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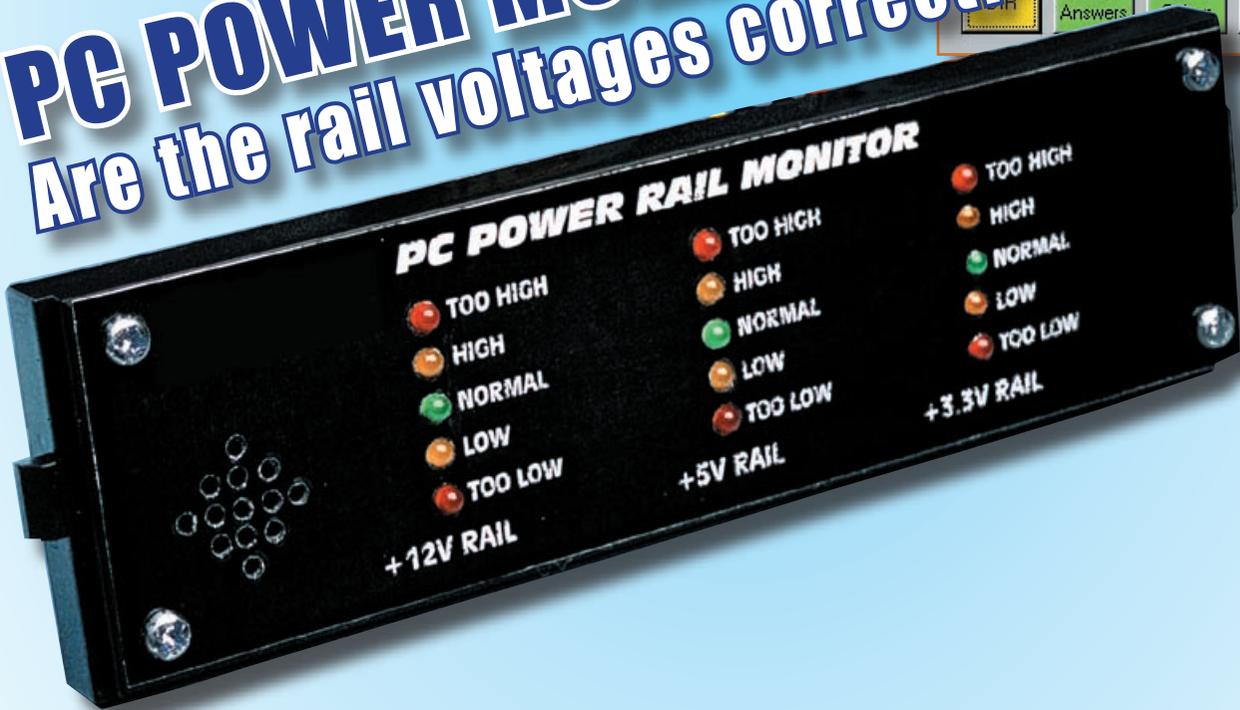
PIC SUDOKU

Hand-held puzzle generator/player

PLUS Puzzle Solving Software



PC POWER MONITOR
Are the rail voltages correct?



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Vol 35 No 7 \$5.95 US \$7.99 CAN
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How Do They Do It?

A DVD player for less than the cost of the latest films on DVD. An automatic cordless kettle for less than the price of a jar of coffee. It seems the world of technology is beating everything else on price hands down. These products are made in China and shipped half way around the world, then a wholesaler and a retailer add their mark-up before we pay for them. Whilst this is obviously good for the consumer in the short term, is it really sensible to be selling products at such low prices? Presumably the cost of the raw materials is a major part of the total, there can be very little for the manufacturer or the worker and few retailers can survive on ever falling profits, even if the percentage profit per item remains the same.

We have seen it in the hobby electronics area – where there were a large number of component suppliers, say 20 years ago, few now survive as it is difficult to make a profit selling a handful of very inexpensive parts by mail order or over the shop counter. By the time you have sorted and stored them, picked and packed them, banked the payment and done the accounts, VAT etc., where is the profit to pay staff when all the components for a hobbyist project may only cost a few pounds.

Problems

I fear that this dramatic reduction in the cost of many household electrical and electronic items may significantly add to the problems of the local economy. What it might do for the Chinese economy is also questionable.

I'm not a politician and don't want to get into the politics of this – protectionism etc., besides that we have just purchased a new office kettle from a major supermarket for a fiver! It's automatic and cordless too, looks smart and works a treat. I wonder how many they have to ship at once to get the carriage price right, and how much of our £5 is for raw materials and manufacturing?

Most kettles don't last too long in our office, where they are in very regular use, so it will be interesting to see how this one shapes up – I guess for a fiver if it lasts a year then it is a bargain, but it will add to the local waste: But that is another story.



AVAILABILITY

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PROJECTS AND CIRCUITS

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 that 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

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

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BIG BROTHER'S BROTHER'S COMING

Barry Fox gives a stark warning to all drivers

DRIVERS could soon face a completely new kind of Big Brother on the roads, which detects vehicle speed, and even loaded weight, using sound. The new system, being developed by the University of Tennessee's Battelle Institute in Oak Ridge USA, is purely passive. Drivers who currently rely on radar or laser detectors to sense tell-tale radiation coming from any speed traps ahead will find their early warning equipment useless against the new system.

Details of Battelle's research into audio trapping are revealed by recently filed patents. The patents also tell that the work is being undertaken for the US Department of Energy, and the funding contract has bought the US government the right to use the technology (Ref Contract No. DE-AC05-00OR22725).

Mic Monitored

Microphones hidden by the roadside capture the sound of a passing vehicle and record it as a PC WAV file. Digital filtering removes background noise to leave the sound of the engine and any turbocharger used to increase power by forcing extra fuel into the cylinders. The Doppler shift which makes the pitch of this sound rise and fall as it approaches and passes the microphones gives an instant tell-tale of road speed – just as the sound of a car siren or clanking bell changes as it comes and

goes. Engine speed and turbo speed in rotations per minute are detected from the pulsing sound of the pistons firing and the fuel-pumping turbo vanes.

Loaded Weight

To measure the loaded weight of a vehicle the microphones are put on a slope with known incline, so that the engine sound is recorded as it starts to climb and use more power. Correlating the simultaneous changes in road speed, engine speed and turbo speed as the vehicle starts labouring up the known slope angle gives a good estimation of its weight. Comparing the sound signature of the engine with a reference store of known signatures, makes the correlation more accurate.

To prove the system concept, Battelle made 64 recordings and used a Windows PC (with LabVIEW software from National Instruments) to estimate truck speed successfully for 32 out of 33 experiments. "This result", says Battelle's patent, "is very encouraging".

Undetectable

The microphones are easily hidden in street signs, adds the patent, so drivers do not get any advance warning. "An obvious application", the patent says, "is as a new, undetectable vehicle speed gun used by law enforcement agencies". It can be the

core of a new device. "The person driving the vehicle being monitored is unaware that the speed of their vehicle is being measured".

Battelle claims that as well as telling the speed of the vehicle, engine, and turbocharger, the acoustic signature can also tell what type of vehicle it is e.g. tractor-trailer, dump truck, cement truck. This, says the patent, is good for homeland security; it could also trap big trucks which speed through little villages.

Battelle's patent tells that the basic system can be extended to spy on "other vehicles", which suggests ongoing research into ways of using audio to trap cars by acoustic signature and Doppler. The research institute was clearly none too pleased that publication of the patent has spilled the beans. Calls for comment were initially ignored, then stalled.

Controversial

Finally, Curtis Ayers, one of the three inventors of the system, made a comment which suggests that Battelle and the US government are well aware that news of the system could prove very controversial: "There is some ongoing work, still under development and sensitive, that is using aspects of this technology – vehicle speed and engine characterisation, but we are not free to describe that work as of yet"

Easy Battery Tester

Discharging batteries to check their performance is an expensive and time consuming business and in many situations, simply cannot be done economically in the time available. The new BZT1 fast battery tester from battery testing specialists Astratec Electronics provides a solution to this problem!

In just 10 seconds, the easy to use BZT1 estimates the performance of the sealed lead-acid batteries that are found in a wide range of popular applications, including security alarms, fire alarms, golf trolleys, electric scooters, mobility aids, electric wheelchairs, standby lighting and many more.

The BZT1 uses a unique form of voltage and battery impedance analysis to estimate battery performance. The last 40 tests are automatically saved and can be easily downloaded to a printer or PC spreadsheet making this a really useful field service tool. An internal date and time marker records on the test report, the date and time of each test. Self-adhesive test result labels can also be printed at the end of each test and attached to the battery, providing a permanent record of the test date and results.

The standard BZT1 works with both 12V and 24V batteries, other voltages including 6V versions are available.



Every unit carries a full 12 month warranty and comes complete with a soft protective carry case.

For more information browse www.astratec.co.uk, tel +44 (0) 1327 705936 or email sales@astratec.co.uk.

VCR Security Role

Don't relegate that VCR to the attic yet! Connect it to a video camera via a video motion detection module and you have an inexpensive state-of-the-art security system that will start a tape rolling whenever the camera detects movement – stopping automatically when there is no longer any motion. You can also connect a security light or alarm to complete the setup.

Farco Technologies manufacture video motion detection systems that are used in high-end Traffic Enforcement and Traffic Management applications – red light cameras and signals controllers. This same high speed image processing technology can bring new life to that VCR, giving it a great new role in the home, monitoring and recording events in the field of view of the camera.

One of the benefits with these systems is you don't have to scroll through endless tape footage to find activity. The tape only starts recording when there is activity and it shuts down when the activity stops. Of course, this makes a standard 180 or 240 minute VHS tape last a long time in most situations.

The simplest solution is to connect Farco's Wachit in the line between a camera and the VCR. The Wachit is a neat little metal box all ready to be plugged into the cable. It will be positioned close to the VCR because it uses infra-red codes, the same as the remote control, to record, pause and stop the VCR.

Farco cunningly designed it so it would learn the remote codes of most standard VCRs so there is no need to program it for your particular model. The Wachit can be

connected to a security system so it becomes armed when the security system is armed. There is a relay output on the back of the box that can be connected to activate an alarm system or security lights, both if you want – so you not only get the recording of activity, you get a warning as well. Another

output is also available to trigger an alarm if the video signal is lost – which might mean the camera has been tampered with.

Whereas most other sensors have range limitations, Video Motion Detection has the advantage that any image in the field of view of the video camera can be analyzed for movement and alerts triggered.

A practically unlimited range of applications exists. The detection (or absence) of motion can be used to activate or de-activate many different types of device such as alarms, lighting systems, cameras, audio or video recording devices. Wachit features: VCR/DVD-R Record, Pause, Stop; Video Loss Detection Alarm/Alert; Security Lights On/Off; Alarm On/Off; Gates Locked/Unlocked; Door Up/Down; Lighting control.



We hope to be able to publish a constructional project based on the principal component of the Wachit, the VMD-19 module in a future issue. The project will use image processing technology to activate recording plus several security functions and video signal loss warning. The module is an 18-pin, standard 0.6 inch wide IC board. It can be directly connected to a composite video and detect motion of objects within the video signal. Designed for implementations by manufacturers and electronics enthusiasts, the VMD-19 costs less than £20.

For information contact Murray Downes, Farco Technologies Limited, 200 Armagh Street, Christchurch, New Zealand. Tel: +64.3.374.5534. Web: www.farco.co.nz.

New Design Website

Knaresborough based GSPK Design Ltd have just announced the launch of their new website: www.gspkdesign.ltd.uk.

The company are a dedicated electronic design team specialising in assisting innovative companies with new product development and existing product portfolios. By utilising emerging technologies, GSPK Design Ltd work extensively within consultancy, design and development, right through to manufacture and assembled product.

The company's philosophy in supporting the local economy i.e. Yorkshire and the surrounding area, has led to astounding success – and as a result, they have needed to establish a website to reflect their market position.

The company found the ideal solution to their web design requirements by enlisting the expertise of Extreme Creations based in Ripon, North Yorkshire, who have worked exclusively with the GSPK Design team.

Paul Marsh, Managing Director for GSPK Design Ltd said, "The development of our new website will help us to fly the banner and raise the profile of GSPK Design Ltd. We know this initiative will help us to communicate our core capabilities to both existing and potential new customers – but it will also help raise brand awareness..."

Paul continues, "We hope that this new marketing initiative will help us form valuable partnerships with predominantly

Yorkshire-based companies as we firmly believe in supporting business development within our local economy."

For more information browse the website or contact GSPK Design Ltd, Dept EPE, GSPK Technology Park, Manse Lane, Knaresborough, North Yorks HG5 8LF. Tel: Dianne Latham, 01423 865641. Email: di@gspk.com

Microchip DC/DC Converters

Microchip have announced a new family of positively regulated charge pump DC/DC converters that are amongst the most efficient charge pumps in the industry. Microchip's first fractional charge pumps, the MCP1256, MCP1257, MCP1258 and MCP1259 automatically switch between 1.5x and 2x boost operation to increase efficiency. They are the ideal low-cost, low-power, high-efficiency devices for low-noise, longer-lasting dual-cell alkaline, Ni-Cad, Ni-MH, single-cell MnO₂ and similar coin-cell battery systems.

At light output loads, the MCP1256 and MCP1257 can be placed in a "Sleep" mode, where quiescent current is lowered but regulated output voltage stays the same. Additionally, the MCP1258 and MCP1259 devices provide a bypass feature that connects the input voltage to the output, which provides a bias voltage for the system with virtually no power drain from the charge pump itself. All of the MCP125X devices have a low-noise output ripple of less than

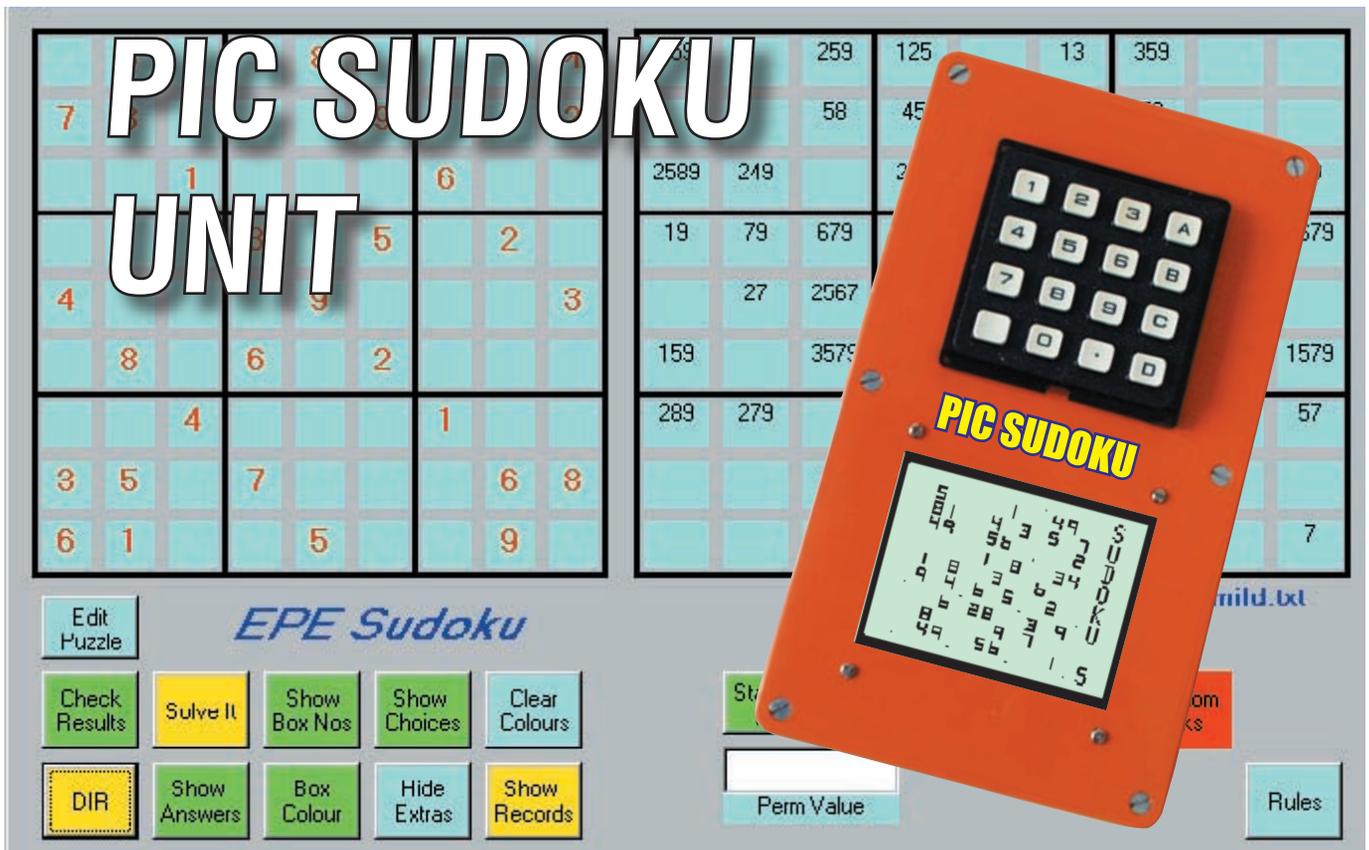
10mVpp at load currents up to 100mA, resulting in less system interference and better overall performance. Other features include soft start, short-circuit protection and thermal protection. In addition, they operate over an extended temperature range (-40 to +125 degrees C).

The MCP125X charge pump DC/DC converters are ideal for battery-powered electronics devices that require low power and utilize white light-emitting-diode (LED) backlights for liquid-crystal displays. The MCP1256, MCP1257, MCP1258 and MCP1259 devices are available in 10-pin MSOP or 3x3mm DFN packages.

For more information, contact Microchip Ltd. Microchip House, 505 Eskdale Road, Winnersh Triangle, Wokingham, Berks RG41 5TU. TEL: +44-(0) 118-921-5869 FAX: +44-(0) 118-921-5820. Web: www.microchip.com/MCP125X.

IU APRIL 2006

We regret to report that the circuit published in our *Ingenuity Unlimited* column for a Sound Effects Generator by Craig Kendrick Sellen of Carbondale, PA, USA was in fact a copy of a circuit previously published in *Radio Electronics*, June 1987. We apologise to readers and the copyright holders for Mr Sellen's deception.



Joining the ultimate brain challenge craze!

By JOHN BECKER

SOLVING Sudoku logic puzzles is an obsession that has swept the UK, and no doubt elsewhere. The Japanese puzzle was first introduced to the UK by *The Times* newspaper in November 2004. A certain Wayne Gould had apparently turned up at the paper's headquarters carrying such a puzzle under his arm, wondering if it might prove an "absorbing time-filler" for readers (www.timesonline.co.uk).

It certainly has! When travelling on public transport we are surrounded by people doing them in newspapers, magazines, and even on mobile phones. The puzzles are hailed by teachers, doctors and scientists as "the ultimate brain workout".

Sometime ago it occurred to the author that he could design a handheld PIC-based Sudoku unit with graphics LCD (GLCD) and keypad. He later went on to write a PC-based program to automatically solve Sudoku puzzles. More on this later.

Basic Concept

Most people will be aware that Sudoku puzzles are based on a grid of 81 squares, arranged in a 9x9 format, containing a selection of digits and blanks. The idea is to "fill in the grid so that every row, every column, and every 3x3 box contains the digits 1 through 9". Puzzles are solved through reasoning and logic.

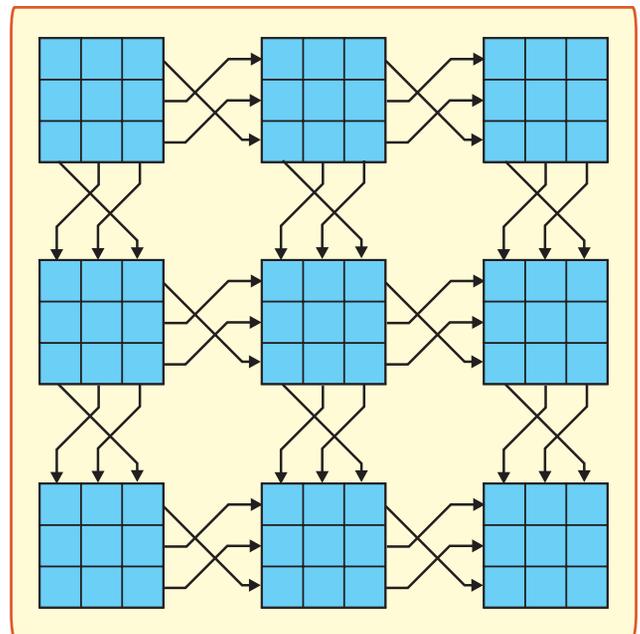


Fig.1. Pseudo random number generation across the 3x3 sub-squares formats

So, in designing a Sudoku puzzle generator, first a complete set of 81 digits must be created in which these simple logic rules apply. Then blanks are added to hide a selection of those digits. The rest is down to the player, to decide which digits the blanks represent.

In the unit presented here, a pseudo random number generator (PRNG) is used to generate the first nine digits which comprise an initial 3x3 square. Permutations of those digits are then copied to the other squares, abiding by the basic rules of no repetition of digits in the rows, columns or the 3x3 sub-squares.

Having generated the first nine digits, the remaining squares are filled using the technique shown in Fig.1, in which rows and columns are copied as indicated by the arrows. Blanks are

then added, using the PRNG to select one of eight pre-arranged patterns. A very large assortment of different puzzles can be generated before repetition occurs.

The resulting puzzle is displayed on the GLCD screen and it's then up to the player to use the keypad keys to select the blanks and the digits to place in them.

PIC Circuit

The circuit diagram for the PIC Sudoku Unit is shown Fig.2. At its heart is a PIC16F877 microcontroller, IC1. This is controlled at 3.2768MHz, as set by crystal X1 in conjunction with capacitors C1 and C2. Power is provided by a 9V battery, B1, or an external 9V DC supply from a mains powered battery adapter if preferred. Diodes D2

and D3 prevent the two sources from adversely interacting.

The 9V supply is regulated down to +5V by voltage regulator IC2, which feeds the rest of the circuit. Capacitors C3 to C5 and C8 provide power line smoothing.

The keypad is a low-cost 4x4 matrixed device, S2. Which key is pressed is decoded via PIC lines RB0 to RB7. The keypad is arranged as shown in Fig.3.

Keys 1 to 9 are the digits needed by the puzzle. Keys A and B are used to scroll the GLCD's cursor up or down respectively, keys *blank* and 0 scroll it to the left or right respectively. Key D selects the generation of a new game. Key "*" shows the answers to a puzzle if you want to take a peek!, it also clears those answers from the screen on the next press. It is an alternating cycle.

