller (IC1) drives four 2-way multiplexed 7-segment l.e.d. displays (X2 to X5), a 14-switch matrix (S1 to S14), two other switches (S15, S16) and three l.e.d.s (D1 to D3). Also provided is a sound output (IC2/LS1) and a serial connection (PL1) to a Slave unit. Given this workload, the PIC16F877 is run at 20MHz.

The two 2-way 7-segment displays X2 and X5 provide an independent count up to 99 for each team, X3 and X4 provide a countdown stopwatch that counts backwards from a maximum 99 minutes 59 seconds (long enough for halves or quarters of most sports).

PIC Port C drives the common anodes of the 7-segment displays via transistors TR1 to TR8, buffered by resistors R1 to R8. The segments are connected to PIC pins RB1 to RB7. To turn on a segment, the relevant Port C bit for the digit is set high, and the Port B segment bit is set low. The program activates each digit for about 2ms once every 14ms, so the flashing is quick enough to deceive the human eye at the expense of slight dimming of the display.

Pushbutton switches S1 to S14 are wired in the form of a 4 × 4 keypad (but with two switches omitted). The PIC drives the rows of the "keypad" through RD0 to RD3 and reads the columns via RD4 to RD7. The use of series resistors R16 to R19 limits the current driven into RD4 to RD7 when they are used as inputs. Pull-up resistors (within resistor module R20) ensure that the PIC software can operate properly when a switch is unpressed.

Light emitting diodes D1 to D3, which show the state of the Scorer and the fastest responding team, connect to RA1 to RA3. Switch S15 turns the timer on and off, and switch S16 enables the "fastest finger" function. They connect to RA4 and RA5, pulled high by resistors R25 and R26.

An audio frequency is output via RA0, coupled to the single chip TDA7052 amplifier IC2 by capacitor C4 and resistor R27.

As 8Ω speakers are relatively more common, resistor R28 can be used to increase the notional impedance of the speaker to 64Ω or, if a 64Ω speaker is used, it can be replaced by a wire link.

For the Master, the power requirement arising from the eight 7-segment digits can be significant, so regulator IC3 is used to provide a stable power supply from a simple mains eliminator. IC3 can provide sufficient power for the Master and can be used without a heatsink for voltages up to about 15V, and probably more. The raw supply voltage is sent to connector PL1 to

Master console and two Slave boards.

Resources

Software, including source code files, is available on 3·5inch disk from the Editorial office (a small handling charge applies – see the *EPE PCB Service* page) or it can be downloaded *free* from the *EPE* Downloads page, accessible via the home page at **www.epemag.wimborne.co.uk**. It is held in the PICs folder, under PICscorer. Download all the files within that folder.

The source code software for the Master Unit is written in C and the Slaves in assembler.

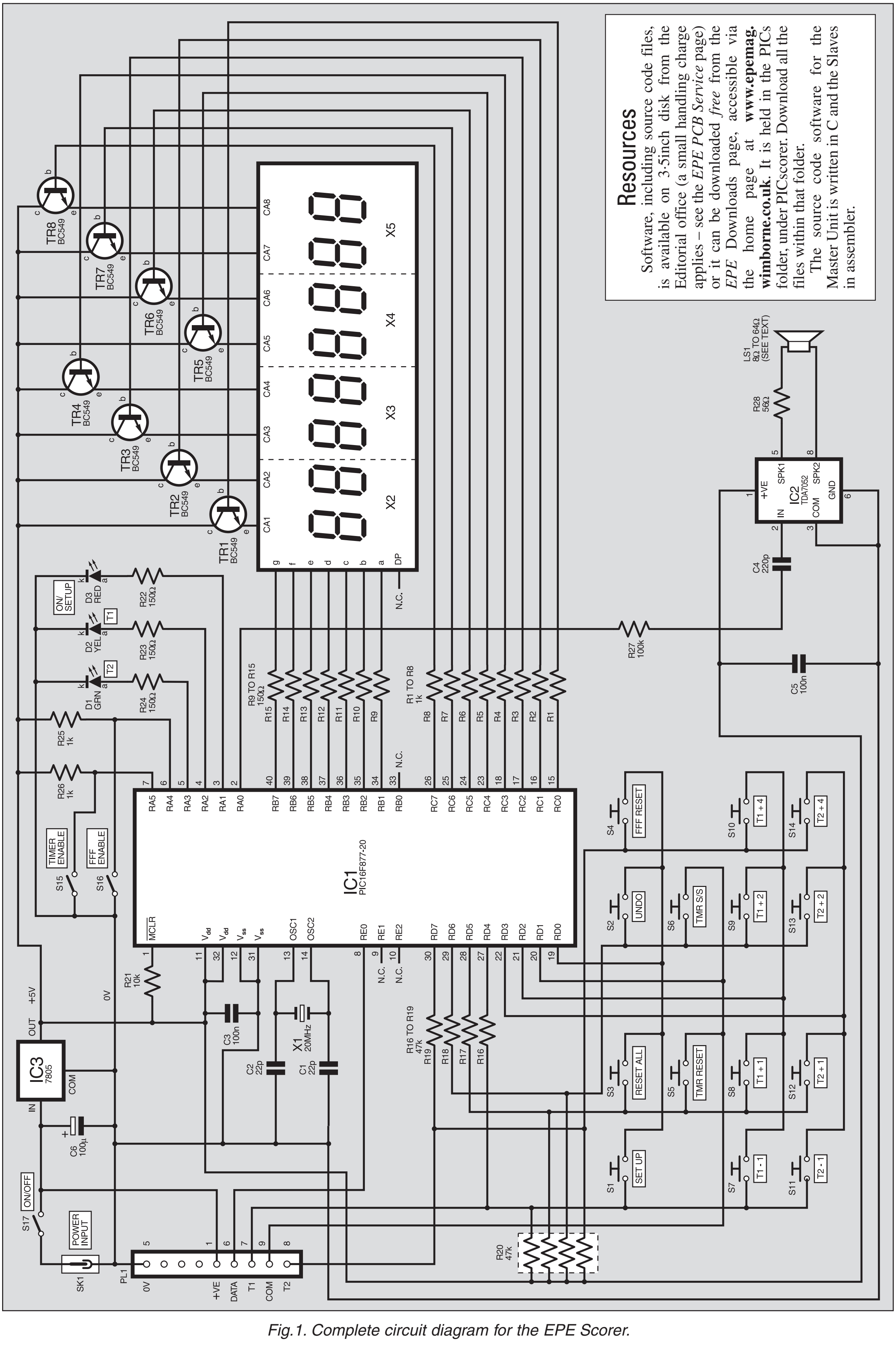


Fig.1. Complete circuit diagram for the EPE Scorer.

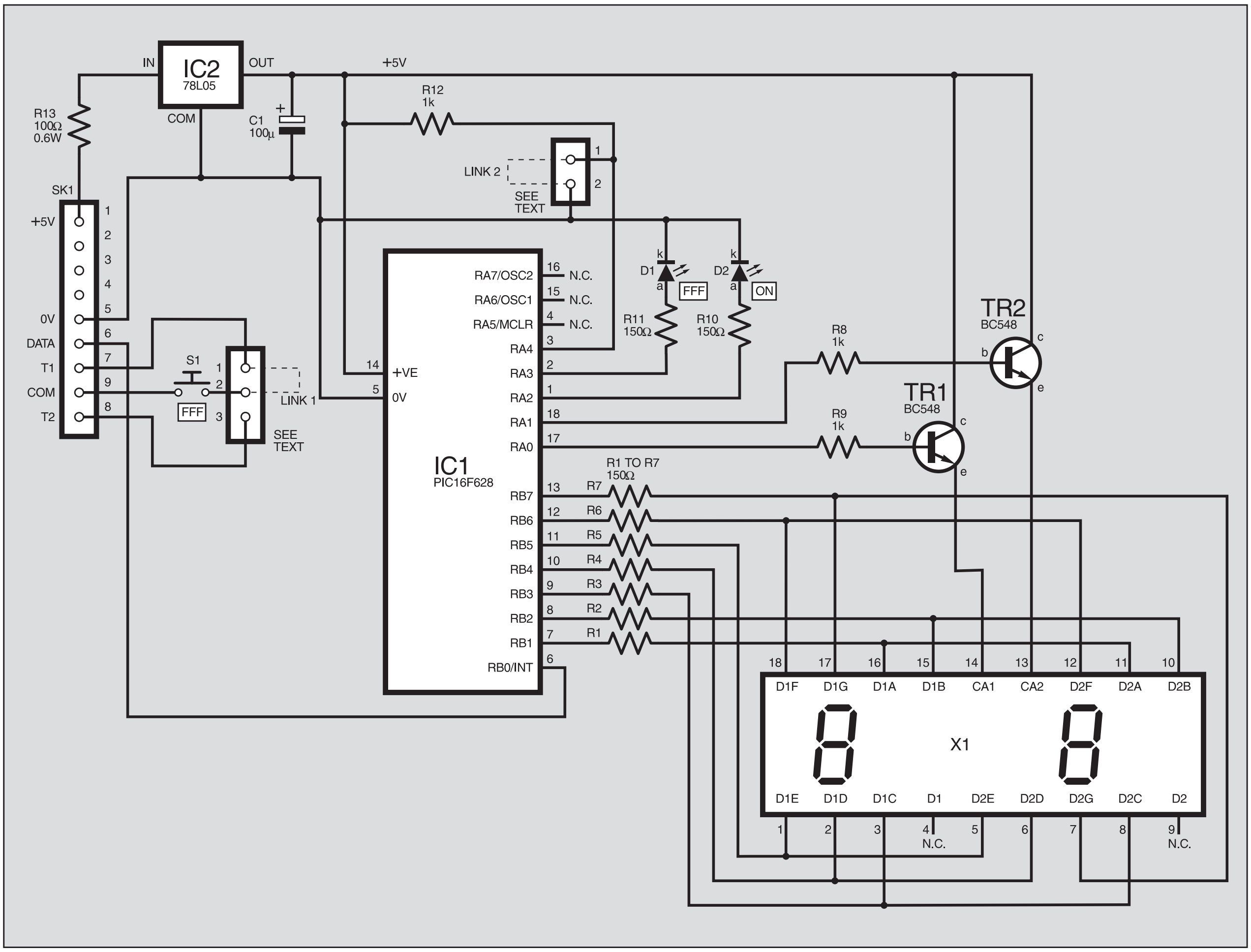


Fig.2. Slave circuit diagram using a PIC16F628 microcontroller.

provide a feed for the optional Slave Units, which have their own voltage regulators. Capacitors C3, C5 and C6 provide supply line decoupling.

A serial data output to the slave(s) is provided to PL1 from RE0.

Slave Circuit

The Slave circuit is shown in Fig.2. The circuit is controlled by IC1, a PIC16F628 operated under internal 4MHz clock mode. The input from the Master Unit connects to pin RB0, which is used in interrupt mode.

The segments of the 2-way 7-segment l.e.d. display (X1) connect to RB1 to RB7, via current limiting resistors R1 to R7. The common anodes connect to RA0 and RA1 via transistor drivers formed around TR1/R9 and TR2/R8. There are two separate l.e.d.s, D1 is the local fastest finger display indicator (see later) and D2 provides a power-on indicator.

The Slave Unit takes its power supply from the Master Unit via connector PL1. Resistor R13 drops the incoming voltage to reduce heat dissipation in the 5V regulator IC2. Capacitor C1 provides smoothing. Current consumption of the Slave Unit is about 80mA.

Pushbutton switch S1 is effectively an extension of the 4 × 4 “keypad” on the master device. Link 1 is used to select the connection for either Team 1 or Team 2. PIC pin RA4 is pulled high or low via the setting of Link 2, to ensure that the display corresponds with the switch and is read by the software to determine which team’s score to show.

The master/slave connection is run as a “bus” system, so the slave units can both be connected to the master, or to each other – although the printed circuit board (p.c.b.) design caters only for direct connection to the Master Unit.

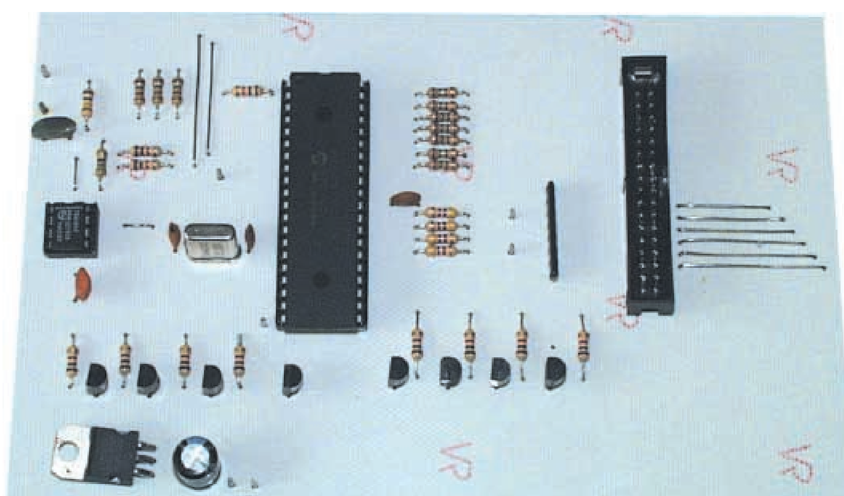
Master Construction

The Master Unit comprises two p.c.b.s, one for the front display panel, including the 7-segment displays and switches S1 to S16, and the other for the main control board. This simplifies construction overall as the front panel display p.c.b. is easier to mount in the face plate of a case. The boards are linked via a 34-way IDC cable and connectors.

The component and track layout details for the boards are shown in Fig.3 (Control) and Fig.4 (Display). These boards are available from the *EPE PCB Service*, codes 461 and 462 respectively.

Note that not all switches or displays need to be used. For example, a minimal unit might comprise only two dual 7-segment displays, plus switches to increase or decrease the score by one.

Begin construction by soldering the wire



Component layout on the Control circuit board.

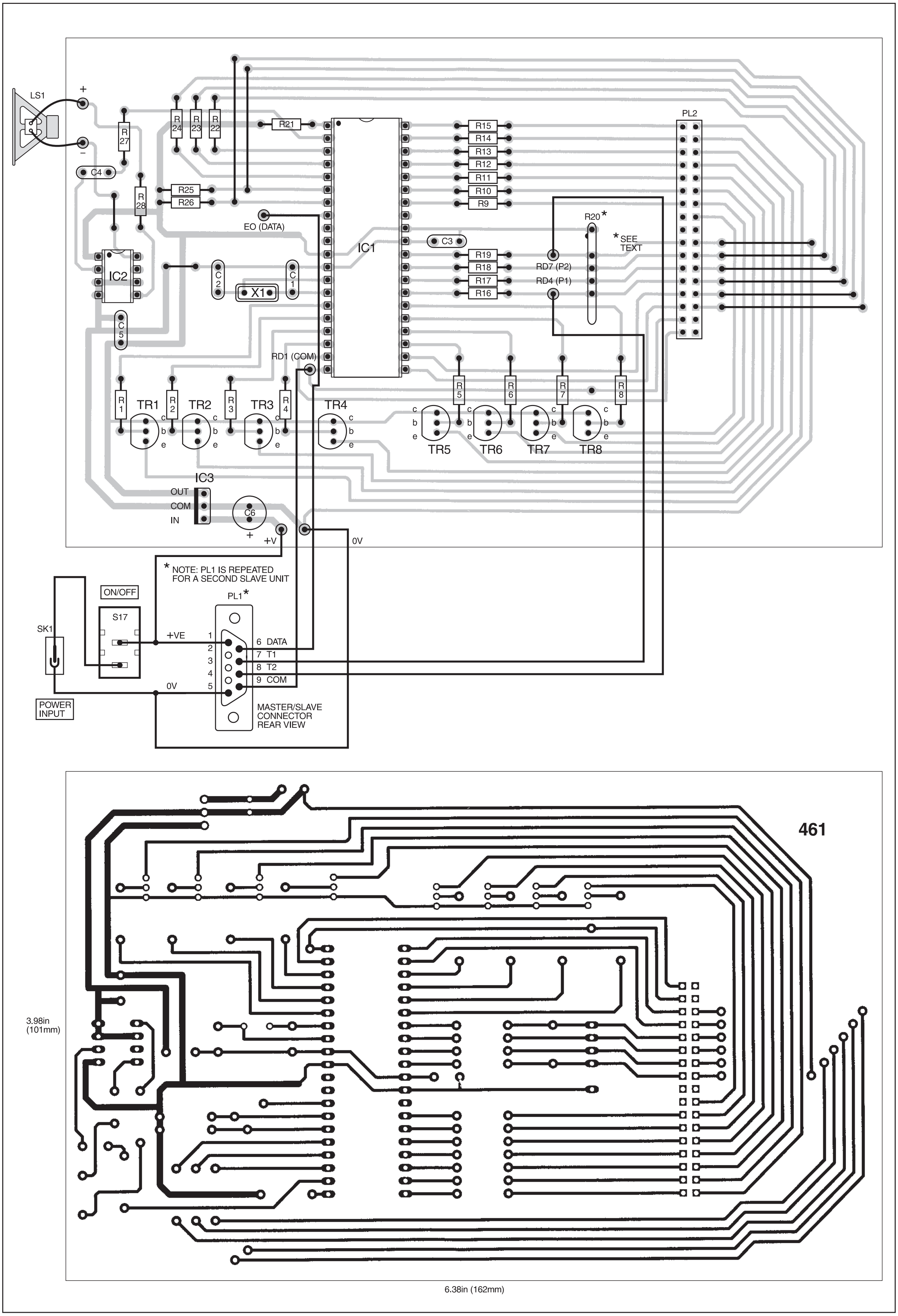


Fig.3. Control printed circuit board component layout, full-size copper foil master and wiring to off-board components.

COMPONENTS

MASTER UNIT

See SHOP TALK page

Resistors

R1 to R8, R25, R26	1k (10 off)
R9 to R15, R22 to R24	150Ω (10 off)
R16 to R19	4k7 (4 off)
R20	47k 8-way commoned resistor module (see text)
R21	10k
R27	100k
R28	56Ω

All 0·25W 5% carbon film or better, except R20

Capacitors

C1, C2	22p ceramic disc, 5mm pitch (2 off)
C3, C5	100n ceramic disc, 5mm pitch (2 off)
C4	220p ceramic disc, 5mm pitch
C6	100μ radial elect. 16V

Semiconductors

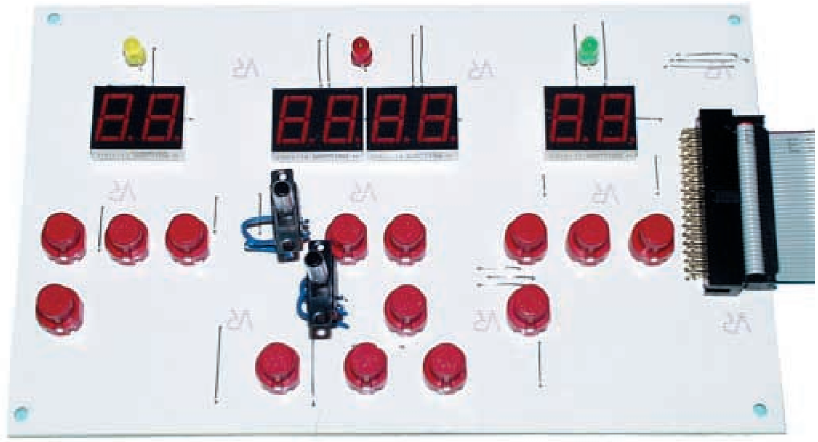
D1 to D3	green, yellow, red l.e.d., panel mounting (1 off each)
IC1	PIC16F877-20 microcontroller, pre-programmed (see text)
IC2	TDA7052 amplifier i.c.
IC3	7805 +5V 1A voltage regulator
TR1 to TR8	BC549 npn transistor (8 off)

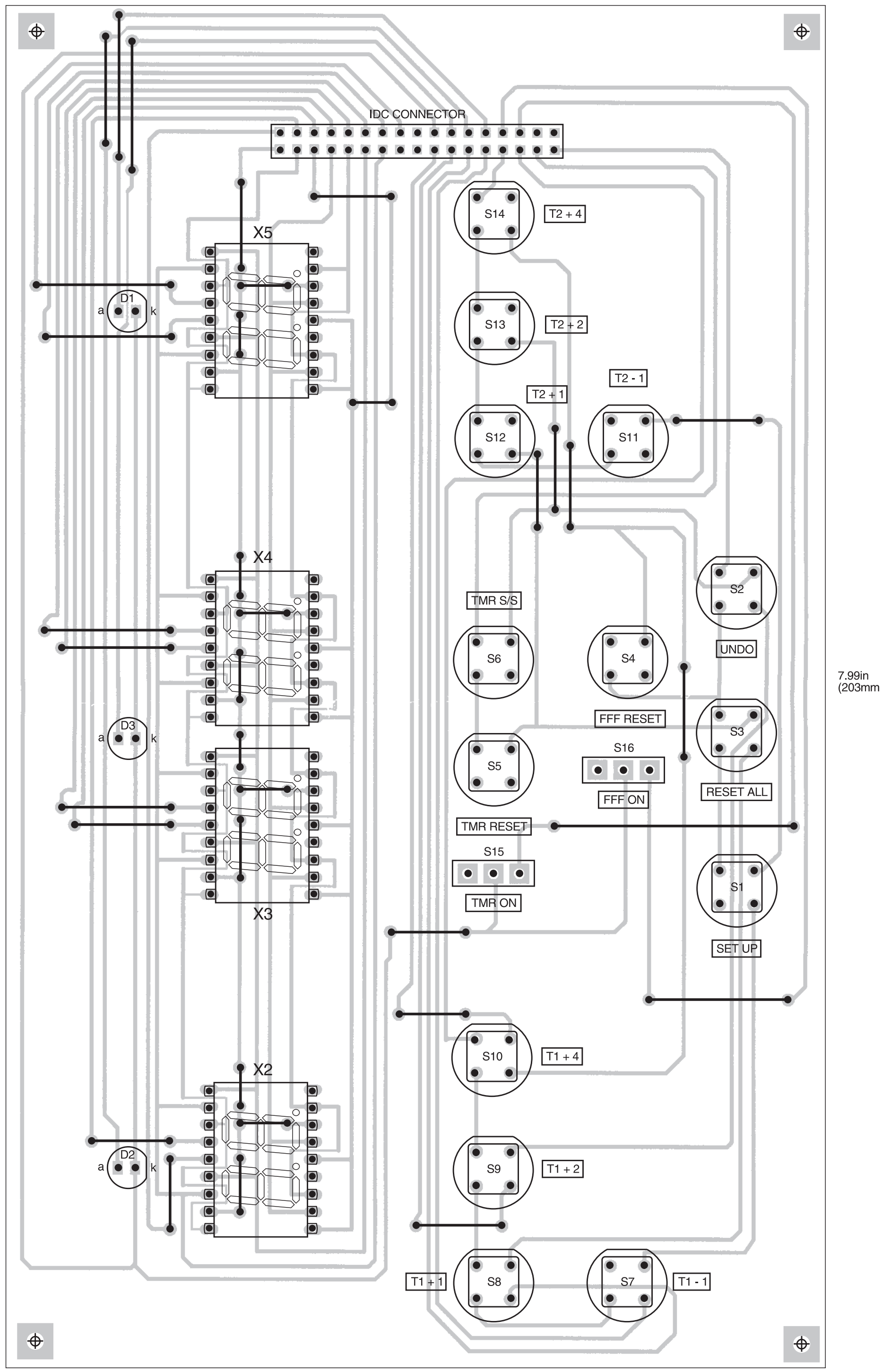
Miscellaneous

LS1	min. 8Ω to 64Ω loudspeaker, panel mounting (see text)
PL1	9-pin D-type serial connector, male, panel mounting (2 off, see text)
S1 to S14	s.p. push-to-make switch, robust, p.c.b. mounting (14 off)
S15, S16	s.p. slide switch, toggle operated, panel mounting (see text) (2 off).
S17	s.p.s.t. switch
SK1	d.c. power input connector, panel mounting
X1	20MHz crystal
X2 to X5	2-digit 7-segment l.e.d. display, common anode (4 off)

Printed circuit boards, available from the *EPE PCB Service*, codes 461 (Control) and 462 (Display); plastic case, sloped panel, 240mm (w) x 185mm (d), min height 65mm, max height 100mm; 36-way IDC connector, male, p.c.b. mounting (2 off); 36-way IDC connector, female, cable mounting (2 off); 36-way IDC cable, approx 30cm; mounting nuts and bolts, to suit; connecting wire; solder, etc.

Approx. Cost Guidance Only **£35** *excl. case*





links, followed by the other components in ascending order of size, ending with the 7-segment displays, pushbutton switches and the IDC connector.

Resistor module R20 is in fact an 8-resistor component and the unused pins should be cut off. There is a marking on the module's case to indicate the common connection. Note that slider switches are used for S15 and S16. Whilst panel-mounting switches were used with the prototype, connected by short flying leads, these could be p.c.b. mounted types if you prefer. A vice is a handy tool for connecting the IDC sockets to the ribbon cable.

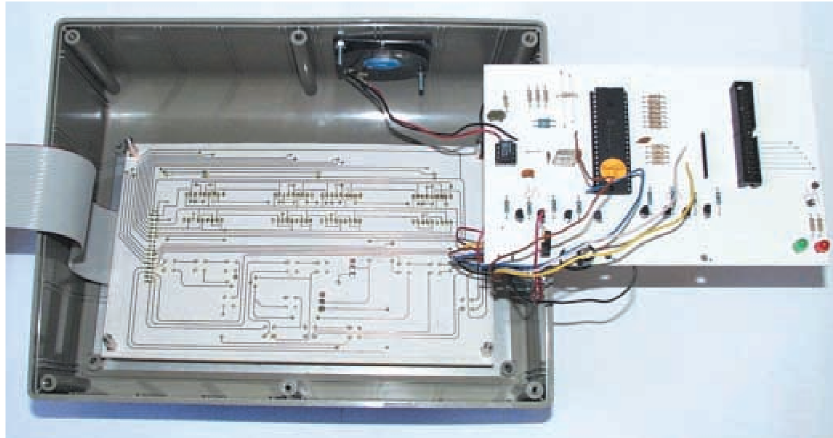
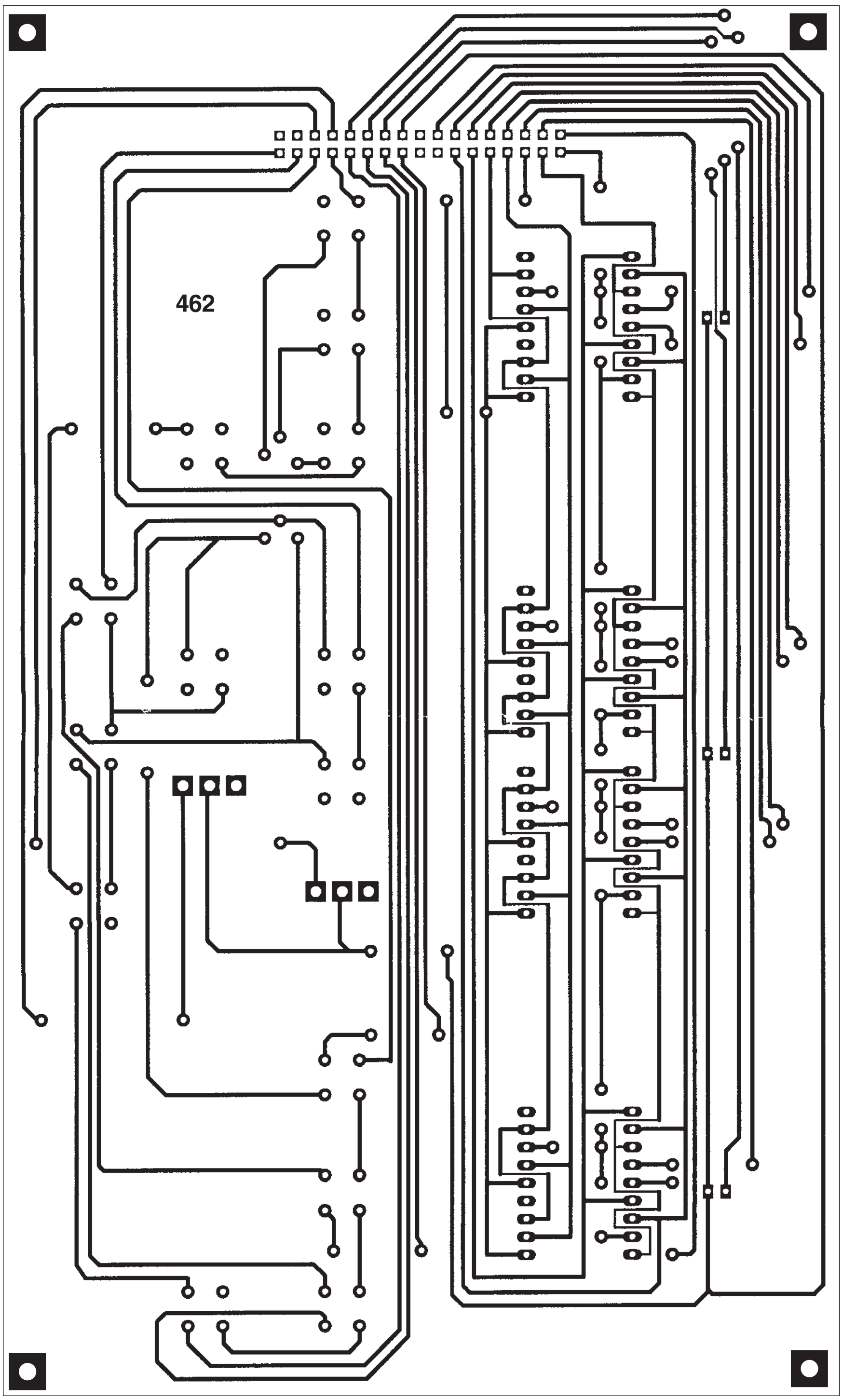


Fig.4. Front-panel Display p.c.b. component layout (opposite page) and full-size foil master (below).



Master Testing

The Control board should be connected to the front-panel Display board and tested using a temporary power connection before being inserted into the case. First check that there are no obvious short circuits. *Before inserting the PIC (IC1) and other d.i.l. i.c.s,* apply power and check that the +5V regulated voltages are correct.

Insert two wander leads into pins 11 (+VE) and 12 (0V) of the PIC socket. Connect the lead from pin 11 to each of pins 15 to 18 and then pins 23 to 26 (Port C) in turn. Whilst each Port C pin is connected to pin 11, use the second wander lead to apply 0V in turn to pins 34 to 40 (Port B). One l.e.d. segment should light for each connection.

Slave Unit Construction

Construction of a Slave Unit is very straightforward based on the p.c.b. whose component and track layout details are shown in Fig.5. This board is available from the *EPE PCB Service*, code 463 (Slave).

Assemble in the same order as the other boards, again check thoroughly. Link 1 and Link 2 should be configured to set the board to Team 1 or Team 2 according to the following:

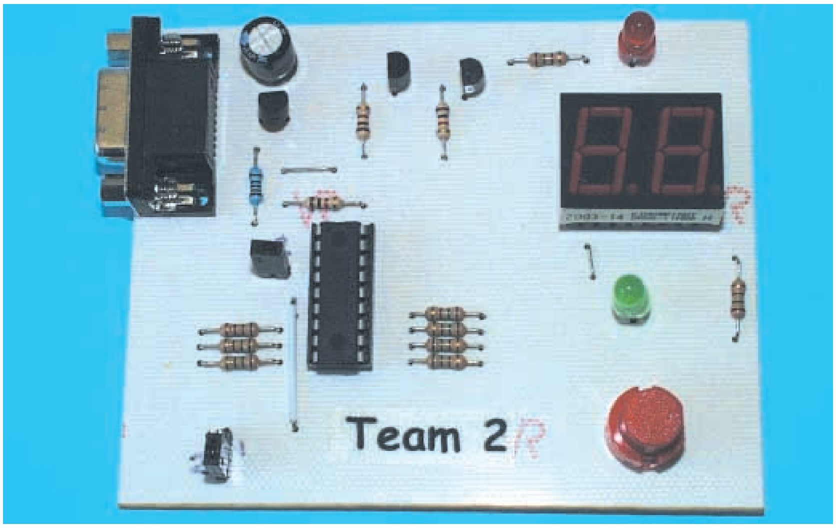
Mode	Link 1	Link 2
Team 1	1-2	Unconnected
Team 2	2-3	Connected

Setting Up

The prototype has been tested with slave to master distances of up to six metres.

When the main unit is powered up with the PIC installed, the default settings are one, two and four points for the score adjustment switches and 30 seconds for the countdown timer. The display will show 0 points for each team, and have 30 seconds on the clock.

To change the default, should you wish to, first press the Setup switch, S1. The display will show "SEt U1" (in 7-segment speak!) and l.e.d. D3 will flash. Switches S12 (T2+1) and S11 (T2-1) can now be used to change the value associated with user programmable switches S8 and S12. To adjust user programmable switches S9 and S13, press switch S9 (T1+2). The display will show "SEt U2 02" and the point value that will be associated with S9 and S13 can be adjusted as above. Similarly use S10 (T1+4) to adjust user programmable switches S10 and S14.



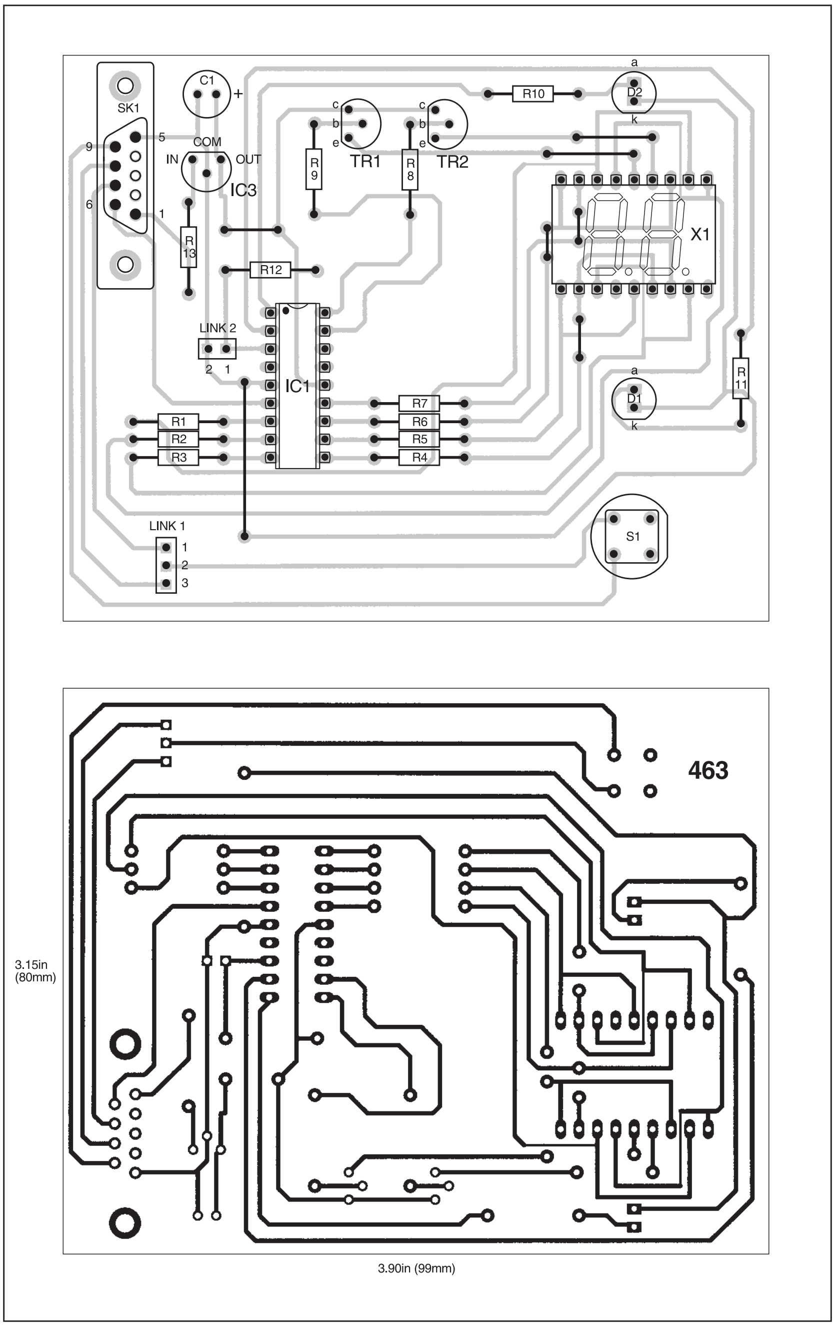


Fig.5. Slave p.c.b. component layout and full-size copper foil master. A completed board is shown above.

COMPONENTS

SLAVE UNIT
(1 off, two required, see text)

Resistors

R1 to R7, R10, R11	150Ω (9 off)
R8, R9, R12	1k (3 off)
R13	100Ω 0.6W

All 0·25W 5% carbon film or better, except R13

Capacitor

C1	100µ radial elect. 16V

Semiconductors

D1, D2	red l.e.d. (2 off)
IC1	PIC16F628 microcontroller, pre-programmed (see text)
IC2	78L05 +5V 100mA regulator
TR1, TR2	BC548 npn transistor (2 off)

Miscellaneous

S1	min. push-to-make switch
SK1	9-pin D-type serial connector, female, p.c.b.
X1	2-digit 7-segment l.e.d. display, common anode

Printed circuit board, available from the *EPE PCB Service*, code 463 (Slave); 9-way connecting cable; 2-pin and 3-pin 2·5mm single row p.c.b. header plug (1 off each); 2-pin 2·5mm jumper link (2 off); solder, etc.

Approx. Cost Guidance Only **£15**

To change the countdown time, press the Start/Stop switch (S6) when the unit is in Setup mode. The display will now show “SEtt 30”. Switches S12 and S11 (T2-1 and T2+1) adjust the value of seconds up or down, and S13 and S14 (T2+2 and T2+4) likewise adjust the minutes. When setup is complete, press switch S1 again and the unit is ready for action.

Use switches S7 to S14 to adjust the scores for each team, as programmed above. Switch S16 enables or disables the “fastest finger” switches (S1 on each slave unit). If this functionality is enabled, l.e.d.s D1 and D2 flash together with the corresponding l.e.d.s (D1) on the slave units. When a team presses their button, the l.e.d.s on both master and slave of the winning team are turned on and the other team’s l.e.d.s are turned off. The slave switches are then disabled. The FFF Reset switch (S4) re-enables them.

Switch S15 (Timer Enable) turns the countdown timer on and off. The timer can be started and stopped using S6 (TMR S/S), and reset to the original value via S5 (TMR Reset).

Switch S2 is an “Undo” key which takes the scores back to their values prior to the last adjustment. □

News . . .

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

THE IMPORTANCE OF BEING CE MARKED

Barry Fox reports on the state of the consumer electronics industry as analysed by Marantz.

IT'S now war between the consumer electronics and computer industries, warns Japanese electronics specialist Marantz. "The trade has to realise that the computer is now a CE product – whether we like it or not". So said Marantz's Brand Ambassador, Ken Ishiwata at the company's annual press and trade seminar in Barcelona in early June. "Microsoft and Intel officially declared war on the CE industry at CES in Las Vegas".

The term CE is the abbreviation for the French phrase "Conformité Européene" which literally means "European Conformity". CE marking on a product is a manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety and environmental protection legislations.

Continued Ishiwata, "I said this would happen, last year, and some of you looked surprised. At CES 2004, Bill Gates launched Media Center Extension and Windows Portable Media Center. Dell, HP and Gateway are using it for large LCD sets. Intel unveiled LCOS (liquid crystal on silicon) for rear projectors. That's Intel's first CE product. There is just one standard chip size, 0·8-inch, regardless of picture size or number of pixels. Now almost anyone can make a projection set."

Ishiwata was giving his now traditional annual analysis of current world electronic markets and future market predictions, based on figures from JEIDA, the Japanese Electronic Industry Development Association. He now admits he hates doing the massive amount of work involved in analysing "boring stupid numbers", but continues "because the British press make me do it".

Number Crunching

The press lap up Ishiwata's crunched numbers because they are the best distillation of industry trends available. But his slides are only briefly flashed on screen, for copyright reasons. So those who know what to expect, write notes very fast.

The total TV market worldwide, last year was running at 130 million sets. By 2008 JEIDA expects it to be 142 million. Last year one million of these were plasmas, and this year the number is very nearly doubling to 1·95m – with 15·9m l.c.d. sets expected to sell by the end of the year.

The world market for DVD players was 62m last year, with 70m expected this year, but the number rising only to 72m by 2006. "The market is stagnating" says Ishiwata.

And in Japan last year 38% of all consumer DVD players already had a recording function. By 2008, 94% of Japanese DVD players will be recorders. As a result, world sales of VCRs were down to 24 million last year and by 2008 the number will be down to 4·6m.

Says Marantz's European MD, Terrie O'Connell: "Price erosion in Europe is frightening. Home theatre prices have fallen by 48% in the last year, with across-the-board audio prices down by 11·4%. It's scary that 89% of all the DVD players sold this year are priced at under 200 Euros; 44% of DVD players are now below 75 Euros. DVD recorders are already going the same way. Only 2-channel hi-fi audio prices are going up. Dealers can earn more margin from selling a connecting cable than the plasma screen it is for".

Says Product Marketing Manager, Bert Kiggen: "The market feedback we get is that audio customers don't want multichannel. By the end of this year all our CD players will be 2-channel SACD players."

Theatrical Figures

Budget "Home Theatre in a Box" is taking off with 0·85m boxes sold and the number likely to rise to 1·2m in 2008. But world sales of mini and micro audio systems are stagnating too, with 33m last year and reaching only 34·4m by 2008. AV receiver box sales were at 5·3m last year, but will slow down and fall to 5.1m by 2008.

There are no reliable figures yet on iPod-style player sales but the effect is already evident. "Mini Disc is quite stable in Japan but going down in Europe" says Ishiwata. "Sadly for Sony, Walkman time is over. Having an iPod is what matters to people now. People don't want to say I have a Walkman, they want to say I have an iPod"

Last year 4·8m portable Mini Disc players sold round the world, and by 2008 the world number will be down to 4·2m. In Europe, Mini Disc sales last year were 1.1m and this will tail off to 0·85m in 2008.

Likewise portable CD players were at 33·8m last year and are expected to decline to 26·3m by 2008. In the USA, the number was 17m last year, declining to 10·7m in 2008.

Sales of compact cassette players and recorders last year were 13·5m worldwide, plummeting to 4m in 2008.

"Do you know who is the most successful company in Japan today?" asked Ishiwata. "It's Sanyo. They realised that their brand name doesn't mean anything so they concentrate on OEM. They have 30% of the market share in digital cameras, 40% in laser optics for DVD and CD and 50% of rechargeable batteries come from Sanyo. They understand their brand image weakness, and that's their business strength."

RADIO KEYFOBS

The 120 series of FM keyfob transmitter encoders from R.F. Solutions can be combined with any one of a wide range of the company's decoder boards to provide complete remote control systems with a comprehensive array of interfacing capabilities.

The licence exempt CE compliant 433MHz keyfobs are available in one, two or three button variants to suit a wide range of applications. The keyfobs use the highly secure KEELOQ code hopping protocol and have a range of up to 150 metres. FM operation makes the units less susceptible to interference and therefore well suited to use in difficult environments where there is high risk of spurious radio signals.

For more details contact R.F. Solutions, Dept EPE, Unit 21, Cliffe Industrial Estate, South Street, Lewes, E. Sussex BN8 6JL. Tel 01273 898000. Fax: 01273 480661. Email: sales@rfsolutions.co.uk. Web: **www.rfsolutions.co.uk**.

BATMAN AND FLOWCODE

MATRIX Multimedia's Flowcode, which converts simple flow-charts to PIC code, is being used by designers at Elstree studios for the latest *Batman* film. Elstree is a renowned global centre of excellence in special effects development for the movie industry. Development engineers are using Flowcode as a mechanism of rapidly developing electronic panels for various devices in the film.

Paul Zippo, a development engineer working on the film, said "Flowcode is great for this: having designed the layout of the instrument panel I can make a mock-up of how it works in the film, and then sit down with the producers and fine-tune the system as they watch. This saves hours of development time and gives us a better product".

Flowcode is a very high level language programming system for PICs and is based on flowcharts. It uses macros to facilitate the control of complex devices like 7-segment and l.c.d. displays, and motors.

For more information on Flowcode contact Matrix Multimedia Ltd., Dept EPE, The Factory, 23 Emscote Street South, Halifax HX1 3AN. Tel: 0870 700 1831. Fax: 0870 700 1832.

Flowcode is available from *EPE* – see the *CD-ROMs For Electronics* advertisement on page 577 of this issue or via the shop on our UK website at **www.epemag.wimborne.co.uk**.

INGENIOUS MUSEUMS

FOR the first time, people from all over the world will be able to see over 30,000 objects and pictures taken from collections of the Science Museum, the National Museum of Photography, Film and Televisions, and the National Railway Museum, and hear about the stories behind many of them and enter into debates through a unique online resource, **www.ingenious.org.uk**.

The site is the result of an unprecedented collaboration between the three museums that together form the National Museum of Science and Industry (NMSI). It celebrates and explores the many feats of human ingenuity that have shaped our lives, including stories, articles, opinion pieces, images and online debates, providing a fascinating and absorbing insight into science and culture for everybody interested in human invention. Access is free.

BOWOOD MOVES

BOWOOD Electronics, suppliers of electronic components (see our Classified pages) tell us that they are pleased to have moved premises. They are now at Dept EPE, Unit 1, McGregor's Way, Turnoaks Business Park, Chesterfield S40 2WB: Tel: 01246 200222. Please note that they are Mail Order only.

ANDY FLIND

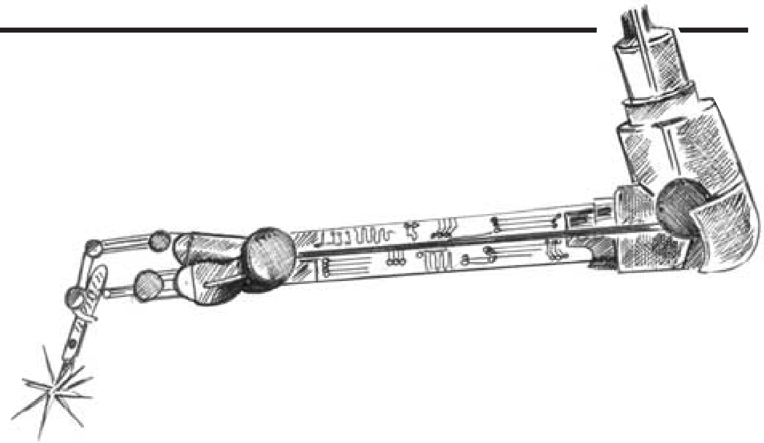
EPE has lost a great friend and contributor. Andy Flind passed away after a short illness on 4th June, just a few weeks after his 60th birthday. Andy had been a contributor to *EPE* since the publication of his highly regarded *Magnum Metal Locator* in 1980. In recent years he had also been responsible for producing half of all the diagrams we use in the magazine.

Andy was an apprentice at Fulham Power Station 40-odd years ago, where he worked with asbestos – the apprentices even slept on it when on night shift. He was asked to leave the apprenticeship because he spent some of his time repairing motorcycles – he even invented steam-heated handlebars for his Velocette Viper; the water was heated from the exhaust pipe. He had been a milkman ("The hardest job I ever did"), a wireman, and spent four years as an instrument craftsman at Hinkley Point Power Station, followed by ten years with the CEGB at Westward Transmission as a technician and five years as a telecoms technician for SWEB. He was self-taught in electronics and produced many of the most popular projects published in *EPE*. His last project – the *Portable Mini Alarm* – was published last month.

A family man with a lovely gentle nature, Andy was always willing to help anyone. We will miss him greatly, our sympathy goes to his wife and family.

Regular Clinic

Circuit Surgery



Alan Winstanley and Ian Bell

This month's column is a light emitting diode extravaganza, looking at the latest l.e.d. power controller chips and answering some basic questions on using l.e.d.s.

In the L.E.D. Driving Seat

A query that crops up quite frequently concerns driving l.e.d.s (light emitting diodes) in parallel or series. Which method is best? What voltages and currents are required? What is the best way to control their brightness?

L.E.D.s can be driven either in series or in parallel, but the two approaches have different characteristics and potential pitfalls. We are assuming, of course, that when driving multiple l.e.d.s we want all the devices to have pretty much the same brightness so that we can create an aesthetically pleasing display or evenly distributed illumination.

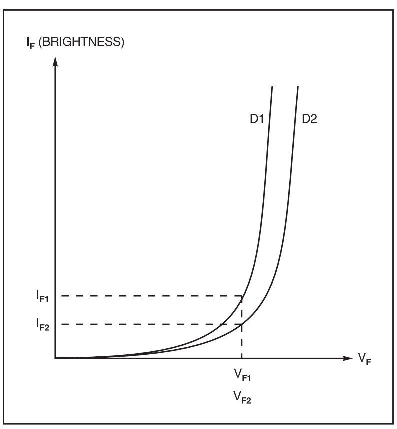


Fig.1. Possible characteristics of two individual l.e.d.s of the same type. With the same forward voltage the l.e.d.s may have different forward current and hence different brightness.

Light emitting diodes are current controlled devices – the light output (brightness) is just about linearly proportional to the forward current. So it is the forward current, not the voltage, which sets the brightness.

Two individual l.e.d.s of the same type will produce the same illumination with the same forward current (I_F), but may have different forward voltage drops (V_F) at this current. The variation in voltage drop between individual devices may be in the range 0·1V to 0·3V for typical l.e.d.s. This is a key factor that needs to be considered when designing l.e.d. drive circuits. Typical l.e.d. characteristics are shown in Fig.1.

Two l.e.d.s driven in parallel are shown in Fig.2. This circuit forces the l.e.d.s to adopt the same forward voltage drop, which means that their forward currents and hence brightness may be different (see Fig.1).

Two l.e.d.s with separate current limiting resistors are shown in Fig.3; we can still get problems with variation between individual devices resulting in varying brightness. An example will help explain this.

Assume we have white l.e.d.s with D1 having a forward voltage drop of 4V at a forward current of 20mA. If the supply (V_S) is 4·5V we have R1 = 25 ohms so that R1 drops 0·5V and we have 4V across D1. If, however, l.e.d. D2 is connected with R2 = 25 ohms as well, but has, say, a forward voltage drop of 3·6V due to variations in individual device characteristics, then the current in D2 will be 36mA . The difference in current will show up as a noticeable difference in brightness.

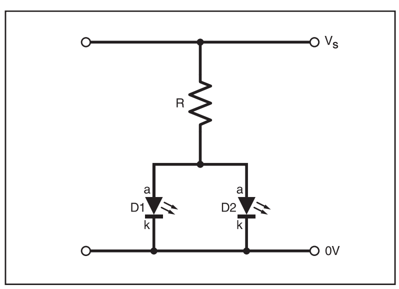


Fig.2. Driving two l.e.d.s in parallel.

If we use a higher supply voltage, then the brightness variation problem is reduced. For example consider a +20V d.c. supply. Let's say we have R1 = 800 ohms to get 20mA with a 4V drop across D1, so the l.e.d. is driven as before. Now consider l.e.d. D2 with a 3·6V drop once again, and R2 as 800 ohms. The current in D2 is 20·5mA, almost the same as that flowing through D1, so both l.e.d.s will appear to be equally bright.

However, this comes at a high price though – the total power dissipation in the two current limiting resistors (R1, R2) is about 0·66W in the second example, which is almost twenty times higher than in the first example. The second circuit is very inefficient and would not be very suitable for battery-powered operation.

In Fig. 4 we show three l.e.d.s driven in series. The current through the l.e.d.s must be equal so their brightness will be equal. A potential difficulty with this circuit is that a relatively high voltage is required to drive the series chain. For example, if we have a 4V drop per l.e.d. (as in the previous example) we need at least a 12V supply.

In Control

An efficient, low voltage solution to the brightness variation problem is to drive each l.e.d. from a separate constant current

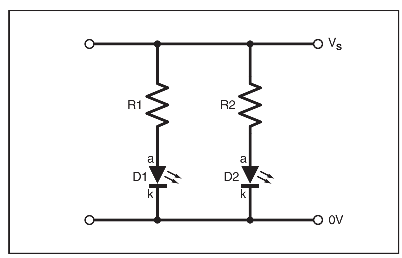


Fig.3. Two l.e.d.s with separate current limiting resistors.

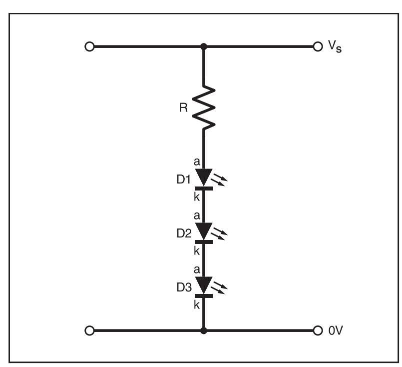


Fig.4. Driving l.e.d.s in series ensures the same forward current but requires a higher drive voltage.

source that is set to the required forward current. The current in every l.e.d. circuit could then be modulated by a single control voltage if brightness variation was required.

This solution would need a number of discrete components to implement, however a number of i.c.s performing exactly this function are available, some also have controls to enable the l.e.d.s to be pulsed. However, these devices may be surface mount types (as may the l.e.d. chips that they are often designed to drive). If you can obtain and handle these SM chips then it is worth experimenting.

The chips typically have two to four l.e.d. drive outputs and are aimed at driving white l.e.d.s. Examples include the LM3595 from National Semiconductor (**www.national.com**) in a leadless package that hobbyists will struggle to use, and the MAX1916 from Maxim (see **www.maxim-ic.com**) – see Fig.5.

The best average light output is obtained by d.c. drive, with control of forward current being used to control brightness. Short duration, high current pulsing is most appropriate when the l.e.d. is used to send a signal to a photodetector.

The switching of l.e.d.s for human viewing is of course needed in applications where groups of l.e.d.s. form symbols or messages, as in a multiplexed 7-segment display. However, PWM is used quite frequently for varying l.e.d. brightness for human viewing because it is easy to implement using purely digital circuits – it does not require a DAC for a control voltage or current.

When pulsing an l.e.d. a key parameter is the peak junction temperature of the diode. If the maximum junction temperature is exceeded the device will be damaged. For pulse rates below about 1kHz the peak junction temperature is higher than the average temperature so at and below this pulse rate the allowable average current is lower than at higher pulse rates. The power dissipation in l.e.d.s was discussed in *Circuit Surgery*, November '02. *I.M.B.*

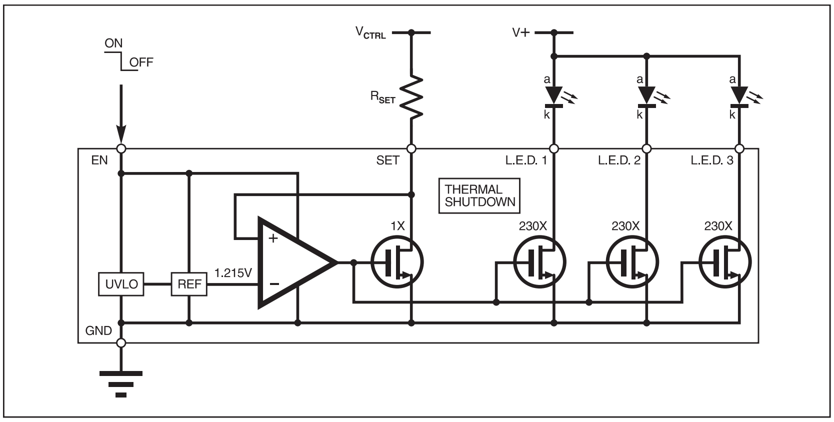


Fig.5. Maxim MAX1916 low-dropout, constant current triple white l.e.d. bias supply.

Chips are also available for producing the relatively high voltages for series l.e.d. driving from lower voltage supplies. These include the MAX1848 from Maxim. Details of this device and other background l.e.d. information are published in their extremely useful Application Note No. 3070 (**http://www.maxim-ic.com/appnotes.cfm/appnote_number/3070**).

Some very sophisticated l.e.d. driving chips are available now to support the use of l.e.d.s in mobile devices such as phones. One example is the LP3933 from National Semiconductor which is described as a "lighting management system for six white l.e.d.s and two RGB or flash l.e.d.s". It features digitally controlled constant current drivers for display backlight brightness control, blink pattern generators, RGB colour control and a flash function for use with phone cameras.

In addition to varying the forward current, l.e.d. brightness can be controlled by pulse width modulation (PWM) – the l.e.d. is switched on for some of the time and off for the rest of the period. As the proportion of on-time (pulse width) relative to off-time increases then the l.e.d. brightness increases.

The pulse rate should be at least 100Hz, but much higher rates are often used. If l.e.d.s are pulsed a square wave should be used because sinewaves result in about two thirds of the light output of an equivalent square wave.

More L.E.D. Questions

I'm trying to wire up an infra-red illuminator using 25 IR l.e.d.s (they are Maplin SFH409 GaAs Infra-red Emitting Diodes) running from a 12V 2·5Ah lead acid battery, each drawing 100mA. Using the l.e.d. resistor calculation $R = (V_s - V_f) / I_f$ *I then calculated a resistance of (12 – 1·3) / 0·1 = 100 ohms. I've rigged them up with 25 × 100 ohms resistors. All seems OK and they do indeed light up* (always a good sign – ARW)*, well . . . not "light up" but you can see them on an infra-red camera.*

The problem is that the resistors seem to get very hot very quickly. So the questions I have are:

Circuit Surgery will wherever possible offer advice or pointers to readers, but we cannot guarantee to do so, and the ease with which queries can be sent by email does nothing to help! It is not always possible to offer either quick "snap" or considered answers to every circuit, especially if it would be necessary to build or simulate the circuit, but we do read every letter, reply where we can and we publish a selection of your queries every month. You can send your emails to **alan@epemag.demon.co.uk**.

a) Why are the resistors getting so hot?
b) How can I stop them from frying?
c) Could I not just use one resistor for all the l.e.d.s rather than one each?

On a separate query, if I connect two resistors in series, both 1/4W 47 ohms I'll end up with the equivalent of a 94 ohm resistor – but what will the wattage be? The same? More or less? Thanks for any help! ***John Neal, Southampton****.*

Checking the specs, the SFH409 infrared l.e.d. (Maplin CY84F) is rated at 1·3V forward voltage at 100mA forward current (1·9V at 1A). Your resistor value is correct, although the specification quotes a surge current of up to 3A.

There are various ways of wiring the resistors. You can opt to use separate resistors with each l.e.d., each unit placed in parallel, so that one l.e.d. adopting a lower forward voltage doesn't shunt others that are in parallel. However, having just one series resistor driving 25 l.e.d.s in parallel is not a good idea because of this l.e.d. "shunting" effect, plus the resistor's power rating would need to be huge (about 25W).

A value of 100mA is extremely high for an ordinary l.e.d. application, and the resistors are responsible for a lot of power wastage. Looking at their power ratings, each one in series dissipates (I^2R watts) = one watt! The resistor rating needs to match this value (which explains why they are getting too hot), but again a total of 25 watts is very wasteful.

In a non-critical application like this, you can afford to wire them in groups of (say) six l.e.d.s all in ***series*** with a resistor, and wire any number of those groups in ***parallel***. Six series l.e.d.s across 12V means a series resistor of 42 ohms, and I^2R is far better at 0·42 watts. The power dissipated (wasted) by the resistors is then just a couple of watts in total.

On the last query: if you connect two resistors in series, their power rating remains the same, at 1/4 watt each! The overall power rating is now 1/2 watt. *A.R.W.*

Constructional Project

Keyring L.E.D. Torch

John Ellis

An "easy-build" torch that will give many hours of pleasure

THIS project started as a solution to the common problem of never having a light when you need it. It then grew into providing Christmas presents last year for the family, when a dozen were made, all of which worked first time apart from one – a copper track fault had to be fixed.

There are l.e.d. torches available in the shops, but those seen usually use three battery cells, none yet being electronic. One objective for this project was to use a single 1·5V cell with a simple converter to run the l.e.d. A small button cell would have been ideal, but the only holders encountered were for the large diameter lithium cells rated at 3V.

The smallest cell for which a suitable holder was found was the N-size, which required the box being slightly larger than the author would have liked, but still compatible with a keyring. The final choice of box was one measuring just 50mm × 35mm × 17mm.

Circuit Details

The full circuit diagram for the Keyring L.E.D. Torch is shown in Fig.1. The circuit has its roots going back to the earliest days of transistors. It is a free-running, ringing choke converter; similar to a blocking oscillator, but has no timing capacitor. When the On/Off switch S1 is pressed, current flowing into the base (b) turns transistor TR1 on and its collector current rises linearly according to:

$$\frac{\delta i}{\delta t} = \frac{-E}{L}$$

The feedback winding L2 provides a 1·5V boost which adds to the battery voltage, supplying transistor TR1 with a 0·7mA base drive. When TR1 collector current reaches about 100mA to 150mA, TR1 is unable to sustain saturation, and the current stops increasing.

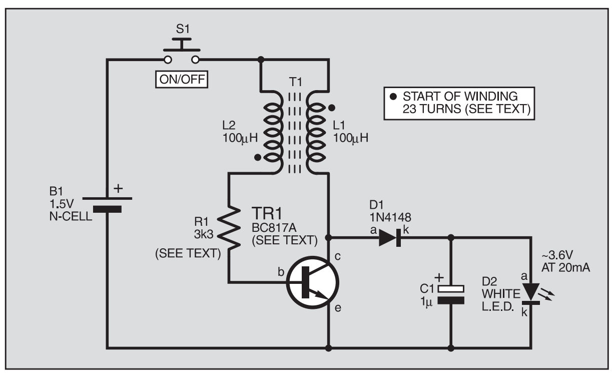
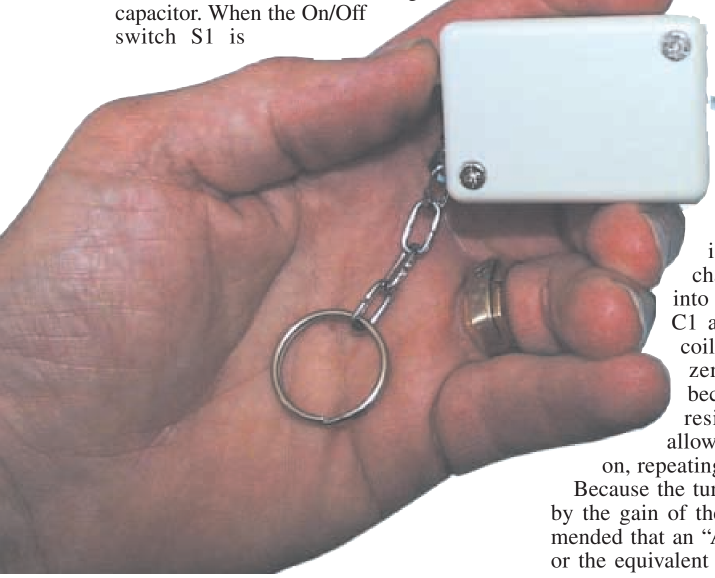


Fig.1. Complete circuit diagram for the Keyring L.E.D. Torch.



Regenerative action quickly causes the transistor to switch off. Then, the stored energy in the choke is discharged through diode D1 into the smoothing capacitor C1 and l.e.d. D2. When the coil's magnetic field reaches zero, the back-voltage becomes zero, and the bias resistor R1 once again allows the transistor to switch on, repeating the cycle.

Because the turn-off point is controlled by the gain of the transistor, it is recommended that an "A" gain group transistor, or the equivalent "-16" type is used. It is possible to use other gain groups, but the base resistor R1 should be altered accordingly – a higher gain group needs a higher resistor. The "off" state timing is efficient because it is set by the stored energy in the coil itself.

Coil

The coil has to be small and a 6·3mm diameter ferrite toroidal ring core was chosen. This is intended for frequencies around 1MHz but because of its relatively low permeability, gives the right inductance for the maximum current required without saturating and without needing an air gap.

The primary and feedback coils require 23 turns, and are wound at the same time, bifilar style. The primary uses 32s.w.g. or 33s.w.g. (0·25mm) wire while the feedback winding can be 38s.w.g. or 40s.w.g. (0·1mm). The coils are wound evenly around the core in one layer from 300mm lengths of wire. The turns ratio is 1:1. The primary inductance is calculated to be 100µH.

L.E.D. Drive

As the input power is limited then the output power will also be limited. So no additional series resistor is needed for l.e.d. D2, and the voltage will adapt itself according to the l.e.d. current.

Although intended to operate with a nominal 50% mark-space ratio, the measured on-off ratio was more like 60%, so with about 150mA peak in transistor TR1, the average input current is around 50mA.

For an l.e.d. current of about 20mA, the maximum voltage possible will be about 3·5V. In practice l.e.d. D2 brightness may vary a little with transistor gain, but can be adjusted by altering the base resistor if desired. The oscillation frequency is about 35kHz.

Construction

Printed circuit board component layout (twice full-size), lead-off wiring details to the l.e.d. D2 and battery, and full-size copper foil master are shown in Fig.2. This board is available from the *EPE PCB Service*, code 456.

In order to get the battery, printed circuit board (p.c.b.) and switch into the specified box, the battery holder is mounted across the diagonal between the two retaining screw pillars. It is a tight fit, but this helps to hold it in place. The circuit board is triangular to fit the top right corner while the switch can then occupy the lower left corner, as shown in the photographs.

On The Surface

The p.c.b. uses "surface mounting" so that all components are soldered onto the copper side – no drilling is necessary, and the board fits flush onto the bottom of the box. The transistor is the only true surface mount device (SMD). The other components are actually conventional types but their leads are bent so they can be soldered onto the board in surface mounting fashion.

The equivalent SMD transistor to the medium current BC337 is the BC817(A). But, a warning – SMDs are TINY and you will need a fine point soldering iron to solder it to the p.c.b. They are supplied in a press-sealed plastic tape, and another warning is to make sure that you don't drop it onto the floor when opening the tape back – or you may lose it! Resistor R1 is a 1/8W part and the smoothing capacitor C1 is a minature type measuring 7mm × 4mm. The diode is a standard 1N4148 signal type.

Circuit Board

Commence construction of the circuit board by soldering in position the ferrite coil L1/L2. The coil needs its four terminals to be tinned and trimmed to within about 7mm of the core, so that it can be connected to the p.c.b. in the order: feedback start (L2●) to the bias resistor R1, feedback finish (L2) to +V (via switch S1); primary start (L1●) to +V (via S1), primary finish (L1) to TR1 collector (c).

Depending on which way you wound the coil you can reverse the start and finish ends on both coils to line up the wires with the copper pads if that is better – but don't reverse only one coil or the circuit won't oscillate.

Transistor TR1 should be soldered next. Hold the transistor in place using a cocktail stick or some such while you make the first joint, or the surface tension of the molten solder may cause the transistor to be picked up by the soldering iron. If you don't want to use an SMD, use a conventional BC337-16 and make tiny L-shaped bends in the leads close to the transistor body to connect these to the p.c.b. pads – not so short though that you cannot get the iron in place to solder it!

Now solder the resistor, diode and capacitor in position, bending the leads down and making little "L" shaped ends in the capacitor leads to make a "surface mount" job. Make sure you bend the capacitor wires correctly so that its positive lead connects to the positive terminal pad on the p.c.b.

Board Check

Before mounting l.e.d. D2 , make sure that no tracks are shorted by the coil, which you should be able to lift very slightly to check. To check that the board works, connect the l.e.d., without bending the leads too much, to their copper pads – taking care to get the leads the right way round (the cathode (k) is the shortest lead and may have a "flat" on its body next to this lead). Attach a short length (about 76mm (3in)) of thin plastic-covered red and black wires to the battery terminal pads on the board.

A word of caution. As this is a simple circuit, there is no protection on the output. If the l.e.d. is wired in reverse, or the leads not connected properly, the oscillator is capable of charging capacitor C1 to quite a high voltage (20V+) which may destroy the l.e.d. So check the connections carefully.

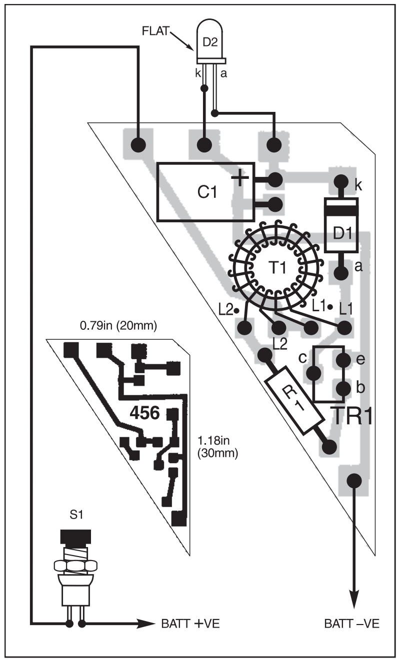


Fig.2. Printed circuit board component layout (twice-size), wiring and full-size copper foil master pattern. Note the components are mounted, surface mount style, directly on the copper pads. The completed circuit board is shown above right.

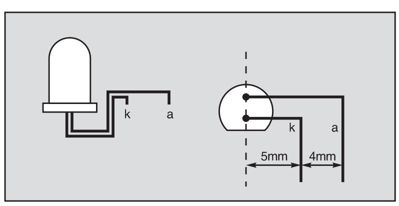


Fig.3. Lead bending guide for the white l.e.d.

Now check that the board lights the l.e.d. by connecting the two supply leads to a battery. Once verified that this works, the l.e.d. should be unsoldered, the leads bent as shown in Fig.3 and then resoldered, so that it will fit a hole to be drilled in the front of the box. Check that the board still works.

The coil can now be fixed permanently in place by lifting it up slightly (without breaking the wires off), squirting a small drop of glue from a hot-melt glue gun onto the board to act as a "bed". Push the coil lightly into position in the glue, allowing some glue to push up through the "ferrite ring" centre hole before it cools.

COMPONENTS

Resistors

R1	3k3 0·125W metal film 1%

See SHOP TALK page

Capacitors

C1	1μ sub-min. radial elect. 25V

Semiconductors

D1	1N4148 signal diode
D2	5mm white high brightness l.e.d.
TR1	BC817A *npn* transistor, surface mount device (SMD), or standard BC337-16 type – see text

Miscellaneous

T1	6·3mm dia. toroidal ferrite ring-core, type B64290P37X33
S1	sub-min. pushbutton switch, push-to-make
B1	1·5V N-cell battery

Printed circuit board available from the *EPE PCB Service*, code 456; small ABS plastic case, size 50mm x 35mm x 17mm approx.; polyurethane (solderable) insulated copper wire for coil, primary winding (L2) 32s.w.g. or 33s.w.g. and 38s.w.g. or 40s.w.g. for the feedback (L1) winding, about 300mm lengths for each; multistrand, red and black, insulated flexible wire; N-cell battery holder; chain links and keyring; solder etc.

Approx. Cost Guidance Only **£10** ***excl. batt., keyring & chain***

Case Preparation

Assuming all is working correctly, it is now time to put the printed circuit board to one side and move on to the next task – case preparation. However, before you do, and because it will not be easy to connect wires to the p.c.b. or battery holder after they are fitted, solder a thin red insulated wire to the battery holder positive terminal. Connect the negative (black) lead from the p.c.b. directly to the battery holder negative terminal, leaving about 80mm to 100mm of wire between them.

The two positive wires (one from the p.c.b. and one from the battery holder) will connect to switch S1, while the battery negative is hard wired to the p.c.b. negative pad. It is also useful to keep checking that the board works because it will not be easy to dismantle it after assembly.

As the circuit board needs to be mounted flat on the base of the case, the front p.c.b. retaining pillar (not the lid retaining screw pillar!) on the base needs to be cut off. Using a small craft knife type blade, slice the pillar off while carefully avoiding slicing your fingers.

Once this is removed, try placing the board and battery holder into the box to check where the l.e.d., switch and keychain links should go. If the board does not fit into the triangle above the battery box, file it down to fit, you must avoid filing any copper tracks. Mark where the switch, l.e.d. and keychain holes go and remove the battery holder and p.c.b. Following the drilling guides shown in Fig.4, the case can now be drilled out.

The holes for the l.e.d. and switch S1 are 5mm diameter. The hole for the l.e.d. is drilled centrally in one short side which will become the front – see Fig.4a. Use a 5mm drill so that the l.e.d. is a tight fit. A sharp drill should cut a clean hole in plastic without needing de-burring.

The holes for the switch and keyring chain are drilled approximately 12·5mm from the sides – see Fig.4b. The key chain hole sizes will depend on what type of chain you use. The author used a standard bath plug chain, with 1·5mm diameter steel wire links, which is rather robust for this application. Two holes of the same

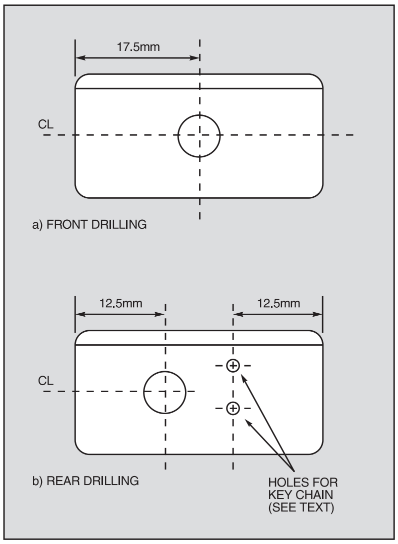


Fig.4. Suggested drilling details for the small plastic case.

diameter, roughly 4mm apart are needed to accept a chain link to hold the box to your keyring.

The chain link should now be formed and fitted into the box. To bend the chain links, you will need a couple of medium size but sturdy pliers. You may need to protect the chain from damage by the pliers jaws.

Straighten and refold one link into a "U" shape with the arms positioned to align with the holes you have already drilled for it. Feed the link into the box. Before folding the arms down on the inside, you may want to attach the rest of the chain so that the protruding part of the U does not inadvertently become too small to take the chain.

Fold the inside of the U arms, lower one up and upper one down, to lock the chain link in place, taking care not to damage the plastic. Use as many links as you wish, but about five is enough, and fit a helical keyring spring at the other end of the chain.

Final Assembly

Now the tricky part. The p.c.b. and battery box need to be mounted together

Completed torch with lid removed showing the tight fit of components inside the small case. The battery holder has to be glued diagonally between the lid retaining pillars.

because the negative lead joins the two, and both are located towards the back. Place a dab of glue in the top right corner to glue the p.c.b. , and carefully but firmly push the l.e.d. into its hole while squeezing the board down onto the glue, sliding it forward and right as far as it will go.

Route the negative lead around the retaining screw pillar, and then use more glue to hold the battery box in place. This is a tight fit, and will need a firm push but make sure that the negative and positive wires do not become trapped. If any glue seeps up through the screw holes in the battery holder scrape it off when it has cooled a little.

Finally, route the two positive wires around the top retaining screw pillar and trim off the ends, leaving enough wire to solder to the switch terminals. After soldering, mount the switch in its hole.

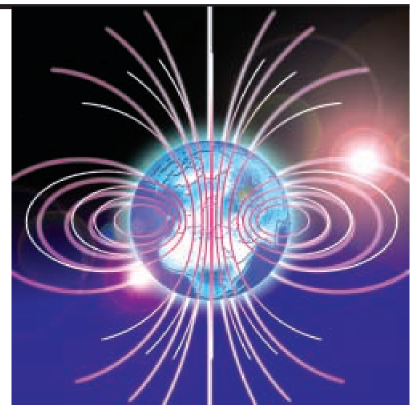
To stop the l.e.d. being pushed backwards into the box, it needs to be glued in position as well. It is worth a final test though before committing it to any glue treatment. Insert the battery into its holder and test. Apply hot glue around the l.e.d. or use plastic-type superglue around it (this is basically superglue with an adhesion promoter for various plastics). Do not use superglue unless you have a tightly fitting hole – you do not want seepage through onto the front panel. Once the glue has set, perform a final check and screw the lid on!

Although the N-cell is larger than would have been ideal, it has the advantage of a fairly large capacity for the application. It should light the Keyring L.E.D. Torch for several hours, longer than would have been the case for a button cell. □

Constructional Project

Magnetometry Logger

Part Two



John Becker

Logging your search for magnetic fields that might reveal hidden artifacts.

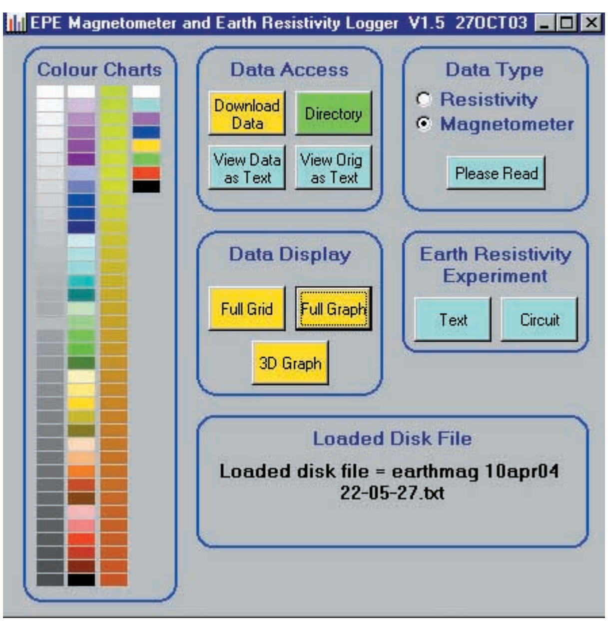
HAVING described in Part One the concept of this Magnetometry Logger, its construction and initial testing, we now conclude by discussing its PC monitoring and display software.

PC Software

Recorded magnetometry data can only be viewed via a PC screen using the specially written software referred to in Part One.

To run the program, open the Magnetometer folder and double-click on **Maggy.exe**. The first time that the program is run it creates several additional files to which it refers each time the program is subsequently loaded. These include various settings which may be changed by the user from within the program, and details of file data paths accessed via the Directory function.

Following this brief procedure, a nearly full-screen display on which graph data will later be drawn is shown. Superimposed on it is a small sub-screen, known to the program as the Main screen.



Main control screen of the Magnetometry Logger.

To the left of the Main screen are four colour charts. These are used by another screen that can be called, the Grid screen, described presently. The various click-buttons will be described as we go along.

First, though, note the box at the top right. Two "radio" buttons are shown, with captions Resistivity and Magnetometer. As said in Part One, this program can be used with the *Earth Resistivity (ER)* project featured in the April/May '03 issues. More on this later.

The Magnetometer option will be seen to be highlighted at present (black dot at the button's centre).

Download Data

The next button of immediate interest is the Download Data button. It is via this option that survey data recorded by the PIC is downloaded.

Note that the data in the PIC's serial memories is unaffected by the download and remains intact. Further recordings may even be made to the memories following a download, and the whole batch input as a block at a later time.

Assuming that you have first Reset the memories, and have already been recording data in several blocks of recording sessions, click on the Download button to reveal the Download screen. Two more radio buttons offer a choice of whether the PC's serial connector path is COM1 or COM2. Connect a standard serial port cable (the same type as you use with a modem) into the COM port socket that you wish to use, and into the Magnetometer connector at the other end. Set the screen COM port choice accordingly.

Follow the screen's instruction to press the PIC's download button (switching S5 to the PC setting – also set the other Mode switches upwards).

On the Magnetometer's screen the message WAITING PC TRIG l.c.d. will be seen. The PIC now waits for a handshake command from the PC.

Click the Start button on the PC's Download screen. It sends the handshake command (the letter "G", for Go), the PIC acknowledges by sending back the letter "R", for Received, and starts to output the stored serial memory data to the PC, in blocks of 1024 bytes.

On receipt of each data block the PC and PIC again exchange "G" and "R" and another block is sent. This continues until the PIC recognises two zeroes in the data being extracted from the memories, or until the data in all memory locations has been sent. The PIC "knows" how many memories are installed and behaves accordingly.

A bargraph shows the download progress. Data is transferred at 9600 Baud, 8 bits, no parity.

Once the PIC has sent all the required data, it displays the message SET BACK TO RUN, meaning that you should switch S5 back to the Run setting. Once the PC recognises that a time-out has passed during which it has received no data, it exits Receive mode and outputs the received data to two text (TXT) files in the same folder as the other Magnetometer files are held.

These are named with prefixes of "EarthMagOrigData" and "EarthMag", followed by a unique date and time identity, as applies at the time of the download.

The first file contains the original data as received from the PIC, but now in ASCII text format compiled from the binary format in which the PIC sends it.

The second file comprises "processed" data in which the values of the two sensors are subtracted from each other and output as the difference value. It is this file that the PC uses when it displays graphics generated from survey data.

With both files the values are output as separate "sentences" whose length depends on the number of values received for each recording session. Both files contain the GPS and temperature data recorded at the start and end of each recording session, placed at the end of each line.

Viewing Data

The files can be viewed as text data by clicking the Main screen's View Data as Text and View Orig as Text. The data is input to either Windows Notepad or Wordpad, depending on its length.

Note that it is possible to amend the "processed" data file and for the amended values to be input next time the file is loaded via the Directory option. Whilst the original data can also be changed via the text editor through which it is viewed, the file cannot be "recompiled" to a "processed" file, so changing it has no practical benefit.

Text file viewing is only available once the complete download cycle has been completed. Once the text files have been stored to disk, the program automatically hides the Download screen and reveals the Full Graph screen, plotting the processed data onto it as waveforms relating to the data values. The speed at which this happens depends on the amount of data being processed and the speed at which your PC operates.

Before plotting each waveform line, the software reads its first value and then subtracts this value from itself and all other values in the line. This is to standardise the relative starting position of the separate lines on the screen.

Before examining the options available via the Full Graph screen, click on the top-left button marked Main to return to the main screen via which you can examine the two text files just created. This action is purely for interest at this stage. To return to the graph screen click on the Main screen button named Full Graph.

Graph Display

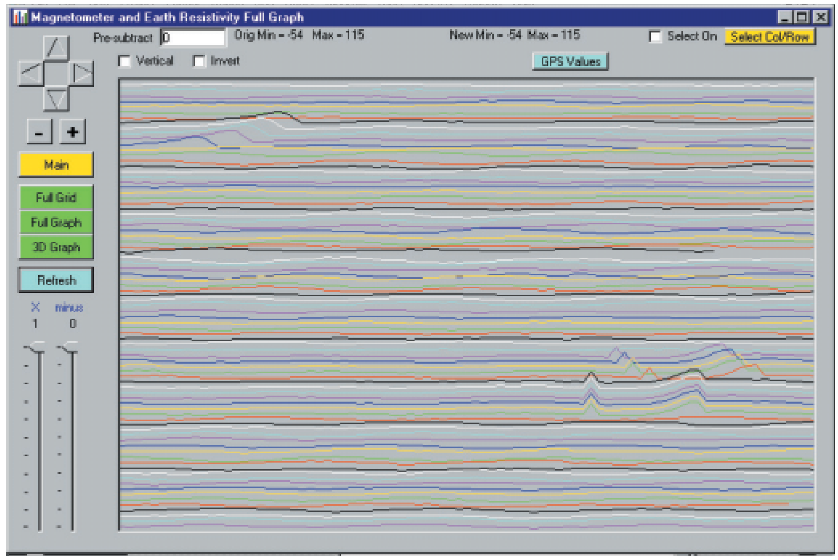
There are several click-options on the Full Graph screen which allow you to manipulate and examine the waveforms in greater detail. Their functions are briefly described by a "tooltip" text box if you hover the mouse cursor over them.