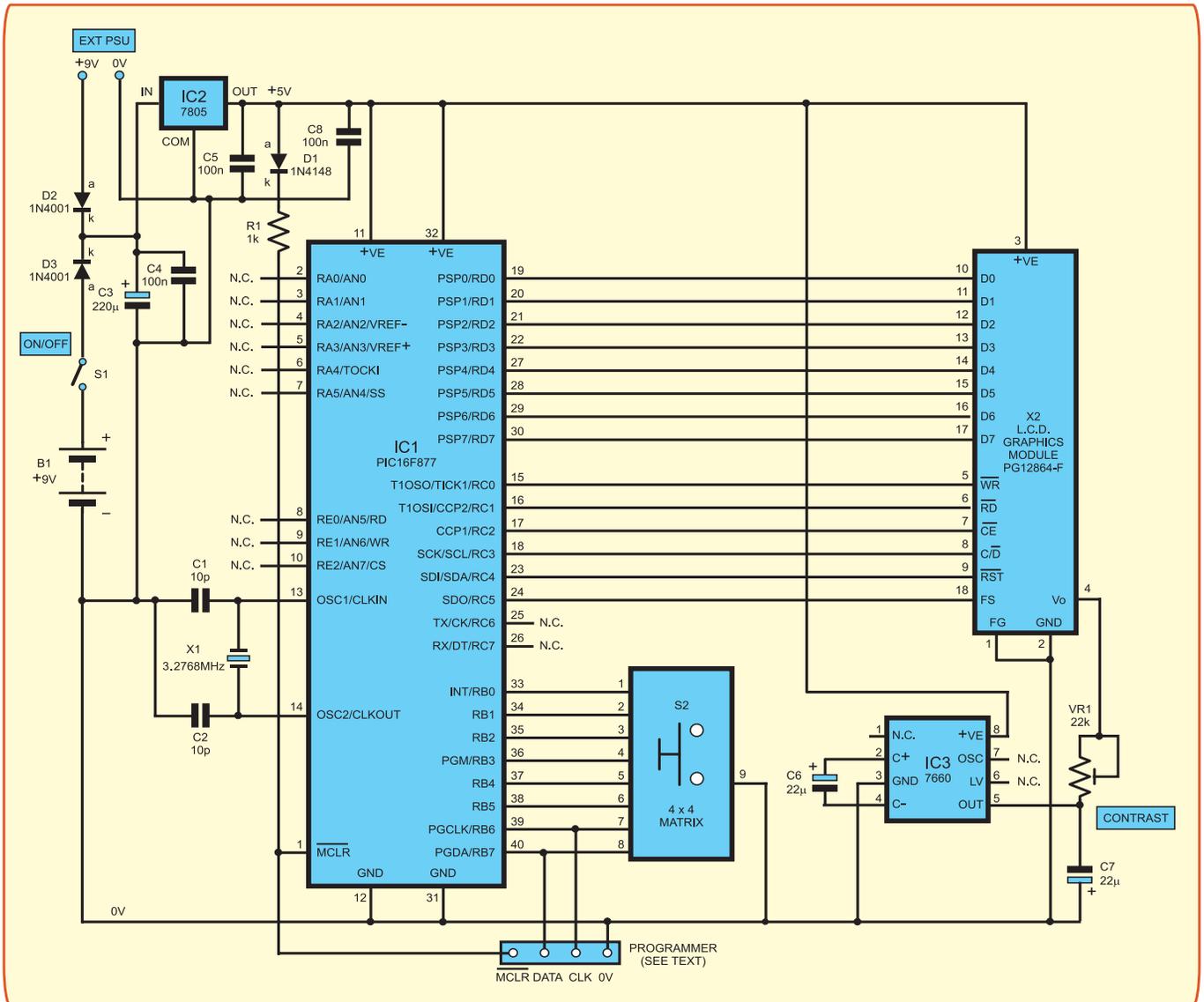


Fig.2. Complete circuit diagram for the handheld PIC Sudoku Unit

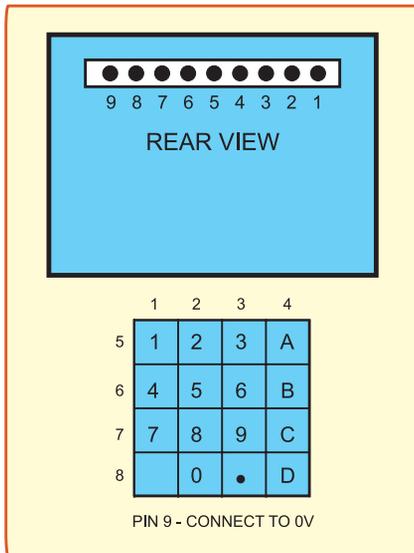


Fig.3. Keypad layout and pin details

Pressing key C checks the answers you have given against the known answers, highlighting any which are wrong. It too is on an alternating cycle, clearing the highlights on the next press.

A summary of key use is in Table 1.

The GLCD, X2, is the Powertip PG12864-F 128 x 64 pixel display described and used in the author's previous GLCD designs. It is controlled by PIC lines RC0 to RC5 and RD0 to RD7.

Table 1. Keypad keys use summary

Key	Function
1 to 9	digits 1 to 9
A	cursor up
B	cursor down
blank	cursor left
0	cursor right
*	show/hide answers
C	show/hide results
	check
D	start new game

The display needs +5V, 0V and -5V DC power. The -5V is generated by voltage inverter IC3 in conjunction with capacitor C6. Capacitor C7 smooths this supply. The screen's contrast is adjustable by preset VR1.

The PIC can be programmed with its Hex code in the author's usual fashion, from a suitable programmer such as *Toolkit TK3*, via pin connector TB1. Diode D1 and resistor R1 prevent the +5V power line from being affected by adverse programming voltages. The PIC source code and pre-programmed PICs are available as stated later.

The remaining PIC pins are unused, as shown in Fig.1.



Assembly

The printed circuit board component and track layout details are shown in Fig.4. This board is available from the *EPE PCB Service*, code 575.

Assemble the board in the usual order of ascending component size, starting with the few wire links (some of which go under IC positions), ending with the 9V PP3 battery connector. Correctly observe the polarity of the electrolytic capacitors, and of the ICs, omitting the DIL (dual-in-line) ICs and GLCD until the correctness of the +5V supply has been checked.

Connections for the GLCD are shown in Fig.4, and those for the keypad in Fig.3. It is recommended that colour-coded ribbon cable is used for the connections.

A plastic case measuring approximately 190mm x 110mm x 60mm was used for the prototype. If you can find a suitable slimmer plastic case, use it! Carefully cut out the GLCD viewing slot, first drilling a series of peripheral holes, and then cutting out and filing smooth the edges. The GLCD has mounting holes for which matching holes should be drilled in the case, securing it using nuts and bolts.

Also cut case holes for an external power socket if preferred, and one for the on-off switch, S1. Additionally cut a slot for the keypad pins and drill holes through which to mount it.

First Tests

When the fully assembled and checked unit is switched on, the GLCD will show an opening message as a display simply stating "Press key D", horizontally, and the title "Sudoku", vertically. Adjust preset VR1 until the

Parts List – PIC Sudoku Unit

- 1 PC board, code 575, available from the *EPE PCB Service*, size 78 x 94mm
- 1 plastic case (190 x 110 x 60mm - see text)
- 1 9V PP3 battery and PC-mounting battery clip
- 2 multi-way ribbon cables (see text)
- 1 socket to suit external 9V power source (optional - see text)
- 1 8-pin DIL socket
- 1 40-pin DIL socket
- 22 1mm terminal pins or 1mm pin headers
- 8 nuts and bolts for mounting GLCD and keypad
- 1 22k min. round preset potentiometer (VR1)
- 1 min. s.p.s.t. toggle switch (S1)
- 1 4 x 4 matrixed data entry keypad (S2)
- 1 3-2768MHz crystal (X1)

- 1 PG12684-F graphics LCD, 128 x 64 pixels (X2)

Semiconductors

- 1 PIC16F877 microcontroller, pre-programmed (see text) (IC1)
- 1 7805 1A +5V voltage regulator (IC2)
- 1 7660 voltage converter (IC3)
- 1 1N4148 signal diode (D1)
- 2 1N4001 rectifier diode (D2-D3)

Capacitors

- 2 10pF ceramic disc (C1-C2)
- 1 220µF radial elect. 10V (C3)
- 3 100nF (0.1µF) ceramic disc (C4-C5, C8)
- 2 22µF radial elect. 10V (C6-C7)

Resistors (0.25W 5% CF)

- 1 1k (R1)

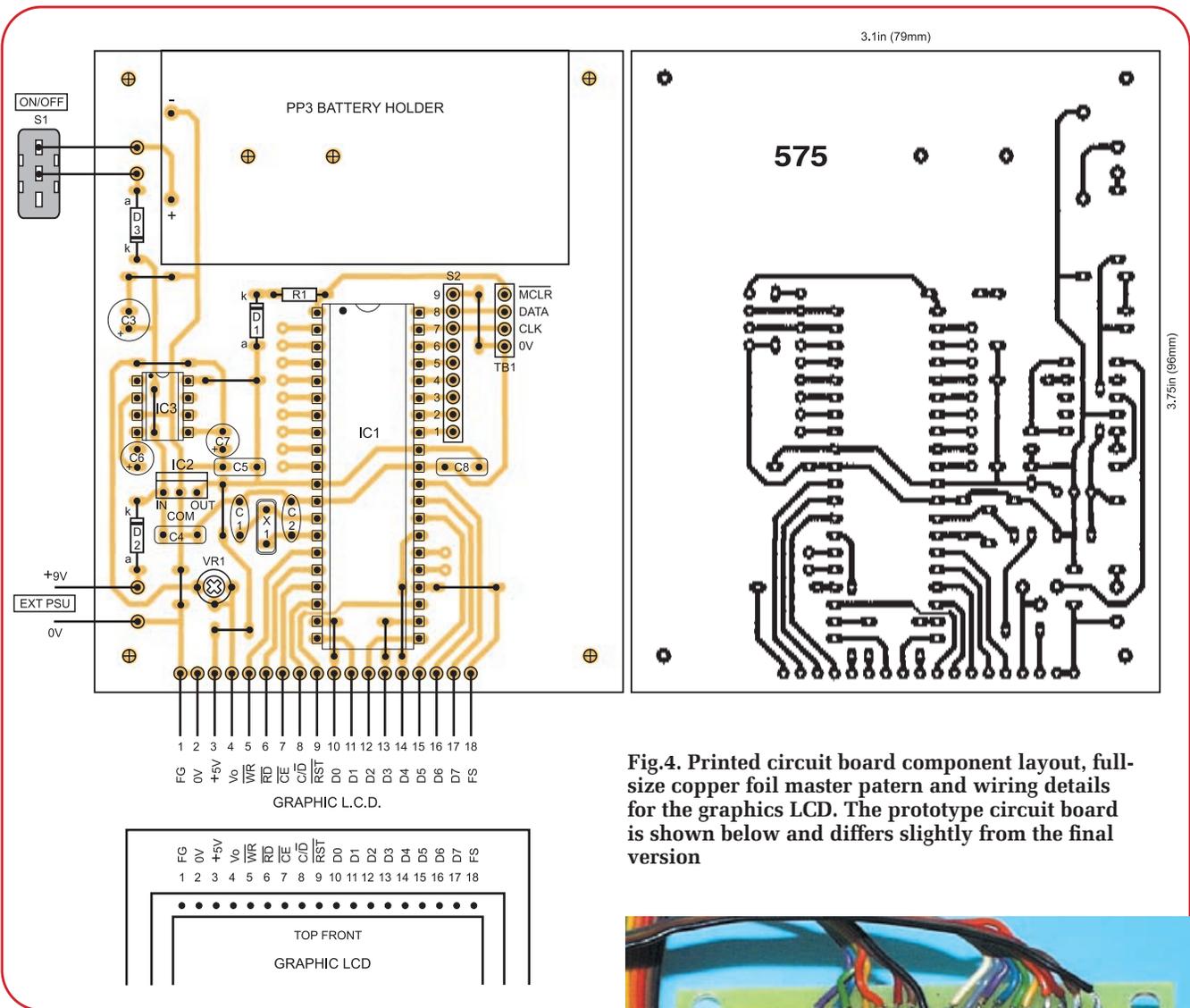


Fig.4. Printed circuit board component layout, full-size copper foil master pattern and wiring details for the graphics LCD. The prototype circuit board is shown below and differs slightly from the final version

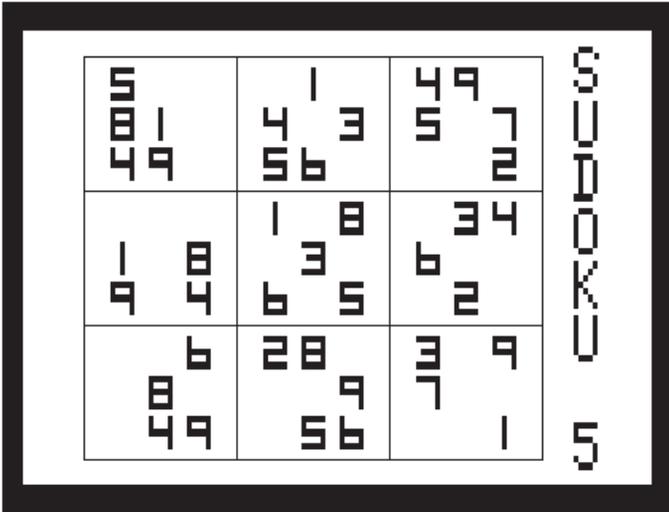
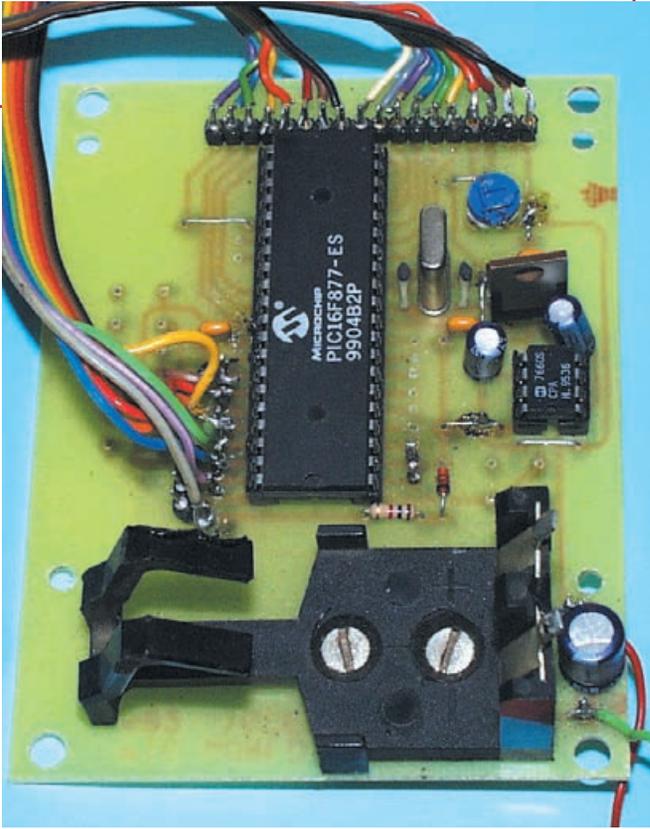


Fig.5. Representation of a typical screen display. The number immediately below the Sudoku title indicates which blanks pattern has been selected

screen contrast is satisfactory. Pressing key D will then clear that screen to display a Sudoku puzzle, such as that in Fig.5.

The numeral immediately below the vertical Sudoku title indicates which blanks pattern has been selected. A different puzzle and pattern can be selected by pressing key D again, until you see one which suits you!

Pressing cursor keys A, B, 0 and blank will cause a GLCD cell to be highlighted (reversed-out image). Any blank selected can then have a digit placed into it by pressing the appropriate digit key. The correctness of that choice can be checked by pressing key C. It will be highlighted if incorrect, and a message will appear at the left of the display indicating how many errors you have made so far!

If a digit selection is incorrect, it may be changed by moving the cursor over it again and keying in another (more appropriate!) digit.

Keep on filling in choices until the whole grid is filled. At any time you may press the “*” key to show the answers, pressing it again to hide them, leaving the display as previously.

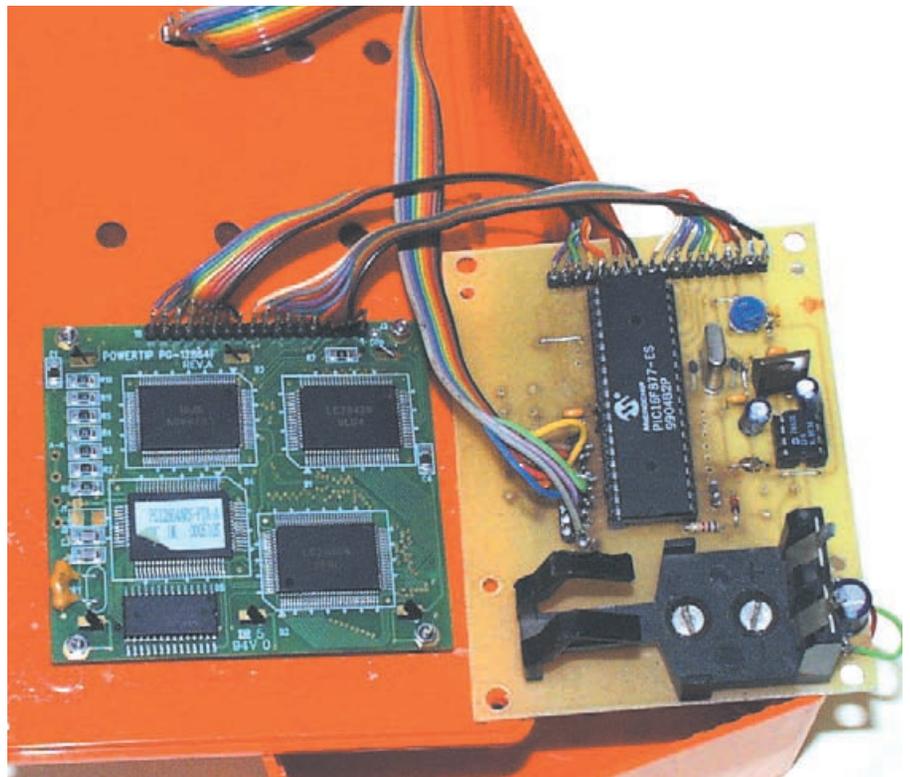
The next game can be selected at any time by pressing key D.

PIC Program

The PIC's program is too complex to discuss in full detail, but a few points are worth highlighting.

The GLCD has its own internal character generator, but this only allows eight lines to be shown, whereas a Sudoku puzzle needs a minimum of nine lines. Consequently, the PIC was programmed to generate a series of digits as bit maps for use with the GLCD. These digits are formed on a 5x5 matrix to make them smaller than the standard ones. They are held in the PIC's EEPROM (electrically erasable read only memory), which retains data even when the PIC's power is switched off.

The pseudo random number generator is based on a technique which Mike Hibbett highlights in the June '06 *PIC n' Mix* column. A basic “seed” value is held in the PIC's EEPROM. Each time the program is run, this seed is extracted, placed into the PRNG, incremented and returned to the EEPROM to be used on the next occasion. The PRNG is updated whenever the program is waiting for a key to be pressed.



Prototype PIC Sudoku model showing multi-coloured ribbon cable wiring from the PCB to the lid-mounted Powertip graphics display module

The “blanks” patterns are also in the EEPROM. There is normally no way to change them. However, readers who have *TK3* can write their own blanks patterns through *TK3*'s make and send EEPROM Message facility.

To do so, first download the existing EEPROM data from the PIC via *TK3*. Make a copy of that file in case you want it again, then amend the blanks data in the copy, and send it back to the PIC. A 0 indicates a blank, and a 1 that the digit should be shown.

It is imperative that the digit locations are not changed in any way. EEPROM locations 67 to 209 are those which hold the blanks data. Examine the ASM file to find their format.

PC Program

The Sudoku PC program was written for the author's own entertainment and is not supplied as an essential part of the *EPE PIC Sudoku* design, but it is hoped that you may also find it to be of interest. It is supplied “as is” without any guarantees.

This first part of the text describing it is in two main parts, notes regarding the PC generation and playing of Sudoku puzzles, and then a description of the PC program which solves most published Sudoku puzzles with

which it has been used by the author. It is not claimed that it will solve all Sudoku puzzles.

The generation of Sudoku puzzles aspect was written prior to designing the published *EPE PIC Sudoku* unit to prove the technique required. The software for the PIC unit is based on this PC program, although there are differences.

Puzzle Loading

There are two ways to load this program with a puzzle, either via the internal generator, or by inputting them from a text file which has been created by the user.

Each time the program is run it defaults to the internal puzzle generator, which gets its data through a random number generator. There are then eight patterns of blank spaces, any one of which it selects at random when the Random Blanks button is clicked to reveal a tick mark. When there is no tick shown, the same blanks pattern is always used, but the numbers themselves are always selected at random.

The resulting pattern of numbers and blanks is then displayed in the left-hand set of 81 boxes. The answers to that puzzle can be shown in the

righthand set of 81 boxes by clicking the Show Answers button. They can be hidden again by clicking Hide Extras. A typical main screen image is given in Fig.6.

Puzzle Playing

To play a selected puzzle, click on the blank box to which you want to add a number to the pattern, then use your keyboard to enter the number you want. Repeat the process until all blanks are filled,

according to the normal simple rules as shown on screen when the Rules button is clicked. Any chosen number can be changed in the same way if you wish. Keying a "0" entirely clears that box of a value. Only numbers you have chosen (in black) can be changed. Those coloured red can never be changed.

At any time during the game you may click Check Results to show which of your choices are correct (providing answers have been included with the same text file). Correct choices are shown with a green background. Red indicates an incorrect choice. Remaining blanks are highlighted in blue. Click Clear Colours to remove the coloured highlights.

If all boxes are filled correctly, you will be told so when clicking Check Results.

A new game may be started at any time by clicking Set New Game, or clicking Random Blanks. Clicking the latter always alternates between the tick being on or off.

You may always click the Key Press ? button to reveal a tick mark, when all subsequent data entries to the main 81 boxes are automatically checked for correctness (again, providing answers have been supplied). Click the button again to clear the tick and checking facility. It is an alternating cycle.

Option Choices

Clicking Show Choices causes the righthand set of 81 boxes to show the

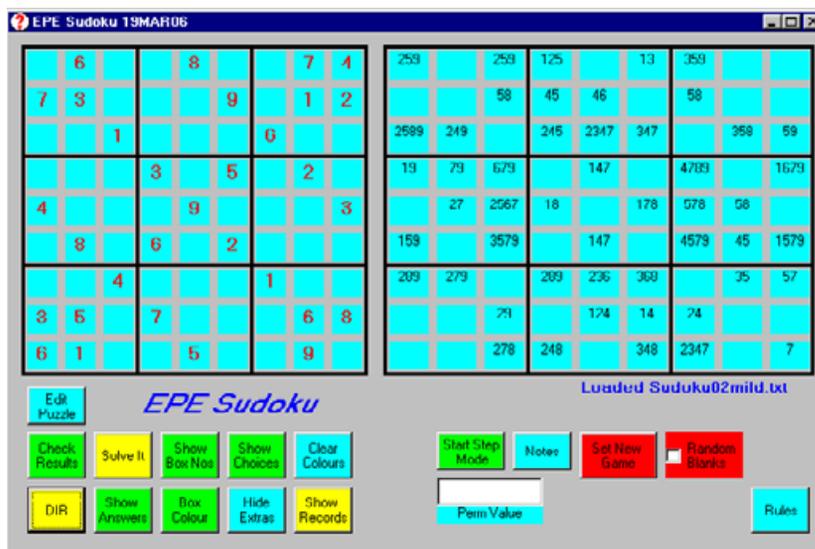


Fig.6. PIC Sudoku's main image function options screen shot

options which are currently available to be used in any main box. You may also key in your own notes into any of the righthand boxes, indicating to yourself which are the options you think might apply. There is a limit of five consecutive digits which can be entered into the RHS boxes. Such notes are over-written when the Show Answers, Show Choices, Show Box Nos or Hide Extras buttons are clicked.

The Show Box Nos button probably has little practical benefit, but shows in the RHS boxes the numbered order of the LHS boxes, from 1 to 81, top left to bottom right.

There are two main choices of background colour you may choose to use for the boxes, light blue or white. Click Box Colour to alternate between them. You may prefer light blue when working on a puzzle. White may be chosen should you wish to do a "screen dump" of the whole screen, pasting it into the Windows Paint facility prior to printing out the image to paper via a printer.

Screen Dump

To use the screen dump facility, jointly press the keyboard Alt and PRNT SCRN keys to place the current image onto Windows' Clipboard. Then click the Windows Start button, select Programs, Accessories and then Paint. Once in Paint, click Edit and then Paste to paste the image into Paint's screen.

The image may be saved to disk via the File/Save As option. The image may be edited in Paint to extract (cut) the area which you want, then click Image/Clear Image and then Edit/Paste to repaste the selected image on screen. Choose Paint's Help button for info on how to extract an area (via the dotted box in its toolbars).

External Puzzles

Externally generated puzzles can be loaded and worked on via the DIR button.

This reveals a Directory screen through which puzzle files can be loaded. There is a selection of puzzles provided with this program, those which the Author used when developing it. Click the Directory screen's Notes button for more info on using it.

You may key in your own puzzles, say from the details published in newspapers etc, and then load that file into the program. Examine one of the existing files for the layout. Basically the format is for the first nine lines to hold the puzzle, with a space (" ") indicating each blank. Each line must be nine characters long (blanks count as characters). If you already have the answers, they can be entered as the next nine lines, again nine characters per line. If you don't have the answers, leave these lines blank (don't enter any data).

To enter puzzle detail, either do so via Windows Notepad through the Windows normal selection option, or go into Sudoku's Directory screen via DIR. At the bottom of the Directory screen is an oblong box through which you can create a blank file. Type in the name you wish to use for this file, then click the screen's Make File button. This creates a file of that name, confirms that it's been created (or telling you that name already exists – it cannot overwrite an existing file). Then it opens the new file in Notepad so that you can enter your data, do so. Save the file in the usual Notepad way when finished. A typical example of file data is shown in Fig.7.

Then click DIR on the Sudoku screen again and select that file to load it as a Sudoku puzzle.

Each file when loaded is automatically checked for whether or not answers are provided. If they are, they are checked to see that they conform to the standard Sudoku rules. If they don't, you will be told so (a typing error intercept routine); re-examine the file through the Edit Puzzle button and amend any errors (duplicated/missing numbers). Resave it and reload.

The file name of the selected program is displayed near the bottom right of the main screen. If it is too long to be fully visible, left-click on it to display a Message box with the full details,

Automatic Puzzle Solving

The other main aspect of the Sudoku PC program is that of attempting to automatically solve a Sudoku Puzzle. The puzzle may be that automatically generated internally by the program, or an external one selected via the DIR button.

With the puzzle you wish to have solved displayed on screen, click the Solve It button. The program uses logic to fill in the blanks on your behalf. It is not claimed that all Sudoku puzzles can be solved in this way, but most of the ones with which it has been used by the author have been solved automatically.