At the top left four "arrowed" buttons arranged in a cross allow the display to be scrolled and panned. Below them the buttons marked "–" and "+" are zoom controls.

The "pre-subtraction" text box at the top allows you to enter a value which is then subtracted from the survey values for each waveform line. Values may be positive or negative.

To the right of this box are stated the original minimum and maximum values found in the survey block being displayed. To their right are stated the minimum and maximum values after subtraction and correction according to the sliders at the bottom left.

Above the sliders will be seen a division ("/") symbol and the word "minus". The



Typical example of the Full Graph screen.

positional values of the sliders are respectively divided into and subtracted from the survey values. Respectively clicking on "/" and "minus" swaps the functions for multiply ("X") and "add". Again clicking them reverts back to the previous function, on an alternating cycle. The Refresh button must be clicked to implement any slider change. The slider ranges are 100 and 1000.

The Invert box allows the waveforms to be drawn "the other way up", peaks becoming troughs, and vice-versa. Click the box to change direction.

Clicking the Vertical box alternates between the waveforms being drawn horizontally and vertically. This will be explained more fully when survey plotting is discussed.

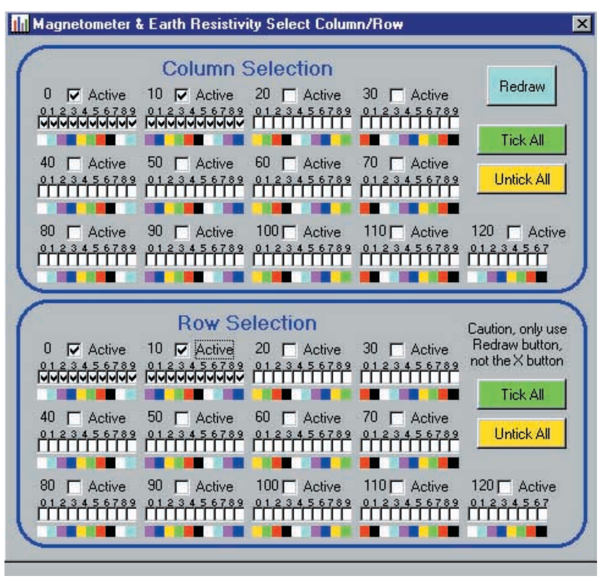
Selected Viewing

Two controls at the top right are used to select which survey columns and rows are displayed, allowing better examination of selected survey areas. Clicking on the Select Col/Row button displays a sub-screen in which the individual tick boxes allow the required rows or columns to be activated. Their selection is made by clicking their box. It is an alternating on/off cycle.

The Tick All and Untick All buttons affect all tick boxes equally within the row or column zones. The Active tick boxes affect only the blocks immediately below them.

The waveforms are redrawn when the Redraw button is clicked, which also closes the Selection screen. However, for the selection to be implemented, the Select On box on the full Graph screen must be ticked. This function when clicked alternates between on and off.

It is important to note that any new tick selection in the sub-screen is only valid if the screen's Redraw button is used. If you use the Windows X button at the top right to exit the screen, all the boxes will revert to their default of all unticked and the graph will not be redrawn when the screen closes.



Screen through which data columns and rows can be selected or inhibited for viewing.

GPS Values Button

Clicking on the GPS Values button reveals a box in which the GPS start and end coordinates of the numbered survey grid lines are listed. If GPS has not been active during a survey line, the message "No GPS recorded" is shown.

To the right of each list line are shown the start and end values read from the temperature sensor. As said earlier, they are only for information and have no practical value.

Clicking the button again hides the list and redraws the graph.

3D Graph Display

Clicking on the 3D Graph button at the left of the Full Graph screen selects the display mode in which data is plotted as vertical bargraphs which have been given a bit of a "3D" appearance.

It has to be said, though, that the 3D effect is not as good as Windows Excel can produce. The VB6 Learning Edition in which the Magnetometer software was written does not allow selective colour painting of bordered areas (unlike QBasic, which has a very useful Paint function for colour-flooding selected areas).

All the functions described for the Full Graph screen are available in this mode.

Full Grid Display

Clicking the Full Grid button calls up a screen in which the survey data is plotted as rectangles, tinted according to the value. This is a display that was written for *ER* but which is less useful for the Magnetometer data.

The reason is that the *ER* data values fall into a much narrower range than Magnetometer values. As a maximum of only 36 shades are available for the rectangles, it is far less easy for the Magnetometer data to be corrected to show meaningful shade differences.

The function has been retained, though, as this software can also be employed by *ER* users. Nonetheless, for the sake of good order, the screen is used as follows:

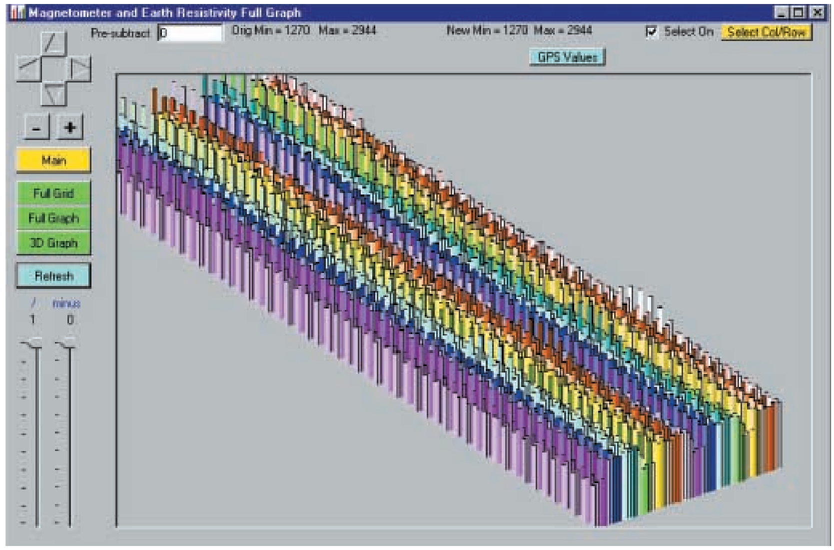
Panning and scrolling are performed by using the sliders immediately above and to the left of the display area. Zooming is performed by using the small slider at the top left of the screen.

Pre-subtraction values can be entered in the same way as with the Full Graph, with minimum and maximum values shown to the top right. The values can also be adjusted by the two sliders at the left.

To implement the slider changes, click on the Refresh button.

Above the sliders, the four radio buttons allow the colour scheme to be selected. The colour options are those shown at the left of the Main screen. Changing the colour option causes the display to automatically redraw in the new colours.

The Invert option behaves in the same way as with the Full Graph screen.



Example of the 3D Graph display.

The Matrix button when ticked causes the display boxes to be drawn to a size related to the survey value.

When in Matrix mode, the Show 0 button alternates between matrix dots being shown or not shown when survey plot values are less than one (which are always limited to a minimum of zero).

(When used with *ER* data, a Current click box is also shown, whose function is described in the published *ER* text.)

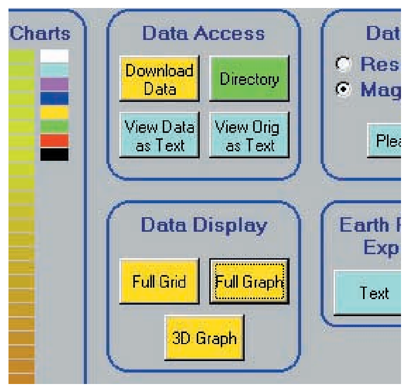
A "show coordinates" option is available with the Grid display. Click the mouse on any square and its column and row coordinates are shown at the bottom left. The mouse can be moved while its button is held down and the values change accordingly.

From the Grid screen an exit to the Full Graph or Main screens can be made via their allocated buttons.

Main Screen Again

On the Main screen, it will be seen that the Full Grid, Full Graph and 3D Graph screen can be called via click-buttons.

The Directory button allows you to select previously recorded data files for display. The Directory screen is similar to those used with the author's other VB6 programs. Full details of its use can be read via the Notes button.



Commonly used control buttons on the Main screen.

In brief, folder paths are selected via the lefthand path menu, and files within a selected path selected by double-clicking on a named file in the righthand list. This causes the Directory sub-screen to close and the file data to be loaded. If a file name is only clicked once, it is not actually selected, but is just highlighted and a return to the Main screen can be made by using the Exit button.

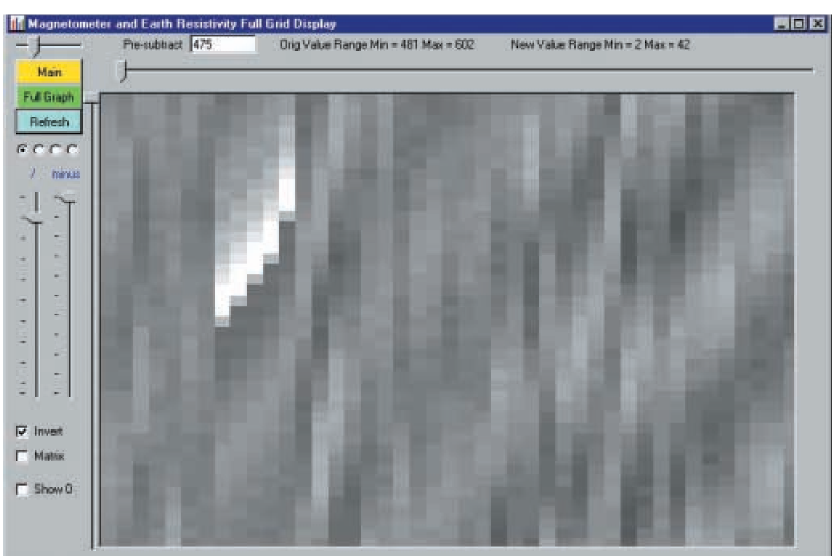
All path files are pre-selected for a prefix of either "EarthMag" or "Earth Res", depending on which Logger option has been selected on the Main screen.

You may also add your own filter to this prefix via the text box provided, allowing file names that only conform to the prefix and filter characters to be listed, so permitting selection by date, for example. The filter function can be turned on and off via its click box.

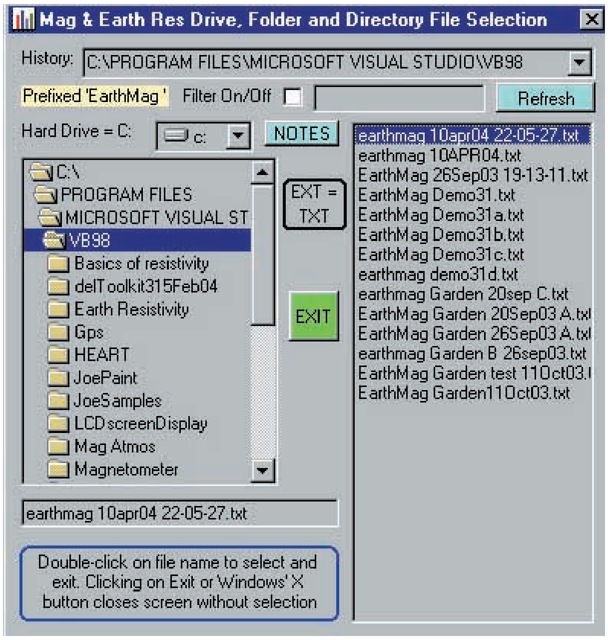
A history of the folder paths accessed is recorded to disk when new ones are selected. This is recalled each time the program is loaded and a particular path can be selected via the dropdown History option.

Experiment Buttons

The Earth Resistivity Experiment buttons at the right of the Main screen are



Example of the Full Grid screen, a facility better suited to Earth Resistivity monitoring rather than to magnetometry.



Example of the Directory screen through which files prefixed "EarthMag" can be selected for input.

for the interest of *ER* users. They respectively reveal a text file describing an experiment, and an illustration of a circuit for it.

Final Exit

The only way to totally exit from the Magnetometer program is to use the Windows X button at its top right. On other screens, the X button only causes a return to the previous screen.

Earth Resistivity

Several references to the *Earth Resistivity Logger* have made during this article. The Magnetometer program is an enhanced version of that written for *ER* and is compatible with the hardware of both designs.

Although the *ER* program itself can be used with the Magnetometer hardware, it is strongly recommended that the Magnetometer should ONLY be used with the software described here.

If you are an *ER* user you may use either *ER*'s own program as described in the published article, or the Magnetometer program, selecting the correct option via the main screen. However, there are a few matters that *ER* users should consider:

The *ER* software offers two options through which data could be downloaded from the hardware. One was based on a DLL function, the other via Joe Farr's OCX, as used in the Magnetometer.

The Magnetometer does not include the DLL download function and those who are currently using *ER* with the DLL need to make minor changes to its p.c.b. These changes are described both in *ER* itself and via the Please Read button on the Magnetometer's Main screen.

Secondly, it will be seen that this Main screen differs from the *ER* Main screen. That screen included small graph and grid display areas, limited to a 20 × 20 matrix. Magnetometer surveying can cover much vaster areas than required for an *ER* survey and so these sub-display options are irrelevant and have been dropped.

If you are an *ER* user and would like to use the Magnetometer software instead, DO NOT copy the Magnetometer files into the *ER* folder otherwise unpredictable conflicts might occur. You must only copy the Magnetometer into its own folder as described in Part 1.

The files from either Logger can be accessed from either program.

Magnetometry Surveying

The whole scope for surveying using a magnetometer is much greater than for *ER* logging. In the latter, more painstaking techniques are used within a small grid area. With the magnetometer you can stride great distances, recording data at whatever stride length and rate you prefer.

The program has been written so that a survey area is covered by walking in one direction to any point of your choosing, whether it is 10 paces or 1000 (or more). The recording is switched on at the start of the walk and switched off at the end of the chosen distance or number of paces. You then shift to the right of the first track by whatever amount you want, turn around, switch on recording and pace back to the original base line, in parallel with the first track, and switch off recording.

This process can be repeated for as many "columns" as you want so that the whole area required is covered. If aching feet cause you to break between columns, just resume when you are ready.

There is a protocol that should be observed, though, as illustrated in Fig.7. The software assumes that recording for the first column starts at the bottom left of the survey grid (C1/R1) and proceeds to the top left for a given number of paces (as can be viewed on the l.c.d.). You then turn right into column two and return for the same number of paces as for column 1. Then repeat along the other columns in numerical order.

It is important that the Record switch should be switched off at the end of a column and switched on again for the next column. Failure to do so will cause the software to regard two or more columns as a single one of much greater length.

When downloading the recorded data, it is retrieved in strict numerical order of memory locations. It is then split into separate columns whose length is the number of samples taken before recording is stopped. Odd-numbered columns (e.g. 1, 3, 5 etc.) keep the data in the original order. Evenly-numbered columns (e.g. 2, 4, 6 etc) have their data order reversed.

This alternating order makes it easier for the software to display the recorded values in a meaningful sequence.

On Full Graph screen, however, the columns are plotted *across* the screen from

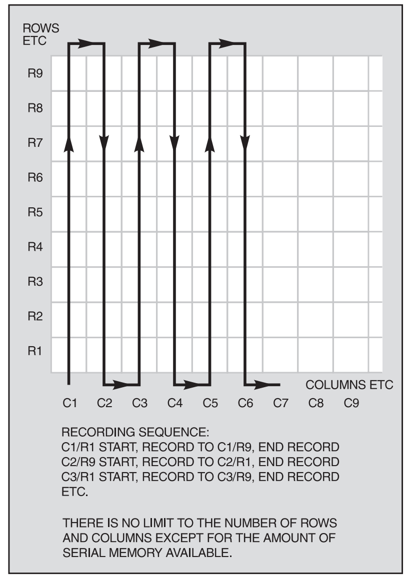


Fig.7. Order of surveying columns and rows of a survey area.

left to right, top to bottom. Column 1 thus starts at the top left of the screen and ends towards the right. Column 2 starts at the left of the next allocated position downwards, and so on (see Fig.8).

Experiment showed that the variations in waveform values were much more readily viewable when plotting in this fashion, with peaks pointing upwards, rather than plotting with waveforms peaking to the right.

Vertical plotting can be selected, as mentioned earlier. This, though, shows waveforms relative to the value differences between column coordinates in the same row. You will probably agree that it is less easy to interpret!

Full Grid displays are in the same direction as for Full Graph.

With 3D Graph displays, the data is plotted as shown in Fig.9. The start of column 1 is at front right, its end at front left. Column 2 is behind it, etc.

Note that it is moderately important that the pace count should be the same for each survey column. A few paces different between columns should not cause significant displacement of the results on screen. But don't have widely different column pace counts otherwise displacement will occur, since all columns are assumed to be positioned at the same upper and lower base lines.

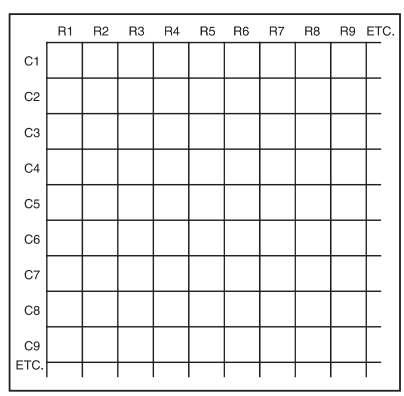


FIg.8. Orientation of columns and rows as displayed on PC screen when in Full Graph mode.

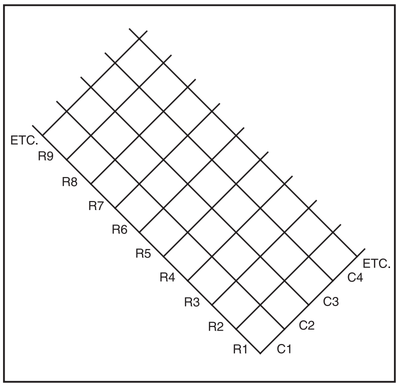


Fig.9. Orientation of columns and rows on PC screen when in 3D Graph mode.

Obviously, pace lengths as well as pace counts should be pretty consistent otherwise again displacement will occur. It is believed that the 1Hz sampling rate is easy to follow when pacing a column.

Probe Orientation

Three points to note about using the probe – in order to nullify as much as possible the influence of the Earth's magnetic field upon the probes, surveying should be carried out from east to west (or west to east). Furthermore, in case your sensors are not *absolutely* aligned, always keep the probe assembly facing in the same direction relative to north. (Remember this when turning from one column to another!) The "handle" on the author's probe assembly assists direction keeping.

Thirdly, the probe assembly may be used in a vertical or horizontal position. Horizontal positioning, with the probe bar held out in front of you across your body, provides the widest field of coverage, but with reduced sensitivity. Holding the probe vertically in front of you provides best sensitivity to small changes in magnetic field density, but has a narrower field of coverage.

Graphical Analysis

The downloaded survey data is formatted suitably for use with Windows Excel software. Excel, or variants of it, is available as standard on many PCs and is believed to be part of the Windows Office suite. As well as offering graphing facilities, Excel provides for mathematical expressions to be computed. These options allow the survey data to be examined in more substantial detail than the Magnetometer program can offer.

Brief information about using Excel was given in *ER* Part 2, page 363. Excel's own Help file, though, taught the author all he knows about it. Read it and experiment to find what Excel can do!

Survey Courtesy

Anyone may use the magnetometer to search for magnetic sources on their own property. You may also, of course, set up the unit on your own property and monitor the movement of magnetic fields beyond it, such as vehicles passing.

Remember, though, that all land in the British Isles belongs to someone and so any surveying on it requires the permission of its owners. However, the author feels that there should be no intrinsic problem about carrying an active magnetometer along public footpaths and across common land where the public are permitted free access.

What you MUST NOT do, is to dig on any of that land without permission. If you find a location that has magnetic anomalies that you wish to further investigate, permission must be obtained. Furthermore, if you suspect that the anomaly is due to something of archaeological interest, do not dig in that area without the involvement of someone with archaeological knowledge. You could otherwise destroy vital historical evidence.

To get archaeological help, contact a local archaeological society, whose details can be obtained through your library.

Having said that, there are many ways in which a magnetometer can be beneficially used to search for magnetic artifacts that are not of archaeological interest. A short list of possible uses was quoted in Part 1, in relation to what Speake & Co say about their FGM-3 sensors.

MAGNETIC VALUES

Magnetic Flux Density

	gauss	tesla	gamma
1 gauss	1	10^{-4}	10^{5}
1 tesla	10^{4}	1	10^{9}
1 gamma	10^{-5}	10^{-9}	1

Magnetic Field Strength

	amp/metre	oersted
1 amp/metre	1	0·01257
1 oersted	79·58	1

Speake & Co say that technically the FGM-3 sensor measures flux density, in gauss, but since in vacuum (and virtually in air) the units of flux density are the same magnitude as those of field strength, and since the sensor can only really be used in air, oersted can be regarded as equivalent to gauss.

In the past, the author has also been involved with magnetometers on scuba diving forays off the UK coast, searching for wrecks (and finding them!). If this is your intention, make sure that the entire electronics and probe assembly are fully protected from sea water damage. Note, too, that equipment on the boat will affect readings.

In answer to some questions that periodically appear on our *Chat Zone*, the design is not suited to locating precious metals or other non-ferrous materials.

Acknowledgements

The author gratefully offers his thanks to the following:

Anthony Clarke for his book *Seeing Beneath the Soil*. Routledge. New edition 2000. ISBN 0-415-21440-8.

Nick Tile for various invaluable chats about magnetometry, and for the loan of Anthony Clarke's book.

Carl W. Moreland and his website at **www.tthn.com/geotech**, which gave the author further insights into magnetometry.

Speake & Co, and Bill Speake in particular, for providing the author with some FGM-3 sensors and informative application notes. Website **www.speaksensors.co.uk**.

Mission Invisible

The art of disguise now plays its role in the comms arena, as Andy Emmerson reports

Look up to the skies! Is it a tree, is it a flagstaff, is it a lamp post? It's certainly not Superman and looks can be deceptive!

These days things are truly not what they seem. Take telegraph poles for instance. For the past 30 years or more British Telecom has done its best to eliminate the things, placing comms cables underground where they can come to (virtually) no harm. In which case, you may ask, why on earth are brand-new telegraph poles sprouting up across the country? There must be a reason...

And there is – they're dummies and very convincing ones in the main, with authentic wood-grain surface features and iron climbing steps at the top. The only give-away is the lack of any wires aloft and the fact that they often stand in open country away from any visible habitation.

Environmental Advantage

In point of fact they are microcell antennas for the Orange network, providing low-power fill-in coverage at places the network would not otherwise reach. Because we're so used to seeing telegraph poles at the roadside they blend in "invisibly" and the old adage of "out of sight, out of mind" has laid down the rules of the game for mobile phone companies. "Mission Invisible" is the assignment facing them and a number of manufacturers have taken up the challenge to provide them with ingenious solutions for cleaning up the landscape and cityscape.

As a techie – and radio ham – I find sophisticated antenna arrays a truly wondrous site and you may well admire them too. For the rest of the population, however, they are an eyesore and a prime target for environmentalists determined to eradicate all visual clutter. It's hard to argue either, particularly when it's now so easy to make antennas melt into thin air.

Conjuring tricks are not involved but there's more than a taste of technical wizardry applied in the concealed antenna solutions supplied to mobile operators now. The fact that few people notice this invisible infrastructure, or are even aware of its existence, demonstrates the effectiveness of these solutions. Illuminated advertising signs, weather vanes and parapet walls conceal some of them, whilst other antenna housings are disguised as telegraph poles, flag posts, lighting columns, even trees.

Ingenious Solutions

The British manufacturer with the widest range is AlanDick Ltd of Cheltenham and such is the company's expertise and range of solutions that it has built up a worldwide market for its products. According to sales director Robert Sedgbeer, these "invisible" designs satisfy an increasing demand from operators, planning authorities and environmentalists for antennas that don't offend the eye. Consequently the firm offers all manner of off-the-shelf designs as well as all manner of bespoke solutions.

Perhaps the strangest of the made-to-order antennas has been a complete three-sector cellsite array that was secreted inside the minaret of an Indonesian mosque. As solutions go it was both ingenious and logical: for centuries minarets have been used for calling the faithful to prayer, for which purpose they have high balconies to achieve maximum all-round "signal coverage". Similar requirements apply to cellular antenna systems and for this installation the company was able to house the antenna structure inside a carefully engineered r.f.-transparent radome indistinguishable from a normal cupola.

Other smart solutions include architectural features looking like buttresses or parapets mounted on the roofline of buildings. These are carefully colour-matched to blend imperceptibly into surrounding brickwork or masonry and are designed to be easily relocatable, requiring no drilling or specialist installation tools. Weird and wonderful is the only way of describing some of the design challenges: a windmill is not too strange but perhaps the most unusual was for antennas to be housed inside the bodywork of a "gate guardian" aircraft at the entrance to an air base.

Forbidden Territory

Lighting masts for shopping mall car parks and the like also make good places to hide cellsite antennas. The solution is unobtrusive, blending imperceptibly into the urban environment, and provides a reliable platform up to 35 metres above the ground. The "cellular lamp post" is a fully functional lantern but also contains antennas for a microcell, whilst the "telegraph pole" has a bark effect external finish that surrounds the feeder cables and antenna within.

In fact its appearance is so realistic that examples were given permission for erection in a Yorkshire Dales National Park where antenna structures were previously outlawed entirely. Environments like this were previously forbidden territory for mobile operators, but following meetings between the company and the Council for the Preservation of Rural England, together with discussions between the Mobile Operators' Association, the Association of National Park Authorities and the Association for Areas of Outstanding Natural Beauty, a "treaty of best practice" was agreed this year, allowing sensitively disguised antennas to be erected in all 13 national parks.

Appropriate Structures

Other environmental structures appropriate for situations like this include an old-fashioned "wooden" water tower and a mock ranger station on four stilts resembling the elevated huts that keepers use to look out over forests for fires. Radio and electrical equipment are housed inside a log-cabin-style structure nearby.

Another absolute natural for such areas is the growing (pun entirely intentional!) range of "tree" antennas pioneered in Britain and subsequently developed for the worldwide cellular market. Copied but never equalled technically, they carry the name Cellular Tree, a registered trade mark, and are available in several different "species". For European installations the "Scots Pine" and "Conifer" are most suitable, with antennas fixed among the "branches" and coloured to match in with the main tree structure.

A variant produced for South Africa was re-engineered to resemble a native African species. The "Lightning" tree, looking like an ancient tree rent asunder by a thunderbolt, contains all fixtures inside its "trunk", whilst the "Palm" tree provides a solution for locations closer to the Equator, with a highly effective palm bark and frond appearance.

Global Business

As befits its global presence, an increasing volume of these products is going to export markets worldwide, including the Netherlands, Australia, China, Singapore, Thailand, Malaysia, Egypt, Saudi Arabia and South Africa. There is significant sales interest in North America too. Product ranges are tailored to each regional market: products designed for European environments have little application in the Asia-Pacific region for instance, where there is little interest in pine trees but plenty in flagpoles and lamp posts.

Another reason why off-the-shelf European products cannot be used "as is" in the Pacific region is technical performance (products made for temperate climates may be unable to withstand the extremes of temperature and humidity encountered "downunder"). The successful suppliers are those that have redesigned their product range to suit local requirements, both for technical performance and for blending in with the local scenery.

It's fascinating to know that there are still some fields where British expertise leads the world.

Constructional Project

Simple F.M. Radio

Raymond Haigh

Wide range tone controls and a 2W audio output make this an out-of-the-rut domestic receiver.

FOLLOWING the recent *Practical Radio Circuits* series (June '03 to Jan '04), a number of readers have requested a design for a simple v.h.f. f.m. receiver.

Three types of circuit meet the requirement for simplicity. The first two, super-regenerators and synchronous oscillators, were rejected because they can be difficult to set up and operate, and the lack of automatic frequency control causes problems in use.

The third utilizes the superhet principle, but adopts a simple resistance/capacitance coupled intermediate frequency amplifier instead of the conventional tuned circuit arrangement. The aerial input is broadly tuned to the f.m. band, and only the oscillator has a variably tuned circuit. This greatly simplifies the construction and setting up of the chosen Simple F.M. Radio design described here.

A Good Combination

Readers will, no doubt, have their own ideas about audio amplifiers, speakers and cabinet size, so the F.M. Tuner section is assembled on a separate printed circuit board (p.c.b.). It can be combined with simple amplifiers – such as those described in the *Simple Audio Circuits* (May '02 to Aug '02) series or the radio series mentioned at the start – to form a small portable, or it can be teamed with more ambitious audio stages to produce an out-of-the-rut domestic receiver.

The latter approach has been adopted here, and details of a wide range tone control unit, a "robust" audio amplifier, and a mains power supply are included.

Radio Chip

The internal structure, in block form, of the TDA7000 f.m. radio i.c. is shown in Fig.1.

Signals picked up by the aerial are combined with locally generated oscillations in the mixer stage. The resulting intermediate frequency (i.f.) is amplified by two filter amplifiers and a limiter amplifier. Together with external capacitors, the filter amplifiers centre the intermediate frequency around 70kHz. The limiter amplifier provides automatic gain control (a.g.c.) and suppresses amplitude modulated (a.m.) signals.

Because of the low intermediate frequency, the deviation produced by signals that are heavily modulated must be restricted to around plus/minus 15kHz. This is achieved by feeding the output from the demodulator back to the local oscillator (via the loop filter) and using it as a control voltage to shift the oscillator frequency in the opposite direction to the i.f. deviation. The oscillator stage incorporates on-chip tuning diodes to enable this and other control voltages to shift its operating frequency.

The correlator and muting sections suppress image responses that would otherwise be an irritating problem with the low intermediate frequency. (Stations would tune-in at two points on the dial.) This complex circuitry, made possible by the large-scale integration of components, sets the design apart from earlier valve versions.

The muting circuits result in a complete absence of noise when tuning between stations. Searching for zero hiss is, however, the customary way of locating a station and precisely tuning the receiver to it. To give radios using the chip a conventional "feel", Philips included a noise source that simulates the inter-station hiss.

Demodulation is by means of a quadrature detector which requires the production of a 90 degree phase-shift in the signal (hence quadrature). Again, this is complex circuitry that can only be realized, in practice, by the large-scale integration of resistors and semiconductors.

A stage of audio amplification is included on the chip, and the output is approximately 75mV r.m.s.

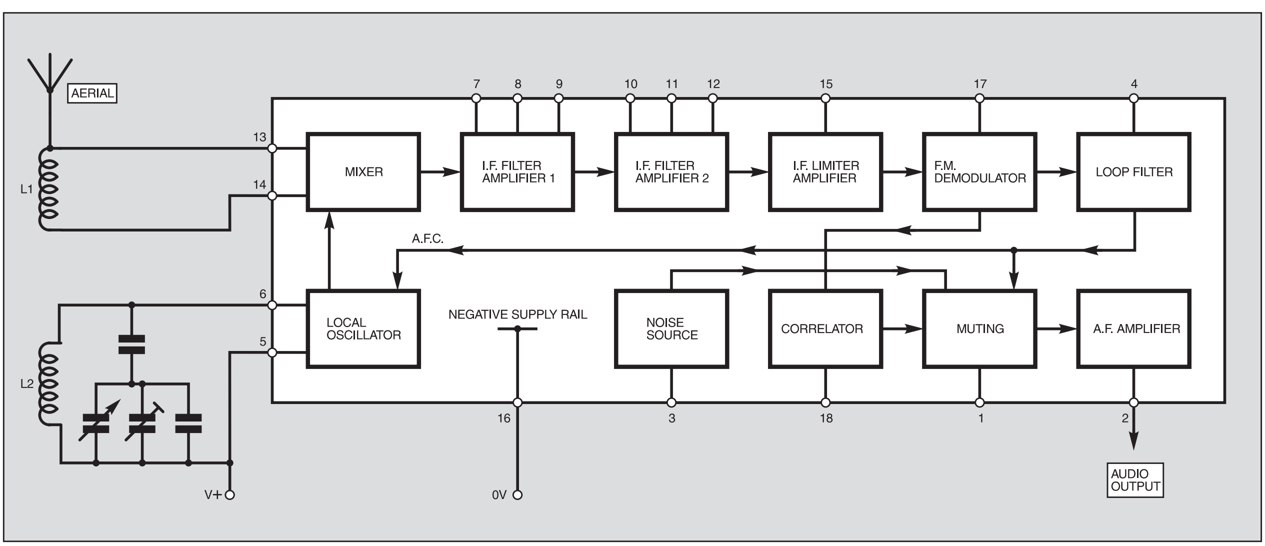


Fig.1. Block diagram showing the internal arrangement of the Phillips TDA7000 f.m. radio integrated circuit.

F.M. Tuner

The full circuit diagram of the F.M. Tuner section of the receiver is shown in Fig.2. On-chip bias resistors damp the input circuit so heavily that variable tuning is pointless. Accordingly, the aerial coil is broadly tuned by self and stray capacitance to the v.h.f. f.m. band. The circuit is isolated from low level, low frequency a.c. and d.c. inputs by capacitor C1, and the "earthy" end of L1 is grounded by C2.

The oscillator stage is tuned by coil L2 and variable capacitor VC1. An integral trimmer capacitor, VC2, adjusts the minimum capacitance in circuit and sets the upper frequency limit coverage.

The combination of fixed series capacitor C11 and parallel capacitor C13 modify the effect of tuning capacitor VC1 and vanes (spindle) of the tuning capacitor, VC1, to be connected to the positive supply rail. The tuning capacitor spindle ***must***, therefore, be *insulated* from any grounded metal front panel or case.

Filter Amplifiers

Capacitors C6 and C15, together with on-chip resistors, set the cut-off frequency of the first, low-pass, filter. The bandpass response of the second filter is set by C8, C9 and C12 (see Fig.1 and Fig.2).

Two capacitors, C3 and C4, are combined to produce a difficult-to-obtain value for the component that determines the time constant of the muting circuit.

The time constant of the internal feedback loop is set by C7. This capacitor

Smooth Output

Supply line decoupling is provided at radio frequencies by capacitor C10, and at audio frequencies by resistor R2 and capacitor C18. Decoupling capacitor C21 inhibits radiation of the oscillator signal by the battery or power supply wiring.

Inter-station noise is set by capacitor C5. Increase the value of this capacitor to make the hiss louder; delete it for completely silent tuning. Audio output is developed across resistor R1, and C19 provides audio de-emphasis.

Coils

Details of the self-supporting coils and the connections to typical polyvarycon (polythene) tuning capacitors are given in Fig.3.

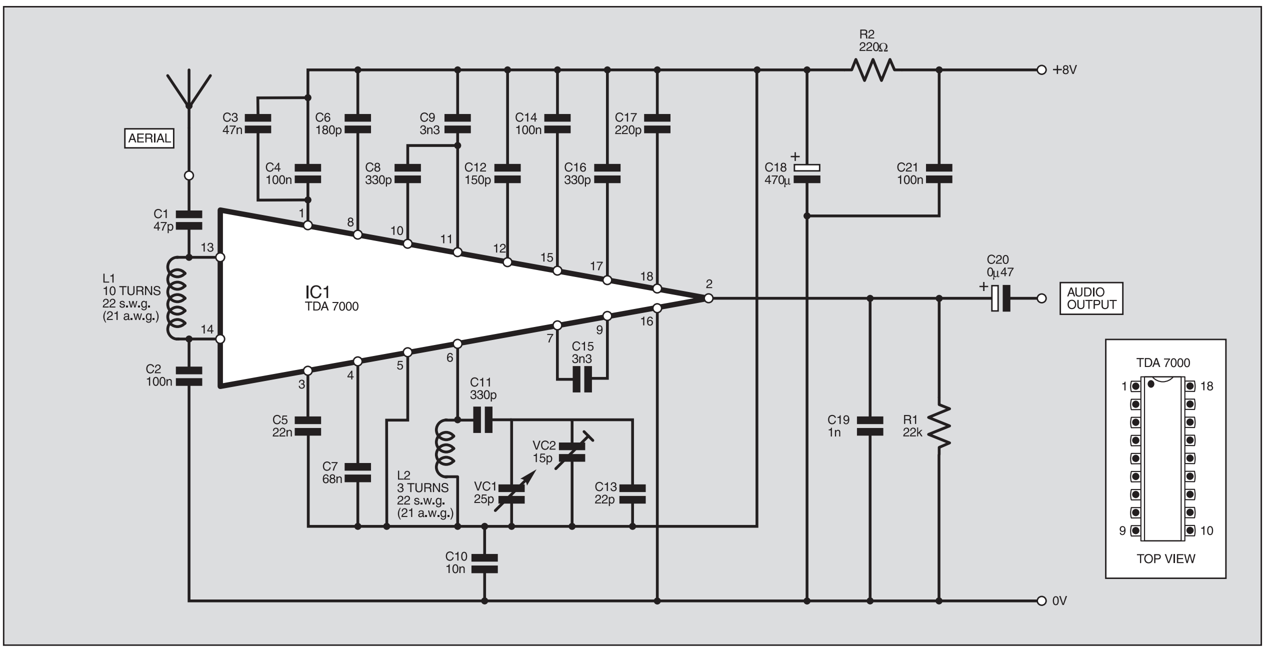


Fig.2. Complete circuit diagram for the F.M. Tuner section of the Simple F.M. Radio.

spread the 88MHz to 108MHz band over its entire swing. This makes tuning the receiver much easier.

Constructors should note that the on-chip oscillator circuit calls for the moving

influences the willingness of the receiver to lock onto weak signals and thereby affects sensitivity. Too low a value makes the circuit reluctant to lock; too high a value reduces response to the upper audio frequencies.

The value suggested by the manufacturers is 10nF, but a higher value will improve performance in areas where signals are not strong. A 68nF component is fitted in the prototype receiver as this seems to give the best overall results. The barely perceptible reduction in treble response is made good by reducing the value of the audio de-emphasis capacitor C19, and the tone control circuit described later.

History

Some of the first superhet receivers, produced during the early 1920s, had resistance/capacitance coupled i.f. (intermediate frequency) stages. The absence of tuned circuits meant that the i.f. amplifier made no contribution to the selectivity of the receiver, and the practice was soon abandoned.

Frequency modulation broadcasting (f.m.) was established in the 1950s. This system requires the i.f. amplifier to have a wide response; i.e. to lack selectivity. Resistance/capacitance coupled i.f. stages could, therefore, be used, and valve circuits of this kind reappeared to meet a demand for simple and inexpensive receivers.

The concept was resurrected again by Philips in the late 70s when they were attempting to form an f.m. receiver on a single chip. The outcome was the TDA7000 integrated circuit, which is still widely available. Ingenious circuitry, made possible by combining many resistors and transistors on a tiny wafer of silicon, overcome the drawbacks of earlier valve designs.

Form the coils by tightly winding 22s.w.g. (21a.w.g.) enamelled copper wire onto a length of 6mm (1/4in) potentiometer spindle. It is a good idea to bend the ends and scrape them "bright-metal-clean" of enamel before removing the winding from the spindle.

The aerial input coil L1 is not at all critical, but the oscillator coil L2 should be carefully spaced, as shown in the illustration.

COMPONENTS

F.M. TUNER

Resistors

R1	22k
R2	220Ω

All 0·25W 5% carbon film

See SHOP TALK page

Capacitors

C1	47p ceramic
C2, C4, C14, C21	100n ceramic (4 off)
C3	47n ceramic
C5	22n ceramic
C6	180p ceramic
C7	68n ceramic (see text)
C8, C11, C16	330p ceramic (3 off)
C9, C15	3n3 ceramic (2 off)
C10	10n ceramic
C12	150p ceramic
C13	22p "low k" ceramic
C17	220p ceramic
C18	470μ radial elect. 25V
C19	1n ceramic
C20	0μ47 radial elect. 25V (preferred) or polyester film
VC1, VC2	miniature a.m./f.m. polythene dielectric tuning capacitor, with integral trimmers (only one f.m. section – 25pF – and one trimmer –15pF – used)

Semiconductors

IC1	TDA7000 f.m. radio i.c. (Philips)

Miscellaneous

L1, L2	coils hand-wound with 22s.w.g. (21a.w.g.) enamelled copper wire – see text and Fig.3 for winding details

Printed circuit board available from the *EPE PCB Service*, code 458; 18-pin d.i.l. socket; 50g (2oz) reel 22s.w.g. (21a.w.g.) enamelled copper wire for coils; spindle extender for variable capacitor and/or spindle coupler (see text), and slow motion drive (optional); large control knob; telescopic whip aerial (see text); multistrand connecting wire; solder pins; mounting nuts, bolts and washers; p.c.b. stand-offs; pillars; solder etc.

CABINET

Medium density fibreboard (mdf), 12·5mm thick; glue and moulding pins; filler and car spray paint; speaker and rear vent grilles; speaker fixing screws; carrying handle; back fixing screws and rubber feet (4 off); materials for front panel.

Approx. Cost Guidance Only* £15 *excl. cabinet materials

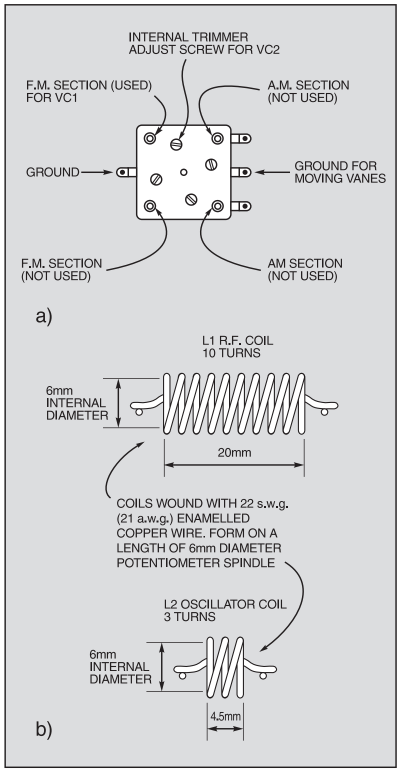


Fig.3. Tuning capacitor connections and coil winding details. Connections are typical of most polythene dielectric variable capacitors – but check.

Tuner Construction

Apart from the telescopic "whip" aerial, all the components for the F.M. Tuner are mounted on a small single-sided printed circuit board (p.c.b.). The topside component layout, full-size copper track master and wiring details are shown in Fig.4. This board is available from the *EPE PCB Service*, code 458.

You should use an i.c. holder for the TDA7000 integrated circuit as this will make it easy for any substitution and checking purposes. Mount the d.i.l. holder on the board first. Solder pins will ease the task of off-board wiring, and these should be inserted into the board next. Follow with the coils, L1 and L2, inserting them until the windings almost touch the surface of the board.

The two resistors can be fitted now, then the capacitors, smallest first. Mount the tuning capacitor VC1 last. Take care to orientate this component correctly to ensure that an f.m. tuning section is connected into circuit.

If an a.m. section is inadvertently connected, tuning will be abrupt and the band will be confined to only part of its swing. It may be necessary to countersink the tuning capacitor spindle hole, on the component side of the board, to ensure that the capacitor seats properly.

Check the completed p.c.b. for poor soldered joints and bridged tracks. Double-check also component placement and particularly the orientation of the electrolytic

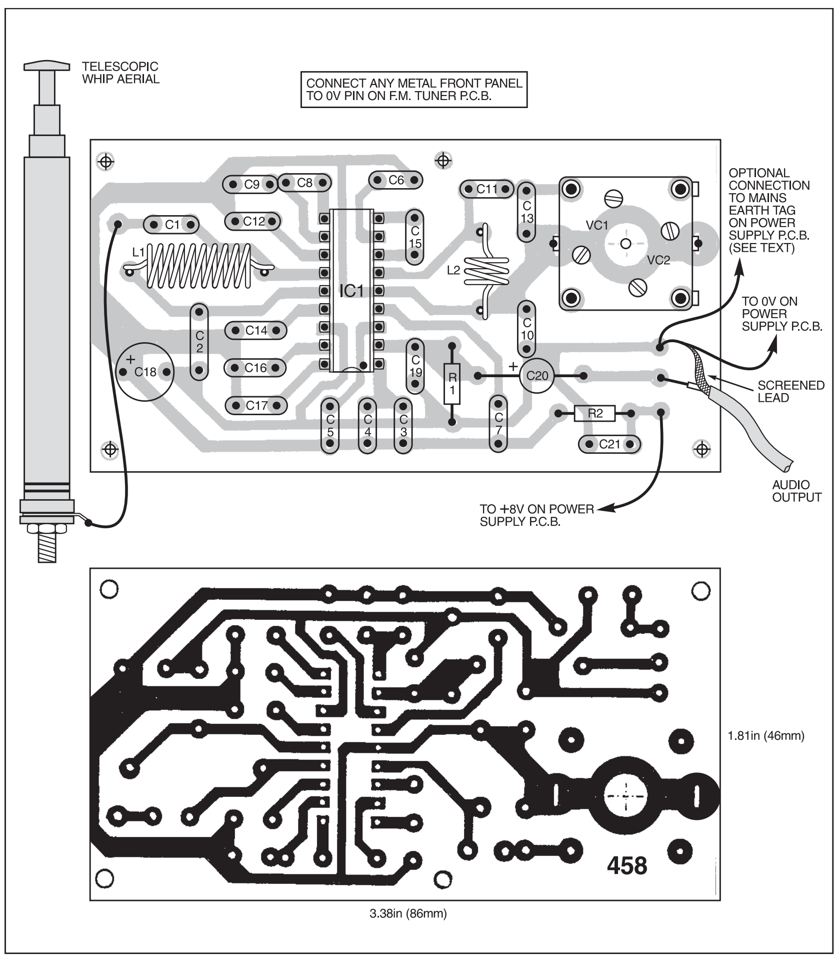


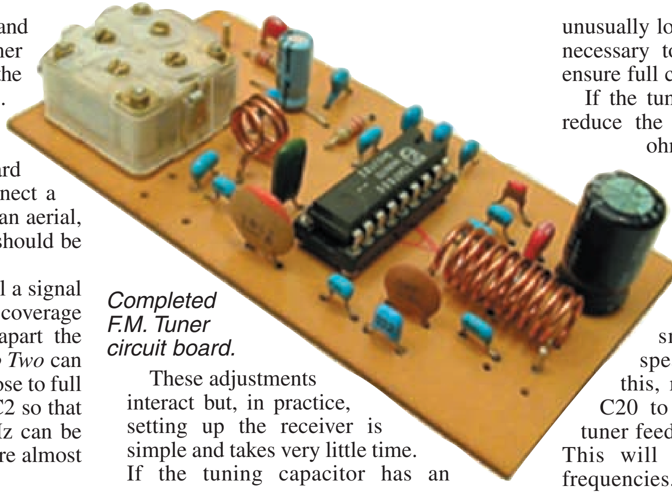
Fig.4. F.M. Tuner printed circuit board component layout, wiring details and full-size copper foil master pattern.

capacitors, the integrated circuit and the tuning capacitor. Set trimmer capacitor, VC2, at half mesh (the vanes can be seen through the case).

Tuning In

Connect the finished Tuner board to an amplifier and speaker. Connect a couple of metres of flex to act as an aerial, and connect a 9V battery. A hiss should be heard from the speaker.

Rotate the tuning capacitor until a signal is received. Set the low frequency coverage by *gently* squeezing or pulling apart the oscillator coil L2 until *BBC Radio Two* can be heard with the vanes of VC1 close to full mesh (closed). Adjust trimmer VC2 so that any local station close to 108MHz can be received when the vanes of VC1 are almost fully open.



Completed F.M. Tuner circuit board.

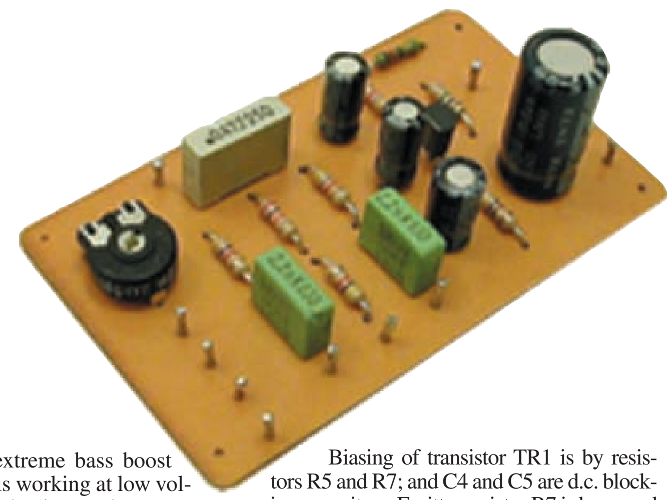
These adjustments interact but, in practice, setting up the receiver is simple and takes very little time.

If the tuning capacitor has an unusually low value (not likely), it may be necessary to short out capacitor C11 to ensure full coverage of the band.

If the tuner is used with a 6V battery, reduce the value of resistor R2 to 100 ohms. If low frequency instability is encountered when the value of R2 is reduced (not likely), increase the value of C18 to 1000μF.

The tuner's extended bass response can cause severe overloading when small audio amplifiers and speakers are used. To prevent this, reduce the value of capacitor C20 to 100nF or even 47nF if the tuner feeds into a high impedance load. This will attenuate the lowest audio frequencies.

Add-On Audio Circuits



A PORTABLE receiver with a powerful output and an extended bass response can make listening to music more pleasurable. With this in mind, a Tone Control unit, Audio Power Amplifier and Power Supply are detailed next. Assembling these units on individual printed circuit boards permits maximum flexibility in laying out the F.M. Radio.

A larger speaker is needed to deliver the extended low frequency bass response, but the increase in cabinet size need not be excessive, and it will permit the installation of a decent whip aerial.

Tone Control

First published by P. J. Baxandall fifty years ago, the Tone Control circuit illustrated in Fig.5 is found, with variations, in most high fidelity amplifiers. All tone control circuits produce "boost" in one region of the audio spectrum by reducing response at all others. This arrangement uses gain reducing negative feedback to achieve the desired result.

Potentiometers VR2 and VR3, and capacitors C1, C2 and C3, form a frequency selective network that controls the feedback from the collector (c) to the base (b) of transistor TR1. Interaction between Bass control VR2 and Treble control VR3 is limited by resistors R2 and R3.

Increasing the value of the F.M. Tuner's loop lock capacitor (C7 on the Tuner p.c.b.) makes the audio output a little bass heavy. When this is augmented by the tone control circuit, the result is more bass than most reasonably sized speakers and amplifiers can handle when delivering a good level of sound.

Bass control VR2 can, of course, be turned back to avoid overloading, but a better arrangement is to make provision for switching in the extreme bass boost when the receiver is working at low volume. Sound reproduction at low outputs can lack presence, and the bass emphasis will help to overcome this.

Preset VR1, connected in series with one arm of Bass control VR2, enables the bass boost to be set below the overload point when the receiver is used at high volume. Switch S1 shorts out the preset and allows the bass boost to rise to its maximum level for quiet listening.

Biasing of transistor TR1 is by resistors R5 and R7; and C4 and C5 are d.c. blocking capacitors. Emitter resistor R7 is bypassed by C6. Audio output is developed across collector load resistor R6 and the stage is decoupled from the supply rail by R8 and C7.

A d.c. blocking capacitor for the output signal path is provided on the power amplifier printed circuit board. Readers wishing to use this circuit with other equipment should take the output from the collector of TR1 via a 4·7μF capacitor.

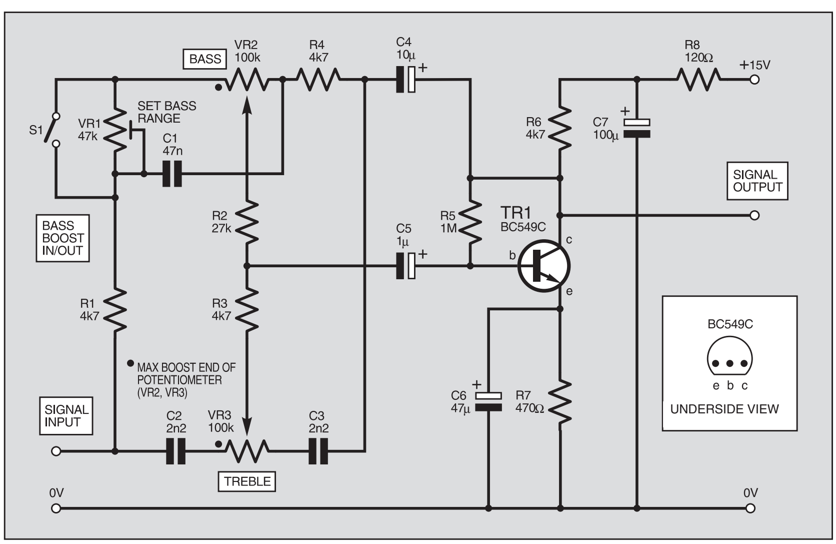


Fig.5. Circuit diagram for an add-on Tone Control Unit.

Power Amplifier

The circuit of the Audio Power Amplifier is given in Fig.6. Designed around SGS Thomson's TDA2003 i.c., the circuit will deliver a clean 2W into an 8 ohm speaker when connected to a 15V power supply.

The signal input from the Tone Control circuit is applied via Volume control potentiometer VR1 and d.c. blocking capacitor C1. A second blocking capacitor, C2, must be provided to prevent disturbance of a bias voltage on the input pin (1) of IC1.

Supply decoupling capacitors, C3 and C4, ensure stability at low and high frequencies, and the gain of the circuit is determined by resistors R2 and R3, which fix the level of negative feedback. The value of R3 has been reduced from its more usual 2·2 ohms to increase gain.

In the interests of stability, the high frequency response of the amplifier is rolled off above 15kHz by the combination of resistor R1 and capacitor C5. The output signal is coupled to the speakers by d.c. blocking capacitor C7. Zobel network R4 and C8 ensures that the speakers always present a resistive load to the amplifier. Without these components, high level transients could damage the internal output transistors of IC1.

Power Amplifier p.c.b. A heatsink will be required for the i.c.

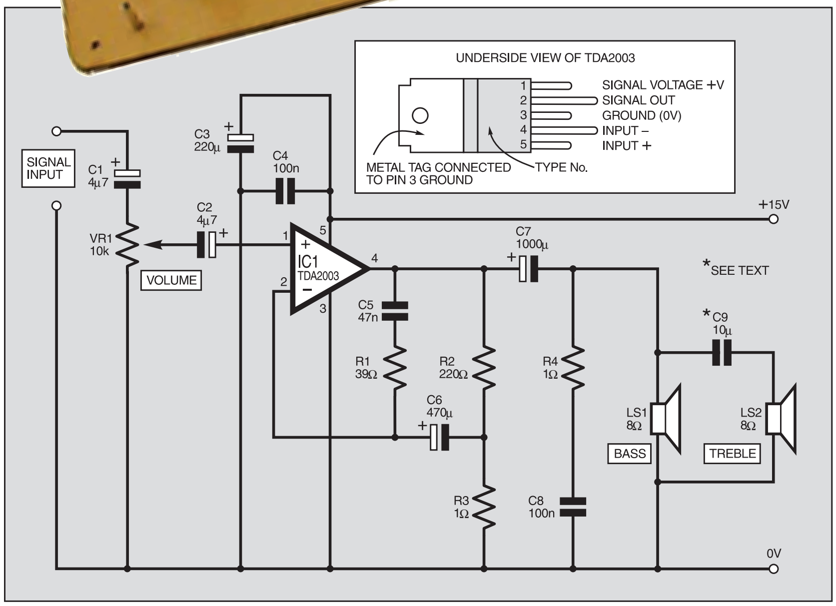


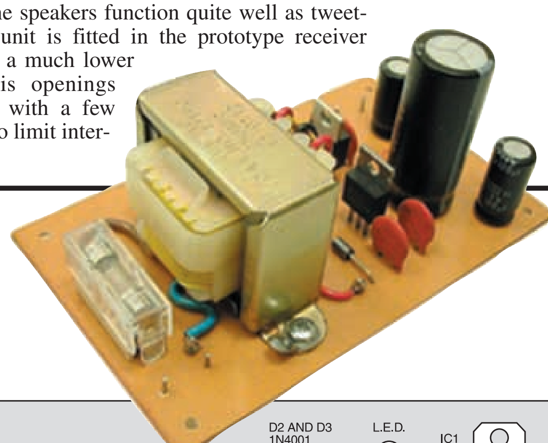
Fig.6. Circuit diagram for the Audio Power Amplifier.

Speakers

Generating a decent low frequency output from a modest electrical input calls for a speaker of reasonable diameter. To get the best out of the receiver, the Bass speaker should be at least 200mm (8in) in diameter. Reproducing deep bass will involve fairly large cone excursions, and it should, if possible, have a foam surround. Units of this kind are available at modest cost.

A "tweeter" or Treble speaker will add brilliance to the reproduction, and a moving coil unit is suitable. It should be connected across the bass speaker via a 10µF bipolar electrolytic capacitor (C9 in Fig.6).

Inexpensive Mylar cone speakers function quite well as tweeters, and a 75mm (3in) unit is fitted in the prototype receiver (smaller units tested had a much lower output). Tweeter chassis openings should be covered over with a few layers of insulating tape to limit interaction with the bass unit.



Mains Power Supply Unit

It is not feasible to power a receiver as potent as this from dry batteries, and a mains power unit should be regarded as essential. ***Readers who have no experience of mains-powered equipment should remember that the voltages involved are LETHAL.***

If there is the least doubt about your ability to build and commission a mains unit, ***you must*** either seek assistance from an experienced constructor or combine the tuner with a smaller amplifier that can be powered by batteries.

Circuit Details

The circuit diagram for the Mains Power Supply Unit (p.s.u.) is given in Fig.7. A bi-phase full-wave rectifier circuit has been adopted, and this calls for a centre-tapped mains transformer, T1. Low value fuse, FS1, increases the safety of the equipment.

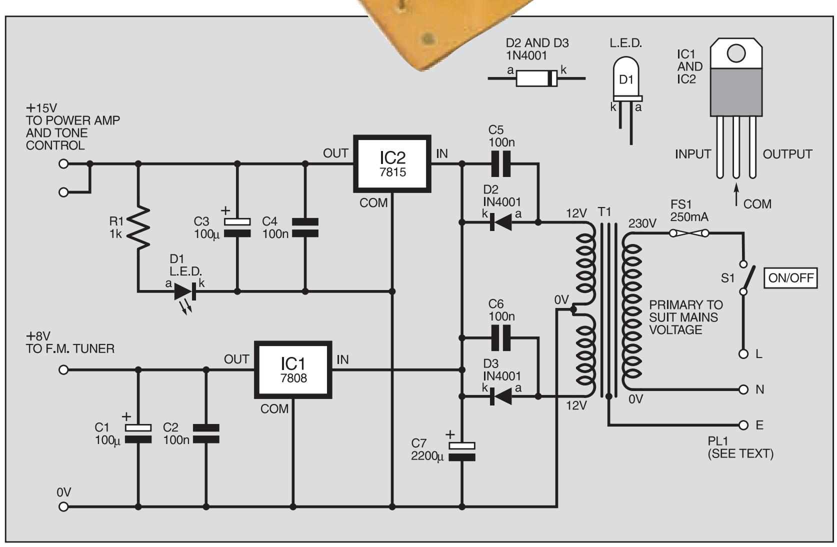


Fig.7. Circuit diagram for the Mains Power Supply Unit.

The switching action of rectifier diodes D2 and D3 can modulate radio frequency currents picked up by the mains wiring. The resulting signal manifests itself as a tunable hum in receivers connected to the power supply. However, including shunt capacitors C5 and C6 prevents this interference arising.

Reservoir capacitor C7 smoothes the output from the rectifiers and enables the d.c. voltage to approach its peak value when current drain is low. With a 12V transformer, the supply rail can have a potential of more than 18V. This exceeds the maximum working voltage for the power amplifier, and greatly exceeds the voltage required for the tuner.

Regulators IC1 and IC2 deliver the appropriate 8V and 15V outputs for the tuner and amplifier. These devices produce low-level wideband electrical noise, and this is bypassed by capacitor combinations C1/C2 and C3/C4.

Light emitting diode D1, powered via its dropping resistor R1, acts as a power-on indicator. On/Off pushswitch (or toggle switch) S1 is connected in the Live lead of the mains supply. Mains Earth is connected to the frame and core of mains transformer T1. It is recommended that a standard three-pin mains-input Euro plug be mounted in the cabinet.

COMPONENTS

TONE CONTROL

Resistors

R1, R3, R4, R6	4k7 (4 off)
R2	27k
R5	1M
R7	470Ω
R8	120Ω

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers

VR1	47k enclosed carbon preset
VR2, VR3	100k rotary carbon, lin. (2 off)

Capacitors

C1	47n polyester film
C2,C3	2n2 polyester film (2 off)
C4	10µ radial elect. 25V
C5	1µ radial elect. 25V
C6	47µ radial elect. 25V
C7	100µ radial elect. 25V

Semiconductors

TR1	BC549C *npn* low power transistor or similar

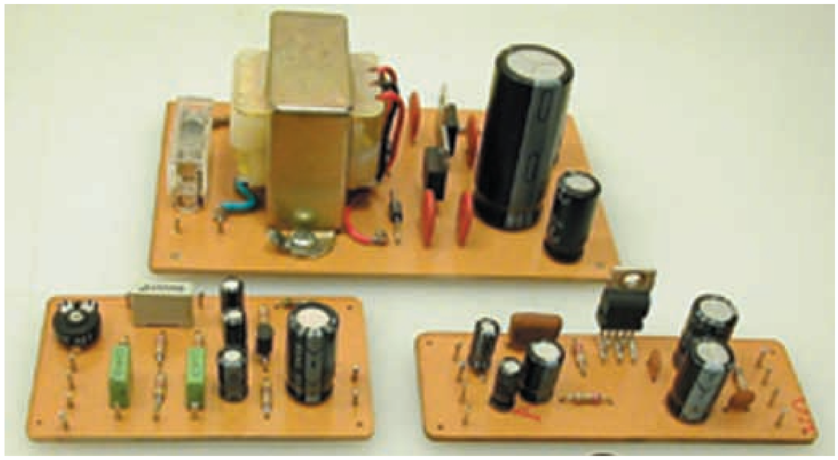
Miscellaneous

S1	pushbutton locking switch, push-to-make, or s.p.s.t. toggle switch

Printed circuit board available from *EPE PCB Service*, code 459; audio screened cable; small plastic control knob (2 off); multistrand connecting wire; mounting nuts, and washers; p.c.b. standoff pillars (4 off); solder pins; solder etc.

Approx. Cost Guidance Only **£10** ***excl.***

CONSTRUCTION – TONE CONTROL ● POWER AMP ● PSU



Final Assembly

The Tone Control Unit, Audio Power Amplifier and Power Supply Unit are assembled on individual printed circuit boards (p.c.b.s).

The board for the Tone Control, together with the connections to the Bass and Treble potentiometers, is shown in Fig.8, together with the full-size copper track master. This board is available from the *EPE PCB Service*, code 459.

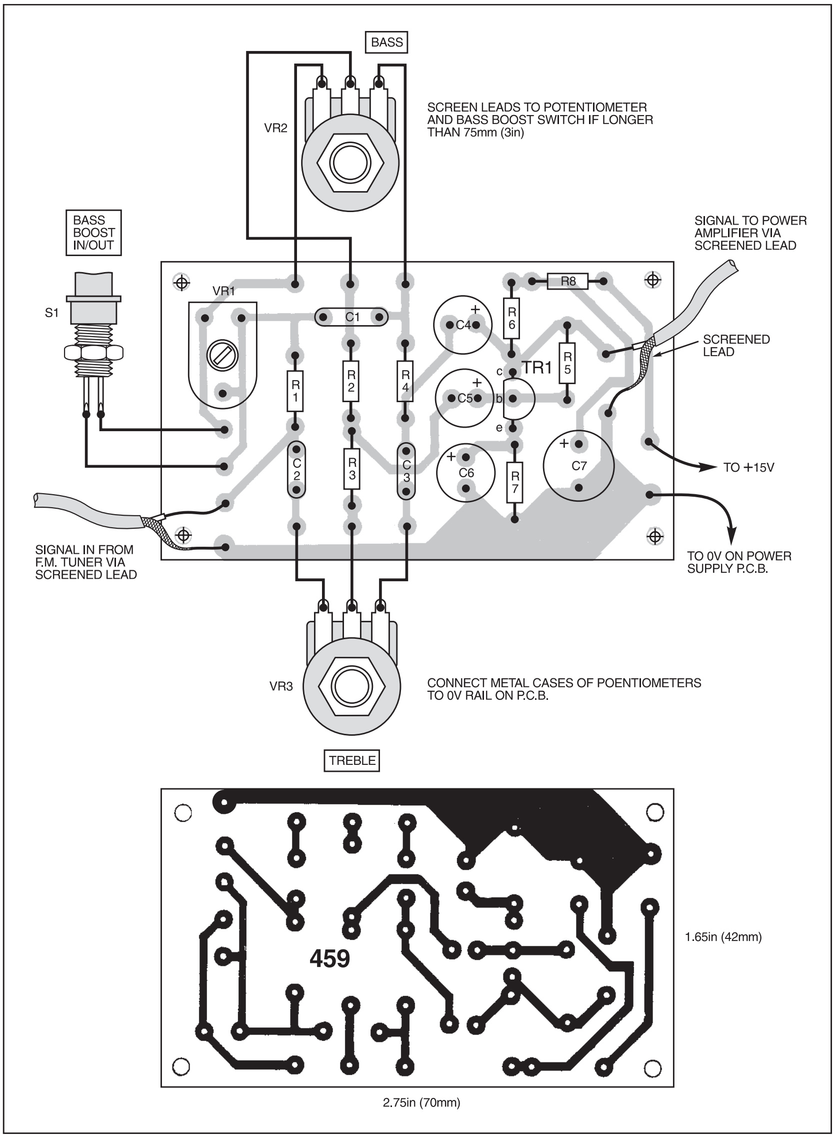


Fig.8. Printed circuit board component layout, wiring details and full-size copper foil master for the add-on Tone Control.

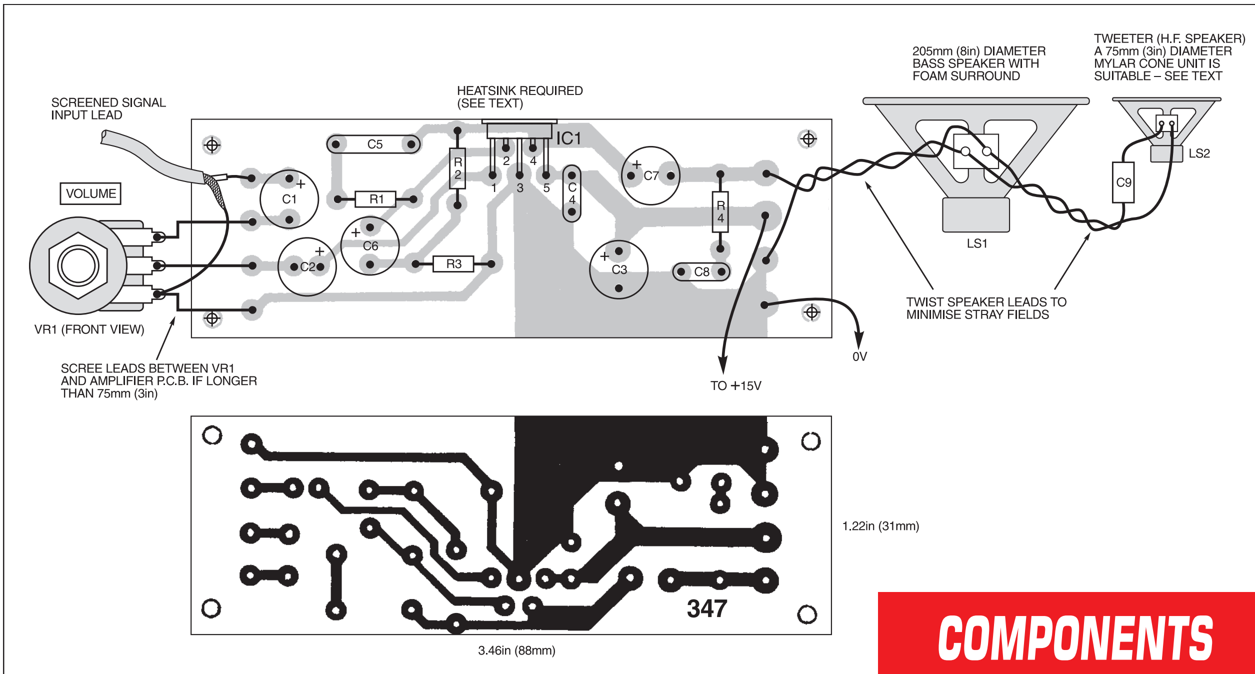


Fig.9. Audio Power Amplifier printed circuit board component layout, full-size underside copper foil master and interwiring details from the p.c.b. to the Volume control and speakers. Note, the bipolar electrolytic capacitor (C9) is mounted directly on the Bass speaker terminals.

The component side of the TDA2003 Power Amplifier printed circuit board, full-size underside copper foil master and wiring to the Volume control and the two speakers are illustrated in Fig.9. (This board is also available from the *EPE PCB Service* and is the same one from the *Audio Circuits* series, code 347.)

The component side of the Power Supply p.c.b., full-size copper foil master pattern and wiring details to off-board components are shown in Fig.10. This board is available from the *EPE PCB Service*, code 460.

As before, solder pins, inserted at the lead-out points, will simplify inter-board wiring. They should be inserted first, followed by the resistors, then the capacitors, beginning with the smallest. Semiconductors should be soldered in place last.

The mains transformer is bolted to the power supply board and its frame is isolated from the 0V rail. Place a solder tag beneath one of the fixings for the mains earth connection.

On completion, check the boards thoroughly for poor soldered joints or bridged tracks. Check the placement of components and the orientation of semiconductors and electrolytic capacitors.

A Hot Point

The TDA2003 amplifier (IC1) is internally protected and will shut down if its temperature rises excessively, or if its output is short circuited. Heat sinking is essential for the proper operation of this device.

Bolt the metal tag on the audio amplifier i.c. to a piece of 16s.w.g. aluminium at least 50mm × 50mm (2in × 2in) or a commercial heatsink of equivalent area. In the prototype receiver, the bracket that attaches the amplifier to the front panel acts as the heatsink.

Power supply regulators, IC1 and IC2, will function without heatsinks. Current drawn via the 8V regulator is quite low (8mA), and the minimal (2·5V) voltage drop across the 15V regulator keeps dissipation within the device at a modest level.

Miniature mains transformers tend to run quite warm, even when lightly loaded. The receiver case must, therefore, be adequately ventilated to keep the temperature rise of this component within acceptable limits.

Connect the power supply unit to the mains and check the output voltages before wiring it into the receiver. **Extreme care must be taken when building the Mains PSU as lethal mains voltages are, of course, present. It should only be put together by an experienced constructor.**

Interwiring

Screened audio cable should be used for all signal leads longer than 75mm (3in). If a non-metallic front panel is used, remember to connect the metal cases of potentiometers and switches to the 0V rail (ground).

Similarly, any metal front panel should be connected to the 0V rail. Constructors are reminded that the spindle of the tuning capacitor is connected to supply positive, and it must be insulated if it passes through a metal front panel.

Do not rely on screened cable braiding to carry the 0V rail to the printed circuit boards. A separate connection must be made, from the designated point on each board, to the 0V pin on the power supply.

At f.m. band frequencies, the mains wiring will sometimes act as one half of a dipole aerial (the whip aerial is, of course, the other) and increase signal pick-up. Situations vary, and a temporary connection should be made between the mains earth solder tag at transformer T1 and the 0V pin on the tuner board. Make the test with the receiver tuned to a "difficult" station. If the arrangement improves reception, a permanent connection can be made.

COMPONENTS

AUDIO POWER AMPLIFIER

Resistors

R1	39Ω
R2	220Ω
R3, R4	1Ω (2 off)

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometer

VR1	10k rotary carbon, log.

Capacitors

C1, C2	4µ7 radial elect. 25V (2 off)
C3	220µ radial elect. 25V (2 off)
C4, C8	100n ceramic (2 off)
C5	47n ceramic
C6	470µ radial elect. 25V
C7	1000µ radial elect. 25V
C9	10µ bipolar elect. 25V (or wire two 22µ 25V standard electrolytics in series – negative connected to negative)

Semiconductors.

IC1	TDA2003 audio power amp. i.c. (SGS Thomson)

Miscellaneous

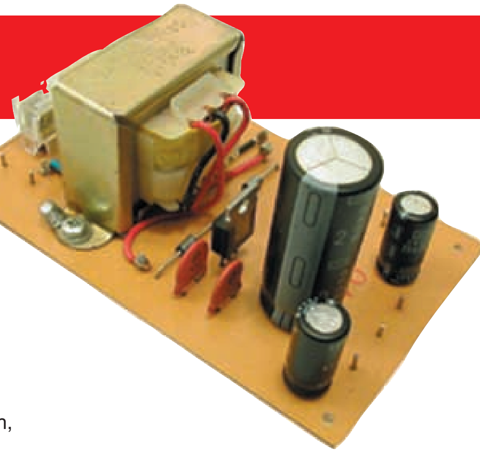
LS1	8 ohm 205mm (8in) diameter, foam surround, loudspeaker – see text
LS2	8 ohm 76mm (3in) diameter, mylar cone, loudspeaker, or "tweeter" unit (optional)

Printed circuit board available from *EPE PCB Service*, code 347; audio screened cable; piece of 16s.w.g. aluminium, 50mm (2in) x 50mm (22in), for heatsink (see text); small control knob; multistrand connecting wire; mounting nuts, bolts and washers; p.c.b. stand-off pillars (4 off); solder pins; solder etc.

Approx. Cost Guidance Only **£10** *excl. speakers*

COMPONENTS

Approx. Cost Guidance Only excl. mains plug & cable **£16**



POWER SUPPLY

Resistors
- R1 — 1k 0·25W 5% carbon film

See SHOP TALK page

Capacitors
- C1, C3 — 100µ radial elect. 25V (2 off)
- C2, C4 — 100n ceramic (2 off)
- C5, C6 — 100n ceramic, 50V (2 off)
- C7 — 2200µ radial elect. 25V

Semiconductors
- D1 — 5mm red l.e.d.
- D2, D3, — 1N4001 50V 1A rect. diode (2 off)
- IC1 — 7808 8V 1A voltage regulator
- IC2 — 7815 15V 1A voltage regulator

Miscellaneous
- T1 — miniature mains transformer: primary 230V a.c.; secondary 12V-0V-12V, rated at 250mA (size 43mm x 35mm x 36mm with 51mm fixing centres)
- S1 — pushbutton locking switch, push-to-make, or s.p.s.t. toggle switch, both with mains rated contacts
- PL1 — 3-pin Eurostyle mains inlet plug
- FS1 — 250mA 20mm fuse, with p.c.b. mounting fuseholder and protective cover

Printed circuit board available from the *EPE PCB Service*, code 460; l.e.d. holder; solder tag for Earth connection; mains cable; multistrand connecting wire; mounting nuts, bolts and washers; p.c.b. stand-offs; pillars (4 off); solder pins, solder etc.

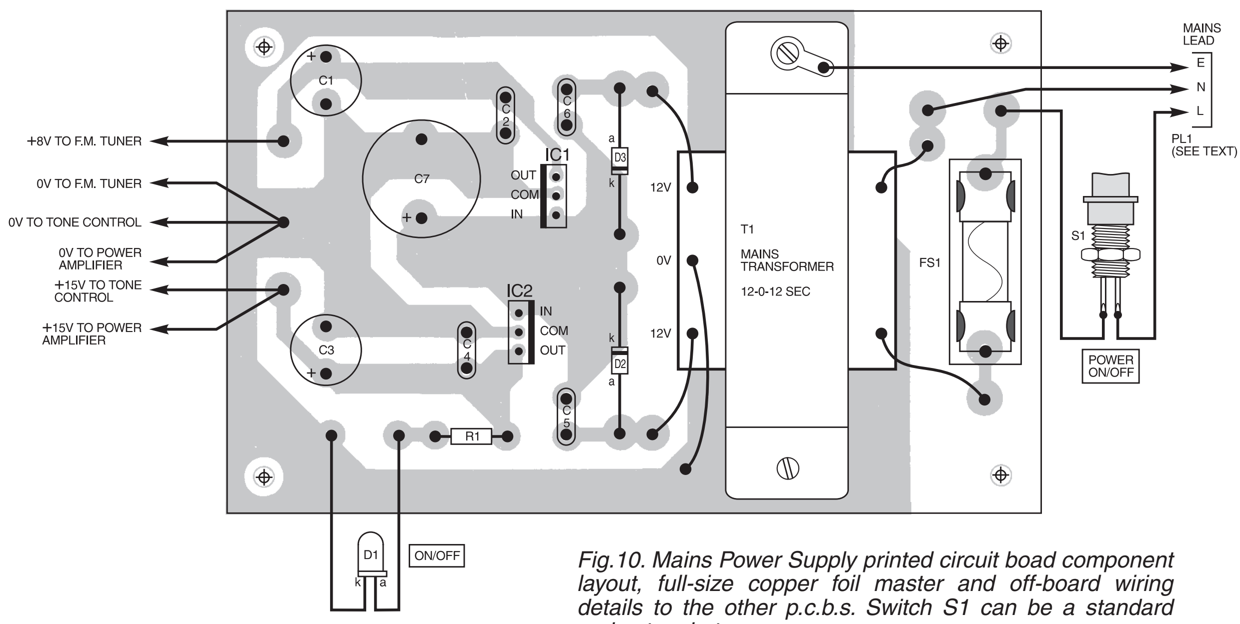
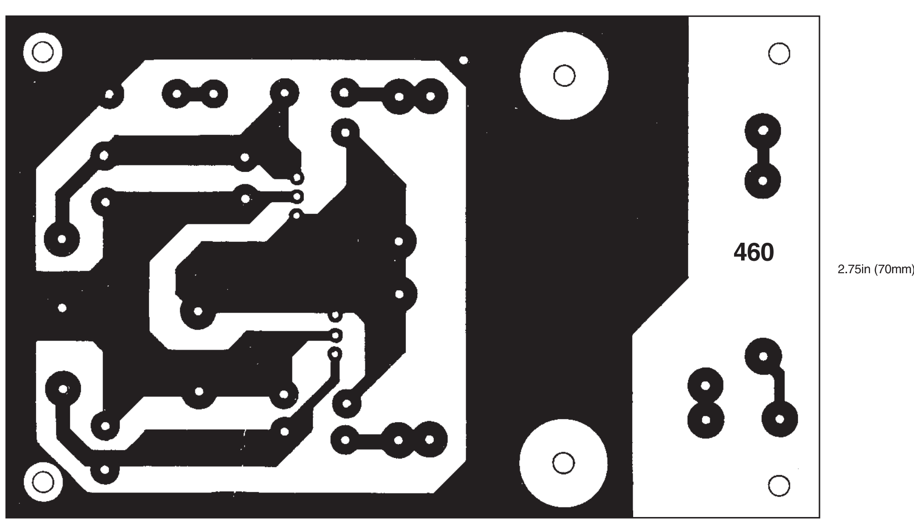
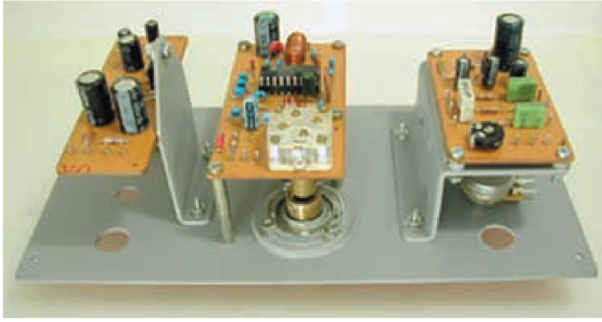


Fig.10. Mains Power Supply printed circuit boad component layout, full-size copper foil master and off-board wiring details to the other p.c.b.s. Switch S1 can be a standard mains toggle type.





The Power Amp, Tuner and Tone Control p.c.b.s mounted on spacers and brackets behind the radio front panel. Note the Power Amp bracket acts as a heatsink for the amplifier i.c.

Front panel control layout for the F.M. Radio.

Set Building

Tuner, Tone Control and Power Amplifier printed circuit boards are all mounted behind a front panel that carries all of the controls. A 205mm × 105mm (8in × 4in) piece of double-sided fibre glass printed circuit board forms the panel in the prototype receiver, but a piece of 16s.w.g. aluminium would do just as well.

Mounting the boards on long stand-offs holds them above the associated potentiometers and the inter-connecting leads can then be kept short.

The power supply is mounted on the side of the cabinet, and the entire arrangement is depicted in the various photographs. Note that for safety reasons no metal fixings for the power supply p.c.b. must be allowed to pass through the cabinet – use nylon bolts or short wood screws to fix the p.c.b.

Dial-up

In the prototype radio, an epicyclic slow-motion drive is fitted to the tuning capacitor. This is not essential, but it does make the receiver more pleasant to operate. The polythene dielectric (polyvaricon) type tuning capacitor spindles are short, so a spindle coupler and short length of plastic potentiometer spindle may still be needed to connect capacitor to drive. The plastic spindle insulates the tuning capacitor (see earlier).

The Bass speaker and p.c.b.s mounted inside the wooden case. The h.f. speaker is glued to the back of the speaker grille.

The prototype front panel is annotated with rub-down lettering applied to white card and protected by a piece of 2mm thick acrylic sheet (the kind of material used for DIY double glazing). A pointer for the dial is made from scrap acrylic sheet.

Cabinet

Cabinet size is determined by speaker size, and the prototype is just wide enough, internally, to accommodate the 205mm diameter (8in) speaker. Constructed from 12·5mm ($^{1}/_{2}$in) MDF, the overall dimensions of the cabinet are approximately 230mm wide × 330mm high × 120mm deep (8in × 13in × 5in).

The MDF panels are glued and pinned, and the cabinet finished with car spray paint. The tweeter unit is attached with cyanoacrylate adhesive (superglue) to the back of the speaker grille.

The speaker cutout must be extended beyond the foam suspension or the foam may clap against the case when heavy bass is being reproduced. Aperture diameter in the prototype cabinet is too small, and the speaker had to be held off the front panel by a ring of plywood.

Rear panel showing the four speaker vent holes. These holes also ensure adequate airflow to cool the transformer and heatsink.

When speakers are mounted in comparatively small enclosures, vent area in the back panel must approach the effective area of the speaker cone or the sound will seem muffled and "boxy". Four 75mm (3in) diameter holes are about right for the 205mm diameter speaker. This arrangement also ensures an adequate air flow to the mains transformer and the heatsink.

Aerial

Advantage should be taken of the cabinet's height and stability to install a long telescopic aerial. Aim for an extended length in excess of one metre (say 3ft 6in). The improvement in signal pick-up makes a difference with "weak" stations.

The case handle is formed by sandwiching 12mm × 3mm ($^{1}/_{2}$in × $^{1}/_{8}$in) steel strip between strips of wood, but a ready-made item would be equally suitable.