It is worth noting, though, that it has been found that some more difficult puzzles may have more than one perfectly legitimate solution, each of which conforms to the basic Sudoku rules, but which does not necessarily match the published answers.

This is particularly so with puzzles in which at some stage there is a choice of numbers which could be placed in a box, but there is no logical indication of which is the correct choice of two numbers, or of the correct route which should be taken following that choice. With some Sudokus encountered, several points have occurred at which such a choice must be made, and then later on another choice of options is presented at which further decisions must be made, and sometimes yet more decision points further on.

With one puzzle there were at least four levels of options at which a choice was needed. In-depth analysis by the author failed to reveal any way in

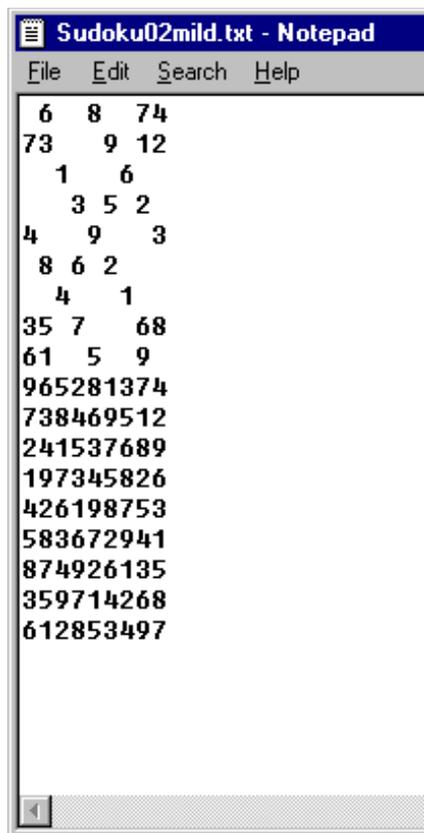


Fig.7. An example file data image

which the choices could be logically made. In all respects the grid usually could still be filled completely, but the results failed to correspond with the published answers, although such answers had been reached by the program in its various permutations of the options.

It is worth commenting, though, that most Sudoku puzzles tried could be solved in one pass of the program, without any dual choices being encountered.

Permutations

The program has been written so that when choices are presented, it goes into a cycle in which all permutations of dual choices are performed, with the results put out to a file on the hard drive for later examination by the user.

During this process, each set of options is examined to see if it would contravene the logical rules of Sudoku. If they do they are ignored. There are two conditions which are recorded to the file, those which result in the full grid being filled, and those in which the result is an equal number of blanks

remaining compared to the number of unused further options which are possible.

The file in which these results are recorded is shown by clicking the Show Records button, which loads the file into Notepad for viewing. Sometimes the file may be too long for Notepad, in which case the choice of opening it through Wordpad is presented. If so, accept the offering. The file shown is always the last one created when permutations are encountered. The file name to which it refers is given at the top of the first page.

Only where there is a choice of one or the other of two values is the choice recorded and processed. Choices having multiple options greater than two are ignored as these will ultimately reduce as the program progresses. The program assesses how many permutations there are to process all the dual choices available. If there are more than 16 you are asked if you want to continue or abort at this point. Processing too many permutations would take too long for slower PCs, although with one of the author's faster PCs several complete permutations of choices occur per second.

With one puzzle there were first 128 permutations to begin with, later resulting in a choice of 2048 permutations offered. Another puzzle resulted in 524,288 permutations being offered (2 to the power of 19). As it turned out, there was only one result of that vast series which was worth pursuing further by manual examination – and then it was the second choice of the dual pair pointed to which was correct!

On another occasion, the indication of filled and unused options was equal at a Perm value of 47, yet analysis of the published answer revealed that a Perm value of 43 was the correct route, but resulting in further choices having to be made along that route.

Grid Copies

Where permutations are encountered you are asked if you would like to make a copy of the grid as it now stands before the permutations are performed. This is created as a separate file with an extension number relevant to the base file name and which can be loaded later to try out and examine the results of suggested possibilities of choice. Normally, the same recording file name is used on each occasion, overwriting the data from a previous

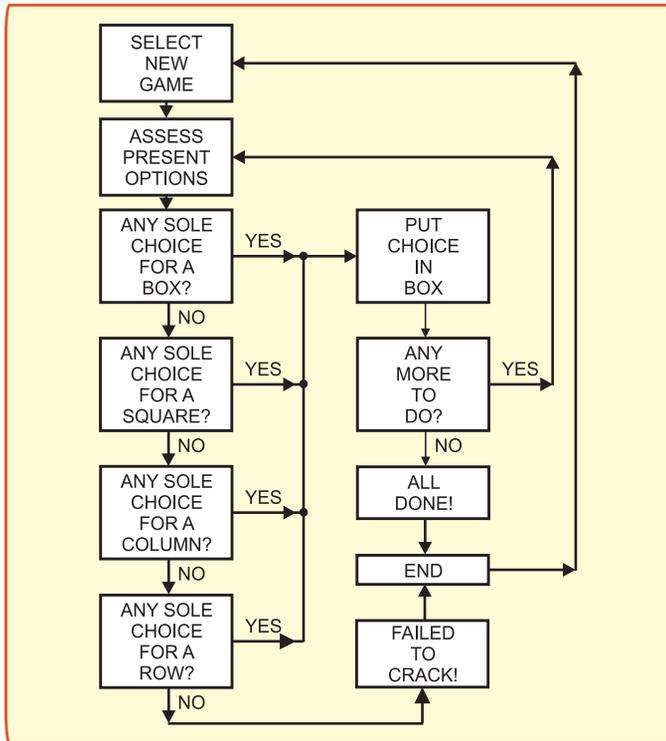


Fig.8. Sudoku's basic puzzel-solving program flow chart

Resources

The source code for both the PIC and PC programs is available for free download from the *EPE* website, access via www.epemag.co.uk. It is in the Downloads section under PICs/Sudoku.

The PIC's ASM code was written in the TASM dialect, but may be translated to the MPASM format by those who have TK3, and the wish to make changes to the code.

The supplied HEX file is in the MPASM format and does not need changing, If you wish to program your own PIC, simply load the code "as is" into your PIC via your PIC Programming software and hardware.

Pre-programmed PICs can be bought from Magenta Electronics (contact details as in their advert in this issue).

The PC program was written in Visual Basic 6 (VB6). It is supplied both as the source code files, and a standalone run file (**sudoku.exe**). The latter does not need VB6 to be installed on the PC, just double-click the EXE's icon to run it.

Copy all the supplied VB6 files into a new folder named Sudoku (or any name of your choosing) before running the EXE.

run. If you want to keep a particular file's details, make a copy of that file and rename it as you wish.

Having selected a choice from those permutations listed, enter that permutation number into the Perm Value text box and press <Enter> on the keyboard. This reloads the file and applies just that permutation to the choices. The binary value of the permutation's decimal number is used, in which each bit applies to a particular choice pair, 0 selecting the lefthand

value, 1 selecting the right. During the processing of multiple options, the Perm value is incremented by one for each permutation, to the full quantity of the permutations available (always 2 to the power of the number of pairs found).

Step Mode

When using the auto-solve facility, a step-mode can be entered so that each stage of solving can be examined. Having loaded a required puzzle file,

click Start Step Mode, to reveal a Step button. The program then pauses each time a process results in a box being filled, highlighting the background colour of that box. Having examined the result, click Step again to move on to the next stage.

So, have fun with this program. It kept the Author engrossed over about three month's writing it. Excellent value and entertainment!

The program's basic Sudoku solving flow chart is shown in Fig.8. **EPE**

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TERAHERTZ: THE ANTI-TERRORISM SOLUTION

Sometimes described at the last unexplored frontier in electronics, terahertz frequencies offer considerable promise for combating terrorism, medical use and other applications, as Mark Nelson describes.

If the tribulations of terahertz and the infamous "terahertz gap" have passed you by, you're probably in good company. Just as people had a pretty hazy notion of short waves back in the early days of broadcasting, most of us have the same kind of disinterest in the terahertz region right now.

Soon this may change. Recent developments in ultra-fast pulsed laser technology look set to generate bright prospects for the commercial exploitation of this dingy domain. So where does this terahertz territory lie and what are those unique characteristics that make it such attractive territory for prospectors?

Cambridge-based research and development company TeraView Ltd provides a straightforward description, explaining that the Terahertz region is where radio waves and light meet. Terahertz (1THz = 10^{12} Hz) radiation occupies the electromagnetic spectrum between 100GHz (10^{11} Hz), just above the microwave region where satellite television and mobile phones operate, and 30THz (3×10^{13} Hz), adjacent to infrared frequencies used in devices such as television remote controllers. We're talking about light waves but the frequencies are invisible to the naked eye.

Mind the Gap

The expression "terahertz gap" refers to the fact that until recently there were no bright sources of light or sensitive means of detection available for this frequency range. Conventional microwave sources do not work fast enough (i.e. at high enough frequencies) to produce radiation efficiently in these frequencies, whilst laser diode sources that might work adequately have been limited by thermal effects, says the company.

However, recent advances in ultra-fast pulsed laser technology have led to the generation and detection of broad-bandwidth terahertz light for the first time. This dramatic advance was made possible by applying new concepts in semiconductor physics to these commercially available laser systems.

TeraView Ltd, spun-out of Toshiba Research Europe in April 2001, is one of the new breed of companies looking to fill the gap. It aims to apply its proprietary Terahertz Pulsed Imaging (TPITM) technology platform to exploit the many medical and non-medical applications that exist thanks to the unique imaging and spectral characteristics that lie in the terahertz light spectrum.

Terrorists Take Note

What makes terahertz radiation so special is its application in non-destructive and non-harmful imaging. In other words, it works like an X-ray but without any health risks,

making it ideal for scanning passengers at airports and railway stations for terrorist weapons and contraband.

The reason, as a report on the THzNetwork website explains, is because although terahertz waves can penetrate materials such as paper, fabrics, plastics, wood and human tissue, they are blocked by many drugs and explosive compounds. This makes the invisible light potentially very useful for security or forensic scanning, spotting drugs and explosives concealed in packages or under clothes. Once perfected, scanning devices of this kind could become a standard fixture at airports and stations, in mail-sorting offices and police stations or deployed in mobile forensic labs.

A demonstration of how this could work was given a few months ago by Professor Malcolm Dunn of the University of St Andrews in Scotland, when he showed off a prototype scanner to a meeting of forensic technologists in London. Although his concept model is "the size of a ski-boot box", Dunn says he is hoping it could ultimately become no bigger than a shoebox.

The chief reason why miniature devices do not exist yet is the technology used to produce these waves. One way, says THzNetwork, is by firing a "pump laser" into a material known as a parametric generator, usually the chemical lithium niobate. Dunn and his team, it continues, created a compact terahertz generator by installing the parametric material inside the machinery that generates the pump laser, rather than outside. This also makes the device more efficient, they say, as less strength is lost from the laser source. And because it will be years rather than months before a compact scanner can be realised, Dunn and his team are now seeking industrial backers to develop a prototype that can be tested in the field.

Medical Uses

An important characteristic of scanning with terahertz light is its ability to distinguish different materials. Many common substances and living tissues are semi-transparent and have "terahertz fingerprints", permitting them to be imaged, identified and analyzed. Moreover, the non-ionizing properties of terahertz radiation and the relatively low power levels used make this a safe process. Medical applications of this technique present enormous potential savings to surgeons and health providers.

Conventional body imaging methods, dedicated chiefly to scanning for cancer, are not particularly effective for problems in the epithelium, the area near the surface of various tissues located either inside or on the outside of the body. This is where 85 per cent of

all cancers lie. TeraView's TPI technology is particularly suited to detecting early-stage epithelial tumours such as skin, breast, prostate or lung cancer.

Tooth decay, one of the most common human disorders, is another potential beneficiary. X-rays, one of the accepted methods used to detect decay, reveal the problem only at a relatively late stage because of the absence of visual features on the tooth surface. Terahertz imaging, on the other hand, is able to distinguish between the different types of tissue in a human tooth by exploiting the differences between the refractive index in tooth enamel and dentine.

Not New

There's nothing new about terahertz radiation of course; the novelty is these new and more effective technologies for exploiting it. For instance, the notion of using terahertz waves to scan for drugs and bombs was already recognised five years ago. At that time a team at Japan's RIKEN Laboratories demonstrated a terahertz generator for this very application. According to THzNetwork, however, their device was huge and cumbersome because the way it created terahertz waves required "a clunky array of lasers".

Other applications were under consideration even earlier. Back in the 1980s the maverick inventor Norman Rutherford set up a company called THz Technology to manufacture lightwave communication devices that could substitute for microwave links or cable circuits. The municipal authorities in Nottingham used his equipment to link surveillance television setups from a number of residential tower blocks to a central monitoring station.

Norman Rutherford had a track record of developing new technologies ahead of their time. Even if you don't remember his name, you may just recall the "Telcan" home video recorder that he and business partner Michael Turner launched back in 1963; long before Philips and the Japanese entered the home video market.

The Telcan recorder used standard open reel quarter-inch recording tape. This was run at the mind-boggling speed of 120 inches per second past a fixed head in a recorder mounted on the top of a television receiver cabinet. The tape carried two 15-minute tracks but delivered sub-standard images.

The inventors earned their place in history but little else, as Telcan was never a commercial success. The components manufactured for factory assembly were eventually shipped to the USA and sold as construction kits for a hobby magazine project.

Multiplexing – A Trick or Two

ONE of the great features of the Microchip range of processors is the variety they offer – around 300 variations on our last count, ranging from tiny 6-pin SOT-23 packages up to 100-pin devices offering 70 I/O pins. For the hobbyist that choice rapidly shrinks when you take into account what you can actually buy, and how skillful you are at soldering: few of us have the equipment to place a 100-pin QFP package onto a PCB when the pins are spaced 0.5mm apart!

PIC Choices

The choices available to us still remain high though, and one of the main challenges when starting a new project is trying to choose the best part for the job. Does it have the right number of I/O pins? Does it have the peripherals I need? Will it run fast enough? Does it work at the voltage I want to operate at? Can I solder the darn thing?

While one can simply throw the largest part available at the problem, that doesn't satisfy the desire to "do the job right" – make it as small as possible, low power and cheap. And sometimes this may be a necessity: designing a handheld game or remote control that runs the batteries flat in an hour isn't going to be very rewarding!

Thankfully Microchip and others provide us with that range of choices to make these designs possible.

Once Upon A Time

It wasn't always this way; in the '70s and '80s microcontrollers were very much like microprocessors: you might get a few I/O pins and a serial port, but if you wanted any more you were on your own. A classic example was (and indeed, still is) the 8051, a processor that pretends to have lots of I/O, except that you need most of them to address your code in an external ROM. So we should be thankful that the problem has been, to a great extent, taken away from us, and now that our devices are equipped with on board Flash, RAM in the kilobytes range and a multitude of peripheral features we can relax and concentrate on coding.

More often than not though, you discover that your perfect processor is one I/O pin short of meeting your requirements, or perhaps it's not quite quick enough to generate the serial bit stream you want. When this happens, you discover that the next processor in the family has an additional 30 I/O pins, costs twice as much and cannot be soldered. Or worse, your supplier doesn't stock it!

Like most engineering tasks, solving this problem is a case of making the most of what you have, and examining your project in a bit more detail. The task is a balance between reduction in pin count verses code complexity. Can I live with the extra processing time? Can I cope with the restraint

that I may not be able to refresh the LCD while processing a key press?

One of the nicer points about some of the smaller parts like the PIC12F629 or the PIC16F688 is that they operate at very low voltages, and are well suited for running of 3V Lithium coin cells. But their I/O count is low, so let's take a look at some of the possibilities for making the most of what we have. These ideas are very general and are not tied to any particular processor, so you are free to use them where you wish. We start with a common peripheral, keys.

Keyed Up

If you need lots of keys, say for a numeric or telephone keypad, then you are going to need lots of inputs. Fortunately there is a simple solution to this, one that keypad manufacturers are well aware of: *multiplexing*. Most 12 and 16 button keypads are designed to be multiplexed. A typical example is shown in Fig.1. Four input pins are required, pulled up in the normal fashion. Three output signals, normally driven low, are used to scan columns of keys, looking for a change from the default of "all ones". When a change is detected – one of the inputs goes low – you raise each output signal in turn until the input returns high. This gives you the row and column of the button. Note that in Fig.1 the bottom "output" signal is actually tied to ground, since it does not need to be toggled. This means that a 16 button keypad can be implemented with just seven I/O pins.

Within many PICs there is a feature that can be particularly useful when using keyboards like this, called "Interrupt on Change". Typically implemented on PortA or PortB, it allows an interrupt to be generated when the level on a collection of inputs changes. This can be put to great use with battery powered equipment that only needs to run when a key is pressed, since you can put the PIC into sleep mode and wait for a keypress to wake it up. For an example of how this can be done, look at the *Car Computer* source files in the Downloads page on the *EPE* website (via www.epemag.co.uk).

ADC Trick

If you are really short of I/O lines for your key inputs, there is a rather cute trick that can be used if you have an analogue to digital port pin available. Many PICs implement 8-bit or 10-bit ADCs, many with multiple inputs. By using a resistor divider chain it is possible to have several keys – up to 10, maybe more – on a single input. The trick is to choose values of resistors (taking into account the resolution of the ADC and the tolerance of the resistors)

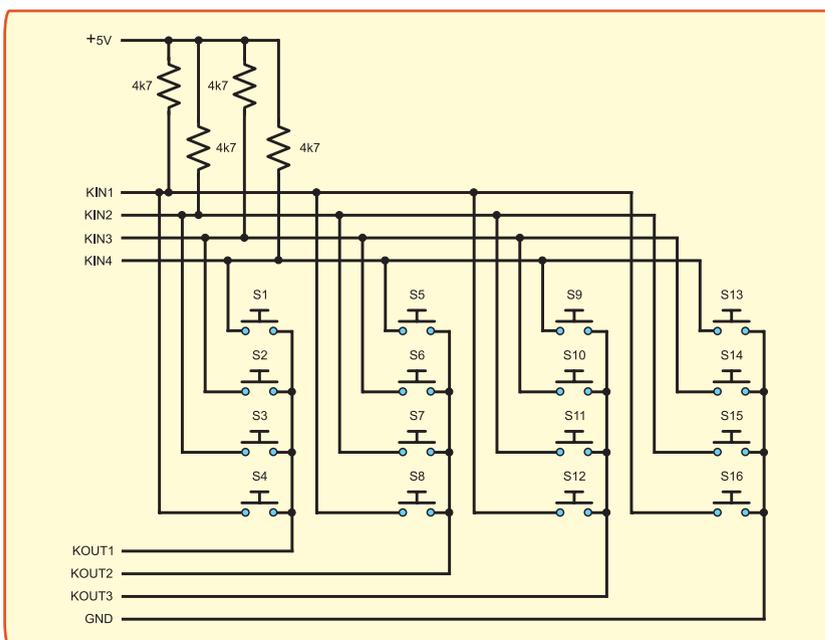


Fig.1. Multiplexing a 4 x 4 keypad

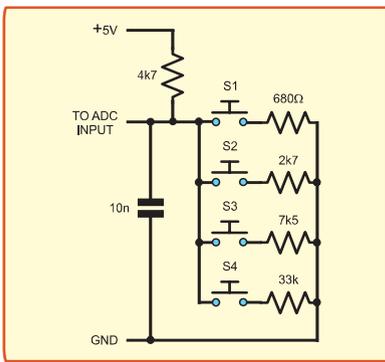


Fig.2. ADC monitoring for four keys

that provide unique no-overlapping voltages. It then becomes a simple case of sampling the ADC input periodically and performing a series of comparisons on the analogue value to determine which key is pressed.

In Fig.2 is shown an example with four keys, which will require just four byte subtractions to identify which key if any is pressed. The resistor values have been calculated on the basis that the ADC has been setup for 8-bit resolution and should have 5% tolerance.

As you can see, there is a trade-off for the reduction in pin count – increased code complexity. The increase is marginal however, so if you have the need to free up a few I/O lines, the only cost is a few extra resistors and a little brain power!

Going back to the idea of multiplexed keys, bear in mind that you are not limited to having keys on the 4-bit input “bus”; you can have other things too. Fig.3 shows how you can multiplex a keyboard with, for

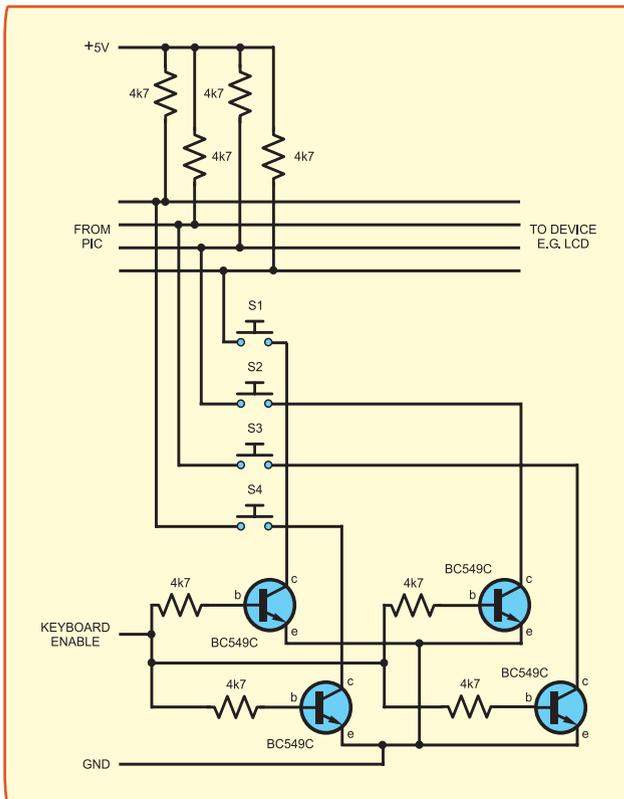


Fig.3. More sophisticated multiplexing for four keys and an LCD

example, the data bus of an LCD. When the “Keyboard Enable” signal is low, the four transistors are switched off, so pressing a key will not affect the data on the 4-bit bus. When “Keyboard Enable” is high, however, pressing a key will pull the corresponding input low. The trade-off here is that the keyboard cannot be tested while the other device on the bus is being accessed. Again, with a little thought you can see in the case of an LCD update that this time is so short you will be able to poll the keyboard without any perceivable delays. Even this example can be improved upon; if you are using an I²C device, consider using the “Keyboard Enable” signal as the I²C clock line. It does work!

Debouncing

A final note about keyboard routines: you must “debounce” them, whichever technique you use. When you detect a key has been pressed, wait a short time, then check again. You should do the same on key release to minimise the chance of producing double-key events by accident. The debounce time can be quite long, and varies significantly between key types. For example the small PCB mounting “click feel” buttons have a much cleaner switching action than the panel mounting barrel switches, and therefore a shorter debounce time. Keys that have a positive click response will require a debounce time typically around 10ms to 20ms, whereas the larger keys may require up to 100ms. You will find that you need to tinker with the debouncing to get a good response.

An example of how to scan and debounce a 12-button keypad is shown in the source file **wakeup.asm** which can be found in the *PicNMix* section of the Downloads area on the *EPE* website (address as earlier). This example also demonstrates how the “Interrupt on Change” feature may be used to enable the PIC to be placed in ultra low power sleep mode until a key is pressed.

You will notice that the keyboard code is quite long; while this is only an example and may be optimised, it demonstrates the cost of multiplexing: increased code complexity.

The I²C bus is an excellent way of expanding a PIC’s capabilities. Although the price will inevitably reduce, don’t expect the packages to get any easier to solder! For now, let’s count ourselves lucky that we can still purchase DIL ICs!

EEPROM, there are many interesting expansion devices designed for it, including parallel I/O expanders and even dtmf/tone generators like the PCF8575 and PCD3312. Always bear in mind the cost of your additional hardware; it may be cheaper (although not easier) to just add another PIC, implement an I²C slave bus and have it provide all the extra functionality you need. Even a few logic chips can sometimes be more expensive than a simple PIC.

If you need to drive a number of outputs, but only one will be active at any one time, consider using a BCD to Decimal converter like the 4028. This IC can take three or four inputs and drive eight or ten outputs.

Logic ICs like the 74HC373 and 74HC374 provide a means of “latching” up to 8-output signals, ideal for driving large numbers of LEDs. The 74HC373 has a “Latch Enable” pin that will transfer the contents of its inputs to the output pins; the outputs will remain in their last state when the LE pin is de-asserted (this is referred to as a *transparent latch*). The 74HC374 is very similar except that data is only transferred to the outputs on the rising edge of the CP input pin. Several of these ICs can be paralleled together to provide a large number of outputs, each chip only requiring a single control signal.