Performance

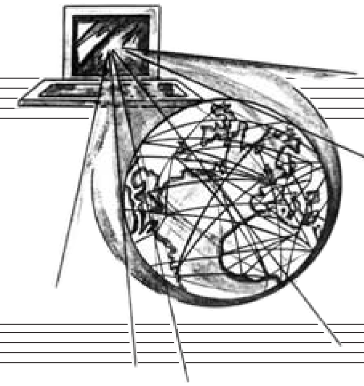
Sensitivity of the receiver is about the same as a conventional f.m. portable. If a commercial set performs adequately in the particular location, this simple design should also.

Bass response is impressive, despite the speaker's limited baffle area, and output more than adequate for domestic listening. The tweeter adds presence, and the overall sound quality is, in the author's opinion, exceptional by portable radio standards.

Some of the ingenious design features of the TDA7000 f.m. radio i.c. impose limits on the fidelity of the audio output, but this is not noticeable. The amplifier and speaker arrangements adopted for this rather potent receiver seem to make the most of its qualities rather than expose any weaknesses. □

SURFING THE INTERNET

NET WORK



ALAN WINSTANLEY

Time for a Move

NEEDING to upgrade a decrepit old PC, I have been sifting through a hard disk full of software that has accrued over the years, in order to decide what to throw away and what to carry over to the new machine (a home-built AOpen PC). Some fundamental decisions needed taking regarding Internet-related software, and so it was time for some belated spring-cleaning. Here's my short list of recommendations.

Both the old and new PCs are initially networked together in parallel as an insurance policy, so that there is always a backup Internet connection available. I like very much my useful Linksys KVM (keyboard-video-monitor) switch that lets me run two PCs with one keyboard and mouse. Simply hit Scroll-Lock twice to switch to the other machine. Buy these online from **www.dabs.com**.

First up will be firewalls. Even though Windows XP has its own firewall, before connecting to the Internet I'll be installing an old favourite as well (ZoneAlarm from **www.zonealarm.com**) which is free. Apart from anything else, I like the little bargraph icon that tells me what's uploading and downloading (as does the shareware Speed-O-Meter from **www.freeturtles.com**). Just set ZoneAlarm and forget it. Of course, the Windows XP Internet Connection Firewall will also be enabled for each connection – you should do this by hitting the "Properties" button when the dialler connection box pops up, then go to the "Advanced" tab and tick the box.

Anti-virus software, in my case Norton Anti-Virus Professional, is the next one on my list. Establish a raw internet connection then fetch and install the latest virus definitions *before* even thinking about installing email.

After a long relationship, ever since Version 1 in the mid-1990s, it's nearing the time to say goodbye to the author's Turnpike email software (**www.turnpike.com**). This program is Demon Internet's own email and news software that has been generally clunky but robust in use. Turnpike was a creation of Locomotive Software, famed for its LocoScript wordprocessor that introduced many a grateful user (including the author) into the exciting world of wordprocessing in the 1980s, using Amstrad's PCW machines.

Turnpike's non-standard and unintuitive design means that it soon lagged behind its more polished rivals. One benefit of having quite obscure software, though, is that no-one ever bothered writing a virus that attacked the Turnpike address book, which is why the author has shrugged off with impunity every mass mailing worm or virus that has brought many other users' systems to their knees.

Turn a New Leaf

Top of my short-list as a Turnpike replacement is Eudora (**www.eudora.com**) which has gained many friends over the years. In theory it is possible to export address books and old emails out of Turnpike, but whether this will work properly on the day remains to be seen. I will print off hard copies of pending emails, and it will be necessary to archive old passwords, legacy software and databases on a DVD as well, in the event that I have to re-install it in the future, perhaps to prove a legal point. You never know.

A POP3 mail client such as JB Mail from **www.pc-tools.net** or Popcorn from **www.ultrafunk.com** is an extremely useful way of debugging mailboxes. You can "prod" the mailbox live on the server and delete forever any unwanted trash before it ever gets delivered.

Microsoft Outlook Express only gets a look-in because I have to know how it works, in order to help other users with technical support. If you do use Outlook Express then an extremely useful address book and database backup/restore tool that helps with migration is available from **www.mta-soft.com**.

Web browsers are something else to take care of: I like to have a Navigator browser available so I'll be fetching the latest version from **http://home.netscape.com** via a tiny link at the bottom. Google's toolbar for Internet Explorer is a must-have, along with Favorites Search from **www.dzsoft.com** so I can pinpoint a favourite link in a jiffy. Secure certificates, such as the one I need to log into HSBC's commercial online banking system, will need to be transferred to the new machine as well. A backup can be kept on a floppy disk, perhaps encrypted using PGP (later). SuperCat from **www.no-nonsense-software.com** is used to index the contents of CDs and Zip disks, and will also find its way onto the new machine.

Other must-haves include my favourite and free LeechGet file transfer manager (**www.leechget.de**), a helper that chops large downloads into "byte-size" pieces. This gives you a fighting chance if suddenly disconnected or the server times out. It has an interesting display that shows clearly what's going on.

Clicking the Start/Programs button on the old system reminds me of other packages I'll have to worry about: PGP (Pretty Good Privacy at **www.pgp.com**) is useful for communicating securely with other PGP users. The PGP program has had a chequered career but, after being starved of development when Network Associates bought and then re-sold again, it has evolved into a solid program for Windows and Mac, with plug-ins available for popular mail clients including Eudora (good). Remember to carry over public and secret keyrings, and *never* allow a secret keyring to fall into the wrong hands.

Choosing and installing the right version of PGP is not trivial and the product's licence options take some fathoming out. In these days of Internet spies and snooping software, PGP is my preferred product for transmitting sensitive commercial or private data by email.

I Spy . . .

On the subject of spyware, I have no less than five software tools in my armoury that are used at one time or another. I'm not as diligent with cookie and temporary file (web cache) file clean-up as I ought to be, but the weapons of choice start with the free AdAware (**www.lavasoft.de**).

Another very useful tool is the SpyBot S&D (Search and Destroy) from **www.safer-networking.org** which has the bonus of wiping any unwanted dialler programs as well (the sort that connects your modem to a phone number halfway round the world, racking up exorbitant call charges at the same time). Spybot S&D is a powerful freeware program with many options, and is worth getting to grips with, especially if you are a confident computer user.

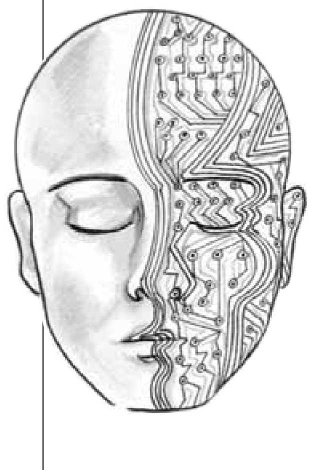
More clean-up programs to look at include the powerful Cyberscrub (**www.cyber scrub.com**) for user-definable file wiping in excess of military standards, Tracks Eraser Pro 5 from **www.ace-soft.net** ($29.95), useful for crunching cookies and cleaning up the cache. WebRoot Spysweeper is also $29.95 (free trial) from **www.webroot.com**.

You should at the very least run AdAware every now and then to clear out advertising cookies, and if you want more control over what footprints you leave when surfing the web, try one of my suggested spyware programs. If you think I'm being a bit paranoid about all this, you're probably right: simply choose what works for you.

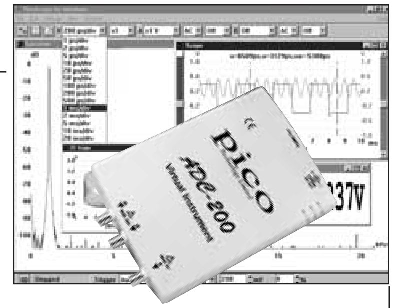
Trying to move many years' worth of programs and files isn't trivial, and is a job best planned well in advance, and allowing plenty of time to work through everything methodically. In coming months I'll be discussing domain names, how to buy them, and how to set them up with a popular domain seller. I'll revisit broadband and discuss the latest options.

You can email comments to **alan@epemag.demon.co.uk**. If the new PC works, I may respond by return!

INGENUITY UNLIMITED



Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been published or submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.**
Send your circuit ideas to: *Ingenuity Unlimited,* Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown Dorset BH22 9ND. (We **do not** accept submissions for *IU* via E-mail.) Your ideas could earn you some cash **and a prize!**



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- 100MS/s Dual Channel Storage Oscilloscope
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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 12 months, Pico Technology will be awarding an ADC200-100 digital storage oscilloscope for the best IU submission. In addition, a DrDAQ Data Logger/Scope worth £69 will be presented to the runner up.

Let There Be Light – Avoid the Bell Hop!

THE author recently obtained a wireless doorbell kit from a local DIY store. The kit contained two battery-operated bell pushes, each with an integral low-power radio frequency (r.f.) transmitter running at a frequency within the general purpose "license free" band of 433MHz. This kit also contained a battery-operated receiver with a built-in moving coil loudspeaker which could play a number of selectable tunes or sound effects when either one of the transmitters was activated.

One of the transmitters is installed near the front door while the other one is installed near the back door. The receiver/sounder is mounted on a wall in close proximity to the fixed on/off switch for the main kitchen light, which is some distance from both doors.

With the addition of a small amount of circuitry it is now possible to turn on the main light in the kitchen by operating either of the transmitters. It remains on for approximately two to three minutes. After this the light automatically turns off.

The connections to the receiver/sounder are shown in Fig.1a, with the additional circuit needed in Fig.1b. The 7555 timer (IC1) is triggered by the signal activating the sounder. This causes MOSFET TR1 to turn on, and so turn on the solid state relay. The relay's switch contacts are connected in parallel with the contacts of the kitchen light switch. If the switch is turned off, the active relay connects the switch's contacts, thus turning on the light.

When the timer times-out, the relay is de-energized, the kitchen light is turned off and its switch then functions normally until the next time one of the transmitters is operated when the switch is in the off position. By changing the values of resistor R1 and capacitor C2, the amount of on time for the light can be changed.

Wiring

There is only a minimal amount of wiring needed to the additional circuitry from the existing receiver/sounder and from the additional circuitry to the relay. Points A, B, C, and D show the relevant existing circuitry within the author's particular receiver/sounder, while points A', D' and C' show the connections for the additional circuit board. The current demands for the additional circuit from the existing battery within the receiver/sounder is modest.

How It Works

MOSFET TR1 takes no current when it is turned off and about 20mA when driving the solid-state relay's internal l.e.d. and its ballast resistor. Timer IC1 requires a modest quiescent current of 100μA or so, which should hardly rise when driving the high impedance gate (g) of TR1. If the configuration for your receiver/sounder is different from the one shown in Fig.1a, the principle of operation remains the same, i.e. tapping off a square wave pulse from the sounder to trigger the timer.

Take into account the power demands of the lamp when selecting a relay. The author's one is capable of switching 400V at a current of 8A and was obtained from Farnell. Data sheets for these devices can be viewed on their CD-ROM catalogue and also via **www.farnell.co.uk**.

The prototype was assembled on a small piece of stripboard, which was mounted in the receiver/sounder enclosure as there was ample space available. **Ensure that the mains electrical supply is turned off before connecting the circuit to the light switch. The connections and relay wiring should only made by a suitably qualified person.**

David Allen, Cheltenham, Glos

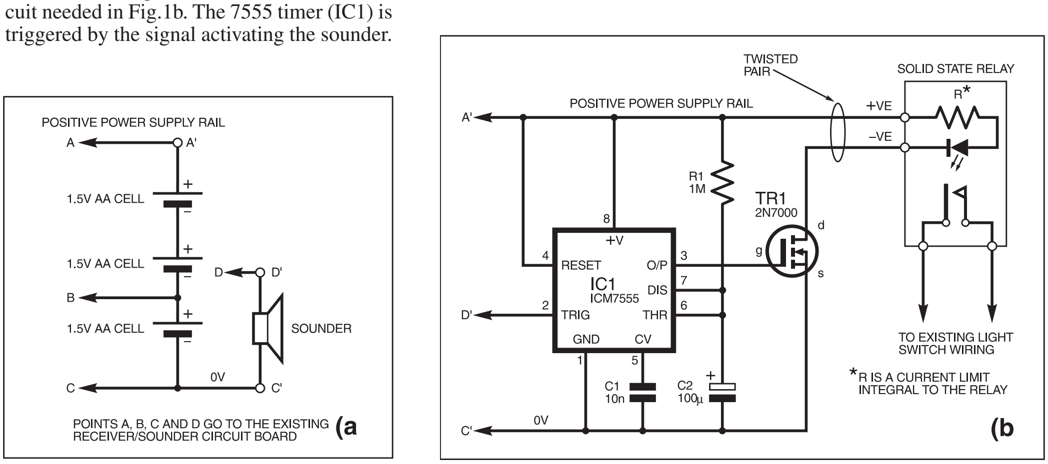


Fig.1. (a) Existing connections to doorbell kit and (b) additional timer circuit diagram.

WARNING
MAINS VOLTAGE CAN BE LETHAL

Manual Bit-Stream Selector – Banishing Bounces

A COMPLEX project needed the selection of one of two bit-streams by manually operating a toggle switch. The requirement was that the switching action itself was not to perturb the output.

For example, if both bit-streams were at rest at the same logic level, then flicking the switch would produce no change and no noise spike ("glitch") at the output. If the two input levels were held at opposite states while throwing the switch, then a smooth glitch-free output transition would also be the result.

Selector Circuit

The control voltage from a switch is useless for this as each break or make of the contacts produces numerous spurious noise signals due to contact bounce. The circuit shown in Fig.2 was developed to get round this problem.

A control signal is produced by flip-flop IC1a as selected by switch S1. While the switch pole is in motion (a quick action to humans but absolutely ages to an electron) the clear and preset inputs are held inactive (high) by resistors R1 and R2, respectively.

The instant that the switch pole lands on a contact, a low signal hits the corresponding input causing immediate change of the output state. Any switch pole bounces have no further effect.

The resulting clean control signals on IC1a output pins 5 and 6 are used to enable data from one channel to flow through NAND gates IC2a or IC2b, depending on which way up (logic-wise) the control signal is held. The combined output at IC2c pin 8 is an exact copy of whichever IC2 input pin 1 or pin 5 has been enabled by the control signal.

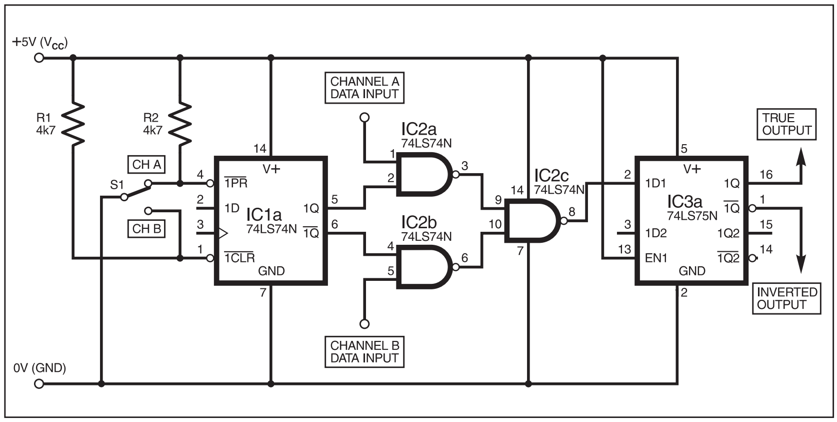


Fig.2. Circuit diagram for a "glitch-free" Manual Bit-Stream Selector.

Final output of the true (same logic level) selected bit-stream is on IC2c pin 8, but an inverted version could be made by passing this through the otherwise unused IC2d gate, with its inputs strapped together as an inverter. Another refinement is synchronous generation of the true and complement bit-streams by IC3a, which is wired as a latch that never latches, its enable pin 13 being held high. As the bit stream entering at pin 2 is clean, so are the complementary outputs at pins 1 and 16.

The spare flip-flop, IC1b, could be used to provide a manual pulse, wiring it exactly as IC1a but with a momentary-action push-switch. Its output pin Q could then become the source of one of the bit-stream channels (leaving pin $\overline{Q}$ unconnected).

Godfrey Manning, Edgware, Middx.

Visual Illusion – Magic Eye

THE circuit shown in Fig.3 shows an electronic version of a powerful visual illusion that the author first saw at the Boston Science Museum. The original illusion used a white 3D face on a white background, which was viewed only with the left eye. The right eye viewed only a white background.

When a brief motion was "superimposed" upon the face (seen only by the right eye), the face completely disappeared. In fact the face was still there – but what had the brain done with it?

The basic illusion may be simulated electronically, if a number of conditions are met. First, each eye needs to have a separate field of vision, which is achieved by looking through two separate eye-glasses or magnifiers. Second, the image in the right eye needs to be visually unobtrusive (in the original illusion, the white background), so that the image in the left eye becomes the full focus of attention.

Objective View

In the author's experiment, the right eye viewed l.e.d. D2, the colour of which blended into the background (e.g. a clear l.e.d. with matching white-grey background, or a red l.e.d. on a similar red background). A small 3D object of about the same size as the l.e.d. was then mounted on the background, to be viewed only by the left eye. Both the l.e.d. and the said object were in sharp focus, and perfectly "superimposed" upon each other when viewed through the two eye-glasses or magnifiers.

With the object in the left eye being the full focus of attention, the circuit was switched on. When l.e.d. D2 blinked, for a moment the object completely disappeared, sometimes seeming very reluctant to reappear.

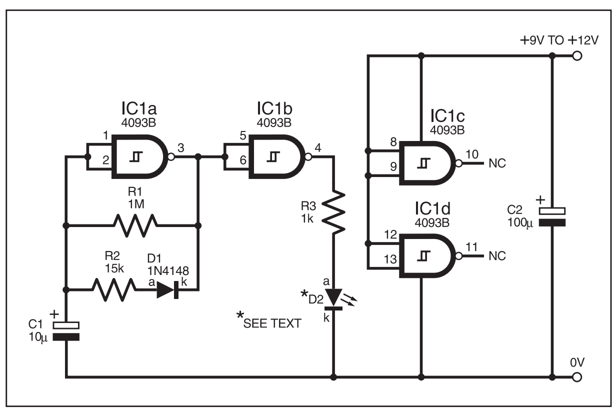
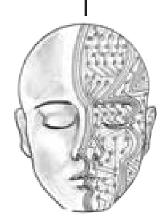


Fig.3. Visual Illusion circuit diagram.

The flashing of l.e.d. D2 is accomplished with a simple "clock generator" formed around NAND gate IC1a, together with a buffer, IC1b, which switches as capacitor C1 charges and discharges. The "on" period of D2 is reduced by the rapid discharging of C1 through resistor R2 and diode D1. The initial "off" period is about fifteen seconds.

Be sure to use a bright l.e.d., but not one of such intensity that it might hurt the eye.

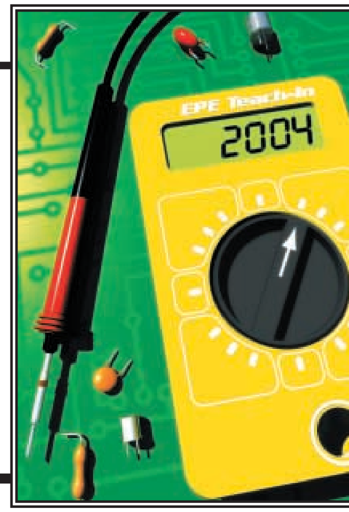
Thomas Scarborough, Cape Town, South Africa



EPE Tutorial Series

TEACH-IN 2004

Part Ten – Motor Control



MAX HORSEY

Concluding this 10-part series in which we have shown you how to apply electronics meaningfully, experimentally illustrating how electronic components function as part of circuits and systems, and demonstrating how each part of a circuit can be understood and tested.

REVERSIBLE motor control sounds misleadingly easy – press a button, motor starts to turn, motor automatically stops at the right moment, motor pauses, motor reverses then stops automatically.

This sequence of operations forms the heart of many projects, from automatic curtain and blind winders, to automated animal doors and model lifts. In the final part of this *Teach-In 2004* series, we show how to design such a system. We explore the use of ordinary switches, followed by relays, then logic circuits including bistable latches and T-type bistables.

Perhaps unsurprisingly, for maximum flexibility with minimal circuitry, we finish with a PIC-based microcontroller solution for curtain winding and blind control.

MOTOR REVERSING SWITCH

The double-pole double-throw (d.p.d.t.) switch, S1, shown in Fig.10.1 forms the heart of a motor reversing circuit. We are assuming that a permanent magnet d.c. motor is employed, the type that reverses if the current is reversed. Note that a.c. motors cannot be reversed in this way, since they are designed to turn continuously in spite of the rapidly reversing supply current.

No provision has been made to stop the motor, so flicking the switch will simply make it reverse. Motors do not react kindly to being reversed too abruptly, and so a separate on/off switch should be added in series with the supply, or a centre-off reversing switch could be employed. This has three positions, and in its centre position the poles are not connected either way.

This type of switching can never be more than fully-manual. In other words, you must physically move the switch to start/stop/reverse the motor. You must wait until the system that the motor is controlling has reached the end of its motion (e.g. the curtains are fully open or fully closed) and then switch off the current.

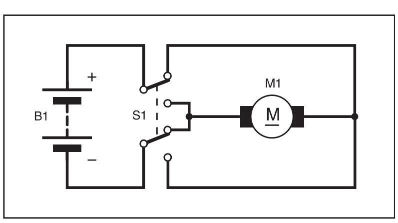


Fig.10.1. Fundamental motor direction control.

RELAY CONTROL

The relay – an electromagnetic switch – offers a much better solution since it can be made to latch and unlatch (reset) automatically. A system based on a d.p.d.t. set of relay contacts is shown in Fig.10.2. One set of contacts is used to switch on the motor and the other set is used to latch the relay.

Pressing the push-to-make switch S1 will latch the relay and start the motor. Pressing the normally-closed (push-to-break) switch S2 will cause the relay to unlatch. Switch S2 could be automatically triggered when the system reaches its stopping point.

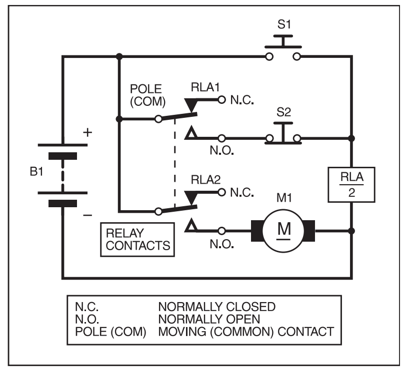


Fig.10.2. Using a relay to assist basic motor control.

As yet, no provision has been made to reverse the motor, and although this could be achieved with relays, a much more flexible system can be devised using transistors.

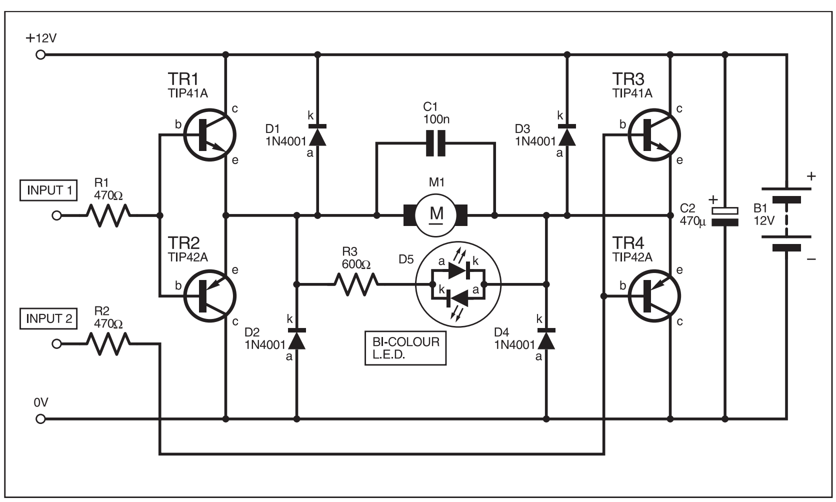


Fig.10.3. Circuit diagram for a transistorised motor reversing control interface.

TRANSISTORISED REVERSING CIRCUIT

The circuit diagram in Fig.10.3 shows how four transistors may be used to reverse a motor. Note the mixture of *npn* and *pnp* transistors. Medium power transistors have been chosen so that a variety of small d.c. motors may be used, including geared motors suitable for curtain or blind winding. For more information about transistors refer back to Part 2.

Assume for the moment that both Input 1 and Input 2 are held at 0V. Transistor TR1 will be switched off, as will TR3. Hence no current can flow through the motor, M1. If we connect Input 1 to 12V, transistor TR1 will switch on, since its base (b) will be 0·7V above its emitter (e) voltage.

Transistor TR2 will be switched off since it is a *pnp* type, and its base must be 0·7V *below* its emitter before it will switch on. If Input 2 is at 0V, the emitter voltage of TR4 will be 0·7V higher than its base voltage, and so it will turn on, hence current flows from the positive supply line, through TR1, through the motor, and down to 0V via TR4. Remember that TR3 will remain switched off since its base will be lower than its emitter voltage.

Now if we return Input 1 to 0V, but connect Input 2 to 12V, the same reasoning will apply, and current will flow via TR3, through the motor (in the other direction) and via TR2 to 0V.

If both inputs are held at 12V, then both TR1 and TR2 will switch on, but TR2 and TR4 will be off, so no current can flow.

Bi-colour l.e.d. D5, buffered by resistor R3, provides an indication of the motor direction.

Diodes D1 to D4 remove voltage spikes produced by the effect of “back-e.m.f”, particularly if the circuit is switched off but the motor is still rotating. Such back-e.m.f. could destroy the transistors if not removed.

Capacitor C1 removes any other voltage spikes produced by the motor. It should be mounted across the motor’s connecting tags, as close as possible to them. Capacitor C2 is a general decoupling capacitor to smooth out ripples in the power supply.

SHORTCOMINGS AND IMPROVEMENTS

It is important that the inputs are switched cleanly between 0V and 12V (assuming a 12V power supply) since if they waver at some intermediate voltage, the transistors could overheat. Also, the circuit that controls the inputs must be capable of supplying adequate current to the transistors, failure to do so could also cause transistor overheating.

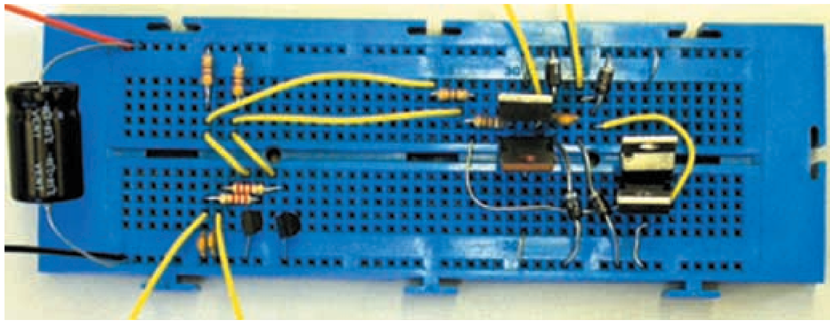


Photo 10.1. Breadboard assembly of the combined circuits in Fig.10.3 and Fig.10.4.

To ensure adequate input voltage and current conditions, an interface such as that shown in Fig.10.4 can be added prior to Fig.10.3. Here two high-gain *npn* transistors (TR1 and TR2), such as BC549, are employed, with their inputs buffered by resistors R1 and R2.

Capacitors C1 and C2 help to remove any voltage spikes or a.c. interference. It is important that these transistors are turned on and off cleanly so that their outputs also change cleanly between 0V and 12V.

Note that as this circuit inverts the polarity of the input control signal, the latter must go *low* (0V) in order to turn on its equivalent input in Fig.10.3.

Note that the 12V supply powering the reversing circuit in Fig.10.3 must also supply the power for Fig.10.4. However, current for controlling the Forward and Reverse inputs can be from a control circuit operating on any supply of between about 3V and 12V.

This interface is ideal if a PIC or other logic circuit having limited output current available is used as the control source.

An example breadboard assembly of the combined circuits of Fig.10.3 and Fig.10.4 is shown in Photo 10.1.

CONTROL CIRCUITS

Having devised the motor’s basic control circuit, we now need to devise a circuit which can provide the necessary control signals to it. We need a system with two outputs which control the motor according to the logic in Table 10.1.

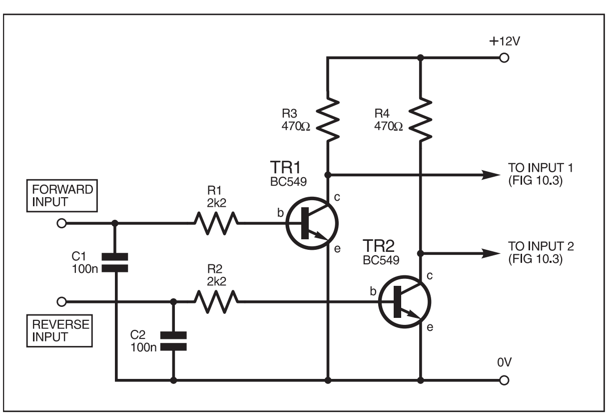


Fig.10.4. This interface circuit helps to provide the circuit in Fig.10.3 with adequate voltage and current conditions.

A circuit using logic gates can be easily configured to achieve this, with the added advantage that automatic stopping and sensor control can be easily incorporated. Hence the system can be operated from push switches, remote control, daylight sensor, etc.

LATCHING SYSTEMS

When you operate a lift, you expect to be able to press a button, and have the lift move to the correct floor without needing the button to be held down. In other words, the system must latch. The latching is achieved electronically, of course, since if a mechanical latching switch were used, it would be difficult to make the system unlatch as required.

Table 10.1. Motor Control Logic

INPUT 1	*INPUT 2*	*OUTPUT*
0	0	Motor stopped
1	0	Motor forwards
0	1	Motor backwards
1	1	Motor stopped

We have already shown in Part 4 how logic gates can be made to latch, and how a bistable latch based on two NOR gates can be interconnected to produce a very reliable *set* (latch) and *reset* (unlatch) system. The circuit in Fig.10.5 shows how two sets of NOR gates can be used to make a set/reset bistable system and provide a pair of outputs suitable for driving the transistors in Fig.10.4.

Gates IC1a and IC1b form the first bistable, and gates IC1c and IC1d form the second.

Although the circuit in Fig.10.5 may appear complicated, only one inexpensive i.c. is required, and considerable flexibility is provided. There are five pushbutton switches, S1 to S5, labelled as though they control the opening and closing of curtains or blinds.

Resistors R1 to R4 ensure that the inputs to the gates are biased low when the switches are not pressed. Capacitors C1 to C4 help to prevent switch-bounce, and also to help signal stability even if a switch is placed a long way from the circuit.

Capacitors C2 and C4 are connected in parallel with switches S2 and S4 in order to provide a brief reset pulse to IC1b pin 6 and IC1d pin 13 at the moment when power is applied to the circuit. Without this pulse, one or other bistable could be randomly triggered with its output high when power is applied.

HOW IT WORKS

Assume for the moment that both bistables are reset, hence IC1b output pin 4 and IC1d output pin 11 will both be low (0V). If Open switch S1 is pressed IC1a pin 1 will go high (logic 1), so triggering the bistable around IC1a/b, and IC1b output pin 4 will go high, triggering the Forward input of the circuit in Fig.10.4.

Current now also flows through diode D2 and causes the bistable around IC1c/d to reset (if it wasn’t already reset). Since

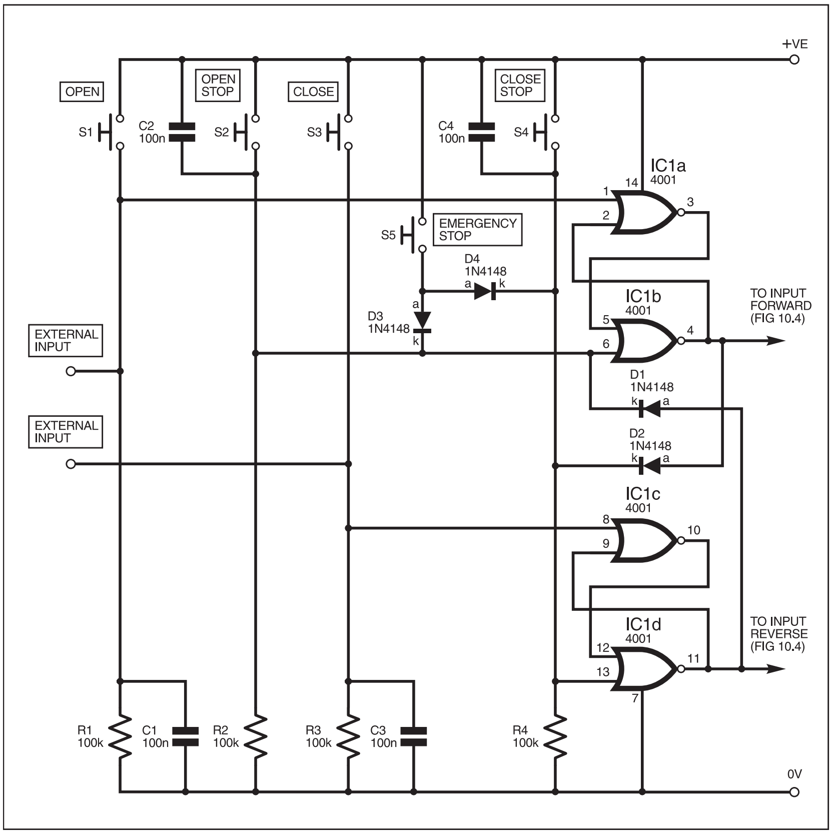


Fig.10.5. Using switches and bistable latches to generate motor control signals.

diode D1 performs the same task for the other bistable, the bistables can never have their outputs high at the same time, regardless of random pressing of the switches.

The Stop switches, S2 and S4, are triggered when the system is fully one-way or fully the other-way, such as curtains fully open or fully closed. Microswitches with levers are suggested. Two separate switches are needed since when, say, the curtains are fully closed, S4 will remain closed, and IC1d pin 13 will stay high. Hence only S1 can operate the system, since the contacts of S2 are open.

The system can be stopped in an emergency by disconnecting the power, but a simpler method is to use switch S5 in conjunction with diodes D3 and D4. When S5 is pressed, the current flowing through the diodes will reset both bistables, but the one-way action of the diodes will otherwise allow the rest of the circuit to function as before.

SENSOR CONTROL

The external inputs in Fig.10.5 could be from a light sensor or any other device, processed to provide a clean switchover between 0V and positive. Schmitt trigger circuits are ideal for this and their principle was described in Part 3 when op.amps were discussed.

A sensor system with Schmitt effect can be made using a ready-made logic device such as the CMOS 4093, in which the hysteresis ratio is fixed during manufacture. Alternatively, if you wish to set your own hysteresis ratio, a single non-inverting gate, or a pair of inverting gates, can be used. The latter technique is illustrated in Fig.10.6, in which two NOR gates are employed. NAND gates or inverters (NOT gates) would be just as effective (logic gates were discussed in Part 4).

The ratio of resistors R3 and R4 sets the switching points of the Schmitt trigger. With the values and NOR gate type indicated, the system will switch high and low respectively when the input voltage at R3 is at about 0·6 and 0·4 of the supply voltage.

Various sensor circuits have been described earlier in the series, but as appropriate to a curtain or blind winding application, an l.d.r. (light dependent resistor) sensor (R2) is shown in Fig.10.6. Its breadboard test assembly is shown in Photo 10.2.

As the light on the l.d.r. falls, the voltage applied to R3 will fall, and at the switching threshold of the system, the output voltage at IC1a pin 3 will go high. The exact point at which this happens can be set by adjusting potentiometer VR1. Resistor R1 prevents excessive current flowing when the l.d.r. is exposed to bright light (hence making is resistance fall to a very low value) if VR1 is reduced to a low resistance.

The output voltage from IC1b pin 4 will switch the opposite way to that at pin 3, and so these two outputs can be connected directly to the Forward and Reverse inputs on the interface circuit in Fig.10.4

The l.d.r. can be replaced by any sensor whose resistance changes in response to external conditions, although VR1 may need to have a higher or lower value to suit. The ideal value for VR1 is approximately equal to twice the value of the sensor's resistance at the point when switching is required. If you select a value which is too low, then switching may never occur; if it is too high, then adjustment is quite difficult. If in doubt, use a higher value for VR1 and experiment!

D-TYPE BISTABLE

Although NOR gates are used in Fig.10.5 there is a device called a D-type bistable which will do exactly the same job.

The functional diagram for a D-type (D for Data) bistable is shown in Fig.10.7a. Its set/reset equivalence to a dual NOR-gate bistable is shown in Fig.10.7b. It has both Set (S) and Reset (R) inputs, along with a normal output (Q) and an inverted output ($\overline{Q}$). There are also Data (D) and Clock (CP) inputs.

The Data input offers a way of controlling the output in synchronisation with a clock pulse applied at CP (sometimes labelled CK, or CLK). Assuming that the Set or Reset inputs are held low, if a logic 1 is applied to

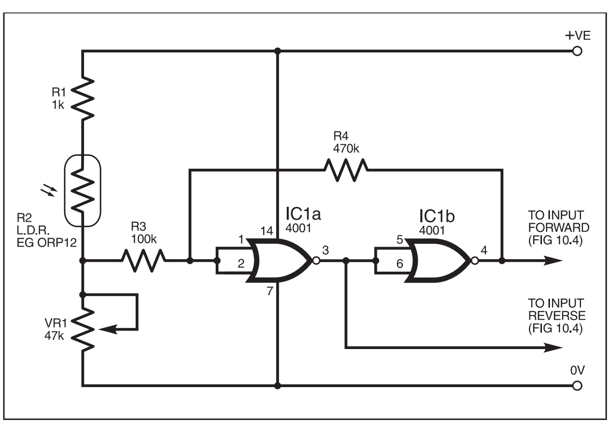


Fig.10.6. A circuit in which an l.d.r. generates motor control signals through a Schmitt trigger interface.

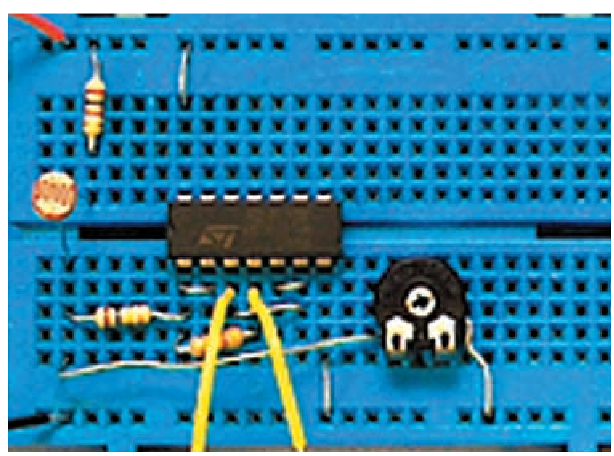
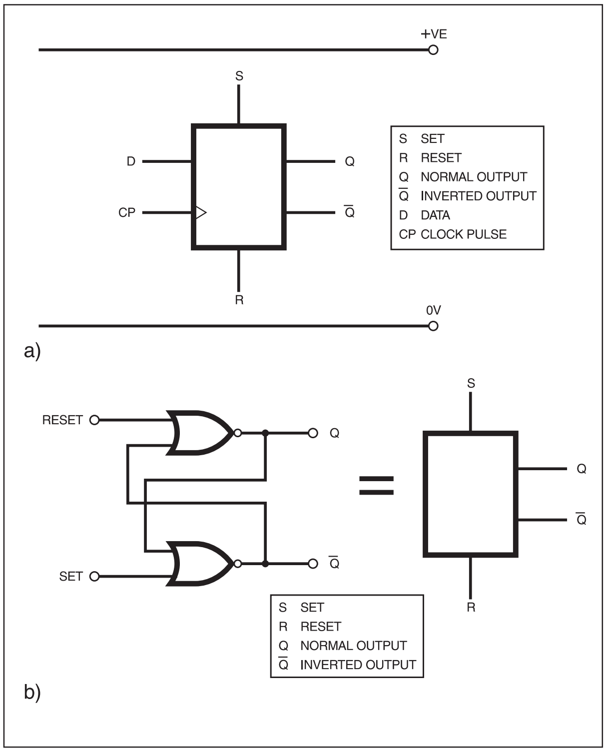


Photo 10.2. Breadboard assembly of the circuit in Fig.10.6.



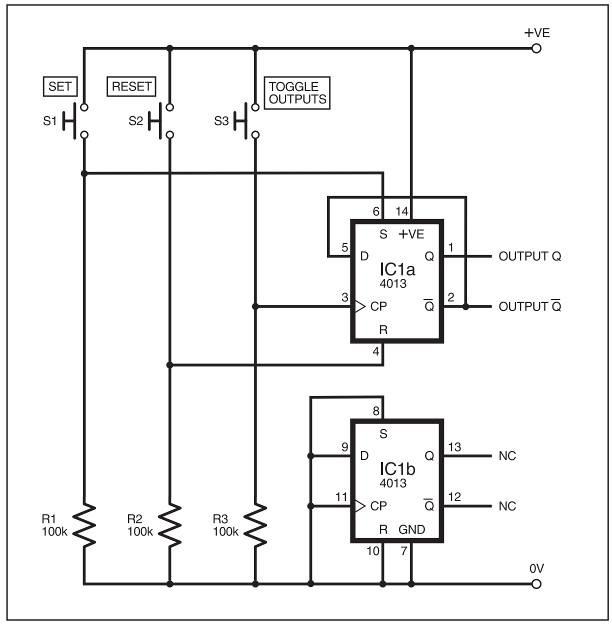


Fig.10.7 (left). Functional diagram for a D-type bistable (a); NOR gate equivalence to the set/reset function (b).

Fig.10.9 (above). Practical implementation using two D-type bistables under set/reset switch control.

input D, nothing will happen. But if a positive-going pulse is applied to the clock input (CP), output Q will copy the logic 1 at D. Output $\overline{Q}$ will be at the opposite logic level to Q, i.e. logic 0.

If the logic level at input D is switched from high to low, nothing will change at the outputs, until the clock is switched high again. This is known as *leading edge triggering*, in other words, the outputs change logic state in relation to the logic at input D only at the moment when the clock input switches from low to high.

Note that if you do not need to use the D and CK inputs they should both be connected to 0V.

This type of bistable forms the heart of many useful circuits including shift registers, binary counters and dividers. But we will examine just one use – the T-type bistable configuration.

T-TYPE BISTABLE

The T-type (T for Toggle) configuration using a D-type bistable is shown in Fig.10.8. It simply involves connecting the inverted output ($\overline{Q}$) to the data input (D). The effect of this is that whenever the clock input logic is taken from low to high, output Q copies D, and since D is connected to $\overline{Q}$, the result will be that output Q always changes state. In other words, each time the clock is taken high, outputs Q and $\overline{Q}$ will change state.

This configuration is sometimes called a divide-by-two module, since if the clock input twice changes state from low to high, the output Q will change from low to high and then low again. So the output frequency will be at half that of the clock input frequency.

This arrangement can be quite useful in applications where you would like a single pushswitch to activate a circuit, and we will look at a practical circuit next.

PRACTICAL T-TYPE LATCHING

The circuit diagram in Fig.10.9 shows how a single T-type bistable configuration can be used in practice. Notice how all the inputs must be tied to a definite logic level, and so IC1a pins 3, 4 and 6 are connected to 0V via resistors, R1 to R3. This allows switches S1, S2 and S3 to take the respective IC1a inputs high when required.

The Set and Reset actions are from switches S1 and S2 respectively, and the toggle action is by means of S3. In other words, whenever S3 is pressed, the outputs change state.

IC1b is not used in this circuit, so the unused inputs are connected to 0V to avoid static damage. Do not connect the unused outputs to anything.

Note that capacitors have not been used in parallel with the resistors or switches (as in Fig.10.5) since they are unlikely to be needed in this simple test circuit. If you only require the toggle action switch S3, then you may omit S1 and S2. In this case you must either retain R1 and R2, or connect pins 6 and 4 directly to 0V.

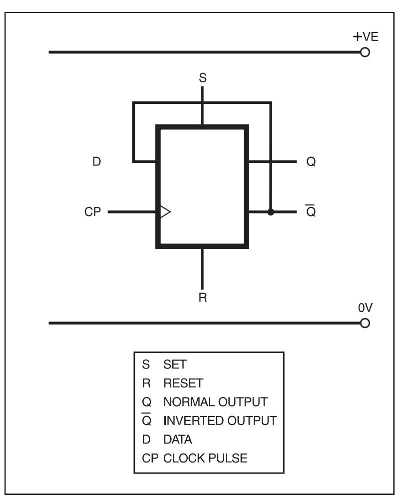


Fig.10.8. Functional diagram for the T-type configuration using a D-type bistable.

SINGLE SWITCH CONTROL

Controlling the entire action of the system with a single switch is particularly useful if the switch is a long way from the circuit. For example, a switch controlling a garage door may be inside the house. Many remote control units employ a single switch, the action of which is as follows:

First Press:	Forward
Second Press:	Stop
Third Press:	Reverse
Fourth Press:	Stop

There are several ways of achieving this, but the circuit shown in Fig.10.10 and Photo 10.3, uses two T-type bistables. Ideally we would employ a pair of logic AND gates for the outputs, but to avoid using another i.c., resistors R2, R3 and diodes D1, D2 are employed to serve the same function.

Switch S1 provides the Forward/Stop/Reverse/Stop function. Resistor R1 holds the clock input at 0V, with capacitor C1 used as described earlier. The two T-type bistables, IC1a and IC1b, are cascaded and the actions of all four outputs are shown as a truth table in Fig.10.10.

It will be seen from the truth table that we want the motor to go forward when output combinations AQ and BQ are both at logic 1. If, for example, IC1a output Q and IC1b output Q are both high, current will flow via R2 and be unaffected by the presence of diode D1, making Output Forward high. However, if IC1b output Q is low, the current from R2 will be routed through

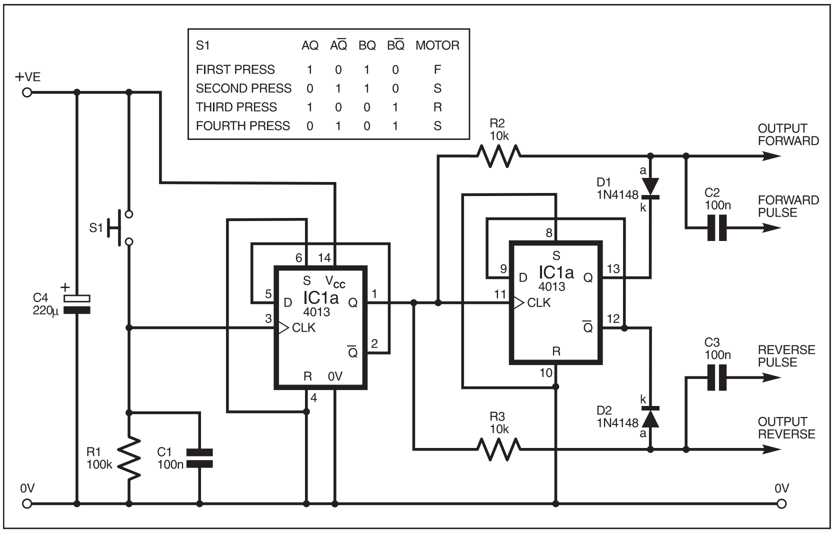


Fig.10.10. Showing how a single switch can trigger two bistables through four output modes.

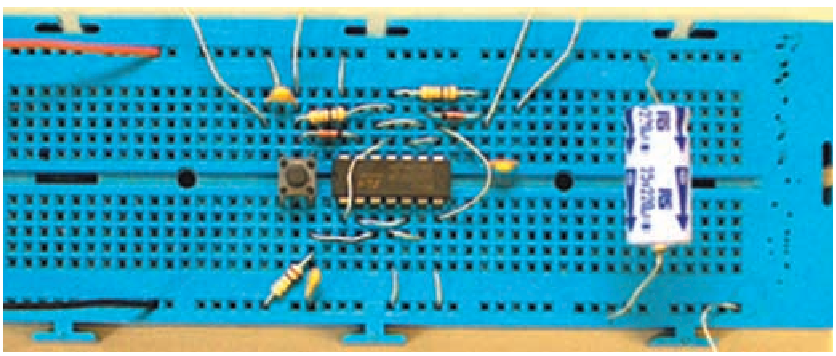


Photo 10.3. Breadboard assembly of the circuit in Fig.10.10.

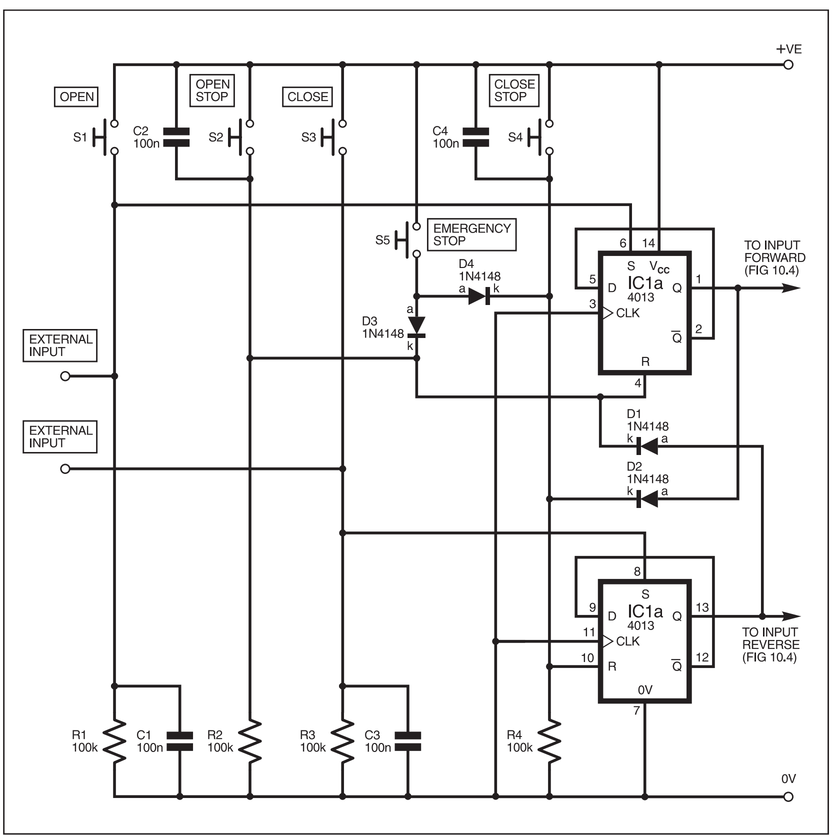


Fig.10.11. Using bistables to replace the NOR gates in Fig.10.5.

diode D1 and into this output, making Output Forward low, irrespective of the state of IC1a output Q.

Diode D2 and resistor R3 perform a similar function with regard to IC1a output Q and IC1b output $\overline{Q}$, and hence controlling Output Reverse.

It should be apparent that the circuit shown in Fig.10.10 can be employed as a self-contained system, since Output Forward and Output Reverse provide a similar pair of control signals to those from IC1 pins 4 and 11 in Fig.10.5. The Set/Reset inputs of the gates in Fig.10.10 could also be employed if desired, as is done in Fig.10.9. The implementation of a Stop function, though, is somewhat more difficult to achieve than it might appear at first sight.

It is also worthwhile noting that if the circuit in Fig.10.10 is connected to either Fig.10.5 (or Fig.10.11 to be describe shortly), an output *pulse* is required rather than a continuous logic 1, in order to reproduce the behaviour of a pushswitch.

To achieve this, capacitors C2 and C3 are employed. Whenever the left-hand side of, say, C2 goes high, the right-hand side will copy. This output voltage will quickly fall back to zero, assuming that the pull-down resistors (R1 and R3 in Fig.10.5) are in place, and that their associated capacitors (C1 and C3 in Fig.10.5) are removed, so ensuring adequate pulse levels are received from Fig.10.10.

Be aware that although the stated value of 100nF for both C2 and C3 in Fig.10.10 should normally provide an adequate pulse level, if long wires are used for the switches in Fig.10.5, then this value may need increasing, to say 470nF or 1µF (non-polarised). Note also that whilst C1 and C3 have been removed in Fig.10.5, the spike-removing action is now performed by C2 and C3 in Fig.10.10.

FURTHER IMPROVEMENT

It should now be apparent that the 4013 dual bistable can be used to replace the four NOR gates in Fig.10.5. The equivalent circuit is shown in Fig.10.11, and in Photo 10.4.

In this circuit, the toggle action offered by the 4013 gates is not required and so their clock inputs are connected to 0V. The data inputs (D) are shown connected to the inverted outputs ($\overline{Q}$), but they could be connected to 0V instead if preferred.

STOP SENSOR

The circuits so far have all included provision for stop-switches, and these offer a good solution for control of curtains, blinds or doors on animal cages etc. However, if the controlled movement jams, the stalling effect on the motor will cause a rise in current, and this rise can be detected by a sensing circuit.

The current sensing circuit can be so reliable that the use of sensing switches on the curtain rails etc. is not required, making installation much simpler.

The principle of current sensing is based on Ohm's Law, which states that a change of current through a resistor will cause a corresponding change of voltage across the resistor. It is this change of voltage which can be used to trigger our circuit.

The circuit in Fig.10.12 illustrates the principle. The voltage at op.amp IC1's

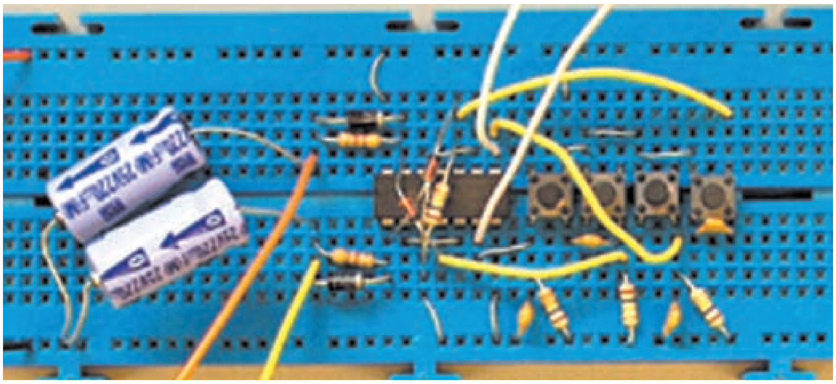


Photo 10.4. Breadboard assembly of the circuit in Fig.10.11.

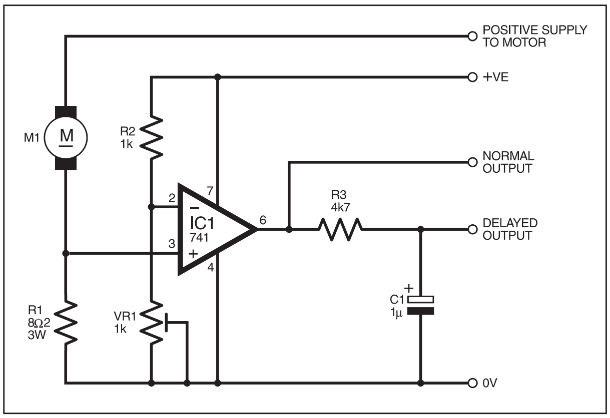


Fig.10.12. Motor current sensing circuit.

inverting input, pin 2, is set by the combination of resistor R2 and preset potentiometer VR1. When current flows through motor M1 and resistor R1, the voltage at IC1 pin 3 will depend upon the resistance of the motor in combination with R1. So we have two potential dividers, one controlled by the setting of VR1, the other dependent upon the resistance of the motor.

When a motor is running at normal speed, the back-e.m.f. generated by its motion reduces the flow of current through its coils. So its effective resistance is much higher than its resistance when stationary. Hence, if the motor stalls, the back-e.m.f. will fall and much more current will flow. This rise of current will produce a corresponding rise of voltage across R1, which is detected at IC1 pin 3. If it rises above the voltage at pin 2, the output of the op.amp at pin 6 will switch from near zero to near positive.

Note, though, that op.amp outputs have voltage swing limitations as discussed in Part 3. Some op.amps, such as the type 741 for instance, cannot necessarily swing low enough to directly control a logic gate or a transistor. Consequently, it is necessary to use an op.amp described as having a *rail-to-rail* output.

The value of 8·2Ω for R1 has been determined by experimentation and is suitable for the motors specified (see later). Note that the power rating of the resistor must be at least 3W. More efficient motors may require a slightly higher resistor value. You could experiment with series and parallel resistor combinations if desired.

The resistor is required to carry a much larger current than is normal in many electronic circuits, and a high-power rating must be employed to prevent the resistor from overheating.

OUTPUT CONTROL

The output from the op.amp at pin 6 is used to provide a Stop signal for the logic circuit controlling the motor. When power is first applied to the motor, the back-e.m.f. will be zero. Hence the circuit will react as if the motor has stalled, and a Stop signal will be sent in error. It is important therefore for the logic control circuit to disregard any brief Stop signals at start-up.

A simple resistor/capacitor combination will achieve this, as illustrated by resistor R3 and capacitor C1. The value of C1 can be increased if a longer delay is required. You may also wish to make R3 a variable resistor so that the stalling time can be adjusted.

PIC LOGIC CONTROL

We have illustrated various techniques for controlling a motor using logic gates, plus an op.amp. As shown in previous parts of *Teach-In 2004*, though, the use of a microcontroller and its customised software program can replace much of the discrete logic and greatly simplify the circuit. It also offers the ability to change how the system operates simply by changing the program.

The example microcontrolled system for winding curtains or blinds was developed using a PICAXE-18A (note that the "A" suffix is important since the program is too long for the standard PICAXE-18 device). Details of the PICAXE system are described in Part 5. A PIC16F819 may be used instead. The software for both devices is available as stated later.

The block diagram of the final circuit is shown in Fig.10.13 and the full circuit diagram is shown in Fig.10.14.

Resistors R1 and R2 and connector TB1 are for in-circuit programming if a PICAXE-18A is used as the microcontroller, IC1. The resistors should be retained even if in-circuit programming is not required in order to bias the i.c. pins to a fixed logic level.

Test points TP1 and TP2 allow the PIC to be reset if the microcontroller program crashes. This will hardly ever be required, and so terminal pins can be used on the p.c.b. Bridging these pins with a screwdriver blade or coin will cause a reset.

PIC pins RB0 and RB1 directly drive l.e.d.s D1 and D2 via current limiting resistors R4 and R5. The l.e.d.s signal "day" and "night" and are very useful when the system is first set-up. Pins RB2 and RB3 are the Forward and Reverse outputs and are connected to the motor control circuit, from transistors TR1 and TR2 onwards.

If you study the circuit carefully, it should become clear how the complete reversing circuit and motor is one-half of a potential divider, the other half being formed principally by resistor R17. A proportion of the voltage at the junction between the reversing circuit and R17 is "tapped-off" by preset VR2 and connected back to PIC pin RA2 (used in voltage comparator mode), which can be regarded as the Stop input. The software senses the voltage level and from it determines whether or not to stop the motor. In practical use, VR2 is adjusted to set the threshold at which the automatic motor cut-out is triggered.

It is important that the voltage at pin RA2 should not exceed 5V. Consequently, a limit of 3·9V is imposed by the inclusion of resistor R16 and Zener diode D8.

Preset VR1 in conjunction with current limiting resistor R6 forms a potential divider with l.d.r. R7. Its junction voltage is monitored via PIC pin RA1 (also in comparator mode). As the daylight falls, the resistance of the l.d.r. increases, and so the voltage at RA1 rises.

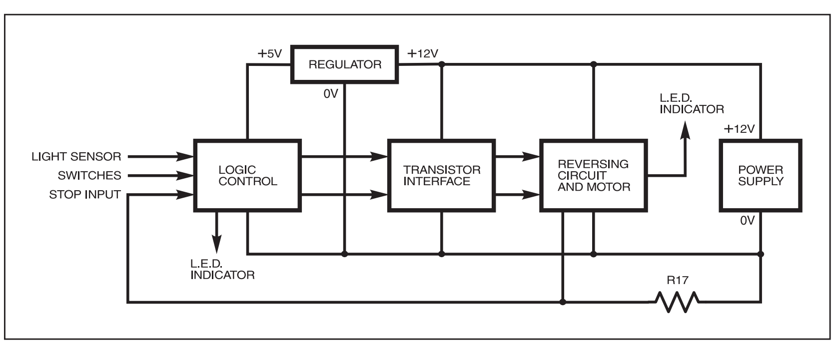


Fig.10.13. Block diagram for the PIC microcontrolled motor circuit in Fig.10.14.

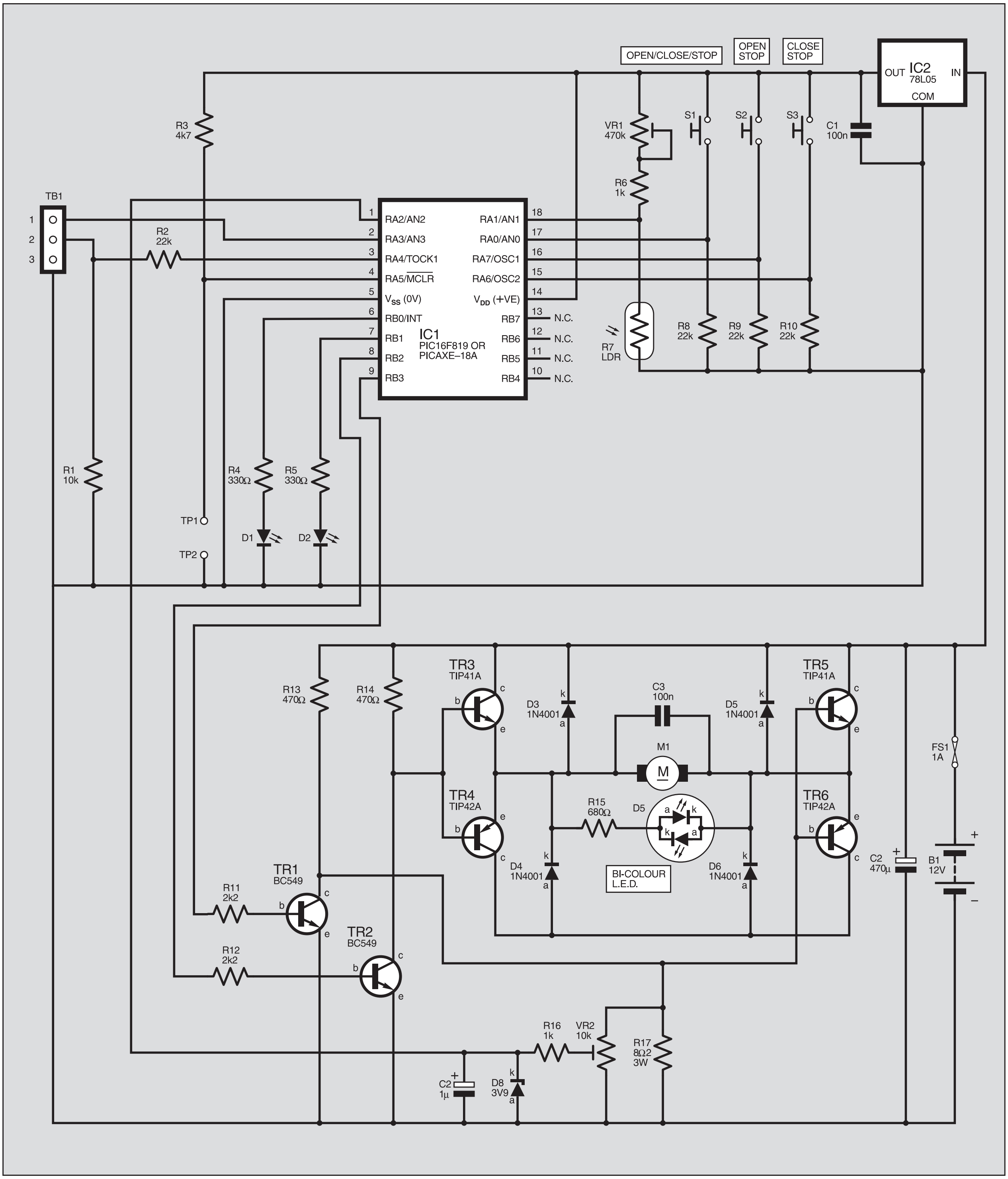


Fig.10.14. Complete circuit diagram for the PIC-controlled Curtain or Blind Winder.

Capacitor C2 and resistor R16 cause a brief delay in the response of the circuit to changes in the tapped voltage level, in order to avoid false motor triggering when the circuit is first powered-up. This delay was discussed earlier and is essential for non-PIC systems. However, in this circuit the PIC program also provides the necessary delay and so relatively low values have been chosen for C2 and R16. Users with PIC programming skills and facilities can adjust the delay if preferred.

Direct motor control by the user is provided via switches S1 to S3, which are monitored via PIC pins RA0, RA6 and RA7. They are biassed normally-low by resistors R8 to R10, respectively going high when the associated switch is pressed.

In the prototype, switch S1 is used as the Open/Stop/Close/Stop switch (functioning as described earlier in relation to Fig.10.10). Switches S2 and S3 can be used as Open-stop and Close-stop controls, but since an automatic stall function is included, as just described, they may be omitted, although resistors R9 and R10 should be retained.

The circuit is powered from a 12V battery. This supplies the motor circuit directly, but is regulated down to +5V by IC2 to suit the voltage limits of the PIC. Capacitor C4 provides overall decoupling for the circuit.

Fuse FS1 protects the battery against excessive current flow in the event of a circuit fault developing. The use of a thermal type is suggested. These are ideal particularly when surges of current (which occur when motors first start-up) might blow a normal fuse.

Whilst the motor-stall feature of the system will switch off the motor current

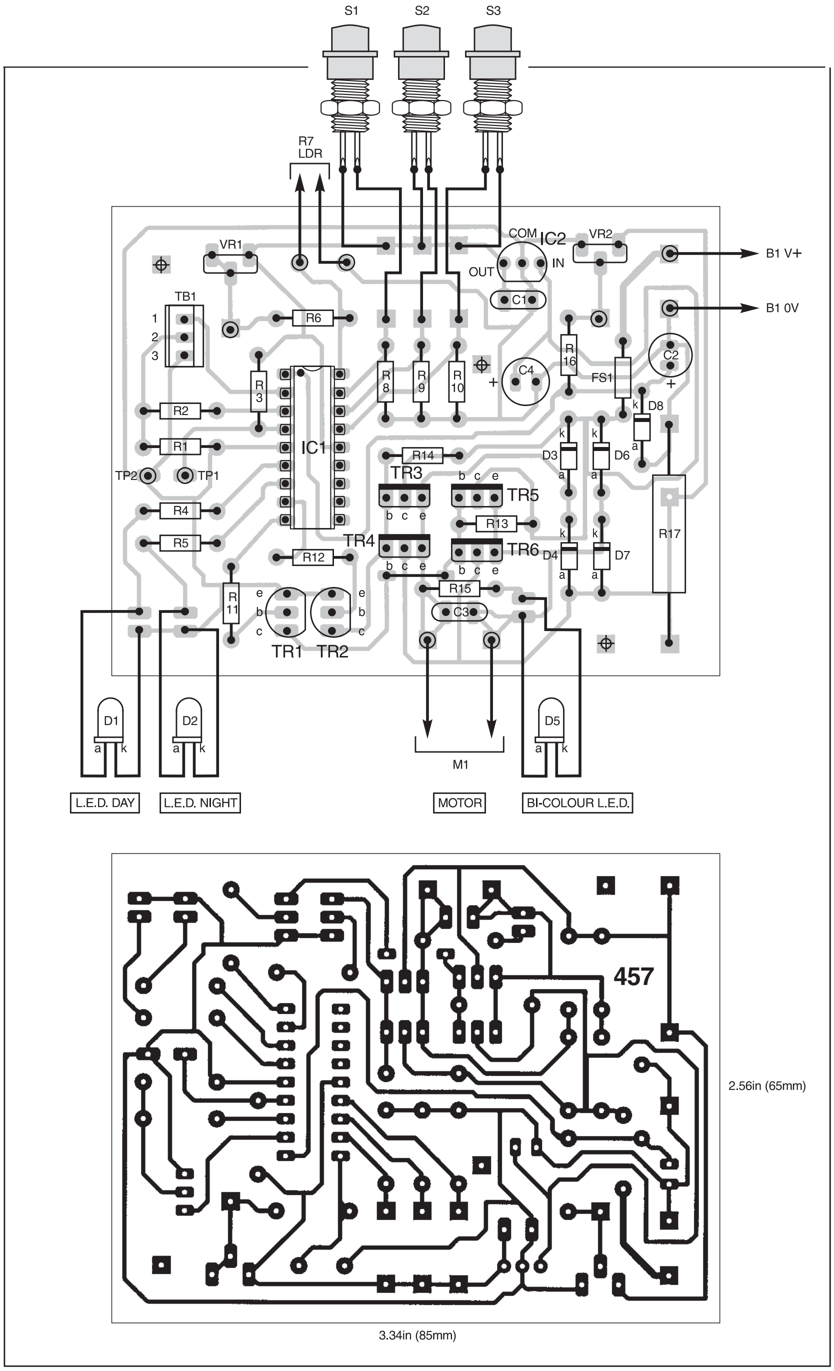
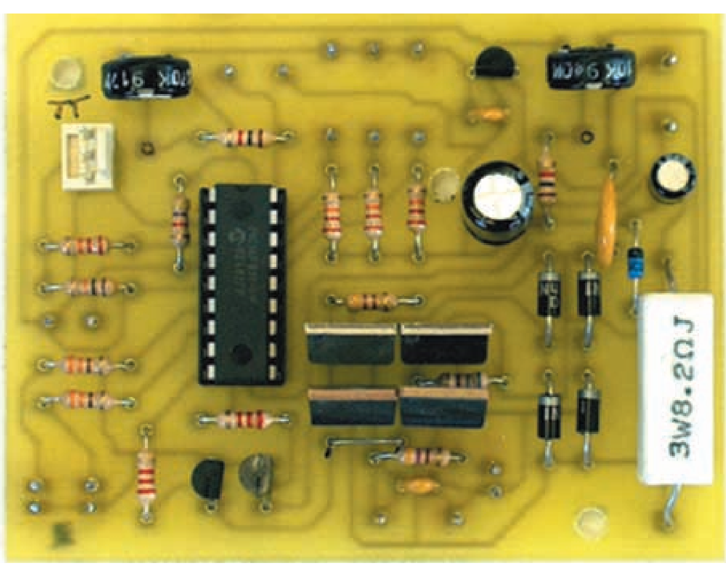


Fig.10.15. P.C.B. component and full-size track layouts for the circuit in Fig.10.14.



COMPONENTS

Curtain Winder, Fig.10.14

See SHOP TALK page

Resistors

R1	10k
R2, R8, R9, R10	22k (4 off)
R3	4k7
R4, R5	330Ω (2 off)
R6, R16	1k (2 off)
R7	l.d.r., e.g. ORP12 or smaller
R11, R12	2k2 (2 off)
R13, R14	470Ω
R15	680Ω
R17	8Ω2 3W

All 0·25W ±10% except where stated

Potentiometers

VR1	470k preset, horiz or vert
VR2	10k preset, horiz or vert

Capacitors

C1, C3	100n ceramic disc (2 off)
C2	1µ radial elect. 16V
C4	470µ radial elect. 25V

Semiconductors

D1, D2	red l.e.d.(2 off)
D3, D4, D6, D7	1N4001 rectifier diode (4 off)
D5	bi-colour l.e.d.
D8	BZYC3V9 Zener diode
TR1, TR2	BC549 or similar *npn* transistor (2 off)
TR3, TR5	TIP41A medium power *npn* transistor (2 off)
TR4, TR6	TIP42A medium power *pnp* transistor (2 off)
IC1	PICAXE-18A or PIC16F819, preprogrammed (see text)
IC2	78L05 +5V 100mA voltage regulator

Miscellaneous

S1	push-to-make switch
S2, S3	microswitch, normally-open (2 off) (optional – see text)
TB1	shrouded 3-pin header (only required for PICAXE)
FS1	thermal fuse 1A (see text)
M1	either: curtains motor, 6V d.c. 60 r.p.m., RS 336-337, or blinds motor, Combo Drills 919D series 4.5V to 15V d.c., with gearbox, ratio 148:1

Printed circuit board, available from the *EPE PCB Service*, code 457; 18-pin d.i.l. socket; plastic case to suit the electronics components assembly; plastic case to suit curtains motor; mechanical parts as required; connecting wire; solder, etc.

Approx. Cost Guidance Only **£19** *excl. batts, motor & hardware*

Left: Photo 10.5. The fully assembled printed circuit board as detailed in Fig.10.15.

if the curtains jam, it is still worth fitting a thermal cut-out device in series with the motor, or in series with FS1. The type of device which is fixed against the motor is ideal, so if the motor overheats for any reason, the flow of current will be broken.

CONSTRUCTION

All components, apart from the motor and curtain winding mechanism may be mounted directly on the printed circuit board (p.c.b.) whose layout details are shown in Fig.10.15. This board is available from the *EPE PCB Service*, code 457.

Begin by soldering in the socket for the PIC, followed by the other components in ascending order of size. Ensure that you observe the correct orientation for the semiconductors and electrolytic capacitors.

If a PICAXE-18A is to be employed, the 3-pin header connector TB1 will allow programming directly from the serial connector of a computer. If a standard PIC is employed, then it will need to be programmed in a programmer (or purchased ready-programmed), in which case TB1 may be omitted.

Assembly of the motor and curtain winding unit will depend on the specific requirements of the mechanics concerned and no advice is offered. However, Photos 10.6 to 10.8 show the basic assemblies used with the prototype curtain winder.

RESOURCES

The program was developed in BASIC using the dialect specific to PICAXE devices. The BASIC listing is fully annotated to show how the system works.

Pre-programmed PIC microcontrollers can be obtained from: M. P. Horsey, Electronics Dept., Radley College, Abingdon, Oxon OX14 2HR. The price is £5 per PIC, including postage. Specify that the PIC is for *Teach-In* 2004 Part 10. Enclose a cheque payable to Radley College.

The software for the PIC program, including a hex file for conventional programming and a BASIC file for the PICAXE option, but excluding the PICAXE programming software, is available on 3·5in disk (*EPE* Disk 7), for which a nominal handling charge applies, from the Editorial Office, see the *EPE PCB Service* page. It is also available for free download via the click-link on the *EPE* home page at **www.epemag.wimborne.co.uk**.

PICAXE programming software can be obtained from: Revolution Education, Dept. *EPE*, 4 Old Dairy Business Centre, Melcombe Road, Bath BA2 3LR. Tel: 01225 340563. Web: **www.rev-ed.co.uk**.

SERIES END

This brings us to the end of our 10-part Teach-In 2004 series, in which we have examined passive components, transistors, logic gates, op.amps and microcontrollers in a variety of applications, including displays, sound level measurement, moisture detection, radio links, movement detection, lock and alarm systems, and finally motor control.

We hope you have enjoyed the discussions and experiments, and learned more about how electronic components function meaningfully as part of circuits and systems. Enjoy your electronics! □

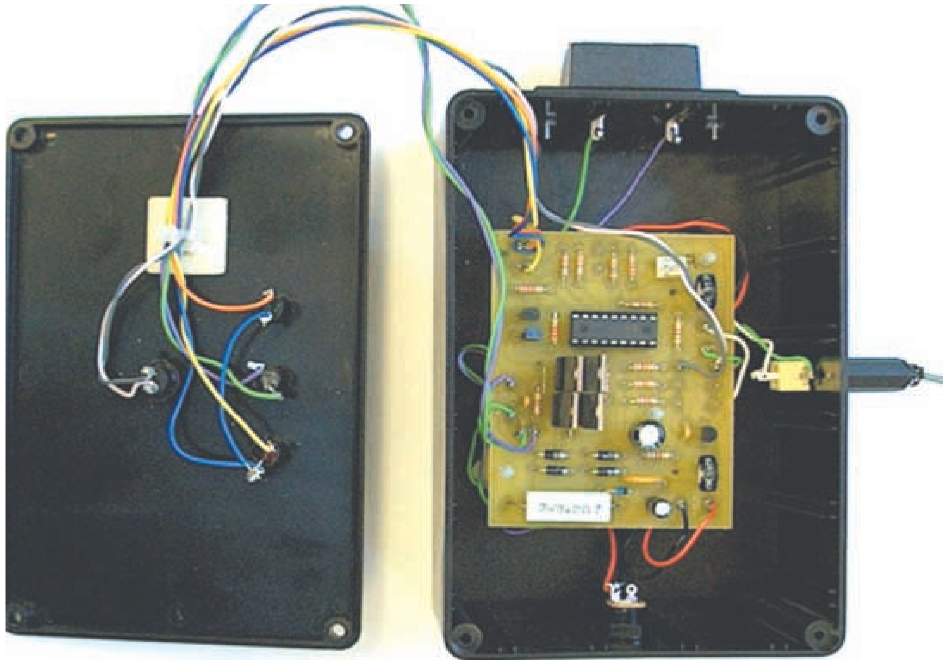


Photo 10.6. Internal view of the completed curtain or blind winder electronics assembly.

Photo 10.7. External view of the prototype control unit.

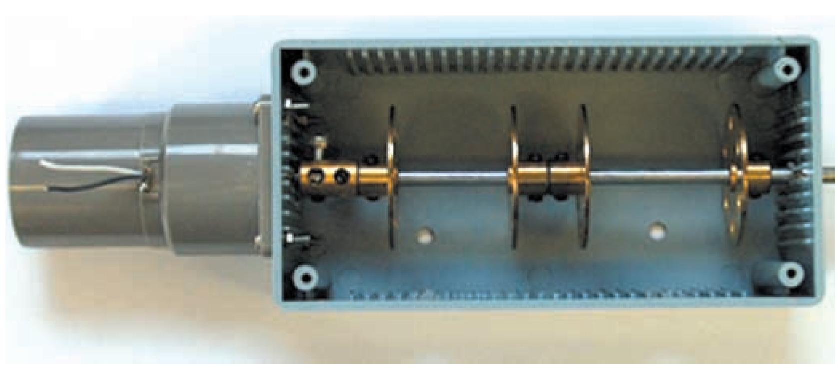


Photo 10.8. Circuit winding mechanism as used with the prototype.

CORRECTION

Teach-In Part 9 July '04. In Fig.9.3 and Fig.9.4 a 1kΩ resistor should be inserted in the line connecting to the gate of SCR1.

READOUT

Email: john.becker@wimborne.co.uk

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

All letters quoted here have previously been replied to directly.

WIN AN ATLAS LCR ANALYSER WORTH £79

An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd., will be awarded to the author of the *Letter Of The Month* each month.

The Atlas LCR automatically measures inductance from 1µH to 10H, capacitance from 1pF to 10,000µF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%.

★ LETTER OF THE MONTH ★

PIC N' MIX N' MORE

Dear EPE,

This is a quick note covering a selection of PIC related topics from recent (and not so recent) *Readouts*, but mainly to congratulate *EPE* on adding Andrew Jarvis' new *PIC n' Mix* column.

I was a bit surprised that you prefer crash and burn "real-time" testing of PIC code running directly on a PIC. I find the power of MPSIM (even the old DOS version) invaluable for quick development of new complex code that can be tested in isolation and with easy access to all variables. I might be interested in writing an article on using MPSIM if you think it would be of general interest.

A couple of years ago I built the delightful *Icebreaker* (March '00) project and that is another good stepping stone for prototyping.

Recently I have been playing with direct drive l.c.d.s for a very low current continuous display. I wanted to make a sidereal clock for astronomy (which runs about 0·3% faster than mean solar time). This low power design uses a 32kHz crystal, PIC16F877 and RS 0·6-inch 4-digit l.c.d. display driven directly – drawing only 22µA total current on 3V. I doubt there is much call for sidereal clocks, though.

I also enclose a few short routines I have developed and which your readers might be interested in, including a computed GOTO that provides a mechanism for a handy variable cycle delay loop.

Although I am a professional software developer, I do not think you should drift towards tutorials on various programming languages like VB, VC++ etc. There are more than enough computer magazines already and only a handful of electronics ones remaining. Your magazine space is too precious to waste on material that has been covered extensively elsewhere. I would be a bit more sympathetic towards cross compiling high level languages onto embedded micros and simple PC interfacing.

I thought the Seismometer project was excellent too. Keep up the good work!

Martin Brown, via email

Thanks for your comments Martin, and appreciation of Andrew's excellent column and my Seismo!

Your code has been put in the PIC Tricks *folder on our website (via* **www.epemag.wimborne.co.uk***) for other readers to access.*

It is regretted, though, that we would not be interested in publishing an article of MPSIM as, generally speaking, commercial software is not something that we as an electronics mag feel we should discuss in depth. Nor do we feel that a sidereal clock would be of interest to enough readers, as was shown many years ago when I did one for PE. *Thanks for both offers though.*

FREQUENCY METER

Dear EPE,

Concerning Thomas Scarborough's *Simple Frequency Meter* (*IU* April '04), the circuit does not perform exactly as described, mainly because of the 1:1 mark-space ratio of the relaxation oscillator IC1a, which means that the reset pin of the 4017 is held high for 50% of the time during which the Q0 l.e.d. is illuminated and no counting takes place.

The problem can be overcome to a certain extent by differentiating the output of IC1a, which provides a reset pulse of much shorter duration, leaving most of the time for counting. A 100pF capacitor and 10kΩ resistor, shunted by a diode to reduce the amplitude of the negative spike, could be used. The Q0 l.e.d. has no significance in the frequency measuring application – it is illuminated even when no external signal is applied – and could thus be dispensed with, unless that is, one wishes to takes up Thomas's suggestion of using the meter for a frequency-to-light display.

Vince Wraight, Basildon, Essex

Thomas responded:

Vince's comment that brief reset pulses would be preferred over the 1:1 mark-space ratio of oscillator IC1a would indeed represent an improvement. The question is the extent of the practical improvement, and would the added complexity of the circuit be preferred? He preferred the improvement, and well done to him for recognising that it was possible. At the same time, the l.e.d.s in both cases sequence from Q0 to Q9 in accordance with the frequency measured.

He says that Q0 has no significance. He is right – except to show that the circuit is "on standby", or that the input is below an "indicatable" frequency – therefore one could omit the corresponding l.e.d. if desired.

It would seem that the circuit worked for Vince, and with that I am pleased – in fact with his modifications he would now seem to have the Rolls Royce version. I would compliment him on his feel for a circuit, and for his keen observation. It is rare to find someone who has the talent to look at a circuit and really understand it.

Thomas Scarborough, via email

CAP THAT JAR!

Dear EPE,

In your reply to Peter Mitchell's *"Radio Constructor"* letter (June '04), you mention jars. Indeed, this is a reference to the Leyden jar and one jar is equivalent to 1·11265 nanofarads.

Every answer commands a question, so tell me the answer to this one! I've just discovered two definitions of the farad. I'm not sure which we use conventionally, but as the difference is parts in ten thousand I don't suppose it matters! One SI farad (Systeme Internationale) equates to 1.0004902 "international" farads. But, why?

Godfrey Manning G4GLM, Edgware, via email

That's an intriguing question Godfrey – I don't know the answer. Does any reader?

ASTRONOMICAL STEPPING

Dear EPE,

I have recently bought my first issue of *EPE* (June '04), a casual purchase on the basis of two articles, Stepper Motors and Peltier Effect. A long time ago I used to receive the predecessor magazine *PE* (from first issue!), however life changes and astronomy now has my focus for hobby activities.

For those who enjoy constructional projects, a lot of electronics can be employed in various ways, from image collection with a CCD to image processing, motor drivers and position encoders and much more. Also, I have recently acquired a Peltier cooled video camera.