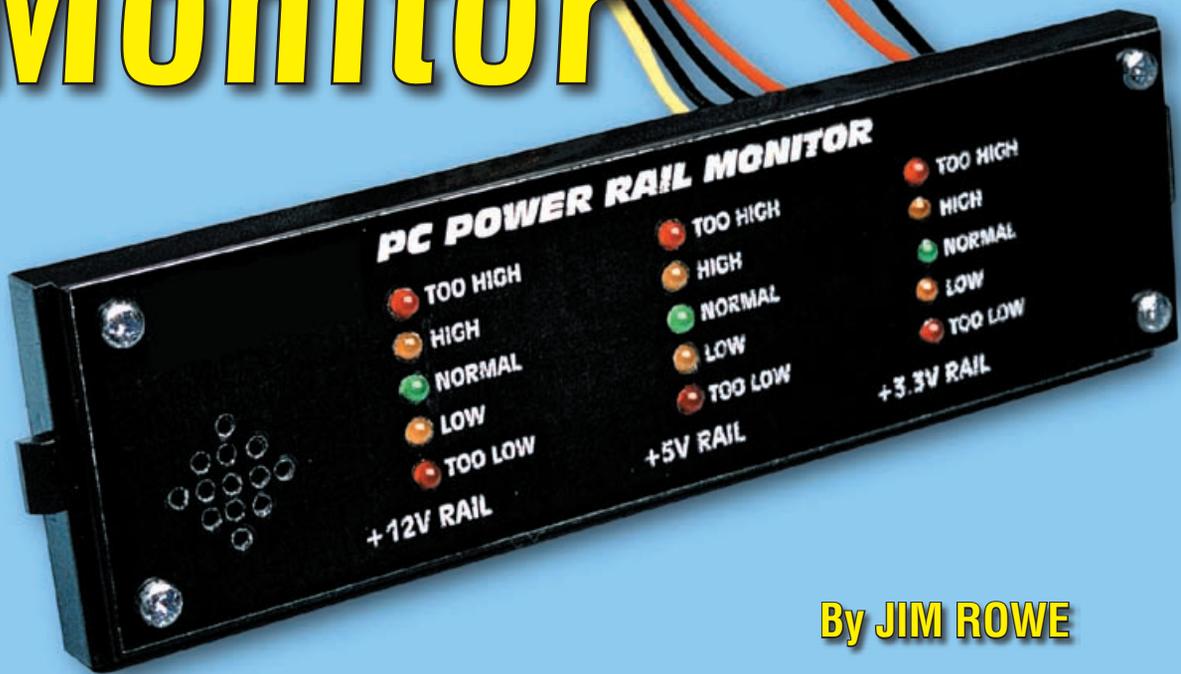
Ripple Counter

Another useful logic device is a “ripple counter”, which can be used to “count” on a series of output lines. These devices are ideal for generating address lines to external parallel bus memory such as EPROM or SRAM. The 4020 CMOS IC is a 14-bit counter that only requires two input signals: a reset signal to clear the outputs to zero, and a clock input to perform the count. Although it has only 14 outputs it can be used in conjunction with other PIC outputs to form an address bus of any size – you can even use several of them together. The drawback of this is that it is slow; to set all output signals high you will have to send 16383 pulses to it, which could take several milliseconds. If, however, fast data access is not an issue, it could save you 12 I/O pins!

The ultimate tool for expanding a microcontroller’s I/O capability has to be the Programmable Logic Device (PLD) or its big brother, the Field Programmable Gate Array (FPGA). These ICs contain large arrays of logic cells that can be “wired” together, either through fuse programming (in the case of PLDs) or by downloading to on-chip EEPROM or SRAM (in the case of FPGAs). FPGAs can hold hundreds of thousands of undedicated logic blocks, enough to be able to implement several microcontrollers inside, and provide hundreds of I/O pins.

The downside? They are expensive. Devices like the PIC microcontroller have displaced the smaller PLDs, and the larger FPGAs are, at the moment at least, very expensive. Although the price will inevitably reduce, don’t expect the packages to get any easier to solder! For now, let’s count ourselves lucky that we can still purchase DIL ICs!

PC Power Monitor



By JIM ROWE

Does your PC crash intermittently? Maybe the hard disk or something else within the machine is not getting the right rail voltage but how would you know? This unit lets you easily monitor the main DC power rails – it clips into your PC and has three LED bargraphs and an alarm to indicate if any of the supply rails swings too high or too low.

AS WELL AS HAVING to provide a number of different DC voltages, your PC's power supply has to deliver an appreciable amount of power – hundreds of watts. This is the main reason why switchmode power supplies are used, because they're much more efficient than the older "linear" type of power supply. However, they're also more complex and this tends to make them slightly less reliable.

Also, some PC power supplies really do have trouble supplying all that current and sometimes they fail to deliver just the right voltage at critical times – like when you are in the middle of a big download off the Internet. If you build this unit, it will give you a visual and audible warning of the problem so that you can have it fixed.

Of course, apart from data loss, if a PC's power supply does happen to develop a fault, this can have quite

disastrous (and costly) consequences. Replacing a blown CPU chip can involve hundreds of pounds, while replacing blown DIMM modules can be almost as costly.

Fortunately, many of the latest PC power supplies incorporate special circuitry to detect when any of the main power rail voltages fail or go high and shut down the supply if such a fault occurs. However, such protection circuitry does not always do the job, so this monitoring circuit can still be a worthwhile addition. It's good to know that if a fault develops, you'll be warned straight away so you can "pull the plug" before much damage is done.

So that's the idea of this project. It's a low-cost, easy-to-build circuit which can continuously monitor the main power rails in a PC and display their status via columns of LEDs. At the same time, whenever it senses that any of the rail voltages has moved out of the safe operating range (too high or too low), it sounds a small piezo

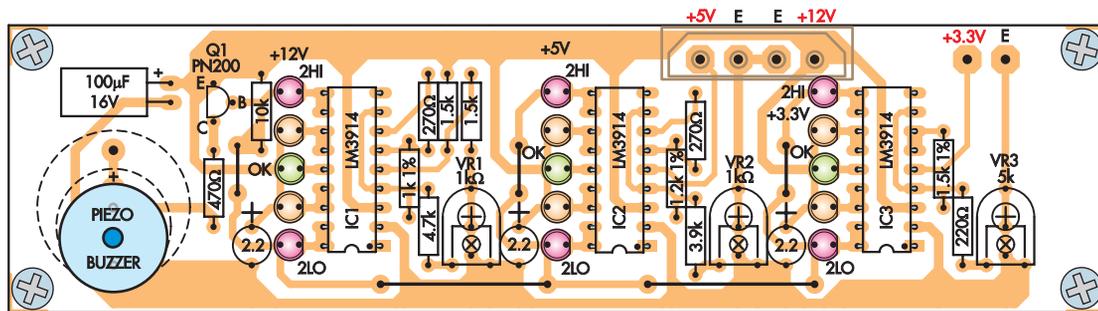


Fig.2: install the parts on the PC board as shown here, taking care to ensure that all polarised parts are oriented correctly. Note that trim pots VR1-VR3 are mounted on the copper side of the board.

Although each LM3914 has 10 output lines, designed to drive 10 LEDs in a normal dot or bar type display,

here we use only nine of the outputs to drive a total of five LEDs per chip. Output O6 in the centre of each chip's voltage range is used to drive the green "OK" LED for that power line, while the remaining eight outputs are connected as four tandem pairs to power the "HIGH", "TOO HIGH", "LOW" and "TOO LOW" LEDs for each supply line.

voltage if you prefer. We recommend that you do monitor the +3.3V line though, because it's easier to do this and therefore less risky.

How do we do the alarm sensing? Ah, that's easier than you'd think. As you can see, the three LEDs which are used to indicate "OK", "HIGH" and "LOW" in each monitor are all connected directly to the +12V line. So when any of these LEDs is illuminated (because there's no serious problem), nothing else happens.

On the other hand, the LEDs at the top and bottom of each monitoring range (ie, LED1 and LED5, etc) are not connected directly to +12V but instead to an "alarm sense" rail which in turn connects to the +12V rail via the base-emitter junction of transistor Q1.

This means that if any of the ICs happens to detect a "TOO HIGH" or "TOO LOW" condition and lights one of these LEDs, this draws base current through Q1 and turns the transistor on. As a result, it conducts collector current and turns on the piezo buzzer. Nifty, don't you think?

Construction

All the components for the power monitor are mounted on a compact PC board measuring 146 x 38mm and coded 576. This board is designed so that it can be mounted directly behind a 5.25-inch drive blanking plate, with the status indicator LEDs protruding via matching 3.5mm holes. An array of even smaller holes at one end of the panel allows the sound from the piezo buzzer to emerge.

Fig.2 shows the parts layout. All parts are mounted on the top side of the PC board except for the three calibration trim pots (VR1-VR3) and the PC board terminal pins, which are used for the power input connections.

Table 1

PROCESSOR SUPPLY VOLTAGES

Motherboard Setting	Processor	
'VRE' (3.5V)	Early Intel Pentium, AMD K5, Cyrix 6x86	
'STD' (3.3V)	Later Intel Pentium	
'MMX' (3.3V & 2.8V)	Intel MMX Pentium	
'3.2V' (3.3V & 3.2V)	AMD K6	
'2.9V' (3.3V & 2.9V)	AMD K6, Cyrix 6x86/M-II	
'2.4V' (3.3V & 2.4V)	AMD K6-2, K6-3	
'2.45V' (3.3V & 2.45V)	Cyrix 6x86LV	
AUTO VOLTAGE SELECTION VIA VID CODING*		
10000 (3.5V)	Intel Pentium Pro (4 VID pins) in Socket 370	
10001 (3.4V)		
10010 (3.3V)		
10011 (3.2V)		
10100 (3.1V)		
10101 (3.0V)		
10110 (2.9V)		
10111 (2.8V)		
11000 (2.7V)		CPU voltage derived from motherboard 3.3V line
11001 (2.6V)		
11010 (2.5V)		
11011 (2.4V)		
11100 (2.3V)		
11101 (2.2V)		
11110 (2.1V)		
(11111= No CPU)		
00000 (2.05V)	Intel Pentium II, Celeron, PIII (5 VID pins) in Slot 1, Pentium 4 in Socket 423 & 478; also AMD Athlon & Athlon XP in Slot A and Duron in Socket A	
00001 (2.00V)		
00010 (1.95V)		
00011 (1.90V)		
00100 (1.85V)		
00101 (1.80V)		
00110 (1.75V)		
00111 (1.70V)		
01000 (1.65V)		CPU voltage derived from motherboard 3.3V line (or auxiliary 12V for later P4 processors)
01001 (1.60V)		
01010 (1.55V)		
01011 (1.50V)		
01100 (1.45V)		
01101 (1.40V)		
01110 (1.35V)		
01111 (1.30V)		

*Voltage selection by four or five coding pins on CPU itself

The location and orientation of all of the components can be seen clearly in the board overlay diagram. As usual, fit the wire links first, so that you don't forget them. The three short vertical links can be made from tinned copper wire or resistor lead offcuts, while the two longer horizontal links (near the bottom edge of the board) should be made from insulated hookup wire.

Once the links are in, fit the six PC board terminal pins that are used for the input connections. As mentioned earlier, these are fitted from the rear of the board and soldered on that side as well.

The fixed resistors can go in next, making sure that you fit each one in the correct position. That done, install the three 2.2µF tantalum capacitors – they all mount with their positive leads towards the top of Fig.2. The last capacitor to fit is the 100µF electrolytic but note that although it mounts on the front of the board as usual, it is mounted on its side to provide clearance when the board is mounted behind a blanking plate or box panel. This capacitor is also mounted with its positive lead uppermost.

The next components to fit are transistor Q1 and the three LM3914 ICs. Note that the ICs all mount with their notched (pin 1) ends facing downwards, as shown in Fig.2.

Fitting the LEDs

You're now ready to fit the 15 LEDs. These are all 3mm-diameter types and there are three green LEDs, six orange LEDs and six red LEDs as shown.

They should all be mounted with 10mm lead lengths (ie, the bottom of each LED should be 10mm above the board), so they they'll later all protrude evenly through the holes in the front panel when the board is

mounted behind it. The easiest way to do this is to cut a short strip of cardboard 10mm wide and then fit each column of LEDs with their leads straddling the cardboard strip. That way, they'll all be automatically set to the correct height before their leads are soldered. It's a simple trick but it works well.

By the way, notice that each LED is fitted with its cathode (flat side) towards the right.

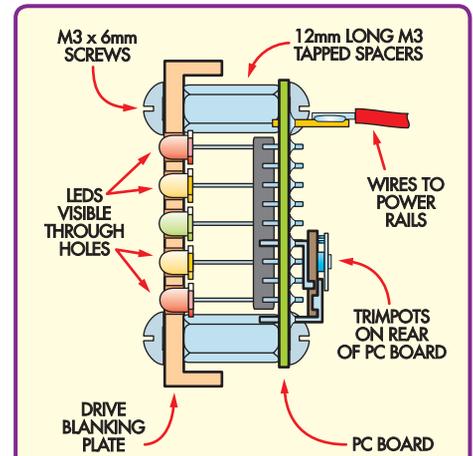
The last component to fit to the front of the board is the small piezo buzzer. This mounts directly to the board via two pins. Because there are several different types of buzzers available, with different pin spacings, we've provided extra pads and holes on the board for flexibility. Note that the buzzer's negative pin should always go through the bottom hole.

Installing the trimpots

The final components to fit are the three trimpots, which mount on the back (ie, copper side) of the PC board. This is done so that they're easy to adjust from the back when the board is mounted on a blanking plate or panel. Make sure you use the 1kΩ trimpots for VR1 and VR2, and the 5kΩ trimpot for VR3.

Once the board is fully assembled, you can place it aside for a few minutes while you drill the holes in the blanking plate or box panel. You can use a photocopy of the front panel artwork (Fig.5) as a drilling guide and template. Note that the holes for the LEDs and the four board mounting holes (in the corners) are all 3.5mm diameter, while those for the buzzer "grille" are 2mm in diameter.

Once the holes in the blanking plate have all been drilled and deburred, you might want to attach another



SIDE VIEW SHOWING ASSEMBLY DETAIL

Fig.3: this diagram shows how the PC board is secured to the rear of the blanking plate using 12mm spacers and M3 x 6mm machine screws. The LEDs protrude through matching holes in the blanking plate – see text.

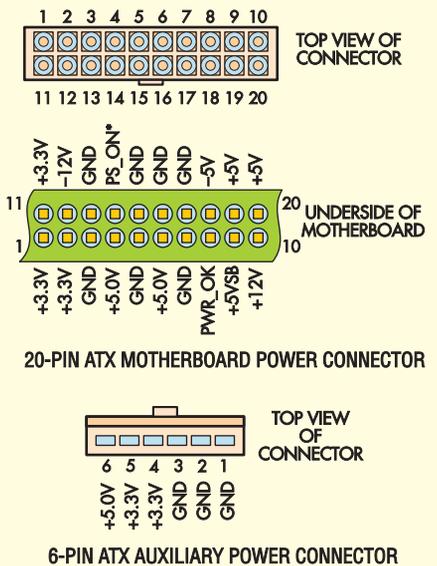


Fig.4: here are the pin connections for a 20-pin ATX motherboard power connector and for a 6-pin ATX auxiliary power connector which is sometimes used on older motherboards.

Table 2: Resistor Colour Codes

No.	Value	4-Band Code (1%)	5-Band Code (1%)
1	10kΩ	brown black orange brown	brown black black red brown
1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
1	3.9kΩ	orange white red brown	orange white black brown brown
3	1.5kΩ	brown green red brown	brown green black brown brown
1	1.2kΩ	brown red red brown	brown red black brown brown
1	1kΩ	brown black red brown	brown black black brown brown
1	470Ω	yellow violet brown brown	yellow violet black black brown
2	270Ω	red violet brown brown	red violet black black brown
1	220Ω	red red brown brown	red red black black brown

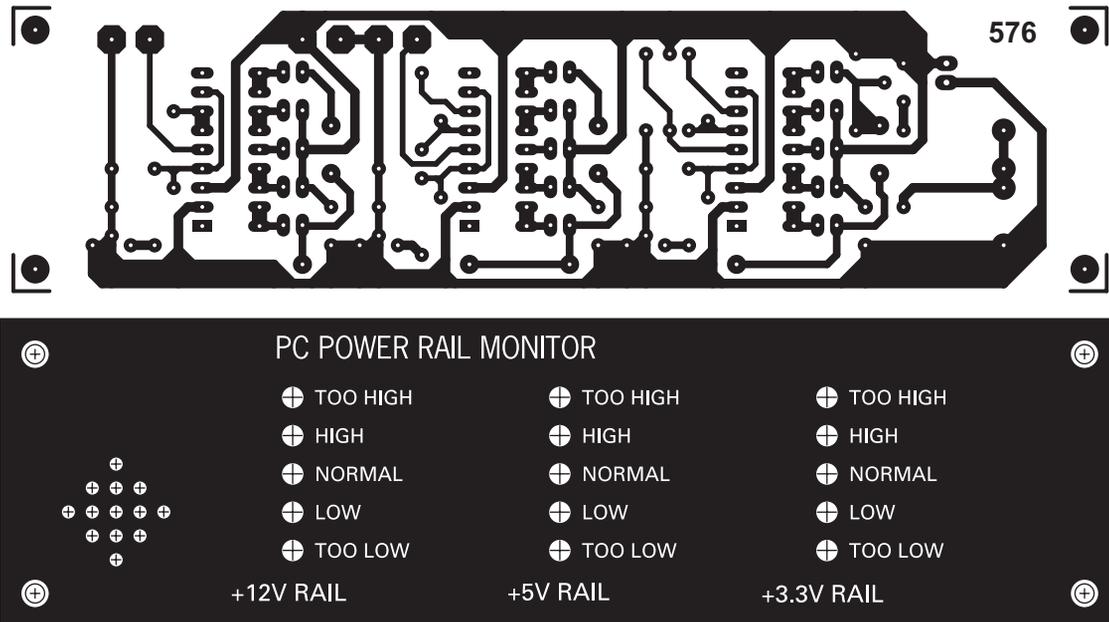


Fig.5: here are the full size artworks for the PC board and front panel. Check your board carefully for defects by comparing it against the above pattern before installing any of the parts.

photocopy of the artwork to the front using double-sided tape, so it will dress the panel up and give a professional look.

The PC board assembly can now be mounted behind the panel on four 12mm-long M3 tapped spacers and secured using 6mm-long M3 machine screws. Fig.3 shows the details. We suggest that you also fit a star lock-washer under each of the rear mounting screws, to ensure that they don't loosen with vibration.

Connecting it up

The easiest way to connect the +12V, +5V and earth (ground) inputs of the monitor board to the corresponding power rails of the PC is by cannibalising the 4-pin plug and one set of wires from a disk drive "Y adaptor" power cable. These are readily available from computer stores and electronics suppliers. The free ends of the wires are then soldered to the four main input pins on the monitor board but make sure you connect them correctly: the

red wire goes to the +5V input, the yellow wire to the +12V input and the two black wires to the centre ground pins.

The 4-pin plug can then be mated with one of the power connectors in the PC, to make all these connections.

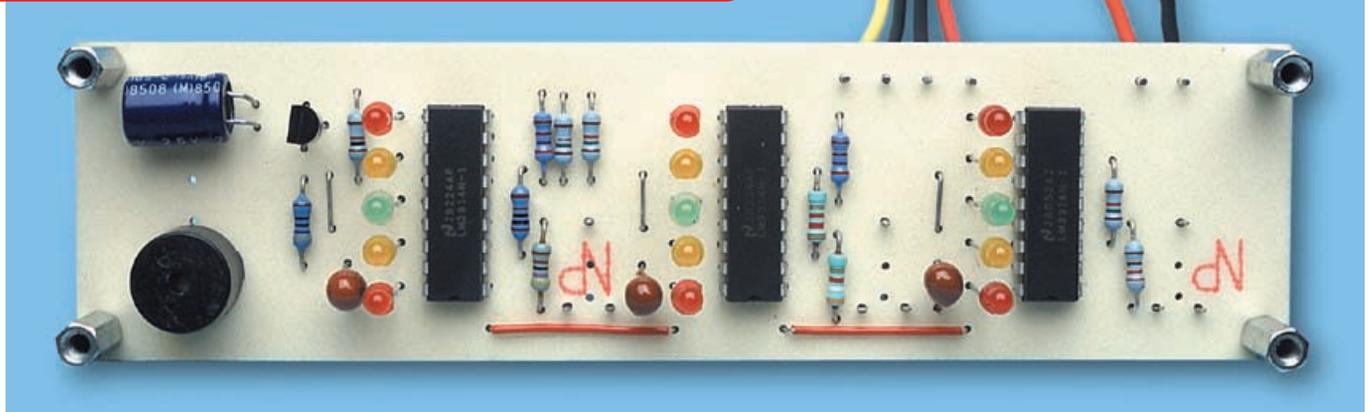
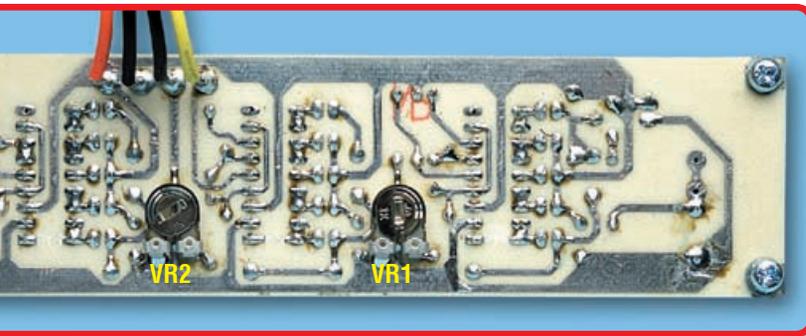
The connections to the PC's +3-3V rail are a little trickier but simple and safe enough if you're careful. To do this, solder a pair of insulated hookup leads about 500mm long to the two remaining pins on the monitor board, using wire with orange insulation for the +3-3V lead and wire with black insulation for the ground lead. That done, remove the cover from your PC so you can gain access to the underside of the motherboard, just below the main power connectors.

In most PCs you should find that the main DC power lead from the power supply mates with the motherboard using a 20-pin Molex type plug and socket (called the ATX power connector). If that's the case with your PC, you can connect the +3-3V and ground wires from the monitor to the underside of the 20-pin motherboard connector, to pins 1, 2 or 11 (orange wire) and 3 (black wire) respectively. Fig.4 shows how to identify the pins on the motherboard ATX connector.

On some earlier model PCs, you may find that this 20-pin ATX connector is "missing". Instead, there will be a pair



The completed PC Power Rail Monitor simply clips in the front of the PC's case, in place of an existing drive blanking plate.



The above view shows the completed PC board from the top, while the inset shows how the three trimpots (VR1-VR3) are mounted on the copper side.

of 6-pin in-line main power connectors (P1 and P2), together with a third 6-pin in-line connector providing the +3.3V power and an additional +5V line. This is known as the 6-pin ATX auxiliary power connector (see Fig.4)

If your PC has this arrangement, the +3.3V lead from the monitor board (orange) should be connected to either pin 4 or pin 5 of the auxiliary connector (under the motherboard), while the remaining ground wire (black) can be connected to either pin 2 or pin 3.

If your PC is even older and doesn't even have the ATX auxiliary connector but just the P1 and P2 connectors, this means that it doesn't have a +3.3V rail. In that case, you won't need to worry about monitoring the non-existent +3.3V rail, so simply remove the orange and black wires from the monitor board pins and ignore the third column of LEDs (which won't light anyway).

Calibration

Calibrating the monitor is quite easy but you'll need a reliable digital voltmeter. The basic idea is that you will be adjusting the relevant trimpot for each of the monitor's three LED voltmeters so that the green LED glows when the input voltage is at the correct nominal value for that power line. When this is done, the other LEDs will

glow for the correct higher and lower voltage levels.

Step one is to measure the +12V line with your DVM. If it's very close to the correct reading (say within $\pm 100\text{mV}$ of +12V), all that you then need to do is adjust trimpot VR1 until the green LED glows steadily in the first column of LEDs. In fact, you should set VR1 to the centre of the small adjustment range over which the green LED glows.

What if the PC's +12V rail actually measures a little below 11.9V, or a little above 12.1V? That's no great problem but it does mean that you should adjust VR1 so that one of the two orange LEDs glows instead – ie, adjust VR1 so that either the lower orange LED is just glowing if the voltage is just below 11.9V, or the upper orange LED is glowing if it's just above 12.1V.

Calibration of the +5V and +3.3V monitors is done in exactly the same way. You simply measure the actual voltage of these power rails first with your DVM, then adjust each trimpot so that either the green LED or one of the orange LEDs for that monitor is glowing, depending on the reading on the DVM.