So to my point of interest, I have a collection of Stepper Motors recovered from laser and ink jet printers, but no ready means to experiment with or control, and more importantly adapt to my astronomy needs.

Andy Flind's article *PIC Quickstep* was very interesting to read, so I have ordered circuit boards from *EPE*, and programmed PICs from Magenta. At a later date I may understand the programming!

In conjunction with the Monmouth Astronomical Research Society, MARS, we are intending to build a Scotch Mount, named after its *English* inventor, Haig. Americans refer to this simple device as a Barn Door Mount. In its simplistic sense the Scotch Mount is a hinged wedge, which is opened at a constant rate, by say a 6mm screwed rod rotating, an ideal application for Stepper Motor drive!

In this connection, readers may be interested by these web sites:

www.sandyloan.f2s.com/Newsletter2.htm
www.astunit.com/tonkinsastro/atm/projects/ scotch.htm

Norman Pomfret, via email

Thank you Norman. Best wishes for your Scotch Mount. I hope that as well as EPE *you also read* Astronomy Now – *I worked alongside it in the late 80s when Patrick Moore and John Mason edited it. I've fond memories of highly interesting chats with them! It still exists, as I found recently when I visited what was previously the Greenwich Observatory at Herstmonceux, Sussex.*

It is now called the Observatory Science Centre and is ideally suited to getting kids interested in science and technology through hands-on experience.

Browse **www.the-observatory. org**.

CHEWED-UP COMMS?

Dear EPE,

In May's *Techno Talk* feature (telephone cabling in sewers), I was a little surprised that no mention was made of vermin in the sewers and their ability to chew through anything made of plastic. Even armoured plastic is no defence against their teeth. That was the reason why electricity was not piped down the sewers successfully. Just imagine a spark down there with all that methane flitting about!

Even out at sea the Bermuda fibre optic cable has been chewed and destroyed many times by almost every sea creature with teeth or pincers.

G. S. Chatley, via email

A good point GS. Anyone know what solution is used?

LAPTOP PSU ESR

Recently a question arose on our Chat Zone (via **www.epemag.wimborne.co.uk***) about the ESR rating of capacitor C4 in the In-Car Laptop PSU (May '04). The design's author, Terry de Vaux Balbirnie, offers the following comment:*

The interplay of the ESR (effective series resistance), ripple current, power dissipation and temperature rise of a capacitor is quite a complex one. The life expectancy of a capacitor is directly related to its operating temperature so it is essential to maintain this as far as possible below its rated maximum. Most of the temperature rise comes about by ohmic heating as the ripple current flows through the ESR. For a given application, all that is usually needed is to ensure that the capacitor is always being used within its temperature rating.

The specified capacitor (and other similar low impedance types having an ESR of some 0.1 ohms or less) has a maximum temperature rating of 105°C. I therefore set out to measure the maximum temperature as used in this circuit (using a very small thermocouple placed in good thermal contact with the can). A current of 3·1A was drawn at an ambient air temperature of 25°C. The end-point temperature was 70°C approximately. Since this provides a generous safety margin, it is reasonable to assume that the capacitor will have a long life.

However, if capacitor C4 does feel very hot in operation, you could connect two 100µF units in parallel (check that they have the same or higher ESR and the same or higher temperature rating). You could select a higher voltage rating to achieve this – this will increase the size of the can and increase the ability to dissipate heat. Two capacitors will share the power dissipation between them. Unfortunately, the ESR rises with hours of operation so no capacitor will last indefinitely!

Terry de Vaux Balbirnie, via email

74HC TTL Logic

Dear EPE,

I refer to my private discussion with John about my recent submission to *Ingenuity Unlimited* (*Repeatable Logic Probe*, July '04). I took up his suggestion of replacing the rail-to-rail op.amp with a 74HC04 hex inverter. Works brilliantly (that is, the l.e.d. lights brightly enough!) and much cheaper. Also there are six gates in the package where the op.amp is only a quad, reducing the total chip count on a large project.

Being CMOS input, the 74HC should also offer the same advantage as an op.amp in that it doesn't use up the fan-out of the signal that it is reading. Also, the mid-rail reference level (that needs to be piped to each op.amp) can be dispensed with.

Godfrey Manning G4GLM,
Edgware, via email

Great! Yes the HCs are an excellent family of gates etc. Perhaps you might care to offer us another IU *proving the principle Godfrey?*

FRONT PANEL OVERLAYS

Dear EPE,

Referring to the July '04 issue, making panel overlays has always been a difficult subject unless you have access to screen printing equipment, and then this is not practical for one-off designs as the overheads of setting-up are costly. An alternative to paper background is to spray the reverse side of the OHP film with aerosol paint, this comes in a multitude of colours so you are not limited to just a white background.

Make it as jazzy or plain as you like. It is best to apply several thin coats of paint rather than one thick one. When the paint has thoroughly dried the overlay can be attached to the panel with spray adhesive. The best kind of spray adhesive I have found is not available in shops, it is used in the textile screen printing industry. These spray cans produce a fine mist giving a thin and even coating of adhesive. If you know of a firm that prints T-shirts you may be able to persuade them to sell you a can.

Another method I have used in the past is to print the panel design onto paper and then protect it with transparent self-adhesive book covering film. I used this method in the days before modern computers when the only materials available were rub-down transfers and, of course, letters were not available as a mirror image.

If your project has l.e.d. displays, a red or green filter will make it look more professional and improve the readability of the display, sheets of coloured film are available from Maplin. They are large and easily cut to size so one sheet will probably last a lifetime

Peter Hemsley, via email

Thanks Peter, that seems very useful!

ANDY FLIND

As you will have seen on the News pages, it is with sadness that we have learned that Andy Flind has died. At the time I also posted the news on our Chat Zone.

I met him in person just twice, about eight years ago and we immediately "got on", over the years periodically enjoying long chats on the phone, ostensibly about EPE matters, but we often got sidetracked into other subjects, including his love of real ale, clocks and horology, kite flying, climbing Snowdon, and of course PICs!

I shall miss him, as shall we all at EPE.

Via the Chat Zone, Thomas Scarborough posted the following tribute to Andy:

It is with great regret that I heard of Andy Flind's death. I was in contact with him through the final weeks of his life, and he faced death, and looked back over his life, with humility and serenity.

Andy brought an inspired streak into electronics. He was interested in electronics for its fascination, and sometimes followed the most unusual ideas – yet ideas that made a fascinating read, with good technical content to boot. His quality of work was superb, and his designs solid, and something the rest of us can only admire and aspire to. He also had a way of doing electronics that made him very popular with beginners, and greatly encouraged their interest.

I came to know Andy at first indirectly through his projects. With his *Buccaneer* metal detector, which still stands here battered and worn, my son Matthew and I realised our fondest metal detecting dreams when we discovered a wreck – and found gold – and Matthew appeared on national TV.

Later, I was privileged to have Andy work on some of the drawings for my own projects. In some way or other, there is surely not one of us who has not been touched by Andy's passion for electronics.

His *Stepper Motor Controller* is bound to be a classic that will live a long time. He was hoping to finish his *Synchronome Driver* project before he died, and I suppose that he never did. Perhaps someone will do an Andy Flind Memorial Synchronome Driver?

Rev. Thomas Scarborough.

Some weeks back I said to Andy that I might be able to complete his synchronome clock for him and bring it to the public's attention, but he said that he would probably offer it to an horological society. He was very proud of it.

PICS AND MATHS

Dear EPE,

Like thousands of other readers I followed your *PIC Tutorial* (Apr-Jun '03), and enjoyed every minute of it. Now for the dreaded *but* – I don't think the tutorial goes far enough in explaining how multiple registers are used when dealing with numbers greater than 255. The frustration of not understanding this concept has had me throwing my toys out of the pram.

As maths is essential to programming PICs – how about a mini tutorial on PIC maths? I'm sure most PIC enthusiasts would welcome such an article.

Thanks for a great mag, reading *EPE* over the years has taught me more about electronics than I ever learned at college.

Craig Patterson,
via email

Thanks for your comments Craig. The intention of my PIC Tutorial *is to show how the commands function – as to how they are ultimately used is entirely up to the user!*

But on maths, we have a suite of 32-bit PIC maths routines and their description coming in soon from Peter Hemsley (with whom I periodically exchange emails), but these routines are already "unofficially" available without description via some of my published design programs, such as PIC LCF Meter, Seismograph *etc, in which I've been "field-testing" Peter's software. These can be downloaded from our site at* **www.epemag.wimborne.co.uk**.

In the pipe-line is another maths article, on floating point arithmetic, from Malcolm Wiles. Also on our site (in the PIC Tricks folder) are other maths progs, including some 16-bit ones from Peter which are very useful.

So tell Mummy to ignore your dropped toys and get you some new ones via our Downloads click-link!

SPACED OUT PICS!

Dear EPE,

I wonder if you can help? I bought and built *TK3* and downloaded some software from your site. All tests are OK – but – I can't assemble a program! I tried TK3TUT1.ASM and TK3TUT2.ASM with the same results:

"Assembly not made as no ORG value found in ASM file".

What's wrong? Any ideas? Any advice (or just a pointer in the right direction) would be appreciated, as I'm keen to start PIC'n.

Chris Harrison,
via email

Chris enclosed the ASM code of his program which he had keyed in by hand, of which these four lines are an extract:

```
ORG0     ;Reset Vector address
GOTO5    ;go to PIC address 5
CLRF6    ;set all Port B pins to logic 0
BSF3,5   ;instruct program that a Bank 1
          command comes next
```

It was immediately obvious what he had done wrong – not put the required spaces in!

A single space is needed between each command and its value. He had also failed to put the commands into what the assembler regards as column 2 and it was reading them as if in column 1, which is where it expects to find "labels", not commands. The above extract lines should therefore read as:

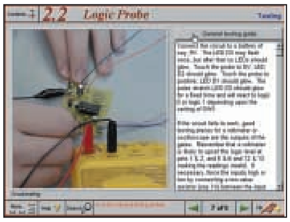
```
    ORG 0     ;Reset Vector address
    GOTO 5    ;go to PIC address 5
    CLRF 6    ;set all Port B pins to logic 0
    BSF 3,5   ;instruct program that a Bank 1
               command comes next
```

Chris later responded that he had made the changes and all was now well! Great – happy PIC'n Chris! Many answers to program problems are obvious when you eventually spot them!

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

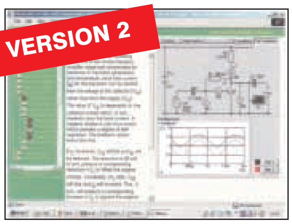
ELECTRONICS PROJECTS


Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture**, **circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

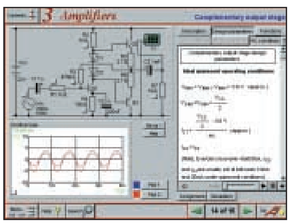
ELECTRONIC CIRCUITS & COMPONENTS V2.0

VERSION 2


Circuit simulation screen

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

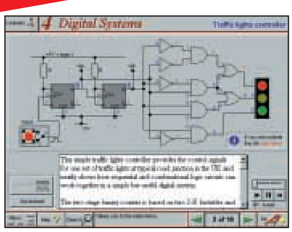
ANALOGUE ELECTRONICS


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

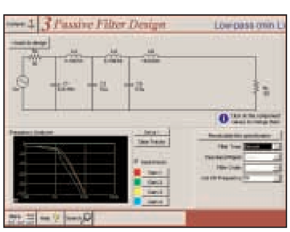
DIGITAL ELECTRONICS V2.0

VERSION 2


Virtual laboratory – Traffic Lights

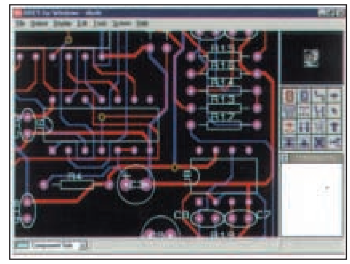
Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

FILTERS


Filter synthesis

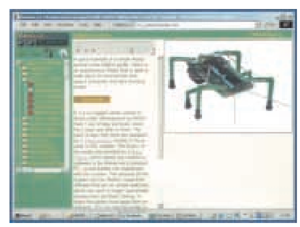
Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ELECTRONICS CAD PACK


PCB Layout

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

ROBOTICS & MECHATRONICS


Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student ....£45 inc VAT
Institutional (Schools/HE/FE/Industry)..............£99 *plus* VAT
Institutional 10 user (Network Licence) ....£199 *plus* VAT
Site Licence...£499 *plus* VAT

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

PICmicro TUTORIALS AND PROGRAMMING

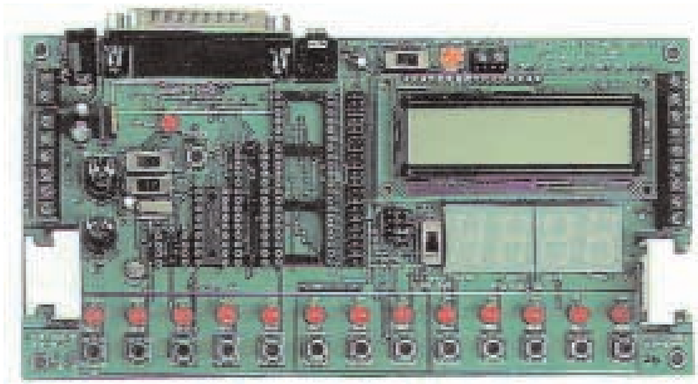
HARDWARE

VERSION 2 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 13 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- All inputs and outputs available on screw terminal connectors for easy connection



£145 including VAT and postage

12V 500mA plug-top PSU (UK plug) £7

25-way 'D' type connecting cable £5

SOFTWARE

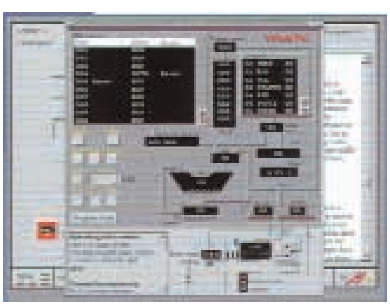
Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V2.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

● Comprehensive instruction through 39 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



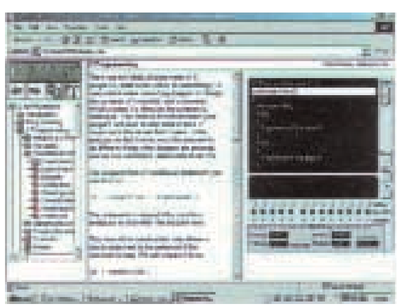
Virtual PICmicro

'C' FOR PICmicro VERSION 2

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

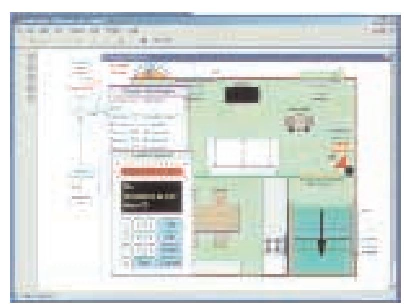
FLOWCODE FOR PICmicro

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex robotics and control systems in a matter of minutes.

Flowcode is a powerful language that uses macros to facilitate the control of complex devices like 7-segment displays, motor controllers and l.c.d. displays. The use of macros allows you to control these electronic devices without getting bogged down in understanding the programming involved.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 2 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols (ISO5807) ● Full on-screen simulation allows debugging and speeds up the development process ● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 8, 18, 28 and 40-pin devices ● Institutional versions include virtual systems (burglar alarms, car parks etc.).



Burglar Alarm Simulation

PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

Hobbyist/Student	£45 inc VAT
Institutional (Schools/HE/FE/Industry)	£99 *plus* VAT
Flowcode Institutional	£70 *plus* VAT
Institutional 10 user (Network Licence)	£249 *plus* VAT
Site Licence	£599 *plus* VAT

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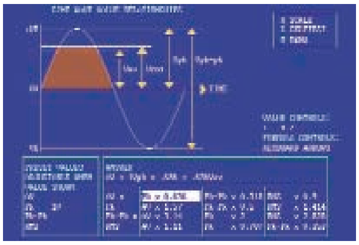
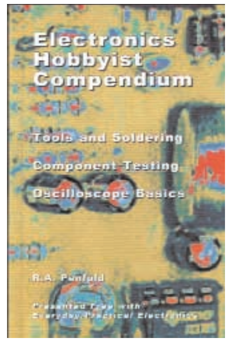
TEACH-IN 2000 – LEARN ELECTRONICS WITH EPE

EPE's own *Teach-In* CD-ROM, contains the full 12-part *Teach-In* series by John Becker in PDF form plus the *Teach-In* interactive software (Win 95, 98, ME and above) covering all aspects of the series. We have also added Alan Winstanley's highly acclaimed *Basic Soldering Guide* which is fully illustrated and which also includes *Desoldering*. The *Teach-In* series covers: Colour Codes and Resistors, Capacitors, Potentiometers, Sensor Resistors, Ohm's Law, Diodes and L.E.D.s, Waveforms, Frequency and Time, Logic Gates, Binary and Hex Logic, Op.amps, Comparators, Mixers, Audio and Sensor Amplifiers, Transistors, Transformers and Rectifiers, Voltage Regulation, Integration, Differentiation, 7-segment Displays, L.C.D.s, Digital-to-Analogue.



Sine wave relationship values

FREE BOOK WITH TEACH-IN 2000 CD-ROM



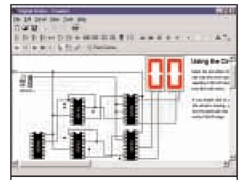
Each part has an associated practical section and the series includes a simple PC interface (Win 95, 98, ME **ONLY**) so you can use your PC as a basic oscilloscope with the various circuits.

A hands-on approach to electronics with numerous breadboard circuits to try out.

£12.45 including VAT and postage. Requires Adobe Acrobat (available free from the Internet – **www.adobe.com/acrobat**).

FREE WITH EACH TEACH-IN CD-ROM – *Electronics Hobbyist Compendium* 80-page book by Robert Penfold. Covers Tools For The Job; Component Testing; Oscilloscope Basics.

DIGITAL WORKS 3.0



Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability ● Software for simulating digital logic circuits ● Create your own macros – highly scalable ● Create your own circuits, components, and i.c.s ● Easy-to-use digital interface ● Animation brings circuits to life ● Vast library of logic macros and 74 series i.c.s with data sheets ● Powerful tool for designing and learning.

Hobbyist/Student £45 inc. VAT.
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Institutional 10 user £199 *plus* VAT.
Site Licence £499 *plus* VAT.

ELECTRONICS IN CONTROL

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

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Contains a range of tried and tested analogue and digital circuit modules, together with the knowledge to use and interface them. Thus allowing anyone with a basic understanding of circuit symbols to design and build their own projects. Version 3 includes data and circuit modules for a range of popular PICs; includes PICAXE circuits, the system which enables a PIC to be programmed without a programmer, and without removing it from the circuit. Shows where to obtain free software downloads to enable BASIC programming.

Essential information for anyone undertaking GCSE or "A" level electronics or technology and for hobbyists who want to get to grips with project design. Over seventy different Input, Processor and Output modules are illustrated and fully described, together with detailed information on construction, fault finding and components, including circuit symbols, pinouts, power supplies, decoupling etc.

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

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

Price £19.95 inc. VAT

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

CD-ROM ORDER FORM

Please send me:

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PIC N' MIX

ANDREW JARVIS

Our periodic column for your PIC programming enlightenment

Hello Again: Simulators, Timers and Finishing Touches

IF you hadn't already realised, the Microchip MPLAB IDE (Integrated Development Environment) is a "must have" addition to the PIC developer's toolbox. OK, some people might be put off by the fact that it's Windows only, and weighing in at a hefty 33MB (v6.5) there's a strong argument for dial-up users to ignore it. But on the other hand, it's free professional software (downloadable from the Microchip website **www.microchip.com**), and it can save bags of time and bother.

You don't have to use it with supported hardware either, simply edit your code using the powerful text editor then assemble it into the same hex format that other programmers are happy to accept. It's impossible to detail all of the reasons to consider MPLAB in the space available, so we'll look at some of the benefits whenever the chance arises.

Hello Again

Last time, we looked at timing loops and cooked up some "Hello World" code that took 197121 instruction cycles to execute, calculated the hard way. The easy way would have been to generate the code and loop values automatically using a program like PicLoops, but that would have also neatly bypassed the learning opportunity. I did, however, suggest that there was a straightforward way to get a second opinion on the maths and for that I was thinking about MPLAB SIM, the PIC simulator built into the MPLAB IDE.

A complete program listing (**pnm0804_loops.asm**) that includes the code from last time (June '04) is available from the *EPE* Downloads site (access via **www.epemag.wimborne.co.uk**), in the **PICS/PICnMIX** folder. It contains some MPLAB specific syntax, which will not assemble with *TK3*.

To have a look at this code under the simulator, first start MPLAB then choose PIC16F628 from the **Configure->Select Device** menu. From the Debugger menu choose **Select Tool->MPLAB SIM**, then **Settings** and set the clock frequency to 4MHz on the first tab. Open the **pnm0804_loops.asm** source file using **File->Open**, then assemble the code using **Project->Quickbuild**.

The program is now ready to run under the simulator (the green arrow showing the first line of code that will be executed). Right mouse click on line 34 (**xorwf PORTB, f**) and choose **Set Breakpoint** from the pop-up menu that appears. Select "run" (F9) and the program should run for a brief time then halt at this line.

Watch Carefully

It's worthwhile looking at PORTB now to see what happens when **xorwf** is executed. Choose **View->Watch** to get the watch window on screen, then choose PORTB from the SFR (Special Function Register) selection box and click **Add SFR** to insert it into the watch window. You might find it conceptually easier to "watch" this port in binary – right mouse-click on the PORTB line you just added, choose **Properties** from the pop-up menu and change the format to binary on the first tab of the dialog. You should see that PORTB has the value "00000000".

Now the fun starts. Arrange the windows in the IDE so that you can see both the watch window and the source code, and step over (F8) the **xorwf** statement. You should see that PORTB has a new value "00010000", because as expected, bit 4 just toggled.

With the Program Counter positioned on line 35 (**decfsz delay1, F**) its easy to prove the instruction cycle count from last time. Choose **Debugger->Stopwatch** from the menu and click "zero" to reset the stopwatch. Choose "run" again to start the program. This time when it halts at the breakpoint, you can clearly see from the stopwatch dialog that the number of instruction cycles elapsed since resetting the clock is the expected 197121.

This is just a flavour of what you can do with MPLAB SIM. You could go further by adding the delay loop variables into the watch window as well (**Add Symbol**), then choose "animate" instead of "run" to watch the variables update in "real time". You can even see bit 4 of PORTB "flashing" as the output is toggled between 1 and 0.

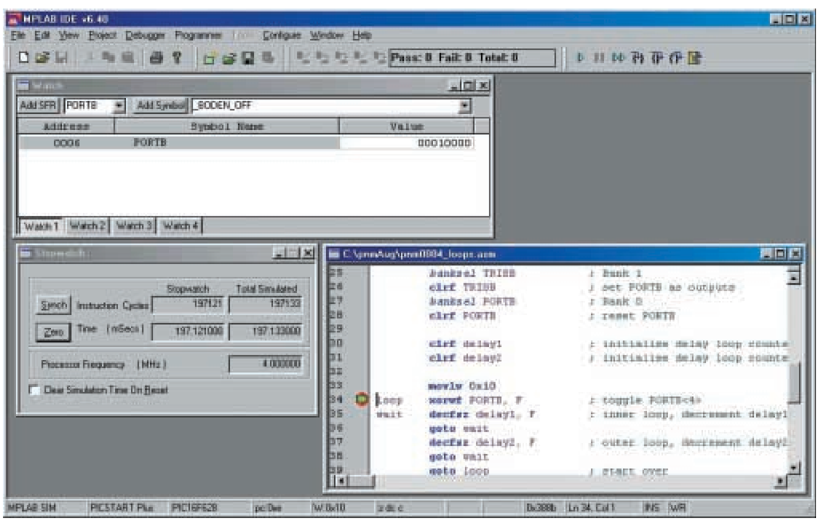


Fig.1. MPLAB IDE showing the source window with breakpoint on line 34, stopwatch, and watch window monitoring PORTB.

Note that "real time" for the simulator is an approximation that depends on the speed of your PC and the jobs that the software has to perform (turning the trace off helps), so it will usually be a lot slower than if you ran the same code directly on the hardware. If you particularly want to see PORTB animate, it's probably a good idea to return to just one loop counter.

PicLoops

It's still a chore to figure out what values you need to use to get the exact delay you are looking for, and one that lends itself well to automation. It's fairly straightforward to develop the two loop solutions into three and more, but it's left as an exercise for the reader to do so.

Needless to say, if you look around the net you'll find it's been done already. One of the best examples of an application that generates timing loops for PICs is the unsurprisingly named PicLoops software, available as a free download from **www.biltronix.com/picloopsv21.zip**. Using this software you can enter the required delay time to calculate loop counter values and vice versa. There's also a great help file that explains all about delay loops and develops the algorithms used for up to four counters. It even generates the code for you.

Good Old Timers

I'm sure there's a place for instruction cycle-based delay loops, but for long delays especially, they appear to over-engineer what is essentially a very simple problem of timing – and one better solved with timers. Continuing with the PIC16F628 and its internal 4MHz oscillator, there are actually three timers that we can briefly attempt to crowbar into "Hello World".

Timer0 has been well covered already, notably in the recently revised *EPE PIC Tutorial V2* (Part 1, May '03 and on the PIC Resources CD-ROM V2), but it's worth quickly noting that this 8-bit timer is incremented every instruction cycle and can generate an interrupt when it transitions from 0xFF to 0x00. With the prescaler assigned to Timer0, the maximum delay you can measure between interrupts is 65536 cycles, or 0·07s.

Remember that each instruction cycle is $1\mu s$, and that Timer0 will transition from 0xFF to 0x00 every 256 cycles, therefore the interrupt is triggered every Tcy ($1\mu s$) × 256 × prescaler seconds. With the prescaler set to its maximum ratio of 1:256, this value is 0·065536s. To get a noticeable, say half-second delay, using Timer0 alone, you'll need to toggle the l.e.d. every eight interrupts (0·524s). Another example file in the PICnMIX downloads folder, **pnm0804_timer0. asm**, demonstrates one way to do this.

It's a Rollover

There's actually no need to count interrupts because the PIC16F628 gives us peripheral interrupts, and opens the door to Timer1 and Timer2. With a few minor differences in setup, Timer1 offers 16-bits through the register pair TMR1H:TMR1L, which can generate an interrupt on rollover from 0xFFFF to 0x0000. The prescaler is configured using only two bits of T1CON, which means there are just four possible ratios as opposed to the eight you might be more familiar with.

The largest prescale value you can use with Timer1 is 1:8, which means it is capable of a maximum delay between interrupts of Tcy × 65536 × prescaler, or 0·524s, perfect! Timer1 overflow interrupts are switched on by setting bit 0 of PIE1, and the timer started by setting bit 0 of T1CON. Also, both global and peripheral interrupts should be enabled (INTCON <7:6>). Using Timer1 in this way is demonstrated in the file **pnm0804_timer1.asm**.

Ultimate 'Hello World'

Of course for a simple job like "Hello World" you could just as easily poll the interrupt flags (INTCON <2> or PIR1 <0> respectively), but doing that binds the processor in much the same way as instruction cycle timing loops. Granted, that's not necessarily important for this application, but the code examples are now rapidly moving toward the "Hello World" zenith, and interrupts were a convenient step in the right direction.

Wouldn't it be better still if they also could be eliminated, if we could effectively delegate the whole deal to the PIC hardware? That's where Timer2 comes in, and more specifically the CCP (Capture/Compare/PWM) module with which it is associated.

In PWM (Pulse Width Modulation) mode, the CCP module allows you to design your own square wave output by configuring some special function registers, which then take care of everything else. You can even alter the register values "on the fly", which makes it easy to vary the PWM period (hence frequency) or duty cycle dynamically.

Unfortunately, there isn't space to explain in detail what could easily take a column, if not an entire article. Suffice to say that, as the CCP module hasn't appeared much in *EPE* to date, it's a good candidate to explore further when space permits.

For now, I'll leave you with the example code in **pnm0804_pwm.asm** that shows an interesting "Hello World" variant using PWM. By slowly increasing the duty cycle of the square wave output, the l.e.d. (connected this time to CCP1, pin 9) appears to "pulse" attractively, instead of flash, as its intensity varies with average current.

Special Feature

PIC To PS/2 Mouse and Keyboard Interfacing

John Becker

How to use a PS/2 keyboard or PS/2 mouse with your PIC designs

MANY circuits based on PIC microcontrollers use switches to set a variety of factors. Sometimes many switches are needed, in some cases requiring the use of multiplexed keypads. However, there are instances where some, if not all, of those switches may only be used rarely, except in the initial setting-up process.

So far we have probably all accepted this situation as a fact of life and not considered the expense of seldom-used switches to be of any significance – it's all part of the process of getting a particular design working as we want it.

Those who are familiar with PIC programming and have suitable facilities, have at their disposal the ability to actually change settings from outside the unit. For instance, there is the option to externally send data codes to the PIC's internal data EEPROM registers, from where the software can pick up the values as part of its general processing.

It's a perfectly viable way of doing things, but there are two other options available for minimising or avoiding the use of control switches, and which have never before been shown in *EPE*. Those options can be provided by two items of equipment that all PIC-programming readers will have – the PC mouse and the PC keyboard.

This article describes how both these items can be used with a PIC, potentially enabling you to replace switches in designs which only rarely need switched control of settings. It is important to note, though, that the discussion is only relevant to mice and keyboards which are PS/2 compatible – the modern standard for such devices (disregarding USB types). The chances are that your PC will have a PS/2 mouse and a PS/2 keyboard, even if it is several years old.

The article should not be regarded as a detailed tutorial on all aspects of keyboard and mouse use. Its intention is to show how these items can be simply interfaced to a PIC for use in your own designs. For those who would like to know more about other keyboard and mouse options, a few web links are quoted later from which data can be downloaded.

Armed with the information provided here, you will be able to write your PIC programs so that their settings can be changed just by plugging a keyboard or mouse into them when required, and then put the said item back into normal use where it belongs, plugged into the PC.

There are also design options that open up from this external control which might never have occurred to you to invent. One such idea is published in project form in the next issue, the *AlphaMouse PIC Game*!

Demo Circuit and Programs

Two demonstration programs have been written to accompany this article, one for a PS/2 keyboard and one for a PS/2 mouse. They may be used as a working basis for your own future programs.

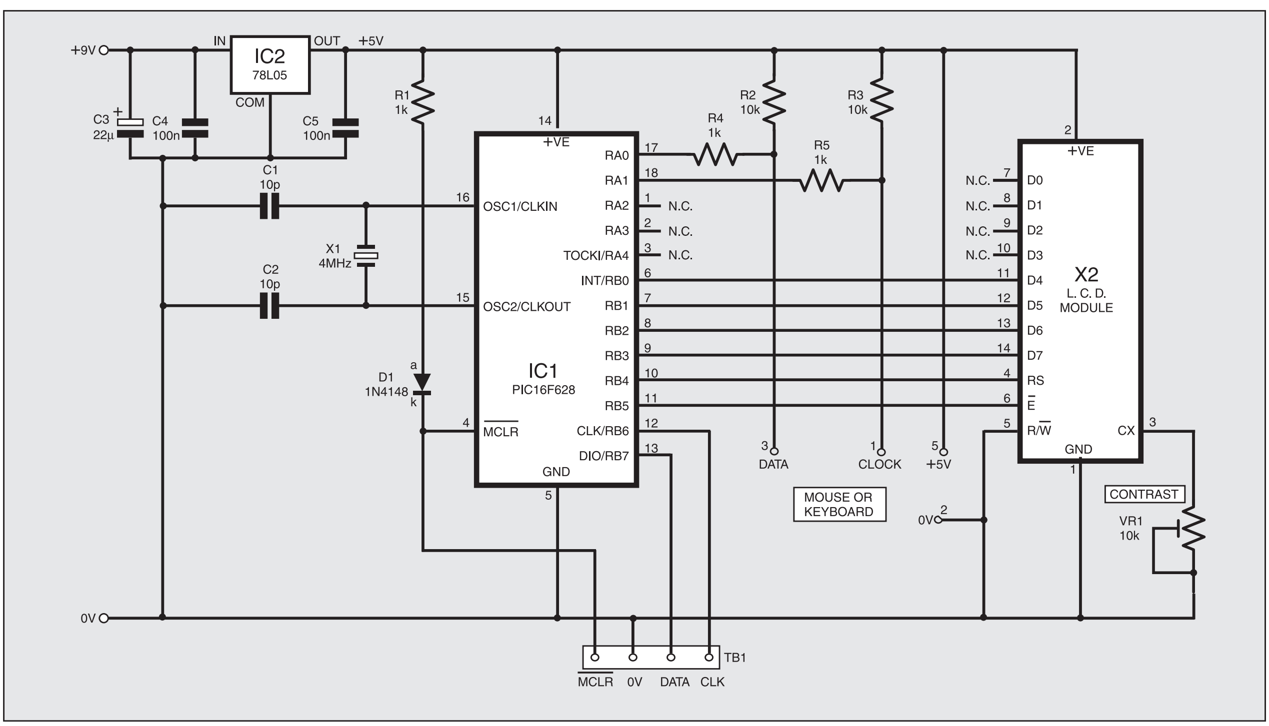


Fig.1. Demonstration circuit diagram, for which the facilities provided by the EPE PIC Toolkit TK3 *board are well suited, with just the addition of resistors R2 to R5 needed.*

The demos have been written for use with the example circuit shown in Fig.1. PIC pin RA0 is used as the DATA line, and RA1 as the CLK (clock) line. Resistors R2 and R3 are required as pull-ups to these pins when they are used in input mode. Resistors R4 and R5 buffer the pins against adverse conditions if both they and the keyboard or mouse to which they are connected have their pins set to output mode.

Although a PIC16F628 is used in the circuit, the demo programs can be used equally well with any PIC. Other pins may also be used as the DATA and CLK pins instead of RA0 and RA1 in other applications, amending the software accordingly.

Additionally, a crystal other than the 4MHz type shown can be used. The use of RC oscillator mode is also valid. Terminals within the TB1 outline can be used for programming the PIC *in situ* using the author's *Toolkit TK3* hardware and software. Resistor R1 and diode D1 prevent the circuit's power line from being affected by the programming voltages involved.

The circuit can readily be built on stripboard (although no constructional details are offered). Alternatively, readers who use the *TK3* printed circuit board (or any of its variants) will recognise that they can assemble the circuit on it. (Full details of TK3 are available on the PIC Resources CD-ROM V2.)

The 2-line by 16-characters per line liquid crystal display (l.c.d.) module X2 is connected in the author's standard order.

The demonstration software for this article is available from the *EPE* Editorial office on a 3·5in disk, for which a nominal handling charge applies, see the *EPE PCB Service* page. Is also available *free* from the *EPE* Downloads site, accessible via the *EPE* home page at **www.epemag.wimborne.co.uk**.

PS/2 Keyboard Protocol

A PS/2 keyboard has its own on-board processor and a dialogue can take place between it and the host (PC, PIC or other device to which it is connected). Data and clock signals are exchanged along two connecting lines, and power to the keyboard is provided by the host on two others, 0V and +5V. The connections are via a 6-pin Mini-DIN plug and socket pair, whose pinouts are shown in Fig.2.

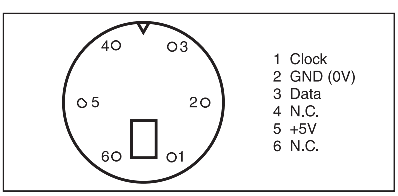


Fig.2. Mini-DIN plug connections for PS/2 keyboard and mouse.

Although the keyboard *can* have commands sent to it, for a general purpose PIC-to-keyboard interface, all that is required is that the PIC should be able to input data bytes from the keyboard as and when it needs. Since the keyboard automatically resets itself when power is applied to it, no commands need to be sent to it by the PIC. All that is necessary is for the PIC to periodically poll the keyboard output to see if any data is waiting to be collected, i.e. assess if a key is pressed, and input its data if it is.

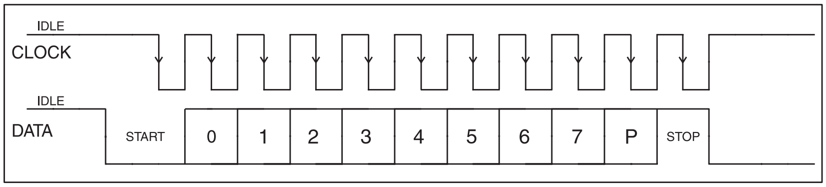


Fig.3. Signal data format sent by PS/2 keyboard.

Receiving Keyboard Data

When receiving keyboard data, the host holds its allocated CLK and DATA pins in input mode. The clock signals are generated by the keyboard and the host reads the data signals in response to the clock signals.

Each data byte is sent in a serial format, commencing with a Start bit, followed by eight bits of data in order of LSB first, MSB last. A Parity bit follows the MSB, and then a Stop bit. The format is shown in Fig.3.

When a data byte is ready to be sent, the keyboard holds the CLK and DATA lines high, in Idle mode. Transmission commences with the DATA line being taken low, shortly after which it takes the CLK line low. The host reads the first bit as the Start bit immediately it recognises the CLK's transition from high to low.

The CLK line then goes high and the first data bit is output by the keyboard, followed by CLK going low again, on which the bit is read by the host. Then follow the other seven data bits in the same manner, followed by the Parity bit, and finally the Stop bit, which is always high. When CLK goes high again, the DATA line is taken low. If further bytes are not be transmitted, both CLK and DATA lines are put into Idle mode once more.

The logic of the parity bit depends on the number of highs in the data byte, if the number is even, parity is high; if it is an odd number parity is low. The PC compares the received parity bit with the number of highs in the received data byte. If the comparison is correct, the data is assumed to have been received correctly. If it is not, the keyboard can be instructed to send the data again (although this is not illustrated here).

Listing 1 shows the sequence of data byte input as written for a PIC, with pins RA0 and RA1 as the DATA and CLK pins respectively, both set as inputs at this time. The received data is held in BYTE, and the

Listing 1. Input data from PS/2 keyboard

```
MAIN:      comf PORTA,W       ; are clock and data lines both high?
           andlw b'0000001'   ; (i.e. is keyboard in Idle state?)
           btfsc STATUS,Z
           goto MAIN          ; no
           call RECEIVE       ; yes, so check if a key pressed
           movf BYTE,W        ; is BYTE > 0 (has a data byte been received?)
           btfsc STATUS,Z
           goto MAIN          ; no, so try again
           btfss PARITY,0     ; yes, is parity bit correct (hi)?
           goto MAIN          ; no, so start again
           call YourRoutine   ; yes (data received ok so use it as you want)
           goto MAIN          ; repeat it all again
RECEIVE:   btfss PORTA,1      ; wait till clock high (idle clock)
           goto RECEIVE       ; not yet high
           btfsc PORTA,0      ; it's high, so is data line low (start bit)?
           return             ; no, it's high, so a false Start bit, try again
           clrf BYTE          ; yes, set BYTE to zero prior to getting data
           movlw 8            ; set loop for 8 data bits
           movwf LOOP
           clrf PARITY        ; clear parity record
RECDATA:   rrf BYTE,F         ; rotate byte to make room for received bit
           call HIGHLOW       ; wait for clock high to low transition
RX2:       btfsc PORTA,0      ; is data low?
           goto RECSET        ; no, it's high
           bcf BYTE,7         ; yes, data is low so clear bit 7 of BYTE
           goto RECNEXT       ; and ignore parity counter
RECSET:    bsf BYTE,7         ; set bit 7 of BYTE
           incf PARITY,F      ; and add 1 to parity counter
RECNEXT:   decfsz LOOP,F
           goto RECDATA       ; loop until all 8 bits have been received
           call HIGHLOW       ; wait for clock high to low transition
           movf PORTA,W       ; get parity bit
           xorwf PARITY,W     ; XOR with parity counter
           andlw 1            ; extract bit 0 of parity
           movwf PARITY       ; and store it
           call HIGHLOW       ; wait for Stop bit (but not actually used)
           return             ; return to main routine
HIGHLOW:   btfss PORTA,1      ; loop until clock is high
           goto HIGHLOW
HL2:       btfsc PORTA,1      ; loop until clock is low
           goto HL2
           return
```

parity bit held in PARITY. The comments in Listing 1 explain the actions. The listing is a slightly modified extract of that used in the demo program that accompanies this article.

Having successfully pulled in a data byte, you then do whatever you want with it, more on which later.

It should be noted that in a real life situation, this data byte receiving routine could get hung up in a constant loop if data is never received, as would happen if the keyboard was not connected to the PIC. To prevent this, a time-out counter should be included in both halves of the HIGHLOW routine, so that if a CLK transition did not occur in a given time, the routine would be exited and a return made to the main calling routine, where appropriate action would then take place, written to suit your own needs.

Interpreting Keyboard Data

When a key is pressed, the keyboard outputs that key's "scan code" to the host (PC, PIC etc). There are two versions of the key codes, one indicating that the key has been pressed (*make*) and normally using a single byte, the other indicating that it has been released (*break*) and normally using two bytes. There are some keys, though, which use other byte quantities.

As an example of such differences, key letter A on the keyboard has a single byte make code of hex 1C and a twin-byte break code of hex F0 1C. However, the righthand Ctrl key has a 2-byte make code of hex E0 14 and 3-byte break code of hex E0 F0 14.

Perversely, the Print Scrn key has a 4-byte make code and a 6-byte break code. Even more curiously the Pause key has an 8-byte make code, but no break code! The logic behind such curious codings is hard to fathom.