Once you've set all three trimpots in this way, your PC Power Rail Monitor is calibrated and ready for use. **EPE**

Parts List

- 1 PC board, code 576. Available from the *EPE PCB Service*, 146 x 38mm
- 1 piezo buzzer, PC mount
- 6 1mm PC board terminal pins
- 4 12mm x M3 tapped spacers
- 8 M3 x 6mm machine screws
- 4 M3 star lockwashers
- 2 1k Ω horizontal trimpots (VR1, VR2)
- 1 5k Ω horizontal trimpot (VR3)

Semiconductors

- 3 LM3914 display drivers (IC1-IC3)
- 1 PN200 PNP transistor (Q1)
- 3 3mm green LEDs (LEDs 3, 8, 13)
- 6 3mm orange LEDs (LEDs 2, 4, 7, 9, 12, 14)
- 6 3mm red LEDs (LEDs 1, 5, 6, 10, 11, 15)

Capacitors

- 1 100 μF 16V radial electrolytic
- 3 2.2 μF 35V TAG tantalum

Resistors (0.25W, 1%)

- | | |
|-----------------|----------------|
| 1 10k Ω | 1 1k Ω |
| 1 4.7k Ω | 1 470 Ω |
| 1 3.9k Ω | 2 270 Ω |
| 3 1.5k Ω | 1 220 Ω |
| 1 1.2k Ω | |

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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

WHEN thinking about starting a new hobby it is usually quite easy to find reasons for not bothering. Finding the courage to take the first step tends to be a bit more difficult. In the case of electronic project construction, concerns about the finished projects failing to work are probably the main reason for would-be constructors never “taking the plunge”.

Duff projects are not a major worry for those with years of experience at building electronic projects. They have the technical knowledge and test equipment to deal with virtually any problem. On the face of it, the opposite situation applies to beginners, who lack the knowledge and resources to deal with projects that refuse to work.

In reality the situation is not quite as dire as that. While it is not totally impossible that your first few projects will produce one or two really awkward problems that are difficult to solve, you would have to be incredibly unlucky for this to happen. An all-important point to bear in mind is that a project is virtually guaranteed to work provided you follow precisely the instructions and any special notes in the article. We would not try to pretend that there are never any errors in *EPE*, but those that do occur are very few and far between. On the rare occasion when an error does creep through it is usually detected quite quickly and a correction is printed one or two issues later.

Basic Choice

The chances of success can be greatly increased by choosing suitable projects. While it is tempting to dive straight in with a “mega-project” that will impress your family and friends, the chances of making a mistake with a large project are much greater. It is perhaps less common now, but in the past it was not unusual to receive a slightly odd letter from someone having problems with a project. On carefully reading through the letter it became obvious that they had little idea of what the finished project was actually supposed to do!

It is not necessary to know how a project works in order to build it successfully. On the other hand, it is necessary to have a proper understanding of what it is supposed to do and how to use it. You can otherwise end up in the position where a supposedly faulty project is actually functioning perfectly.

The usual recommendation is to start with something fairly simple and straightforward like a household gadget. A mundane project of this type provides a more apposite starting point than an advanced piece of test equipment where you need read the article twice before you can

even switch it on! Letters from readers who have “bitten off more than they can chew” are now relatively rare, but it is still a trap that is easy to fall into.

Main Point

Projects that beginners should definitely avoid are those that connect direct to the mains supply. When dealing with the mains electricity supply you have to treat it as potentially lethal, because that is precisely what it is. It follows from this that any projects that connect to it are also potentially lethal.

Projects that are powered from the mains or have any direct connection to it are only suitable for those with a reasonable amount of experience at project construction. Even if a project is extremely simple, if it connects to the mains supply it is certainly not suitable for beginners.

Start with projects that are battery powered. If you should make a serious blunder it is possible that one or two of the components will be damaged, but you should be perfectly safe. In most cases all the components will survive the experience as well.

A project that is powered from the mains via a ready-made adapter should also be safe for beginners. The adapter will presumably conform to the relevant safety standards. It should therefore provide complete isolation from the mains supply, as well as having any necessary fuses or safety cut-outs.

Custom Choice

A variety of construction methods have been used in the past, but these days every project is based on a printed circuit board. There are two main types of board, which are stripboard and custom printed circuit boards (PCBs). Both types of board are straightforward to use, but custom printed

circuit boards represent the more foolproof option. Stripboard (Fig.1 bottom) is a general-purpose circuit board that has a regular matrix of holes, but most projects utilize only a few percent of these holes.

As implied by its name, a custom printed circuit board (Fig.1 top) is specifically designed to accommodate a particular circuit. Consequently, a PCB has just one hole per leadout wire or pin. This lack of excess holes means that there is relatively little risk of making a mistake, and any errors that should occur are likely to be spotted almost at once. However, the numerous unused holes in stripboard tend to disguise mistakes, and some very diligent checking is often needed to detect any errors in the positioning of the components.

Bridge the Gap

Having carefully constructed a well chosen project, what do you do if it fails to work? Always make sure that the first thing you do is to switch it off. Leaving a faulty project switched on risks damaging some of the components. The semiconductors are often the most expensive components in a project, and they are particularly vulnerable if a faulty project is left with its power on. So, switch off a faulty project *immediately* and recheck the component layout, wiring, and so on.

This type of thing should really be checked very thoroughly as construction progresses. The circuit board should also be double-checked prior to installing it in the case. Spotting errors early in the proceedings can save a lot of hassle further down the line.

Having checked for any obvious mistakes, it is then a matter of searching for the types of problem that are trickier to spot. Practical experience suggests that the majority of problems are caused by short-circuits between the copper tracks and pads on the underside of the circuit board. Accidental short-circuits are not a new problem, but the intricacies of modern boards have exacerbated matters. Some boards are coated with a solder resist that is designed to discourage solder bridges. In the absence of this resist it is likely that several bridges of solder will be produced while building each circuit board.

This is not as troublesome as one might think, since most of these bridges will be spotted while the board is being constructed. In most cases they are easily wiped away using the hot bit of the soldering iron. Where there is a great deal of excess solder it is better to use desoldering equipment such as an inexpensive desoldering pump.

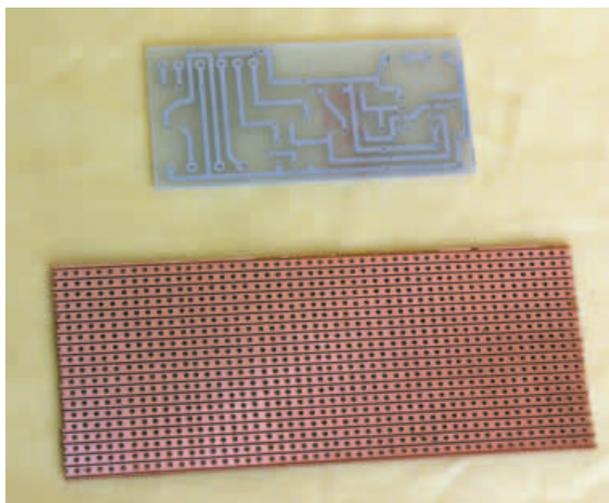


Fig. 1. Two types of “printed circuit” boards; custom PCB (top) and stripboard (bottom)

Try to remove as much solder as possible and clean away burnt flux or other contamination. Then re-do the joint, avoiding an excess of solder the second time around.

Solder bridges that you can see fairly easily are not the main problem. Any of these should soon be located and removed. Short-circuits are sometimes caused by minute trails of solder that are very difficult to see with the naked eye. In some cases the offending solder might not be visible at all by someone possessing average eyesight.

Things are often made more difficult by the trails being hidden under excess flux from the solder. Flux tends to get liberally splattered across the underside of circuit boards during construction. There are various products that can be used to clean the flux from boards, but vigorous brushing with a small brush such as an old toothbrush is just as effective. It is a good idea to thoroughly clean the underside of the board when dealing with a faulty project.

In Eyesight

Even if you have good eyesight there is no guarantee that you will spot any tiny solder bridges. Some form of magnifier now has to be considered part of the standard electronics toolkit, and even an inexpensive plastic magnifying glass will greatly increase the chances of finding an otherwise elusive solder bridge. Using an 8x or 10x loupe (Fig.2) is better though.

These are sold as photographic accessories for viewing slides and negatives, and one of the cheaper ones is perfectly adequate for the present application. Provided the board is properly cleaned first, a thorough visual check using a magnifier should always reveal any solder bridges. The best approach is not to wait for problems before cleaning and inspecting a board. Inspect all completed circuit boards prior to installing them in the case. It is likely that problems will be discovered quite often, and that a lot of dismantling and rebuilding will be avoided.

Problems with so-called "dry" joints date back to the pre printed circuit era. Improvements in solders and components have greatly reduced the problem, but it has certainly not gone away. Soldering is like any skill, and it is a case of "practice makes perfect". The more projects you build the more proficient you will become at soldering. There is not enough space available here for a soldering tutorial, but a good one is available at the *EPE* web site. Soldering irons and soldering kits are often supplied with detailed instructions that have lots of useful tips and helpful information.

Dry Joints

The name tends to imply that a "dry" joint is one that has insufficient solder, but it is not quite as simple as that. What usually happens is that there is plenty of solder, but it does not flow over the joint properly. The joint often looks perfectly plausible unless you look at it very closely. It might even be quite strong physically, but there is either no electrical connection at all through the joint, or an intermittent contact.

The chances of producing a "dry" joint can be greatly reduced by making sure that the two surfaces to be connected are clean. They will normally be clean enough any-

way, but clean any pad, lead, or tag if there is any hint of dirt or corrosion.

Possibly the most common cause of "dry" joints is the soldering iron being left unused for a few minutes before producing the joint. There will often be a significant amount of solder left on the bit. Any flux in this solder will soon burn away and the solder itself will start to oxidise. This does not matter if you clean the end of the bit and tin it with some fresh solder before producing the next joint.

Failure to do so results in the joint containing a significant proportion of old solder and an inadequate amount of flux. The flux should help the solder to flow over the joint properly, and with modern solders it also helps to clean slight traces of grease or corrosion from the two surfaces that are being joined. With too little flux it is likely that an inadequate joint will be produced.

A continuity tester can be used to locate bad joints, but they can usually be found without the aid of any test equipment. There is often a large amount of flux or burnt flux around a "dry" joint, but this clue will be absent if the board has been



Fig.2. Checking a circuit board with a magnifying glass can highlight many soldering problems

cleaned. The surface of a soldered joint is normally quite shiny, whereas the surface of a bad joint tends to be dull or have a crazed appearance. A good joint has a sort of mountain shape, but a "dry" joint is often more globular in appearance, possibly lacking good symmetry as well.

It is a good idea to re-do any joints that look in any way suspicious. Check the two surfaces before soldering the joint again. With modern solders and components it is unusual for minor deposits of dirt or corrosion to cause difficulties. Occasional problems can still occur though, and it is a good idea to clean both surfaces before re-doing the joint even if there is no sign of any contamination. Carefully scraping both surfaces with the small blade of a penknife, etc., is a good way of cleaning the surfaces.

Try to avoid the embarrassment of producing a genuinely "dry" joint, by which I mean one that you have forgotten to solder! Firmly pulling on resistors, capacitors, diodes, etc., will reveal any missing joints, or physically ineffective joints that look plausible.

Hot Stuff

There is a tendency to work faster as you become more proficient at soldering. Initially, things are likely to be slower and

more hesitant, which increases the risk of components being damaged by overheating. Semiconductors are the most vulnerable to heat damage, which is one reason they are mostly fitted on the board via holders rather than being soldered into place. Never be tempted to omit the holders for integrated circuits. The cost saving is minimal and the potential for causing problems is huge.

When other types of component are damaged by heat there are usually some visual clues that all is not well. This can be something subtle like a slight darkening in the colour of the component, or something more obvious such as the component becoming misshapen or leadout wire becoming detached. Replace any components that are "off colour", deformed, or show signs of physical damage.

Second Time Around

Having checked and made any necessary corrections to the circuit board, it is time to reassemble the project and try it out again. Obviously due care must be taken to avoid errors if it is necessary to reinstate any of the hard wiring, but this is also an opportunity to thoroughly check all the wiring. It is relatively easy to make mistakes with this wiring, so check every wire very carefully.

If the project still does not work, take another look at the circuit board. If the project is based on stripboard there will probably be some link wires. Have any been omitted and are they in the right places? Ideally you should get someone else to check your work. Having made a mistake it is easy to fool yourself into thinking that it should actually be that way. A fresh pair of eyes might spot a glaring error that you have managed to repeatedly overlook. Check every component on the circuit board again.

Are the polarised components such as diodes and electrolytic capacitors connected the right way around? The component layout diagrams normally make the correct orientation of these components perfectly clear, but the markings on the components themselves are sometimes a tad confusing. Look carefully at the markings on the electrolytic capacitors to make sure that you have not misinterpreted anything. The cathode of a diode is normally marked by a band around that end of the body, but some diodes have several bands. With these there is one band that is wider than the others, and this is at the cathode end of the body.

Multimeter

In the unlikely event that there really are no errors and the project still does not work, the problem is presumably due to a faulty component. Finding the offending part without the aid of test equipment is probably not a practical proposition.

However, a great deal of useful checking can be undertaken using an inexpensive multimeter, and it is advisable to buy one of these sooner rather than later. Even some of the budget units have facilities for testing capacitors and simple semiconductors, as well as the usual resistance ranges, continuity tester function, and so on. With a multimeter of this type it should not be too difficult to find the cause of the problem.

A dirt cheap, high-current bench supply

Got an old PC gathering dust somewhere? It mightn't be much good these days but its power supply could be . . . especially if you want a high-current 13.5V bench supply! This article tells you how to modify one – at very little cost!

By COL HODGSON, VK2ZCO



One of the nice things about using an old PC power supply is that it already comes in its own case, complete with fan. Some even include the mains switch – though none will have the large binding post terminals! This is a typical XT/AT-type supply, rated at about 230 watts (and therefore capable of 13.5V at 17A). You often find these PCs junked in council clean-ups, etc.

WARNING

This is NOT a project for the inexperienced. DO NOT even think of opening the case of a PC switchmode power supply (SMPS) unless you have experience with the design or servicing of such devices or related high-voltage equipment. Note that much of the SMPS circuitry operates at full mains potential and contact with it could easily kill you. NEVER open up an SMPS case when it is connected to the mains, even if turned off. Beware of any residual charge on the mains capacitors, even if turned off for some time. DO NOT attempt to modify a SMPS unless you are fully competent and confident to do so.

THE CONCEPT of converting a disused computer power supply to 13.5V operation was first mooted in the November & December 1998 issues of the no-longer-published *Radio and Communications* magazine. This article builds on that information.

The process is relatively straightforward and involves removing all the components involved with the existing 5V and 12V outputs, rewinding the main transformer and then changing the feedback components to give an output of 13.5V instead of 5V.

First, a few words on selecting the power supply to be modified. It must be an XT/AT type. It must NOT be an ATX type since they work quite

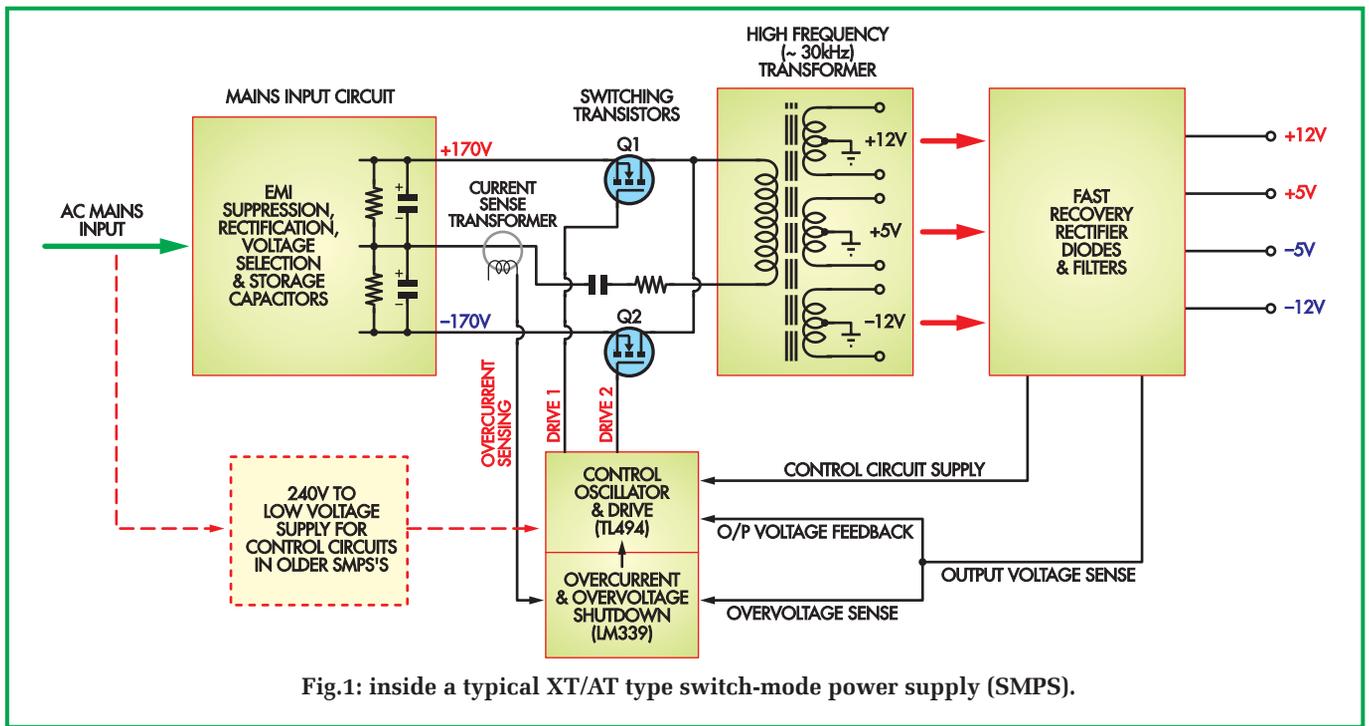


Fig.1: inside a typical XT/AT type switch-mode power supply (SMPS).

differently to the XT/AT types. Then, once you have a supply, check that it will maintain a constant output voltage under load; eg, one or two 12V 50W halogen lamps.

Some SMPS may fail this test if the initial surge current drawn by the test load is too great (due to the overcurrent protection circuit being activated). In that case, switch off to allow the circuit to reset and retest it again, starting with lower wattage lamps and increasing the load in steps.

Reverse engineering and conversion to a new output is difficult at the best of times and nigh on impossible if the thing doesn't work in the first place!

Second, consider your power requirements. If you only need about 10A at 13.5V, you probably don't need to change the main transformer as the original +12V output can be modified

to deliver +13.5V. This means that only the output voltage control sense circuits need changing.

Third, choose a unit that contains the least amount of dust (possibly had the least use!) and check the fan for free movement and lack of "end play" in the bearings.

Fourth, check if the unit uses two ICs in the control circuit: a TL494 and a LM339. Their IC pins and functions are easily identified, making analysis of the circuit much easier. If you can't identify the ICs, you may still be able to modify the supply but you will be very much on your own and the information in this article may not be of much help.

What's involved?

(1) The main transformer will have to be removed, rewound to achieve the desired output and replaced.

Minor modifications are made to the mains circuitry.

(2) The +5V, +12V, -12V and -5V output components are removed, with the exception of the +5V rectifying diodes and transient suppression network. A new output filtering circuit is installed.

(3) The output voltage sensing resistors will need to be replaced. Jumper wires will need to be placed to supply the control circuit and the fan.

Before we get too involved, some theory of operation is required.

Basic principles

The basic principles of typical PC power supplies can be described with reference to the block diagram of Fig.1.

(1) The 230V AC mains input circuit contains the usual suppression components of chokes and capacitors before the four normal rectifier diodes in a bridge configuration. The rectified mains then passes to two storage capacitors connected in series. These capacitors will charge up to about 170V each and may be subject to ripple currents up to 5A or more.

(2) Transistors Q1 and Q2 are alternately switched at 30kHz or more to provide a high-frequency alternating current to the main transformer primary. A small transformer with a single-turn primary winding senses the level of input current in the common line to the main transformer.



The only way you can tell from this angle that this is the modified supply is the absence of a 110/230V switch. This was removed because (a) it is quite superfluous here in the UK and (b) because over the years we have seen too many people flick switches like this with (briefly) spectacular results.

(3) The main transformer has three secondary windings providing the high current +5V and +12V outputs and a low current -12V output.

(4) Large, fast-recovery double diodes (with a common cathode connection) in plastic TO-220 (or similar) packages rectify the high current +5V and +12V outputs, while smaller, fast recovery diodes rectify the -12V output. The -5V line is derived via a 7905 regulator from the -12V output. A large, multi-winding toroid provides initial filtering for the several outputs. Final filtering is provided by electrolytic capacitors and smaller inductors.

(5) The main component in the control circuit is a TL494, Samsung KA7500B or equivalent IC. An RC network controls the operating frequency of the IC. The alternating drive to the switching transistors is pulse width modulated, depending on the load current demand, higher currents being supplied by longer duration pulses up to a maximum duty cycle of 45%.

The output voltage feedback controls modulation width.

The LM339 (and/or discrete transistors) senses over-current or over-voltage output conditions and shuts down the TL494.

Features of the TL494

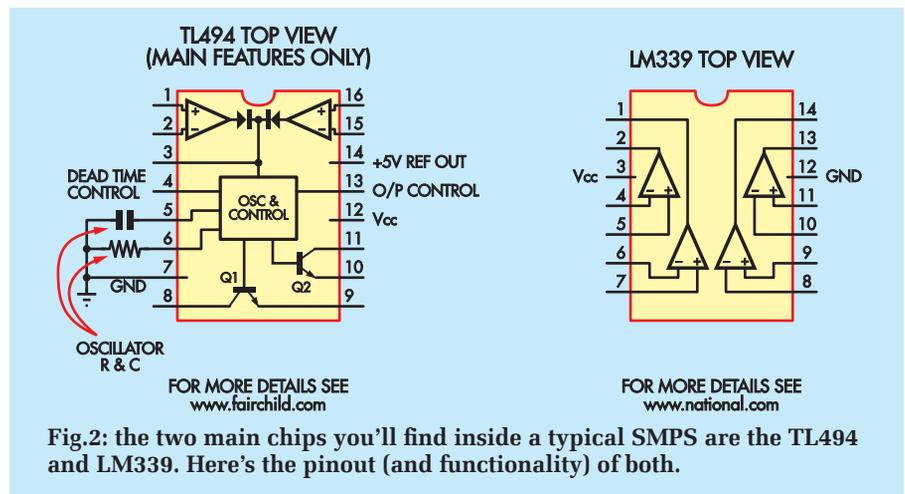
This is only a brief description of the operation of this IC.

The IC contains an oscillator capable of operating between 1kHz and 300kHz. The frequency is controlled by an RC network on pins 5 (C) and 6 (R) – see Fig.2.

Two error amplifiers are included: pin 1 (non-inverting) and pin 2 (inverting) for amplifier 1 while pin 16 (non-inverting) and pin 15 (inverting) are connected to amplifier 2. The outputs from these amplifiers are commoned and internally control the pulse width modulation section of the IC. The common output is also connected to pin 3 to provide external control over the pulse width modulation.

There are two output transistors with open collectors and emitters: Transistor Q1 has pin 8 (C1) and pin 9 (E1) while transistor Q2 has pin 11 (C2) and pin 10 (E2). These transistors can handle up to 200mA.

The Dead Time control (pin 4) limits the duty cycle for each transistor to a maximum of 45% (0V to



pin 4). This provides a 5% protection interval, preventing both output transistors being on at the same time. The Dead Time control is also used to disable the chip if an over-voltage or over-current condition occurs. Pin 13 (output control) may be used in some circuits to disable the TL494.

The input supply (Vcc) is to pin 12 and has a maximum value of 42V. Pin 7 is ground. A reference voltage of 5V \pm 5% is available at pin 14.

Make a drawing

Before commencing testing and modification, I suggest that the underside of the PC board (track side) be scanned and printed (or photocopied)

to produce a grey scale image to fill an A4 page. The components can then be drawn on the page in a contrasting colour (eg, red) to assist tracing and identifying the various circuit features.

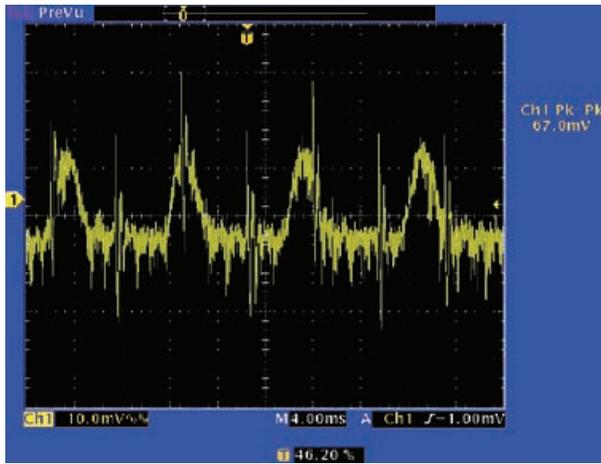
By the way, if you haven't already got the message, modifying one of these power supplies is not a quick or simple job but it does have the big advantage that you get a large output DC supply for very little cost.

Pre-test before modification

Some more recent PC power supplies derive their control circuit power from the +12V output. **This feature allows the control circuit of these supplies to be powered and checked**



Here's what you should find when you lift the lid on the switch-mode power supply. Usually it's only four or so screws to get this far. All of the external cabling will be removed. Never run the supply with the lid removed unless testing – and then only with extreme care. These things can be lethal!



This waveform shows the ripple and noise output of the modified power supply. While it looks horrible it is only 67mV pk-pk. Note: measuring this waveform should be done on the external outputs, not inside the power supply (for safety's sake!).

without connection to the 230V AC mains.

Connect a 33Ω 5W resistor between the +5V output (red) and ground (black) and a 47Ω 5W resistor between the +12V output (yellow) and the +5V output (red). This will maintain an approximate 5V to 12V ratio between the respective outputs.

A variable DC power supply (8-14V range) is connected across the +12V output and ground. Check for power at pin 12 of TL494. It should be almost 0.6V less than the supplied voltage.

In the absence of power, a jumper needs to be placed between pin 12 and the +12V line.

An oscilloscope is used to view the waveforms and operation of the TL494 and LM339 as the applied voltage is slowly raised from 8V to 14V (no higher than 14V). A 30kHz (or higher) sawtooth waveform should be present at pin 5 and square waves should be visible on the ungrounded output pins 8 and 11 (or pins 9 & 10).

These oscillations should stop as the voltage is raised to the level equivalent to the design output. The waveforms should reappear as the voltage is

reduced. If the over-voltage circuit has been activated, the waveforms will not reappear until the circuit is reset by removing the power.

Careful adjustment of the power supply is necessary to demonstrate these two very similar voltage levels.

If no oscillations are observed, pin 4 of the TL494 will need to be isolated from the circuit and connected directly to ground. Follow the track from pin 4, desolder and lift one leg of each component connected to this track. The track can then be grounded by a jumper wire. The over-voltage protection circuit will now be inoperative.

Re-connect the variable DC power supply and a sawtooth waveform should now be visible at pin 5 and square waveforms at pins 8 & 11 (or pins 9 & 10). Do not exceed 14V in an attempt to demonstrate the over-voltage protection mode – you have just disabled this circuit!

Use a multimeter to measure the reference voltage at pin 14; this should remain constant at about 5V, as the supply is varied. Make a note of this reference voltage.

Next, measure the voltages at the input pins to the error amplifiers, pins 1 & 2 and 15 & 16, as the supply voltage is varied. Note: one of these amplifiers may not be used in the circuit. The pin with the constant voltage, pin 2 or 15 (inverting input), is connected to pin 14 via a resistor or a potential divider network and serves as the reference voltage for the error amplifier. Make a note of this voltage too.

The non-inverting input, pin 1 or 16, is connected to the +12V and +5V outputs via another potential divider network to sense the output voltage. You will need to trace the connections to this pin to identify the voltage feedback network.

The signal from the TL494 to the driver transformer can also be checked. The primary of this transformer is a centre-tapped winding with the centre pin grounded. The signal to the other two pins should be identical in shape and amplitude (sketch these waveforms).

A dual trace oscilloscope will show the phase relationship between these waveforms (no overlap at all). The waveforms at the five output pins of this transformer will vary, as the circuitry to the “chopper” transistors is not symmetrical. However, the waveforms should be roughly similar.

Voltage measurements also need to be made at the input pins of the comparators in the LM339 IC. Usually only two comparators are used; the remaining inputs are tied to ground or Vcc.

Two pins (the inverting inputs) should maintain a fixed voltage equal to the reference voltage on the input to the error amplifier in the TL494.

The pin with the varying voltage (a non-inverting input) is connected to the supply output via a voltage



The original transformer, as removed from the PC board.



... allowing fairly easy disassembly. Make sure the ferrites and bobbin are very clean before going any further. Don't worry about the wire – you won't be using any of that.

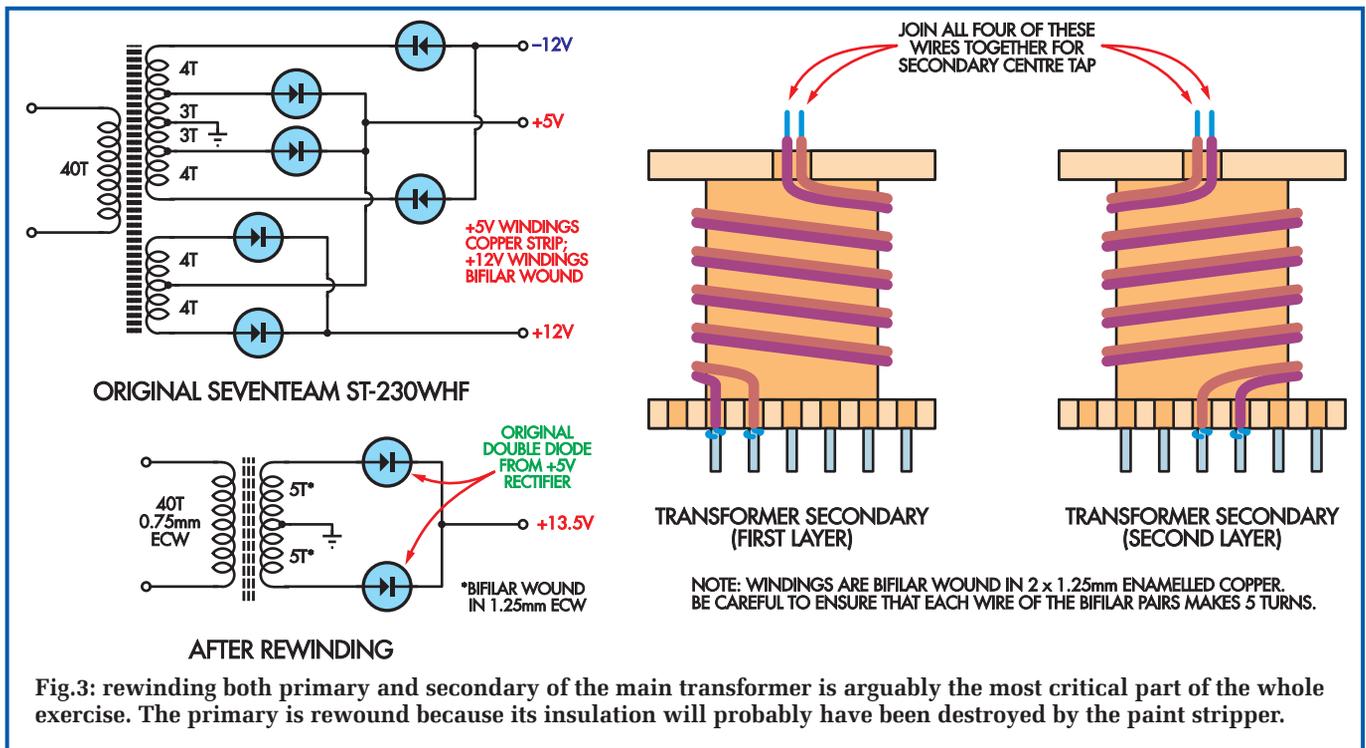


Fig.3: rewinding both primary and secondary of the main transformer is arguably the most critical part of the whole exercise. The primary is rewound because its insulation will probably have been destroyed by the paint stripper.

divider network and senses an over-voltage condition. This part of the circuit will also need to be identified and modified.

The other non-inverting input pin is connected to the over-current protection circuit. This portion of the circuit does not require modification as the over-current condition is detected at the input to the main transformer.

Take careful note of the results from the above testing procedure. The test will need to be repeated after the modifications and transformer rewind, as a final check before applying mains power. **The only difference is that then there will be no output to the original +12V output, the new output appearing at the original +5V output.**

If your PC power supply cannot be tested with an external DC supply, you can still modify it but it will be far more difficult (and dangerous) to do any initial testing. However, you can still trace out the circuit and then follow the procedure within this article to make the necessary modifications.

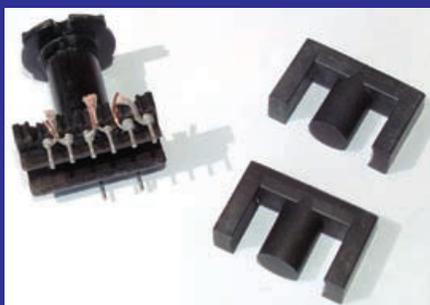
WARNING!

The internal wiring of switch-mode computer power supplies is dangerous when powered up. Not only do you have bare 230V AC wiring to the IEC sockets but a good

portion of the circuitry is at +340V DC and is also floating at half the mains voltage. It is **POTENTIALLY LETHAL!**

Use extreme care if you do decide to take measurements on the supply when the case is open and **DO NOT TOUCH ANY PART OF THE CIRCUIT** when it is plugged into the mains (operating or not). Make sure that it has been disconnected from the mains for about 15 minutes before making any modifications and make sure that all high-voltage capacitors have been discharged before touching any parts.

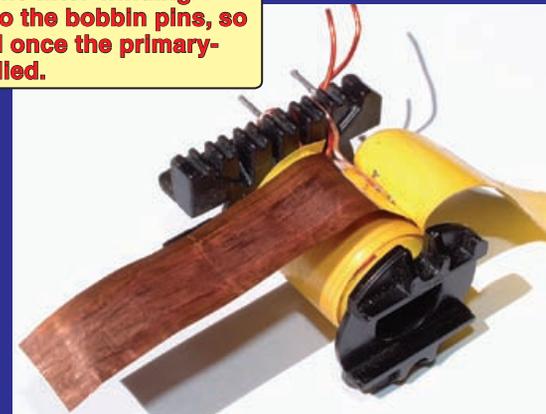
IMPORTANT: although not shown here, fit PTFE sleeving over the primary wire ends (and to the inter-winding shield lead) before soldering them to the bobbin pins, so that no part of them will be exposed once the primary-to-secondary insulation tape is applied.



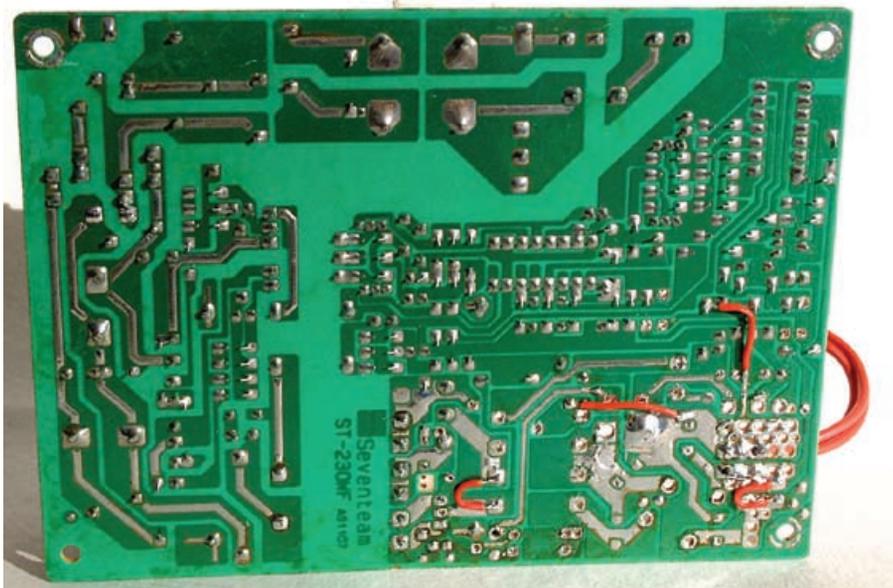
Here's what they should look like after disassembly. The next step is to wind on a new primary, as shown at right . . .



Make sure it is a tight, neat winding – otherwise you might run into space problems.



The original inter-winding shield is re-used. Note the layer of insulation between the windings.



There are a few modifications that you need to make to the PC board. These will vary according to manufacturer so be careful as you trace the circuit out.

Transformer rewind

The main transformer operates at a frequency of between 30kHz and 85kHz and so is much smaller and has a surprisingly small number of turns compared to an equivalent mains transformer operating at 50Hz.

Begin by desoldering and removing the main transformer. Then submerge it in a container of ordinary paint stripper overnight, before any attempt is made at disassembly. **Note: paint stripper is highly caustic and care should be exercised during this operation; use gloves and eye protection!**

The next day, carefully wash all traces of paint stripper from the transformer. The ferrite cores should now slip easily out of the bobbin. Keep careful WRITTEN notes of the windings (number of turns and pin connections on the bobbin) as the transformer is disassembled. In particular note the

primary pin connected to the interwinding shield, if fitted.

Note that ALL windings have to be removed as the primary has also been subjected to the effects of paint stripper.

The ferrite core halves and bobbin should be thoroughly cleaned of all traces of adhesive, potting residue and paint stripper before rewinding. This may involve another overnight soak in paint stripper. Surprisingly, the paint stripper appears to have no effect on the bobbin.

Care must be exercised during rewinding due to the space limitations imposed by the ferrites. All windings must be tightly and closely spaced. Do not overdo the application of insulation tape nor use larger gauge wire than suggested.

Editor's note: we recommend the use of a polyester tape when rewind-

ing the transformer, to ensure adequate high voltage and high temperature ratings.

Rewinding the primary

Rewind the primary with the same gauge wire and the same number of turns as initially used (usually 40 turns of 0.8mm enamelled copper). If the primary has been split into two windings (inside and outside the secondary windings) it should be replaced with a single winding.

The primary is usually wound as two layers of 20 turns each. A single turn plus 10mm overlap of insulating tape is placed between the two layers during the rewind. The overlap must be located on a face of the bobbin not covered by the ferrite cores (see photo).

After each primary layer is wound, install lengths of PTFE sleeving over the wire ends before terminating them at the bobbin pins.

Another single turn plus 10mm overlap of polyester tape is then applied over the final primary layer and the interwinding shield is then replaced. **Note: this shield is approximately one turn and must be insulated so it does not form a single shorted turn.**

Terminate the primary winding and shield to the appropriate pins (in accordance with your written notes!) and cover them with two layers of insulating tape (trim to exactly two turns, no overlap). **Again, fit PTFE sleeving over the lead to the inter-winding shield.**

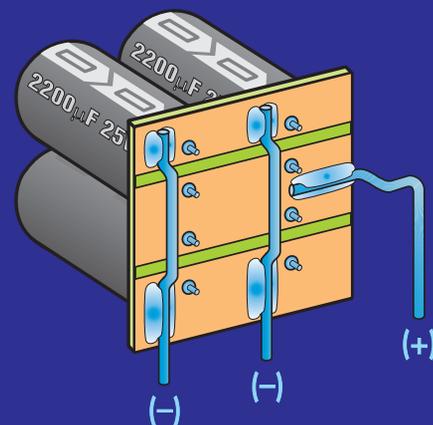
Insulation at margins

After terminating the primary windings and shield to the appropriate pins, use thin strips of insulation tape (trimmed to the appropriate width) to build up the gaps between the ends of the primary winding and the bobbin



Then on go the secondaries. As with the primary winding, this should be nice and tight. The rubber bands are removed before adding the final layer of tape. As before, fit PTFE sleeving over the wire ends before terminating them to the bobbin pins.

At right is one idea for the new output filter electros.



shoulders, to give a complete uniform layer the full length of the bobbin.

Once you have a uniform cylinder, cover the entire winding (right up to the bobbin shoulders) with exactly two turns of insulation tape (no overlap). The idea here is to ensure that all possible points of contact between the primary and secondary windings are doubly insulated.

WARNING: for safety reasons, it's vital that the primary winding be correctly insulated, so that it cannot possibly come into contact with the secondary. If you get it wrong, the supply could be LETHAL if the earthing is incorrect. Do NOT attempt any of this work unless you know exactly what you are doing.

Winding the secondary

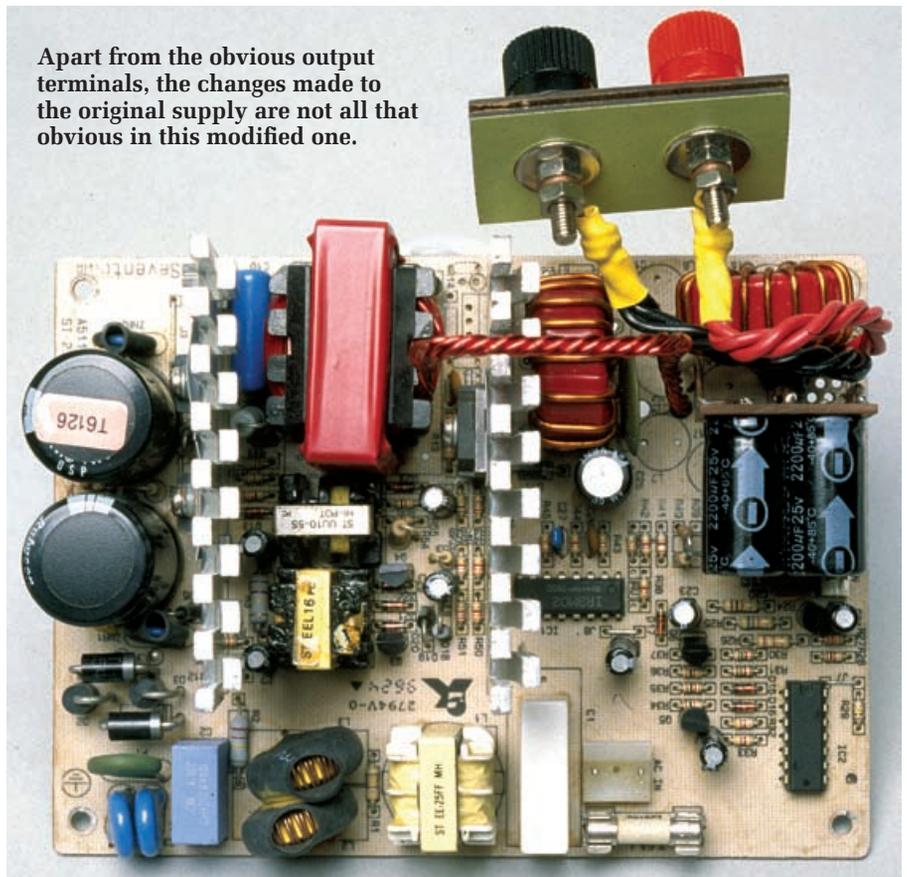
A total of 10 turns, double-wound and centre-tapped, of 1.25mm enamelled wire forms the secondary. This winding is rather difficult to apply because the larger gauge wire has a tendency to spring open. Use a rubber band as a temporary hold after completing each winding.

Start by selecting one of the outside four pins used to terminate the original 5V winding (largest gauge wire). Wind on five turns, tight and closely spaced, in the direction away from the other three pins, bringing the end of the wire up through the notch in the bobbin top. Leave about 20cm of free wire.

Now select the adjacent pin and wind another five turns in the same direction and placed between the turns of the first winding. Allow the first coil to expand lengthwise along the bobbin as needed. Terminate this winding as above.

Check and recheck that you have exactly five turns on each winding, otherwise you will effectively have a shorted turn. Firmly cover this layer

Apart from the obvious output terminals, the changes made to the original supply are not all that obvious in this modified one.



with one turn plus 10mm overlap of insulating tape.

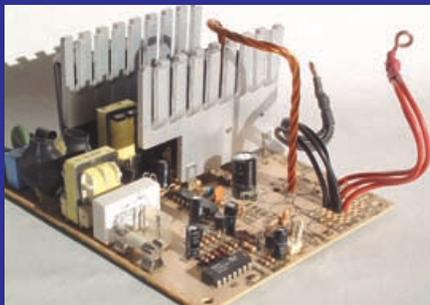
The second layer begins from the outer pin of the remaining original 5V winding pins. Wind five closely spaced turns in the opposite direction to the first layer and terminate through the top of the bobbin. Again, leave 20cm free. Starting from the remaining 5V pin, wind another five turns placed between the turns of this second layer. Terminate as above.

Again, check and recheck for exactly five turns on each winding. Firmly cover this final double winding with two layers of tape.

Refitting the ferrite core

This is the real test of the rewind. Cautiously slide the ferrite core halves into the bobbin; remember, they are very brittle! If you are lucky and have been very careful, they will slip into the bobbin without any obstruction. If not, remove one turn of the outer tape layer and try again.

If you are still unsuccessful, it may be possible to gently squeeze the windings in a vice, padded with two pieces of wood, to press the secondary into a slight oval shape. No vice? Place the bobbin between two pieces of wood and GENTLY tap with a hammer. If the

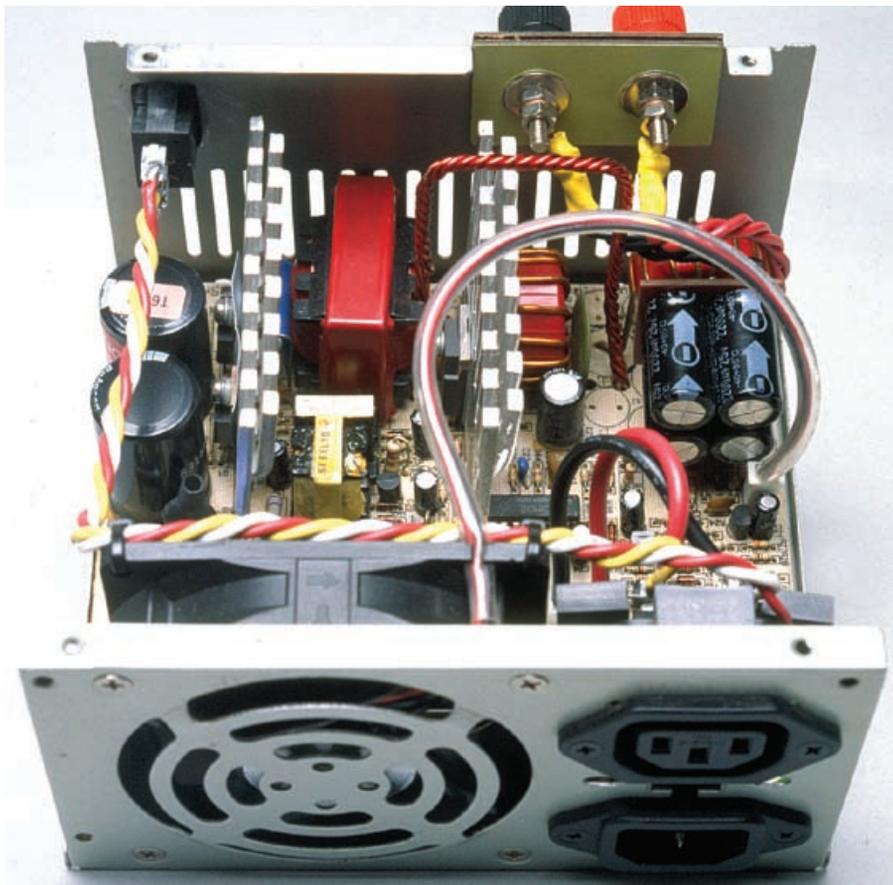


Here's the stripped PC board with the rewound main transformer in place, ready for the new output filter components.



Add a pair of polarised terminals on their own mounting plate and fasten it to the power supply case, as shown at right.





Modified, checked, tested . . . ready for the lid to go back on. And at the risk of sounding boring, for your own safety don't apply power while the supply is in this condition.

ferrites will still not fit, the secondary will have to be rewound

Once the ferrite core halves have been fitted, with no spacing or foreign matter between the joining faces, two layers of tightly stretched tape will hold them together. Start across the base with the first length gently stretched, then tightly stretch the tape after the first corner. Finish with a gently stretched length across the base.

Final assembly

Gently twist the four 20cm centre-tap leads into a rope-like formation. Scrape the enamel off all wires and gently hook them around their corresponding termination pins and solder. Take care – the pins can be broken out very easily, particularly the pins for the secondary terminations.

Replace the rewound transformer on the board and bend the flying centre-tap lead to its connection point on the board. This hole may need to be enlarged slightly. Trim, clean and tin the end of this lead before soldering.

PC board modifications

After identifying the critical circuit features and rewinding the transformer, the PC board modifications are almost an anti-climax. First, remove the input voltage selector from the board. Note: in the 230V position this switch is OPEN. Cover the vacant switch position with a suitable metal bracket.

Next, connect three mains-rated 10nF capacitors (X2 class) across the back of the IEC socket to reduce rectifier noise imposed on the 230V AC mains. The capacitors are connected between Live & Neutral, Live & Earth and Neutral & Earth.

Now we come to the output circuit. Do not remove the lower (earthed) output voltage sensing resistors. Starting from the output leads, work back to the transformer and remove all -5V and -12V components, including the spike suppression resistor-capacitor combination across the -12V winding.

Repeat the procedure for the +12V components, including removing the double fast-recovery diode from the

heatsink. Also, remove all +5V components back to the fast-recovery double diode. Leave the diode and the spike suppression components in place.