It will be apparent that scan code values are different to ASCII character code values. The host has to interpret the scan codes, principally according to one of three possible table sets. The one supported by most modern PCs is Set 2, and is the one used in the demo program. Table 1 shows the details for this set. Note that some keyboards have more keys (with their own codes) than the table shows.

The task of the host is to interpret the scan codes and react accordingly. In the case of the PC, the majority of the keys are simply interpreted as their ASCII characters and typically output to screen by the program which is being run.

In the case of a PIC program, the ASCII values can also be output as characters to an alphanumeric l.c.d. screen which is capable of showing them. However, it is probably more likely that the values (rather than the characters) will be used to control various aspects of the program.

For example, on receiving the value of hex 1C (letter A scan code) the program could be triggered to enter one particular routine. Whereas on receiving the value hex 16 (numeral 1), another routine might be entered, and so on, depending on how the program has been written.

However, as said, there can be more than one byte of data associated with particular keys. The PIC program's routine for reading keyboard data must therefore be written to extract the desired byte as the value to be used.

In the full RECEIVE routine of the extract shown in Listing 1, there are some conditional branches taken depending on the number of bytes involved. Looking at Table 1, it will be seen that in the majority of cases, a key *press* (make) generates just one byte. The release of that key generates two bytes, the first being hex F0, with the second byte having the same value as the make code.

For instance, pressing key V generates the single byte hex 2A, and releasing it generates the two bytes hex F0 and 2A. The PIC program must therefore check whether any key activity generates the byte hex F0. If it does not, the value received is that required. If hex F0 is produced, a second byte reading routine is entered to get the required value. Unless you wish otherwise (i.e. need to know whether a key is being pressed or released), you would then ignore the first byte (hex F0) and use the second value, hex 2A in this case.

As you will see from Table 1, there is a complication! Some keypresses generate hex E0 or hex E1 as the first byte. The program must also respond to these situations. In the case of hex E0, it must then read the next byte, check whether or not it is a value of hex F0, and if so read the third byte of the sequence (whatever possessed the originators of the Set 2 protocol to do it in this complicated way is beyond the author's comprehension!).

If the first byte is hex E1, then an even more complicated sequence of byte reading could be entered. But, since the only time that hex E1 is generated is when the Pause/Break key is used, any interception of it simply causes the program to store that fact, and treat the next byte as though it is the first byte of a "normal" one or two byte sequence.

Table 1. Keyboard Scan Codes Set 2
(All values are in hexadecimal)

Key	*Make*	*Break*									
A	1C	F0,1C	V	2A	F0,2A	‘	52	F0,52	KP 6	74	F0,74
B	32	F0,32	W	1D	F0,1D	,	41	F0,41	KP 7	6C	F0,6C
C	21	F0,21	X	22	F0,22	.	49	F0,49	KP 8	75	F0,75
D	23	F0,23	Y	35	F0,35	/	4A	F0,4A	KP 9	7D	F0,7D
E	24	F0,24	Z	1A	F0,1A	F1	05	F0,05	KP *	7C	F0,7C
F	2B	F0,2B	0	45	F0,45	F2	06	F0,06	KP –	7B	F0,7B
G	34	F0,34	1	16	F0,16	F3	04	F0,04	KP +	79	F0,79
H	33	F0,33	2	1E	F0,1E	F4	0C	F0,0C	KP .	71	F0,71
I	43	F0,43	3	26	F0,26	F5	03	F0,03	BK SP	66	F0,66
J	3B	F0,3B	4	25	F0,25	F6	0B	F0,0B	CAPS	58	F0,58
K	42	F0,42	5	2E	F0,2E	F7	83	F0,83	ENTER	5A	F0,5A
L	4B	F0,4B	6	36	F0,36	F8	0A	F0,0A	ESC	76	F0,76
M	3A	F0,3A	7	3D	F0,3D	F9	01	F0,01	L ALT	11	F0,11
N	31	F0,31	8	3E	F0,3E	F10	09	F0,09	L CTRL	14	F0,14
O	44	F0,44	9	46	F0,46	F11	78	F0,78	L SHFT	12	F0,12
P	4D	F0,4D	`	0E	F0,0E	F12	07	F0,07	R SHFT	59	F0,59
Q	15	F0,15	-	4E	F0,4E	KP 0	70	F0,70	NUM	77	F0,77
R	2D	F0,2D	=	55	F0,55	KP 1	69	F0,69	SCROLL	7E	F0,7E
S	1B	F0,1B	\	5D	F0,5D	KP 2	72	F0,72	SPACE	29	F0,29
T	2C	F0,2C	[	54	F0,54	KP 3	7A	F0,7A	TAB	0D	F0,0D
U	3C	F0,3C	]	5B	F0,5B	KP 4	6B	F0,6B			
			;	4C	F0,4C	KP 5	73	F0,73			

Key	*Make*	*Break*				*Key*	*Make*	*Break*
KP /	E0,4A	E0,F0,4A	END	E0,69	E0,F0,69	PRN SCR	E0,12,E0,7C	E0,F0,7C,E0,F0,12
KP ENT	E0,5A	E0,F0,5A	HOME	E0,6C	E0,F0,6C	PAUSE	E1,14,77,E1,F0,14,F0,77	NONE
R ALT	E0,11	E0,F0,11	INSERT	E0,70	E0,F0,70			
R CTRL	E0,14	E0,F0,14	PG UP	E0,7D	E0,F0,7D			
L GUI	E0,1F	E0,F0,1F	PG DN	E0,7A	E0,F0,7A			
R GUI	E0,27	E0,F0,27	DN ARR	E0,72	E0,F0,72			
APPS	E0,2F	E0,F0,2F	L ARR	E0,6B	E0,F0,6B			
DELETE	E0,71	E0,F0,71	R ARR	E0,74	E0,F0,74			
			UP ARR	E0,75	E0,F0,75			

In this case, on exit from the RECEIVE routine any required action can be taken in response to this key. It is unlikely that most PIC programs will need to know if this key is used, or indeed those keys generating hex E0 for that matter.

Allocating Characters

The demo program having acquired a key value then enters a routine which displays the results on an l.c.d. screen, as follows for example:

HEX	DEC	KEY
001C	28	A

The first two positions for the hex value read as 00 if the a "normal" key press has occurred. They otherwise show F0, E0 or E1, depending on the situation just outlined. The second byte always shows the "required" value. This value is then shown in decimal, followed by information on that value's meaning.

Two lookup tables are used in the demo software to provide that information. The first table (TABLE1) is used if the first hex byte is 00 or F0. In most cases the table simply jumps to a particular line and returns to the calling routine with an equivalent single character value held in W, outputting it to the l.c.d. screen. For instance, key code hex 1C and hex F0 1C have a decimal value for the second byte of 28. The table causes a jump to its line 28, and returns with the l.c.d.'s code for lowercase letter **a** held in W.

There are some keys, though, which do not have a single character description. In this case TABLE1 causes a jump to other routines from which the description is expanded into a meaningful sequence of letters. For example, PAGE DN, INSERT, HOME, L SHIFT, etc, depending on the key.

The second table, TABLE2, is used if the first hex byte holds a value of E0. With one exception, the table causes a jump to a descriptive sequence of letters. The exception is for the forward slash (/) key of the righthand keypad, which is returned and displayed as the symbol itself.

Note that the l.c.d. cannot display the backslash (\) symbol and this key's occurrence generates the description of BK SLSH.

Capital Exclusion

The results of the keypresses described so far are for the "lowercase off" and "Num Lock off" keyboard modes. The only way in which uppercase and Num Lock modes can be determined is by knowing the status of the Shift, Caps Lock and Num Lock keys.

If you need to know the status of these keys, you need to keep track of them being used. The demo program does not include an example of this, but you need register flags to keep track of these keys being used. For Caps Lock and Num lock, the flags should be inverted each time the key is used. It is suggested that the defaults on entry to the program should be 0 (keys not yet used). On one of them being pressed, its flag should be set to 1, then back to 0 the next time it is pressed, and so on.

For the Shift key(s), though, it's a bit more complicated since you need to determine if the key is held down while other keys are being pressed, and whether or not Caps Lock is on, according to its flag.

Experiment with the demo program to find out how to cope with these three situations! But in reality, you may not actually need to know or use the information.

PS/2 Mouse Protocol

A PS/2 mouse has bidirectional CLK and DATA lines, allowing it to output data and receive commands. Both options need to be used.

The mouse connector pinouts are the same as those used for the keyboard, as in Fig.2.

There are four operating modes for a PS/2 mouse:

Reset

The mouse logic generates a power-on reset at power up after 600 milliseconds ±20%. After power up or when receiving a Reset command, the CLK and DATA lines go high. The mouse then waits between 300ms and 500ms, and then sends hex AA to the host, followed by a device ID of 00.

After reset, the mouse is set to its default values: incremental Stream Mode, 1:1 scaling, report rate of 100, six counts per millimetre at 320 DPI (dots per inch) or four counts per millimetre at 200 DPI. It then disables itself and no further action occurs until a command is sent from the host.

Stream Mode

In Stream Mode, data is transmitted to the host if a button is pressed or released, or if at least one count of movement has been detected. The maximum rate of transfer is the programmed sample rate.

Remote Mode

In Remote Mode, data is transmitted only in response to a Read Data command.

Wrap Mode

In Wrap Mode, any byte of data sent by the host, except hex EC or FF, is returned to the host by the mouse. This code remains until hex FF or EC is sent to the mouse.

Mouse Commands

There are 16 mouse commands available, as shown in Table 2. They have the following functions:

Reset (FF). Described above.

Resend (FE). Can be sent if an error in transmission from the mouse is detected. On receipt of this command the mouse retransmits the previous bytes that make up a complete data packet, from one to three bytes.

Set Default (F6). Re-initialises all conditions to the power-on default state.

Disable (F5). Used in Stream Mode to stop transmissions from the mouse.

Enable (F4). Starts transmission if in Stream Mode.

Set Sample Rate (F3, XX). In Stream Mode, sets the sampling rate to the value indicated by the second byte value XX, where XX =

Hex	Rate		
0A	10/sec	50	80/sec
14	20/sec	64	100/sec
28	40/sec	C8	200/sec
3C	60/sec		

Table 2. PS/2 Mouse Commands

Hex Code	*Command*
FF	Reset
FE	Resend
F6	Set Default
F5	Disable
F4	Enable
F3	Set Sample Rate
F2	Read Device Type
F0	Set Remote Mode
EE	Set Wrap Mode
EC	Reset Wrap Mode
EB	Read Data
EA	Set Stream Mode
E9	Status Request
E8	Set Resolution
E7	Set Scaling 2:1
E6	Reset Scaling 1:1

Read Device Type (F2). Always results in a response of 00.

Set Remote Mode (F0). Described above.

Set Wrap Mode (EE). Described above.

Reset Wrap Mode (EC). Resets the Wrap Mode.

Read Data (EB). Initiates transmission of the current three bytes of mouse movement and button data.

Set Stream Mode (EA). Described above.

Status Request (E9). Causes the mouse to send a 3-byte status report, as follows:

Byte 1	Bit 7	Always 0
	Bit 6	0 = Stream Mode, 1 = Remote Mode
	Bit 5	0 = Disabled, 1 = Enabled
	Bit 4	0 = Scaling 1:1, 1 = Scaling 2:1
	Bit 3	Always 0
	Bit 2	1 = left button pressed
	Bit 1	Reserved for middle button
	Bit 0	1 = right button pressed
Byte 2	Bits 0 to 7	Current resolution setting
Byte 3	Bits 0 to 7	Current sampling rate

Set Resolution (E8, XX). The mouse provides four resolutions to be set through the second byte (XX) of this command, where XX is:

Hex	200 DPI	320 DPI	400 DPI
00	1	1	2
01	2	3	4
02	4	6	8
03	8	12	16

Set Scaling 2:1 (E7): Scaling is used to provide a course/fine tracking response when in Stream Mode. At the end of a sample interval in Stream Mode, the current X and Y movement data values are converted to new values. The sign bits are not involved in this conversion. In response to a Read Data command, the mouse transmits the current value before conversion:

Input	Output
0	0
1	1
2	1
3	3
4	6
5	9
N >= 6	2·0 × N

Reset Scaling (E6). Restores 1:1 scaling

Receiving Mouse Data

Movement and button data is output from the mouse as three consecutive bytes having the following format:

Byte 1	Bit 7	Y data overflow, 1 = overflow
	Bit 6	X data overflow, 1 = overflow
	Bit 5	Y data sign, 1 = negative
	Bit 4	X data sign, 1 = negative
	Bit 3	Reserved, always 1
	Bit 2	Reserved for middle button
	Bit 1	Right button status, 1 = pressed
	Bit 0	Left button status, 1 = pressed
Byte 2	Bits 7 to 0	X data, bit 7 = MSB
Byte 3	Bits 7 to 0	Y data, bit 7 = MSB

Data transmission from the mouse to the host uses the same protocol as the keyboard, and is illustrated in Fig.4.

Listing 2 shows the sequence of data byte input as written for a PIC, with pins RA0 and RA1 as the DATA and CLK pins respectively, both set as inputs at this time. The received data is held in BYTEIN, and the parity bit held in PARITY. The comments in Listing 2 explain the actions.

As the clock signals are provided by the mouse, PIC timings are not critical, it just waits until the clock line is at the required level, and then reads the data bit sent.

Because there are three bytes for each batch of data, the Receive Data routine is called three times. Having input each group, you can then do what you want with it, and then get the next batch.

The following points are worth noting:

Bits 4 and 5 of the first byte indicate the direction in which the mouse has moved. With the mouse held with its cable facing away from you, moving to the left is regarded as a negative movement on the X axis and bit 4 is set to 1. If movement is to the right, the bit becomes 0.

Movement of the mouse away from you is a positive Y axis movement and bit 5 is set to 0. Movement towards you is negative, and bit 5 is set to 1.

Each time the mouse data is read, its movement counters are reset to zero. Between each 3-byte read action, any movement increments the counters according to the sampling rate, resolution and scaling settings. If the mouse is moved rapidly over a particular distance the counters may exceed their 8-bit limit (255 increments), in which case an overflow flag is set, bit 6 for the X axis, bit 7 for the Y axis. In this case you can write your program to take this fact into account (or ignore it, depending on what you want to achieve).

In the demo program, the l.c.d. shows the status of the three bytes as follows:

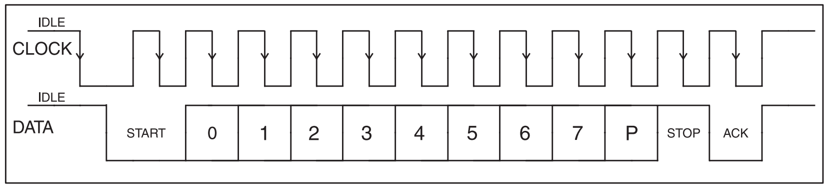


Fig.4. Signal data format sent by PS/2 mouse.

Listing 2. Receive Data from PS/2 Mouse

```
RECEIVEDATA:
        BANK1
        movlw b'11111111'           ; Data & Clk as inputs
        movwf TRISA                 ; (biased high by R1 and R2)
        BANK0
WAITPRESTART:
        comf PORTA,W                ; wait till RA0 & RA1 are both high
        andlw b'00000011'
        btfss STATUS,Z
        goto WAITPRESTART
        call WAITCLKDOWN            ; wait CLK going low
        movf PORTA,W
                                    ; get Start bit
        andlw b'00000001'
        movwf STARTBIT              ; store it
        call WAITCLKUP
                                    ; wait CLK going low
        btfsc STARTBIT,0            ; is Start bit correct (= 0)?
        goto WAITPRESTART           ; no
        movlw 8                     ; yes
        movwf LOOP                  ; set loop for 8 steps
        clrf PARITY
        clrf BYTEIN
RECEIVELOOP:
        call WAITCLKDOWN
        rrf PORTA,W                 ; rotate data bit into carry and into BYTEIN
        rrf BYTEIN,F
        btfsc PORTA,0               ; add 1 to parity count if data high
        incf PARITY,F
        call WAITCLKUP              ; wait CLK going high
        decfsz LOOP,F
                                    ; continue until loops complete
        goto RECEIVELOOP
        call WAITCLKDOWN            ; wait CLK going low
        movf PORTA,W
                                    ; get parity bit
        andlw b'00000001'
        movwf PARITYBIT             ; store it (not used, but must still be read)
        call WAITCLKUP              ; wait CLK going high
        call WAITCLKDOWN            ; wait CLK going down
        movf PORTA,W
                                    ; get stop bit
        andlw b'00000001'
        movwf STOPBIT               ; store it (not used, but must still be read
        movf BYTEIN                 ; put received byte into W
        return                      ; return to calling routine
WAITCLKUP: btfss PORTA,1            ; wait till CLK goes high
        goto WAITCLKUP
        return
WAITCLKDOWN: btfsc PORTA,1          ; wait till CLK goes low
        goto WAITCLKDOWN
        return
WAITDATAUP: btfss PORTA,0           ; wait till DATA goes high
        goto WAITDATAUP
        return
WAITDATADOWN: btfsc PORTA,0         ; wait till DATA goes low
        goto WAITDATADOWN
        return
```

Line 1:

- binary display of all eight bits of byte 1 (status byte)
- Status of button presses in words – NIL, LEFT, RIGHT, BOTH
- A flashing asterisk indicating that sampling is taking place at that rate (two samples for a complete asterisk on/off cycle)

Line 2:

- Letter X (X axis)
- X axis movement direction sign, plus (+) or minus (–)

- value of X axis movement expressed in hexadecimal
- status of X axis overflow, blank for none, hash (#) symbol for overflow
- Letter Y (Y axis)
- Y axis movement direction sign, plus (+) or minus (–)
- value of Y axis movement in hexadecimal
- status of Y axis overflow, blank for none, hash (#) symbol for overflow

Sending Commands to Mouse

Program-wise, sending commands to the mouse is a little more finicky because there has to be a form of handshaking between the PIC and the mouse, involving the use of the DATA and CLK pins in both input and output modes.

Listing 3 shows the sequence of sending a data byte to the mouse as written for a PIC, with pins RA0 and RA1 as the DATA and CLK pins respectively, both set as inputs at this time. The data to be output is held in BYTEOUT, and the parity bit held in PARITY. The comments in Listing 3 explain the actions.

The routine is entered with the command value to be sent held in W. This is immediately stored into BYTEOUT, and the parity byte is cleared.

On entry, the PIC's DATA and CLK pins are both in input mode. First, CLK is set low as an output (marker 1 in the listing) and a wait of at least 100 microseconds must follow, allowing the mouse to recognise this line's status.

Then DATA is set low as an output (2) to send the Start bit to the mouse. After which the CLK pin is set as an input (3) and a wait made until the CLK goes low (4). When this happens, the eight data bits are sent, in order of LSB to MSB (5). Having output a bit the PIC waits for the CLK to go high (6) and then low again (7). The process is repeated for all eight bits (8).

During the loop, parity for that byte is assessed. At the end of the loop it is inverted (odd parity) and output in the same way as the previous bits (9). A wait is then made for the CLK to go up and then down again, after which the DATA pin is set as an input (10).

Next a wait is made until the DATA line goes low, and then for the CLK line to go low (11). Finally, there is a wait for the DATA and CLK lines to go high, one after the other, and the Sending routine is exited.

Initial Mouse Settings

When the PIC is first powered up and the various housekeeping events performed, such as initialising the l.c.d., a sequence of commands is sent to the mouse to put it into the mode that you require. The program then enters its main loop in which the mouse data is read and actioned as you wish (being output to the l.c.d. in the case of the demo program). Listing 4 shows the latter's sequence.

First hex FF is sent to reset the mouse. Although the mouse is automatically reset when power is connected to it, it does not follow that the PIC and mouse will always be connected to the same power source (it is preferable that they should, though). Furthermore, the PIC might be reset without the power being switched off, and the keyboard might have been previously set to modes not consistent with the start of the program. Hence it is preferable to use the software Reset command.

Listing 3. Send Command to PS/2 Mouse

```
SENDCOMMAND:
        movwf BYTEOUT               ; store value brought in on W
        clrf PARITY
        bcf PORTA,1                 ; set CLK low for at least 100µs (1)
        BANK1
        bcf TRISA,1                 ; set CLK as output
        BANK0
        call WAIT50                 ; wait briefly
        call WAIT50
        bcf PORTA,0                 ; set DATA low (Start bit)  (2)
        BANK1
        bcf TRISA,0                 ; set DATA as output
        BANK0
        BANK1
        bsf TRISA,1                 ; set CLK as input (3)
        BANK0
        call WAITCLKDOWN            ; wait till CLK goes low (4)
SENDLOOP: movlw 8                   ; send 8 bits of data bit 0 to bit 7
        movwf LOOP
SEND2: movf BYTEOUT,W               : only bit 0 has any effect
        movwf PORTA                 ; send data bit (5)
        BANK1
        bcf TRISA,0                 ; set DATA as output
        BANK0
        movf BYTEOUT,W              ; get parity bit (bit 0)
        andlw 1
        addwf PARITY,F              ; add it to parity counter
        call WAITCLKUP              ; wait till CLK goes high (6)
        call WAITCLKDOWN            ; wait till CLK goes low (7)
        rrf BYTEOUT,F               ; rotate byte to put next bit into bit 0
        decfsz LOOP,F
        goto SEND2                  ; repeat for all 8 bits (8)
        comf PARITY,W               ; invert parity count (odd parity)
        movwf PORTA                 ; send parity bit (9)
        call WAITCLKUP              ; wait till CLK goes up
        call WAITCLKDOWN            ; wait till CLK goes low
        BANK1
        bsf PORTA,0                 ; set DATA as input (10)
        BANK0
        call WAITDATADOWN           ; wait till DATA goes low (11)
        call WAITCLKDOWN            ; wait till CLK goes low
        call WAITCLKUP              ; wait till CLK goes high (12)
        call WAITDATAUP             ; wait till DATA goes high
        return                      ; return to calling routine
```

Listing 4. PS/2 Mouse Initialisation Settings, and Main Working Loop Example

```
        movlw $FF                   ; RESET command
        call SENDCOMMAND
        call RECEIVEDATA            ; read 1st byte (but ignore)
        movlw $F5                   ; DISABLE command
        call SENDCOMMAND
        movlw $F3                   ; SET SAMPLING RATE command
        call SENDCOMMAND
        movlw $0A                   ; SAMPLING RATE value
        call SENDCOMMAND
        movlw $E8                   ; SET RESOLUTION command
        call SENDCOMMAND
        movlw $03                   ; RESOLUTION value
        call SENDCOMMAND
        movlw $F0                   ; SET REMOTE command
        call SENDCOMMAND
        movlw $F4                   ; ENABLE command
        call SENDCOMMAND
MAIN: movlw $EB                     ; READ DATA command
        call SENDCOMMAND
        call RECEIVEDATA            ; read first byte, but ignore
        call RECEIVEDATA            ; get buttons status etc
        movwf BYTE1                 ; store it
        call RECEIVEDATA            ; get X axis value
        movwf BYTE2                 ; store it
        call RECEIVEDATA            ; Y axis
        movwf BYTE3                 ; store it
        –                           ; do whatever you want with it all
        goto MAIN                   ; repeat for next set of data
```

Following reset, the mouse's initial output byte is then read, but ignored (see a mouse controller's datasheet for information on mouse output following reset).

In sequence, the command for Disable is sent, followed by the commands and values for setting the Sample Rate and Resolution. Next the mouse is set into Remote Mode and finally the Enable command is sent.

The program now enters its main working loop. In Remote Mode, the data is output by the mouse in blocks of four bytes following a Read Data command being sent. The first byte is the response to that command and is not required in the type of application being illustrated (see a mouse controller datasheet). The Read Data command must be sent prior to reading each batch of data.

The next byte of data is then input from the mouse and stored (BYTE1). It contains the mouse status bits as already discussed. In turn the X and Y axis bytes (BYTE2 and BYTE3) are also input and stored.

That completes the input sequence and you can now do what you like with the information (in the demo program it is just output to the l.c.d. as described). The sequence is then repeated.

Using This Information

The demo programs for interfacing a keyboard and mouse to a PIC can be treated as the basis for any program you write. The programs can be copied in full into your program and modified to suit your needs.

There are many more aspects to keyboard and mouse control than have been discussed here, but what has been presented covers the basics of what you need to know. If you want to learn more about the other controls available, do a browse of the web. This is how the author learned his information.

You will find that there are many web links if you use a search engine such as **www.google.com**. The sites from which the author downloaded documents and datasheets are given in the next section.

Useful Links

Data from the following sites was downloaded from the web by the author in connection with this article:

www.emc.com.tw. Datasheet for EM84502 PS/2 mouse controller

www.holtek.com.tw. Datasheet for HT6523 PS/2 mouse controller

www.topro.com.tw. Datasheet for TP8452 PS/2 mouse controller

www.beyondlogic.org/keyboard/keybrd.htm. Useful information on keyboards

www.fiacopetti.it/index_en.htm. Information on PS/2 mouse, partly in Italian

www.networktechnic.com. Some more information on PS/2 keyboard and mouse protocols

www.repairfaq.org/filipg/. A selection of PC keyboard FAQ

http://panda.cs.ndsu.nodak.edu/~achapwes/PICmicro. Information on keyboards and mice. Very useful site

Other sites of possible interest:
www.senet.com.au/~cpeacock.
http://members.iweb.net.au/~pstorr/

Mouse Play

Next month we publish a fun game which uses a PIC and a mouse, and illustrates how such combinations can be used to good effect. It's called the *AlphaMouse PIC Game*.

Furthermore, in the pipeline is a design for which all settings are controlled only by a PS/2 keyboard.

Don't miss these projects! ☐

SHOP TALK
with David Barrington

Simple F.M. Radio

The polyvaricon (polythene dielectric) variable capacitors used in the *Simple F.M. Radio* will normally be found listed as "transistor radio" types and consist of an antenna and oscillator section, plus trimmers. They are currently stocked by **ESR Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code 896-110 and **Sherwood Electronics** (see page 596), code CT9. The one in the prototype was obtained from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code AB11M.

As we have found previously, finding small quantities of enamelled copper wire is very difficult. The author obtained his 22s.w.g. (21a.w.g.) enamelled copper wire in a 50g (2oz.) reel from **JAB** (☎ ***0121 682 7045*** or ***www.jabdog.com***).

The TDA7000 f.m. radio i.c. is currently listed by **Cricklewood** (☎ ***020 8452 0161***), **Sherwood** (see page 596) and **Squires** (☎ ***01243 842424*** or ***www.squirestools.com***). Cricklewood also list the TDA2003 audio power amp i.c. A suitable Bulgin fused Euro-style mains inlet, chassis mounting, plug (code MK18U or FT37S) together with an insulation, rear tag, protective cover (code JK67X) and line socket (UK16S) is listed by **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***).

The four printed circuit boards are available from the *EPE PCB Service*, code 458 (Tuner), 459 (Tone Control), 347 (TDA2003 Amp) and 460 (Power Supply) – see page 593.

EPE Scorer

We do not expect readers to encounter any buying problems when shopping for components for the *EPE Scorer* project. The console type sloping front plastic case, with aluminium front panel insert, used for the Control Unit, is widely stocked, but due to size requirements could prove to be fairly expensive. No doubt readers will have their own ideas about this.

Whilst searching for components for other projects, we found that **Squires** (☎ ***01243 842424*** or ***www.squirestools.com***) stock a similar "wafer thin" 8 ohm 50mm loudspeaker to that used in the model. Their order code is SPK390.

The TDA7052 amplifier i.c. is listed by **Maplin** (despite requests, they have not sent us their latest catalogue or CD-ROM for some time now!) as code UK79L.

The PIC used for the Master Unit must be the 20MHz version of the PIC16F877. The PIC16F628 is used in the Slave Unit(s). For those readers unable to program their own PICs, a preprogrammed PIC16F877-20 (20MHz) microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www. magenta2000.co.uk***) for the inclusive price of £10 each (overseas add £1 p&p). Their charge for a programmed PIC16F628 is £4.90 each (overseas add £1 p&p).

The software, including source code files, for the Master and Slave Units is available on a 3·5in. PC-compatible disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 (UK), to cover admin costs (for overseas charges see page 593). It is also available for *Free* download from the click-link option on the *EPE* home page at **www.epemag.wimborne.co.uk** (take path **PICs/PICscorer**).

The printed circuit boards are available from the *EPE PCB Service*, codes 461 (Control), 462 (Display), and 463 (Slave – of which you will need two if building the full design).

EPE Teach-In '04 Part 10

Most of the components required to construct the *Curtain/Blind Winder* circuit (Fig.10.4), this month's concluding *Teach-In '04* project, should be generally available from our components advertisers. The exceptions being the programmed PIC microcontroller and the two motors.

The 6V d.c. 60 r.p.m. curtain motor used in the prototype came from **RS Components** (credit card only – ☎ ***01536 444079*** or ***rswww.com***), code 336-337. The 4·5V to 15V d.c. Combo Drills series 919D motor, with a 148:1 ratio gearbox, for the blinds, was purchased from **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 37-1238.

The prototype system was developed using a PICAXE-18**A** microcontroller. Note that the "A" suffix is important since the software program is too long for the standard PICAXE-18 i.c. The BASIC program is also available as a hex download for conventional programming with a PIC16F819, which has the required analogue to digital converters.

A pre-programmed PICAXE-18A can be obtained from: **Max Horsey, Electronics Dept., Radley College, Abingdon, Oxon OX14 2HR**, for the sum of £5 per PIC, including postage. Specify that the PIC is for *Teach-In 2004* Part 10 and quote the figure number/circuit for which the device should be programmed. Enclose a cheque payable to **Radley College**.

The software for the PIC program (except for the PICAXE programming software) is available on a 3·5in. disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 (UK), see page 593 for overseas charges. It is also available for *Free* download via the click-link option on the *EPE* home page at **www.epemag.wimborne.co.uk**; enter the PIC microcontroller source codes folder and select **Teach-In 2004**.

PICAXE programming software can be obtained from: **Revolution Education, Dept. EPE, 4 Old Dairy Business Centre, Melcome Road, Bath BA2 3LR** (☎ ***01225 340563*** or ***www.rev-ed.co.uk***).

A printed circuit board for the Curtain/Blind Winder is available from the *EPE PCB Service*, code 457 (see page 593).

Keyring L.E.D. Torch

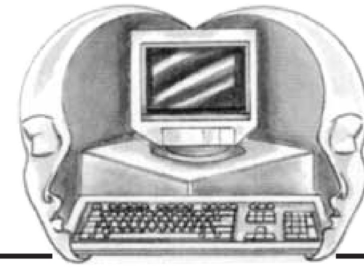
The only component likely to cause concern when looking for parts for the *Keyring L.E.D. Torch* is the 3·6mm diameter toroidal ring-core. This was purchased from **Electrovalue** (☎ ***01784 433604*** or ***www.electrovalue.co.uk***), quote code B64290P37X33.

The small plastic box came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code SC78K. The high brightness white l.e.d. should be one having a clear transparent package. If you feel unhappy about using a BC817A surface mount transistor, then the suggested standard medium current BC337 can be used instead.

The miniature, surface mount type, printed circuit board is available from the *EPE PCB Service*, code 456 (see page 593).

INTERFACE

Robert Penfold



MORE ABOUT ACCESSING A PC'S PARALLEL PORT VIA INPOUT32.DLL

SOME recent *Interface* articles provided a recapitulation of the ins and outs of the PC serial ports. The serial ports can be used to provide a number of input and output lines and they are undoubtedly very versatile.

They are not free from drawbacks though, and one of these is the relatively slow rate at which data can be input and output. Another is the need to encode and decode the serial data.

For many applications the parallel port of a PC offers a more practical approach. The new version of **inpout32.dll** from **www.lvr.com** (and our Downloads site) enables the parallel port to be easily accessed using Visual BASIC when running any 32-bit version of Windows, and gives it a new lease of life for DIY interfacing.

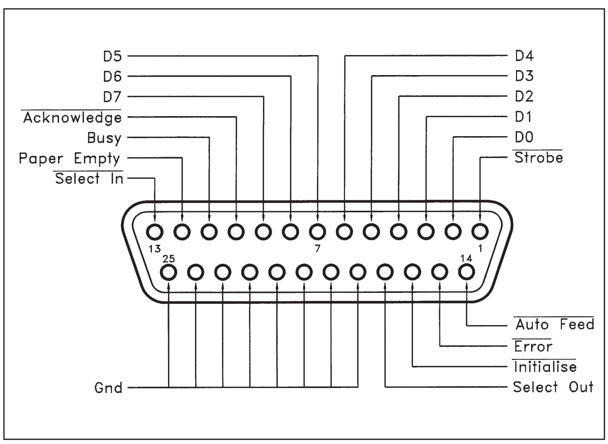


Fig.1. Standard PC parallel port pin functions.

Modern PCs generally have just one parallel port, giving a relatively small number of input and output lines, but the number of lines is still adequate for many purposes. Most printers now use a USB port, leaving the parallel port free for other purposes.

Correctly Addressed

Some circuits that interface via the parallel port will be covered in future articles, so a recapitulation would perhaps be in order before moving on to these. The parallel port is the 25-way female D connector, which on a modern PC is normally in the main cluster of ports. The pin functions for the port are shown in Fig.1.

The eight data lines (D0 to D7) are the ones that are used for inputting and outputting data, and the other lines are for handshaking, error detecting, and the like. Of course, in a non-printer application these lines can be used in any desired fashion, as can the data lines. A few of the handshake lines can be used to send data to a serial A/D converter for instance.

Before a parallel port can be used it is important to know its base address. The normal scheme of things is for the first port to have &H378 (888 decimal) as its base address. Any additional parallel port would normally be placed at base address &H278 (632 decimal).

Incidentally, the operating system will always consider the port at the higher address to be port 1, the port at the next highest address to be port 2, and so on. As with most aspects of computing, the words "normal" and "standard" do not really mean a great deal when applied to printer ports, and not all PCs have the first printer port at address &H378.

The main complication is that some PCs have the parallel port at base address &H3BC (956). This apparently has its origins in the Hercules monochrome graphics adapter that was often fitted to early PCs.

This adapter included a printer port that used this base address, presumably in order to ensure that there were no hardware conflicts with the existing port or ports. Anyway, this address is sometimes available as an option with modern PCs, and in some cases it is used as the default address.

The easy way to determine the address of a serial or parallel port is to go into Device Manager. When using Windows 98 or ME the way to access Device Manager is to first select Settings from the Start menu, and then Control Panel from the submenu that appears. Next, double-click the System icon and select the Device Manager tab in the new window that appears. There is an extra step when using Windows XP, where the Hardware tab must be selected first, and then the Device Manager button is operated.

Once into Device Manager, double-click the Ports entry to expand it and then double-click the entry for whichever port you are interested in. Operate the Resources tab in the new window that appears, and this should produce something like Fig.2.

It is the figures for the Input/Output Range at the top that are of importance, and these give the address range used for the port. In this example the range is &H378 to &H37F, and the base address is therefore &H378.

The data lines of a parallel port are at the base address, and by default this type of port will always operate in the output mode. In order to send data to the port it is therefore just a matter of writing the appropriate value to the base address. With the Inp and Out instructions added to Visual BASIC using **inpout32.dll**, this is just a matter of using an instruction such as:

Out &H378,63

This writes a value of 63 to the parallel port at base address &H378.

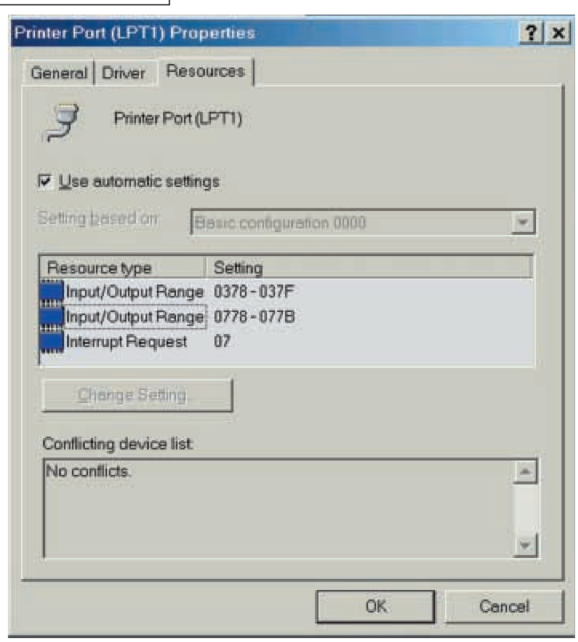


Fig.2. Port addresses can be obtained through Device Manager.

Input Mode

An input mode was not included in the original PC specification, but it should be available using any PC that is not a candidate for *Antiques Road Show*. There have been items of hardware that used the data lines as inputs by using brute force to take the data outputs to the required states. However, this is clearly a bit risky, there is no guarantee that it will work with every PC, and with a modern PC it should be unnecessary anyway.

The input/output switching is controlled by bit 5 of the handshake output register, which is two addresses higher than the port's base address. In other words it is at address &H37A for a port at a base address of &H378.

Writing a value of 32 to this address sets the control bit high and switches the port to operation as an input. Writing a value of 0 to this bit sets the port back to the output mode.

In practice the value used must also take into account the required states for any handshake outputs that are in use. Note that all the data lines have to operate in the same mode and that no form of split operation is supported.

It is standard practice for the data inputs to be driven via series resistors of about 220 ohms in value.

In order to maintain compatibility with the original PC printer port, a modern type will default to the output mode. This means that the outputs of the add-on device will initially be driving the outputs of the port. A program to switch the port to the input mode can be run at start-up, but this still leaves two sets of outputs connected together during the initial testing and boot-up sequence. Using series resistors limits the output currents to a safe level and is a much better solution to the problem.

A Setup

If a PC's serial port will not operate in the input mode it is possible that only the standard (output only) mode is supported. However, bidirectional printer ports were introduced in the late 80486 and early Pentium PCs. Consequently there are few PCs in use today that do not support at least a basic bidirectional mode, which is all that is required in the current context. Current PCs normally use a bidirectional mode by default, but older PCs sometimes operate in the standard mode unless set to an alternative.

The mode of a built-in printer port is usually controlled via the BIOS Setup program. There are various ways of entering this program, which is built into the PC's firmware and is not run from disk.

The most common method is to operate the Delete key just before the computer starts booting into Windows, but other keys and methods of entry are used. Reference to the manual for your PC or its motherboard should give details for entering the Setup program, together with details of the available modes for the printer port.

There will usually be SPP, EPP, and ECP modes available. SPP is the standard parallel port mode, but this is the standard bidirectional mode and not an output only type. It should permit the port to be switched to the input mode, as should the EPP (enhanced parallel port) option. The ECP (extended capability port) mode is a complex type that provides high-speed bidirectional operation, but it does not provide the simple direction control of the other two modes. Therefore it is SPP or EPP operation that should be selected.

Do Not Interrupt

There are five handshake input lines, and these are at bits 3 to 7 of the address one above the base address. In other words, the handshake lines are read at &H379 for a port at the normal base address of &H378. Table 1 provides details of the handshake lines.

It is possible to read in bytes of data using four of these lines plus one of the handshake outputs. The bytes have to be read as two 4-bit nibbles with the output line controlling the switching between nibbles.

The Acknowledge input at pin 10 of the port can generate interrupts, which is fine if you wish to use interrupts. It could otherwise produce erratic results though, so it is probably best not to use this input unless it is the only one available.

Note that the Paper input is inverted, and a value of 0 will therefore be returned from this line when it is high. A value of 128 is returned when it is low. This is not really of any major consequence, but clearly the software must take this factor into account.

Handshake Outputs

There are four handshake outputs that are controlled by the register that is two above the base address, or at &H37A for a normal printer port. The output lines are at bits 0 to 3, and details are provided in Table 2.

Only one of the four lines (the Initialise output) does not drive the port via an inverting buffer stage. Once again, these inversions are not of any great consequence, but their presence must be taken into account when writing the software. Remember that this register also has the direction control bit at pin 5.

When writing software that uses the handshake outputs and the data lines as inputs it is important to ensure that changing the handshake lines leaves the direction control bit unchanged. Assuming that the data lines will only be used as inputs, this just means adding 32 to every value sent to the port, so that bit 5 is always at logic 1.

Net Result

It is worth pointing out again that programs written to use **inpout32.dll** can only operate if this file is available to the system. It must either be placed in the **C:\windows\system** folder, or in the same folder as the program itself.

Table 1: Handshake Lines

Bit No.	*Pin No.*	*Line Name*	*Inverted*
3	15	Error	No
4	13	Select In	No
5	12	Busy	No
6	10	Acknowledge	No
7	11	Paper	Yes

When writing your own programs using **inpout32.dll** merely having this file available to the system is not enough. Additionally, the file with the BAS extension supplied with **inpout32.dll** must be loaded into Visual BASIC before you start programming. Without this file Visual BASIC will not recognise the Inp and Out instructions and error messages will be produced when they are used. The new instructions operate like normal BASIC instructions once the BAS file has been loaded.

Table 2: Handshake Outputs

Bit No.	*Pin No.*	*Line Name*	*Inverted*
0	1	Strobe	Yes
1	14	ALF	Yes
2	16	Initialise	No
3	17	Select Out	Yes
5	–	Direction control	–

There is plenty of information on PC serial and parallel ports on the Internet, and it is worthwhile seeking it out using a good search engine. It is worth paying a visit to **www.lvr.com**, which has some information about PC interfacing in addition to links to other sites of interest. Some of the port information on the Internet is a bit dated but some more up-to-date stuff is now starting to appear.

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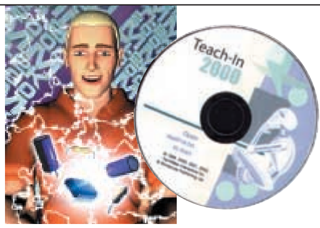

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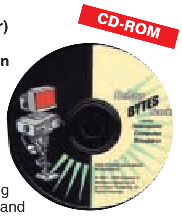

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