The multiple-winding toroidal choke is also removed, stripped of its windings and then rewound with 14 turns of 1.25mm enamelled copper wire (ie, a single winding). Note that you will need two chokes of 14 turns each in the filter circuit – the second toroid can be scrounged from another power supply.

This new +13.5V output filter is a low-pass “T” configuration, with the two rewound chokes in series and four 2200µF 25V electrolytic capacitors from their centre point to ground.

Using the original +5V output copper tracks, insert and solder the rewound filter toroid (**the original +5V output becomes the new +13.5V output**). The placement of the remaining filter components depends on the physical layout of the original +5V output tracks. I used a small piece of PC board to hold the four 2200µF capacitors. This board was then mounted off the SMPS board using some spare 1.25mm wire. (Editor's note: we strongly suggest that the four 2200µF 25V electrolytics should be low ESR types.)

The second toroid was soldered to the +5V output pad and to the first toroid. **A ceramic disc capacitor (100nF 63V) was also added to the SMPS circuit board in parallel with the four 2200µF electrolytics.**

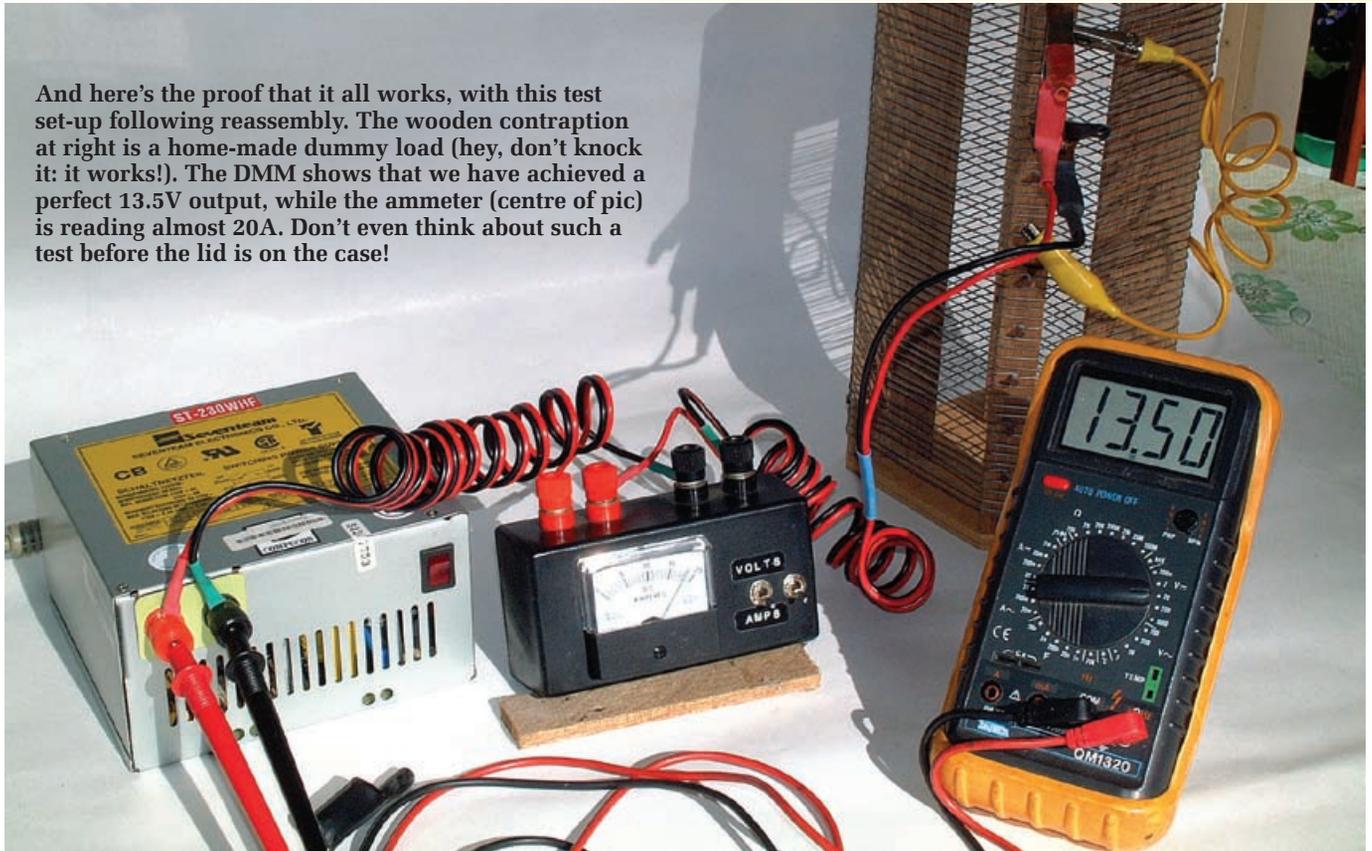
The following jumper wires are needed to complete the circuit:

- (1) Between the common cathode of the fast recovery diodes and the supply circuit for the TL494 IC; and
- (2) between the final output pad and the fan's positive terminal (assuming, of course, that the fan is a 12V DC type). A resistor may be used for this jumper to reduce fan speed and noise. DO NOT make this connection if the fan is mains powered (rare).

New values for the voltage and over-voltage sensing resistors now need to be calculated. These resistors are in divider networks and, in each case, you can leave one of the resistors in place and just change the value connecting to the output.

For example, in the Seventeam ST-230WHF unit shown in the accompanying photos, pin 1 of the TL494 is the non-inverting input of the relevant

And here's the proof that it all works, with this test set-up following reassembly. The wooden contraption at right is a home-made dummy load (hey, don't knock it: it works!). The DMM shows that we have achieved a perfect 13.5V output, while the ammeter (centre of pic) is reading almost 20A. Don't even think about such a test before the lid is on the case!



error amplifier. It has a 3.9k Ω resistor from pin 1 to ground and its reference voltage (set by a voltage divider connected to pin 2) is +2.5V.

We want an output of +13.5V, so we need to calculate a new value for the resistor from pin 1 to the new 13.5V output. From here it is a simple ratio calculation.

$$R = 3.9k\Omega(13.5/2.5 - 1) \\ = 3.9k\Omega \times 4.4 = 17.2k\Omega$$

So you merely have to replace the original resistor with 15k Ω and 2.2k Ω resistors in series.

The over-voltage monitoring network to one of the LM339's comparators may then need modifying to work with the new voltage output. The process of calculating the resistor is similar to that above; leave the resistor from the relevant comparator input to ground in place and calculate a new value for the resistor connected to the output.

Note that the final output voltage may not be exactly 13.5V regulated due to resistance tolerances and the tolerance of the 5V reference from the TL494. Check that the potential dividers are connected between the new 13.5V line and ground. Jumpers may be needed to complete these connections.

If the supply proves to be sensitive to RF fields, 100nF monolithic capaci-

tors fitted between ground and all used inputs and outputs of the ICs should fix the problem. (Editor's note: the addition of these capacitors will severely reduce the transient response of the supply and so it should only be done if the unit is used in conjunction with a radio transmitter).

The configuration of the final output connections is left to the constructor's requirements. Remember that these connections will have to handle up to 18A or so.

The board should now be ready for its first test. Note that you will still need a minimum load such as a 47 Ω 5W resistor. Repeat the low-voltage pre-test procedure described earlier, using if necessary the 33 Ω and 47 Ω resistors connected in series across the output terminations. Hopefully, the earlier waveforms will be observed.

If the connections to pin 4 of TL494 have been removed earlier, restore these connections and check if the oscillations cease as the voltage is increased to about 14V.

If all is well and the modified board behaves as expected you are almost ready for the first big test but first, there's one final safety check. **Both the metal case and the ground (0V) output of the supply should be connected to mains earth. Use an Ohmmeter to**

verify that these connections are in place. Check also that the centre-tap of the rewind transformer is connected to mains earth. Under no circumstances should the output be floated!

Now reassemble the supply into its case. Make sure that all connections are correct and close the case. Place a test load, (eg, a 12V 50W halogen lamp) across the output, plug in to the 230V AC mains and switch on. If the lamp lights, congratulations!

Final testing can now proceed using a series of loads to measure the output current and voltage.

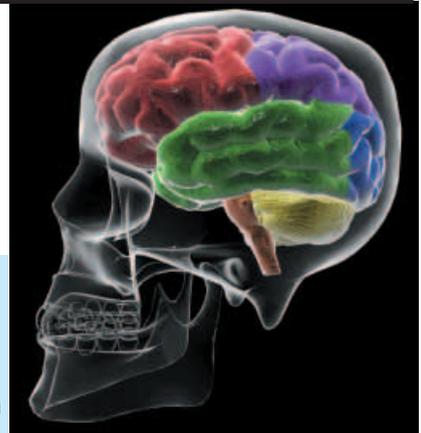
If the lamp does not light, switch off, unplug the unit from the mains and wait for at least 15 minutes to discharge the high-voltage capacitors, before opening the case.

If the lamp "blows" there is a good chance the output voltage sensing circuit is not correctly connected.

Finally, note that PC power supply cases have ventilation slots. For safety's sake, be sure to cover any slots or cutouts that give access to dangerous high-voltage circuitry (eg, by attaching aluminium panels) but make sure there is adequate ventilation overall. **EPE**

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Ingenuity Unlimited

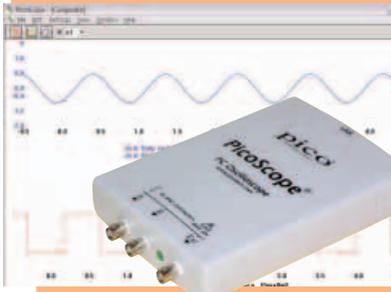


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Magic Bulb – Bewitched, Bothered and Bewildered?

THIS simple device can provide fun and interest at a children's party. The illusion is created that a bulb can be turned on and off by magic.

The key component in the Magic Bulb circuit in Fig.1 is the light-dependent resistor, LDR, whose resistance falls as the light around it increases. When its resistance is low enough, sufficient voltage is supplied to the base of transistor TR1 to turn it on. This in turn switches on TR2, used with TR1 to form a Darlington pair, and the bulb lights. For practical reasons it is best to use a miniature LDR and, as these can vary considerably in their minimum resistance, a different adjustment value for potentiometer VR1 may sometimes be more suitable, finding this by experiment.

The bulb should be a fairly powerful one, such as the traditional 6V 3W bicycle headlamp bulb with its pleasingly large glass. Four 1.5V cells can be used in series to provide the 6V DC power supply. Transistor TR2 must be of a type able to handle the high current without overheating, such as the BD433 shown in Fig.1.

After switching on, VR1 is adjusted to suit the room lighting (which should not be too bright) in such a way that the bulb is normally turned off, but goes on as soon as any extra light is made to fall on the LDR. This can be tested with a torch. Once lit, the bulb itself provides the extra light required to keep the circuit in the "on" state, but it should go out immediately if a shadow is made to fall on the LDR. It will also light, and stay lit, when switch S2 is

closed (providing base voltage and current to TR1 via VR1 and resistor R1). In the same way it will go out, and stay out, when S3 is closed (TR1 base voltage 0V).

Construction and Operation

The following ideas for construction and operation are designed to enhance the "magical" effect. Most of the parts can be mounted on a baseboard cut to fit into a shoebox or similar cardboard box, which is either painted in a mixture of bright colours or covered with suitable giftwrap paper. The bulb is mounted on the lid, with the LDR a few centimetres behind it. A piece of translucent material with a hole in the middle of the bulb can be fitted to hide the LDR from view. The reed switches, S2 and S3 (and others if required), are glued to the inside walls of the box in positions which can easily be recognized from the outside, e.g. behind spots of a certain colour or a particular motif on the decorative paper.

The box can be carried into the room by a "witch" and placed on a small table. The witch then dances round it, mumbling magic spells and waving her wand. A strong magnet concealed

in the end of the wand operates the reed switches when pointed at the correct spots on the box. In addition to this, the witch can extinguish the bulb by holding her hand over it, wagging her finger at it, or making any other movement that interrupts the flow of light from the bulb to the LDR. To complete the performance she can strike a match and light the bulb with it as if it were a candle, and she can appear to blow it out again by holding a cupped hand behind it while blowing.

To suit children who are more familiar with Harry Potter than with traditional fairy-tale characters, the scene can easily be modernised!

Francis Hall, Germany

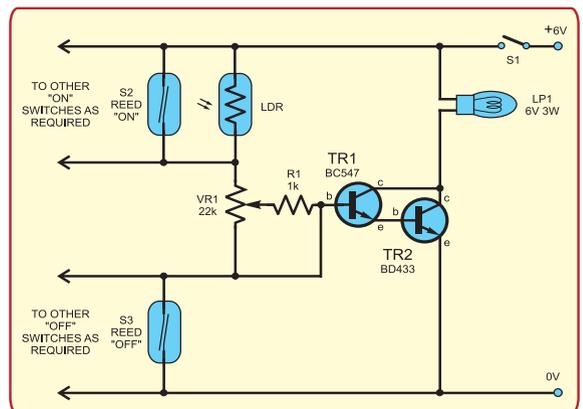
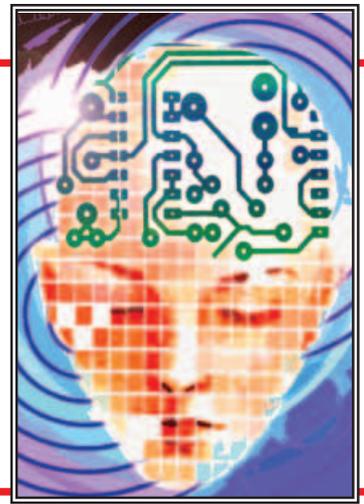


Fig.1. Circuit diagram for the Magic Bulb

TEACH-IN 2006

Part Nine – Bistable Investigation. Microprocessor systems. Data. Internal Architecture. Bus Systems. Interrupts. Input and Output. Programming. Microcontrollers.

MIKE TOOLEY BA



Our Teach-In 2006 series provides a broad-based introduction to electronics for the complete newcomer. The series also provides the more experienced reader with an opportunity to “brush up” on topics which may be less familiar. This month we shall be delving into the fascinating world of microprocessors. We begin, however, with a Practical Investigation based on the R-S bistable that we met last month.

Practical Investigation 9.1

Objective: Following on from Part 8, to investigate the operation of a simple cross-coupled R-S bistable based on NOR gates.

Components and materials: Plug-in breadboard; 9V DC power source (PP9 9V battery or AC mains adapter with a 9V 400mA output); 4001 14-pin DIL CMOS logic integrated circuit; red and green LEDs; resistors of 47kΩ (2 off) and 1kΩ (2 off); insulated wire links (various lengths); short lengths of black and red insulated solid wire.

Circuit diagram: See Fig.9.1

Wiring diagram: See Fig.9.2

Procedure: The required breadboard wiring is shown in Table 9.1.

1. Connect the circuit as shown in Table 9.1 with the 4001 CMOS (quad two-input NOR gate) used for IC1. The wiring layout is also shown in Photo 9.1.

2. Ensure that both Link A and Link B are connected (this corresponds to an input

state of SET = 0 and RESET = 0). Draw a table to show your results (similar to that shown in Fig.8.32 in Part 8), switch on (or connect the 9V supply) and note down the state of the two LEDs. Note that when the Red LED is illuminated this corresponds to Q = 1 and when not illuminated it indicates that Q = 0. Similarly, when the Green LED is illuminated this corresponds to $\bar{Q} = 1$ and when not illuminated it indicates that Q = 0.

3. Disconnect first link A (with link B in place) and then link B (with link A in place). In the first condition SET = 0 and RESET = 1 and in the second condition SET = 1 and RESET = 0. For each of these two conditions, observe the state of the LEDs and add the results to your table.

4. Next, replace link B and check

that the R-S bistable remains in the SET condition.

5. Finally, remove both links (so that SET = 1 and RESET = 1), observe the result (which might be surprising!) and add this to your table.

Conclusion: Verify that the circuit operates as expected and remains in the SET condition (step 4). Comment on the state of the outputs (Q and \bar{Q}) when both the SET and RESET inputs are taken to logic 1.

Why is this undesirable?

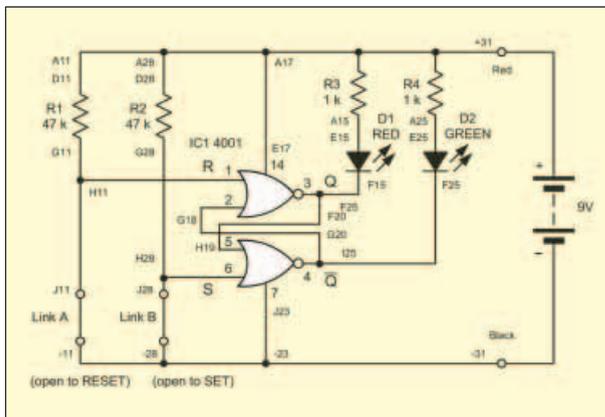


Fig.9.1 Circuit diagram for Practical Investigation 9.1

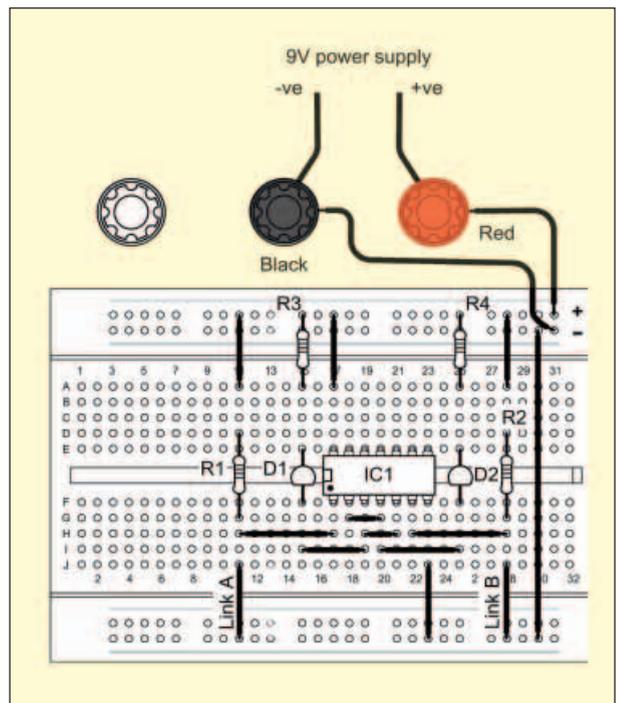


Fig.9.2 Wiring diagram for Practical Investigation 9.1

Table 9.1. Breadboard wiring for Practical Investigation 9.1

Step	Connection, link or component	From	To
1	9V supply (negative)	Supply negative	Black terminal
2	9V supply (+9V)	Supply positive	Red terminal
3	Red wire	Red terminal	+31
4	Black wire	Black terminal	-31
5	Link	-30 (top)	-30 (bottom)
6	Link	J23	-23 (bottom)
7	Link (Link A)	J11	-11 (bottom)
8	Link (Link B)	J28	-28 (bottom)
9	Link	+11	A11
10	Link	+28	A28
11	Link	+17	A17
12	Link	H11	H17
13	Link	H22	H28
14	IC1 4001	Pin 1	F17
15	IC1 (as above)	Pin 7	F23
16	IC1 (as above)	Pin 8	E23
17	IC1 (as above)	Pin 14	E17
18	R1 47kΩ	D11	G11
19	R2 47kΩ	D28	G28
20	R3 1kΩ	+15	A15
21	R4 1kΩ	+25	G25
22	D1 Red LED	anode(a)	E15
23	D1 (as above)	cathode(k)	F15
24	D2 Green LED	anode(a)	E25
25	D2 (as above)	cathode(k)	F25
26	Link	I15	I19
27	Link	I20	I25
28	Link	G18	G20
29	Link	H19	H21

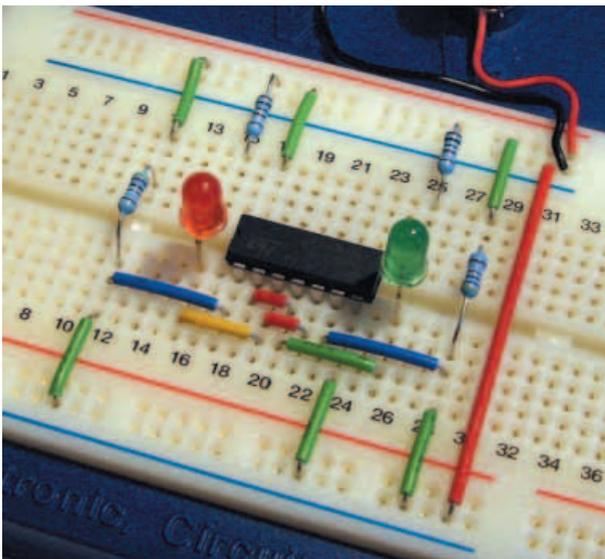


Photo 9.1. Wiring layout for Practical Investigation 9.1

Microprocessor Systems

Most of today's complex electronic systems are based on the use of a complex device called a *microprocessor* or *microcontroller*. Such systems comprise hardware (one or more large-scale integrated circuits) that is controlled by software. If it is necessary to change the way that the system behaves it is usually the software – rather than the hardware – that is changed.

The basic components of any microprocessor system are:

- a central processing unit (CPU)
- a memory, comprising both *read/write* and *read only* devices – commonly called RAM (random access memory) and ROM (read only memory) respectively

by a single very large scale integrated (VLSI) microprocessor chip. This chip is equivalent to many thousands of individual transistors. Semiconductor devices are also used to provide the read/write and read-only memory. Strictly speaking, both types of memory permit “random access” since any item of data can be retrieved with equal ease regardless of its actual location within the memory. Despite this, the term RAM has become synonymous with semiconductor read/write memory.

The basic components of the system (CPU, RAM, ROM and I/O) are linked together using a multiple-wire connecting system known as a *bus*. Three different buses are used in the system shown in Fig.9.3 (also see Photo 9.2), these are:

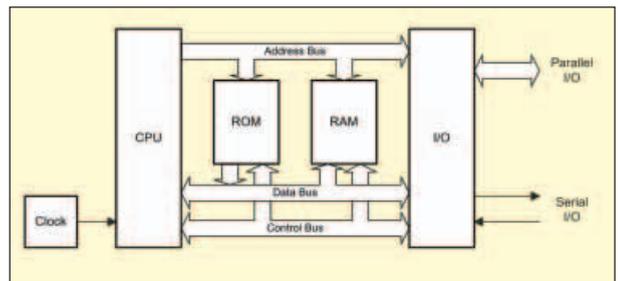


Fig.9.3. Simplified block diagram of a microprocessor system

- a means of providing an input and output (I/O). For example, a keypad for input and a display for output.

Check Point 9.1

A microprocessor bus is a multiple connecting system used to transfer data, addresses and control signals between the various parts of a microprocessor system, including the CPU, RAM, ROM and I/O.

Data Representation

Binary numbers – particularly large ones – are not very convenient. To make numbers easier to handle we often convert binary numbers to hexadecimal (base 16). This format is easier for mere humans to comprehend and offers the advantage over denary (base 10) in that it can be converted to and from binary with ease. The first sixteen numbers in binary, denary, and hexadecimal are shown in Table 9.2. A single hexadecimal character (in the range zero to F) is used to represent a group of four binary digits (bits). This group of four bits (or single hex character) is sometimes called a *nibble*.

A byte of data comprises a group of eight bits. Thus a byte can be represented by just two hexadecimal (hex) characters. A group of

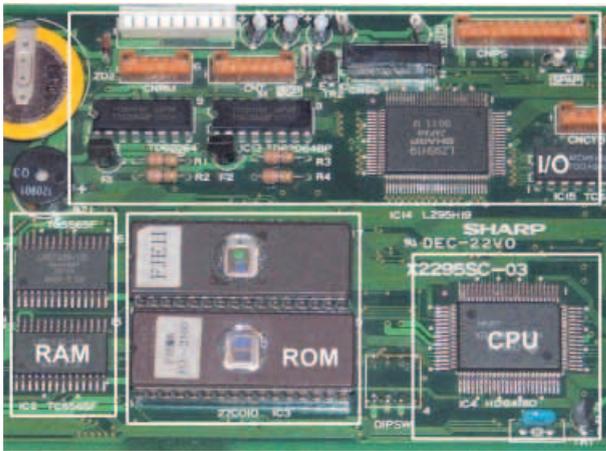


Photo 9.2. A typical microprocessor system showing CPU, RAM, ROM and I/O

sixteen bits (a word) can be represented by four hex characters, thirty-two bits (a double word) by eight hex. characters, and so on.

The value of a byte expressed in binary can be easily converted to hex by arranging the bits in groups of four and converting each nibble (i.e. four byte group) into hexadecimal using the Table 9.2.

Table 9.2. First 16 binary, decimal and hexadecimal values

Binary (base 2)	Decimal (base 10)	Hexadecimal (base 16)
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Example 9.1

Convert hexadecimal value B6 into a binary value.

From Table 9.2, B = 1011 and 6 = 0110. Thus B6 in hexadecimal is equivalent to 10110110 in binary.

Example 9.2

Convert binary value 11101001 to hexadecimal.

From Table 9.2, 1110 = E and 1001 = 9. Thus 11101001 in binary is equivalent to E9 in hexadecimal.

Check Point 9.2

Hexadecimal (base-16) numbers provide us with an easy way of representing data that is to be used by a microprocessor. Hexadecimal numbers can easily be converted to and from binary – remembering that one hexadecimal character is equivalent to four binary digits.

Note that, to avoid confusion about whether a number is hexadecimal or decimal, we often place a “\$” symbol before a hexadecimal number or add an H (upper or lower case) to the end of the number. For example, 64 means decimal “sixty-four”; whereas, \$64 means “hexadecimal six-four,” which is equivalent to decimal 100. Similarly, 7FH means “7F” hexadecimal which is equivalent to decimal 127.

Data Types

A byte of data can be stored at each address within the total memory space of a microprocessor system. Hence one byte can be stored at each of the 65,536 memory locations within a microprocessor system having a 16-bit address bus. Individual bits within a byte are numbered from 0 (least significant bit – positioned at the right) to 7 (most significant bit – positioned at the left). In the case of 16-bit words, the bits are numbered from 0 (least significant bit – rightmost) to 15 (most significant bit – leftmost). Negative (or signed) numbers can be represented using two’s complement notation where the leading (most significant) bit indicates the sign of the number (1 = negative, 0 = positive).

The range of integer data values that can be represented as bytes, words and long words are shown in Table 9.3.

Table 9.3. Range of integer data values that can be represented as bytes, words and long words

Data type	Bits	Range of values
Unsigned byte	8	0 to 255
Signed byte	8	-128 to +127
Unsigned word	16	0 to 65,535
Signed word	16	-32,767 to +32,767

Data Storage

The semiconductor ROM within a microprocessor system provides storage for the program code as well as any permanent data that requires storage (memory). All of this data is referred to as *non-volatile* because it remains intact when the power supply is disconnected.

The semiconductor RAM within a microprocessor system provides storage for the transient data and variables that are used by programs. Part of the RAM is also used by the microprocessor as a temporary store for data whilst carrying out its normal processing tasks.

It is important to note that any program or data stored in RAM will be lost when the power supply is switched off or disconnected. There are two exceptions to this: CMOS RAM that is kept alive by means of a small battery; this battery-backed memory is used to retain important data, such as the time and date. And secondly *electrically erasable*

read only memory (EEPROM), which is used for a similar purpose. Note that, despite its name, EEPROM can also have data written to it.

When expressing the amount of storage provided by a memory device we usually use Kilobytes (Kbyte). It is important to note that a Kilobyte of memory is actually 1,024 bytes (not 1,000 bytes). The reason for choosing the Kbyte rather than the kbyte (1,000 bytes) – note the use of upper and lower case “K” – is that 1,024 happens to be the nearest power of 2 ($2^{10} = 1,024$).

The capacity of a semiconductor ROM is usually specified in terms of an address range and the number of bits stored at each address. For example, 2K × 8 bits (capacity 2Kbytes), 4K × 8 bits (capacity 4Kbytes), and so on.

The basic element of a semiconductor memory is known as a “cell”. Cells can be fabricated in one of two semiconductor technologies: MOS (metal oxide semiconductor) and bipolar. Bipolar memories are now rarely used even though they offer much faster access times. Their disadvantage is associated with power supply requirements (they need several voltage rails, both positive and negative, and use significantly more power than their MOS counterparts).

Random Access

Random access memories can be further divided into static and dynamic types. The important difference between the two types is that dynamic memories require periodic refreshing if they are not to lose their contents. While, in the normal course of events, this would be carried out whenever data was read and rewritten, this technique cannot be relied upon to refresh all of the dynamic memory space and steps must be taken to ensure that all dynamic memory cells are refreshed periodically.

This function has to be integrated with the normal operation of the computer system or performed by a dedicated dynamic memory controller. Static memories do not need refreshing and can be relied upon to retain their memory until such time as new data is written or the power supply is interrupted (in which case all data is lost).

The circuit of a typical bipolar static memory cell is shown in Fig.9.4. The transistors form an R-S bistable (see Part 8) that can be SET or RESET by means of a pulse applied to the appropriate emitter. The CELL SELECT line is used to identify the particular cell concerned. This type of cell uses emitter-coupled logic (ECL) and requires both negative and positive supply rails.

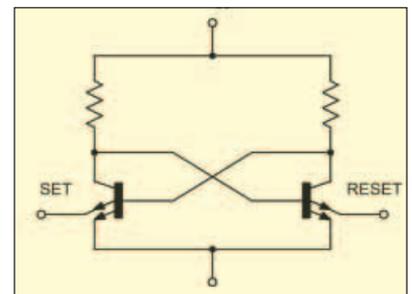


Fig.9.4. Circuit diagram of a typical bipolar static memory cell

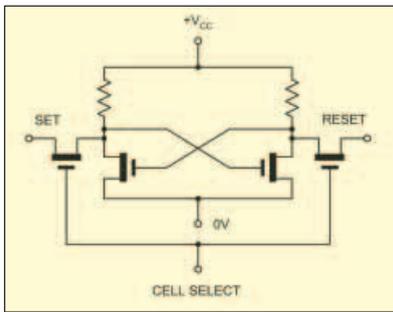


Fig.9.5. Circuit diagram of a typical MOS static memory cell

The circuit of a typical MOS static memory cell is shown in Fig.9.5. This is also clearly recognizable as a bistable element. The CELL SELECT line is used to gate signals into and out of the memory cell. Note that, as for the bipolar cell, the SET and RESET lines are common to a number of cells.

The circuit of a typical MOS dynamic memory cell is shown in Fig.9.6. In contrast to the previous types of cell this clearly does not use a bistable arrangement. Instead, a capacitor, C, is used as the storage element. The capacitor is in fact the input capacitance of an MOS transistor. This is charged or discharged according to the state of the INPUT, OUTPUT and CELL SELECT lines.

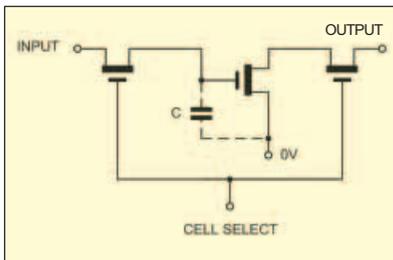


Fig.9.6. Circuit diagram of a typical MOS dynamic memory cell

Check Point 9.3

Digital data is stored in an array of individual memory cells. Each memory cell can store a 1 or 0. Static memories are made up from cells that will retain their contents indefinitely (as long as the power supply is present). Dynamic memories, on the other hand, comprise cells that require constant refreshing in order to retain their data.

Questions 9.1

Q9.1. Convert 2A hexadecimal to binary.

Q9.2. Convert 10011110 binary to hexadecimal.

Q9.3. Which of the following numbers is the largest?

- 10010 binary
- 19 decimal.
- 15 hexadecimal.

Microprocessors

The microprocessor central processing unit (CPU) forms the heart of any microprocessor or microcomputer system computer and, consequently, its operation is crucial to the entire system. The primary function of a microprocessor is that of fetching, decoding, and executing instructions resident in memory (either RAM or ROM). As such, the microprocessor must be able to transfer data from external memory into its own internal registers and vice versa.

Furthermore, it must operate predictably, distinguishing, for example, between an operation contained within an instruction and any accompanying addresses of read/write memory locations. In addition, various system housekeeping tasks need to be performed including responding to interrupts from external devices.

The main parts of a microprocessor CPU are:

- registers for temporary storage of addresses and data
- an arithmetic logic unit (ALU) that performs arithmetic and logic operations
- a means of controlling and timing operations within the system

through the data bus. On the first part of each machine cycle, the instruction is fetched and decoded. The instruction is executed on the second (and subsequent) machine cycles. Each machine cycle takes a finite time (usually less than a microsecond) depending upon the frequency of the microprocessor's clock (see later).

Data Bus (D0 to D7)

The external data bus provides a highway for data that links all of the system components (such as random access memory, read-only memory, and input/output devices) together. In an 8-bit system, there are eight data lines, labelled D0 (the least significant bit) to D7 (the most significant bit) and data is moved around in groups of eight bits, or bytes.

Data Bus Buffer

The data bus buffer is a temporary register through which bytes of data pass on their way into, and out of, the microprocessor. The buffer is thus referred to as bidirectional with data passing out of the microprocessor on a write operation and into the processor during a read operation. The direction of data transfer is determined by the control unit as it responds to each individual program instruction.

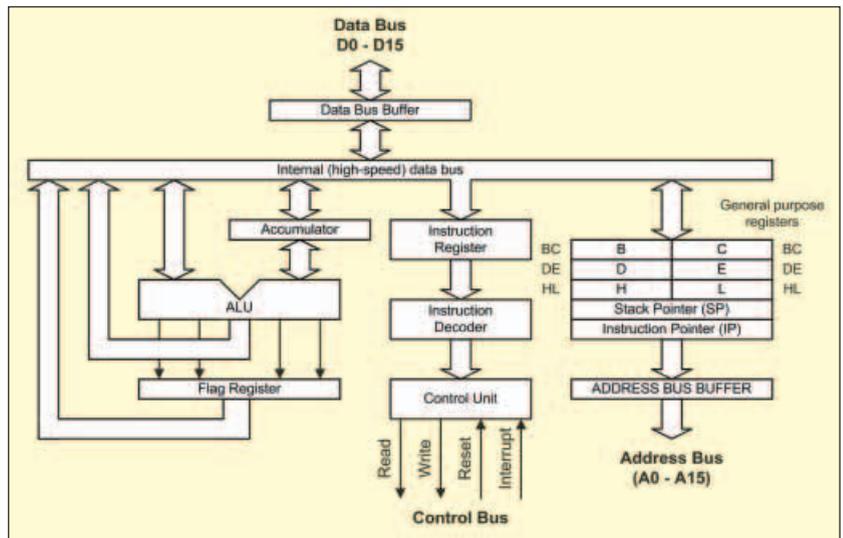


Fig.9.7. Simplified block schematic of a typical microprocessor

Fig.9.7 shows the principal internal features of a typical 8-bit microprocessor. This is a very complex device so we will briefly explain each of these features in turn:

Accumulator

The accumulator functions as a source and destination register for many of the basic microprocessor operations. As a source register it contains the data that will be used in a particular operation whilst as a destination register it will be used to hold the result of a particular operation. The Accumulator (or A-register) features in a very large number of microprocessor operations, consequently more reference is made to this register than any others.

Instruction Register

The instruction register provides a temporary storage location in which the current microprocessor instruction is held whilst it is being decoded. Program instructions are passed into the microprocessor, one at time,

Internal Data Bus

The internal data bus is a high-speed data highway that links all of the microprocessor's internal elements together. Data is constantly flowing backwards and forwards along the internal data bus lines.

General Purpose Registers

Many microprocessor operations (for example, adding two 8-bit numbers together) require the use of more than one register. There is also a requirement for temporarily storing the partial result of an operation whilst other operations take place. Both of these needs can be met by providing a number of general purpose registers. The use to which these registers are put is left mainly up to the programmer.

Stack Pointer

When the time comes to suspend a particular task in order to briefly attend to something else, most microprocessors make use of a region of external random access memory (RAM) known as a *stack*. When the

main program is interrupted, the microprocessor temporarily places in the stack the contents of its internal registers together with the address of the next instruction in the main program. When the interrupt has been attended to, the microprocessor recovers the data that has been stored temporarily in the stack together with the address of the next instruction within the main program. It is thus able to return to the main program exactly where it left off and with all the data preserved in its registers. The stack pointer is simply a register containing the address of the last used stack location.

Program Counter

Programs consist of a sequence of instructions that are executed by the microprocessor. These instructions are stored in external random access memory (RAM) or read-only memory (ROM). Instructions must be fetched and executed by the microprocessor in a strict sequence. By storing the address of the next instruction to be executed, the program counter allows the microprocessor to keep track of where it is within the program. The program counter is automatically incremented when each instruction is executed.

Address Bus Buffer

The address bus buffer is a temporary register through which addresses (in this case comprising 16-bits) pass on their way out of the microprocessor. In a simple microprocessor, the address buffer is unidirectional with addresses placed on the address bus during both read and write operations. The address bus lines are labelled A0 to A15, where A0 is the least-significant address bus line and A15 is the most significant address bus line. Note that a 16-bit address bus can be used to communicate with 65,536 individual memory locations. At each location a single byte of data is stored.

Control Bus

The control bus is a collection of signal lines that are both used to control the transfer of data around the system and also to interact with external devices. The control signals used by microprocessors tend to differ with different types, however the following are commonly found:

READ: an output signal from the microprocessor that indicates that the current operation is a read operation

WRITE: an output signal from the microprocessor that indicates that the current operation is a write operation

RESET: a signal that resets the internal registers and initialises the program counter so that the program can be re-started from the beginning

IRQ: an interrupt request from an external device attempting to gain the attention of the microprocessor (the request may be honoured or ignored according to the state of the microprocessor at the time that the interrupt request is received – see later).

NMI: non-maskable interrupt (i.e. an interrupt signal that cannot be ignored by the microprocessor – see later).

Address Bus (A0 to A15)

The address bus provides a highway for addresses that links with all of the system components (such as random access memory, read-only memory, and input/output devices). In a system with a 16-bit address bus, there are sixteen address lines, labelled A0 (the least significant bit) to A15 (the most significant bit).

Instruction Decoder

The instruction decoder is nothing more than an arrangement of logic gates that acts on the bits stored in the instruction register and determines which instruction is currently being referenced. The instruction decoder provides output signals for the microprocessor's control unit.

Control Unit

The control unit is responsible for organising the orderly flow of data within the microprocessor as well as generating, and responding to, signals on the control bus. The control unit is also responsible for the timing of all data transfers. This process is synchronised using an internal or external clock signal (not shown in Fig.9.7).

Arithmetic Logic Unit (ALU)

As its name suggests, the ALU performs arithmetic and logic operations. The ALU has two inputs (in this case these are both 8-bits wide). One of these inputs is derived from the Accumulator whilst the other is taken from the internal data bus via a temporary register (not shown in Fig.9.7). The operations provided by the ALU usually include addition, subtraction, logical AND, logical OR, logical exclusive-OR, shift left, shift right, etc. The result of most ALU operations appears in the accumulator.

Check Point 9.4

Microprocessors comprise a number of registers for temporary storage of addresses and data; an arithmetic logic unit (ALU) that performs arithmetic and logic operations; and a means of controlling and timing operations within the system.

Flag Register (or Status Register)

The result of an ALU operation is sometimes important in determining what subsequent action takes place. The flag register contains a number of individual bits that are set or reset according to the outcome of an ALU operation. These bits are referred to as *flags*. The following flags are available in most microprocessors:

ZERO: the zero flag is set when the result of an ALU operation is zero (i.e. a byte value of 00000000)

CARRY: the carry flag is set whenever the result of an ALU operation (such as addition) generates a carry bit (in other words, when the result cannot be contained within an 8-bit register)

INTERRUPT: the interrupt flag indicates whether external interrupts are currently enabled or disabled.

Clocks

The clock used in a microprocessor system is simply an accurate and stable square wave generator. In most cases the frequency of the square wave generator is determined by a quartz crystal. A simple 4MHz square wave clock oscillator (together with the clock waveform that it produces) is shown in Fig.9.8. Note that one complete clock cycle is sometimes referred to as a "T-state".

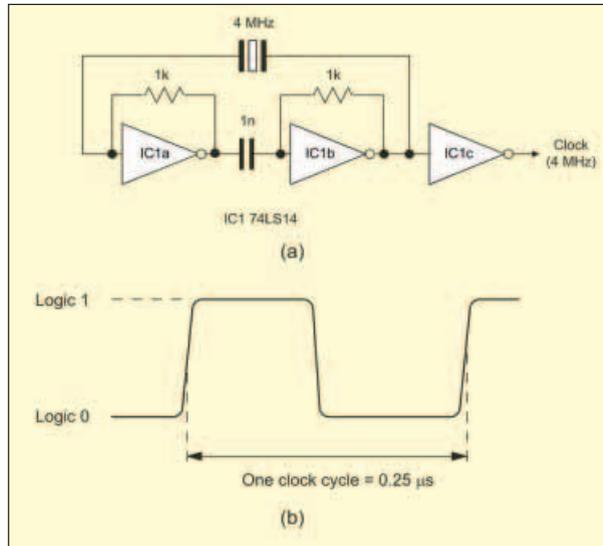


Fig.9.8. A typical quartz crystal controlled clock circuit and the clock signal waveform that it produces

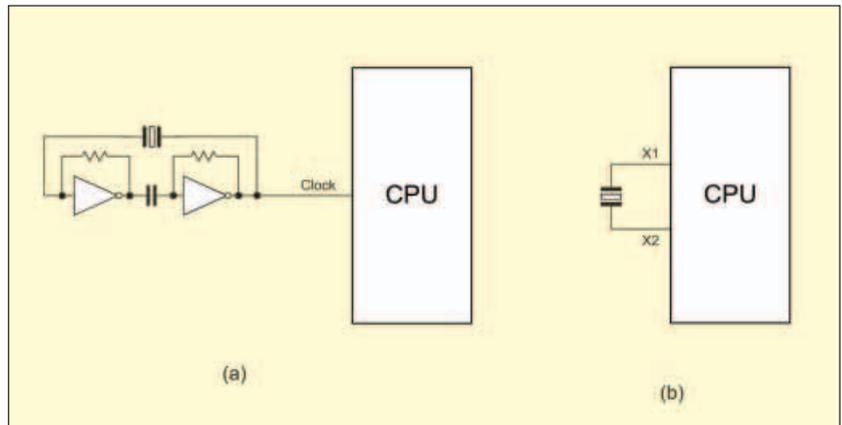


Fig.9.9. External and internal clock arrangements

Clock frequencies from 1MHz, or lower, to even 40MHz for a basic microprocessor controller are common, and even to over 3GHz for the processors used in the latest Pentium-based personal computers.

Microprocessors sometimes have an internal clock circuit in which case the quartz crystal (or other resonant device) is connected directly to pins on the microprocessor chip. In Fig.9.9a an external clock is shown connected to a microprocessor whilst in Fig.9.9b an internal clock oscillator is used.

Microprocessor Operation

The majority of operations performed by a microprocessor involve the movement of data. Indeed, the program code (a set of instructions stored in ROM or RAM) must itself be fetched from memory prior to execution. The microprocessor thus performs a continuous sequence of instruction fetch and execute cycles. The act of fetching an instruction code (or operand or data value) from memory involves a *read* operation whilst the act of moving data from the microprocessor to a memory location involves a *write* operation – see Fig.9.10.

Each cycle of CPU operation is known as a *machine cycle*. Program instructions may require several machine cycles (typically between two and five). The first machine cycle in any cycle consists of an instruction fetch (the instruction code is read from the memory) and it is known as the M1 cycle. Subsequent cycles M2, M3, and so on, depend on the type of instruction that is being executed. This fetch-execute sequence is shown in Fig.9.11.

Microprocessors determine the source of data (when it is being read) and the destination of data (when it is being written) by placing a unique address on the address bus.

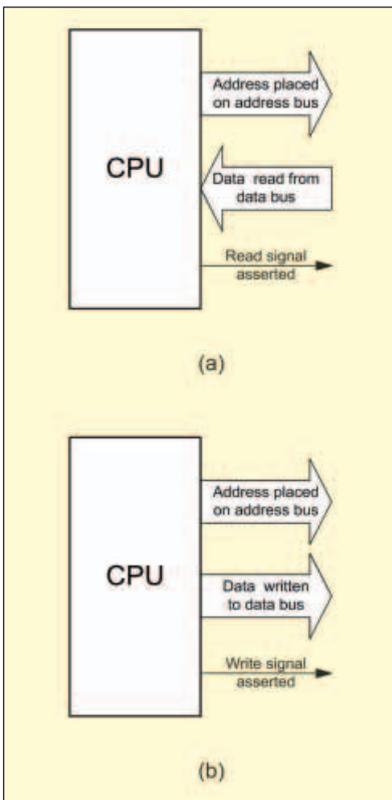


Fig.9.10. Microprocessor signals during (a) read and (b) write operations

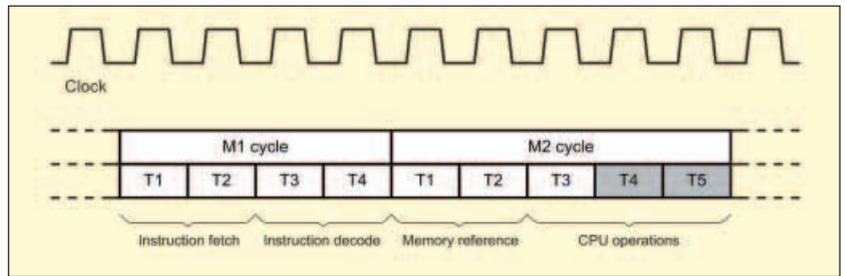


Fig.9.11. A typical fetch-execute sequence

The address at which the data is to be placed (during a write operation) or from which it is to be fetched (during a read operation) can either constitute part of the memory of the system (in which case it may be within ROM or RAM) or it can be considered to be associated with an input/output (I/O).

Since the data bus is connected to a number of VLSI (very large scale integration) devices, an essential requirement of such chips (e.g., ROM or RAM) is that their data outputs should be capable of being isolated from the bus whenever necessary. These chips are fitted with *select* or *enable* inputs that are driven by address decoding logic (not shown in Fig.9.7). This logic ensures that ROM, RAM and I/O devices never simultaneously attempt to place data on the bus!

The inputs of the address decoding logic are derived from one, or more, of the address bus lines. The address decoder effectively divides the available memory into blocks corresponding to a particular function (ROM, RAM, I/O, etc). Hence, where the processor is reading and writing to RAM, for example, the address decoding logic will ensure that only the RAM is selected whilst the ROM and I/O remain isolated from the data bus.

Within the CPU, data is stored in several registers. Registers themselves can be thought of as a simple “pigeon-hole” arrangement that can store as many bits as there are holes available. Generally, these devices can store groups of sixteen or thirty-two bits. Additionally, some registers may be configured as either one register of sixteen bits or two registers of thirty-two bits.

Some microprocessor registers are accessible to the programmer whereas others are used by the microprocessor itself. Registers may be classified as either general purpose or dedicated. In the latter case a particular function is associated with the register, such as holding the result of an operation or signalling the result of a comparison. The principal control and data signals and registers generated by a

typical microprocessor (the Z80, of which there are many current derivatives) are shown (together with its internal registers) in Fig.9.12.

Note that, whilst the data registers are 8-bit registers (and so can hold eight bits of data) they can also be used “end-on” to store 16-bit data. Hence, if the B and C registers in Fig.9.12 respectively contain AF and C9 hexadecimal, the double-length register BC will contain 16-bit data, AFC9 hexadecimal.

Programming

Microprocessor programming is a vast subject and would require far more space than we have available in the whole of the *Teach-In* series. That said, it would be unfair to move on without mentioning the techniques used to program a microprocessor system.

Software (consisting of a sequence of instructions that the microprocessor will recognise and execute) can be generated by various means and using various languages, as appropriate to the application and expertise of the programmer. The lowest level of language that the microprocessor can understand is often referred to as the *machine code*. This consists of a series of instructions and data coded in hexadecimal form.

An improvement on machine code (at least as far as human beings are concerned!) is the use of a mnemonic-based language, known as “assembly language”.

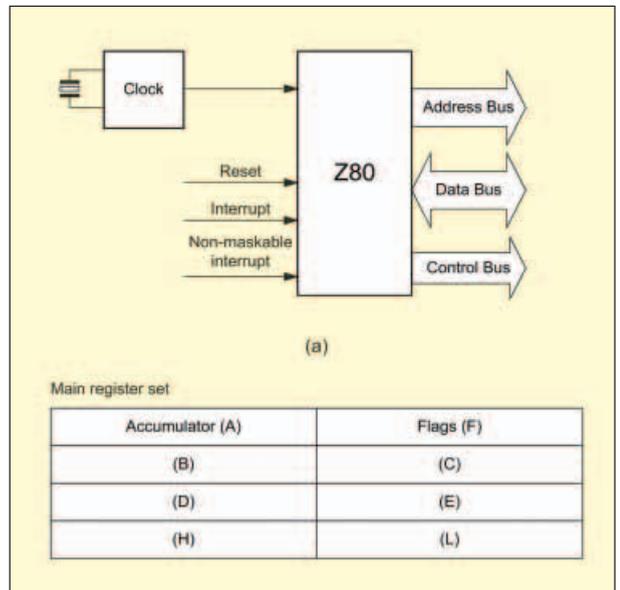


Fig.9.12. Principal Z80 control and data signals and internal registers

This isn't too hard to learn and can be easily converted (using appropriate software) into the machine code that the microprocessor requires. A simple example of an assembly language program (written in Z80 assembly language) is shown in Fig.9.13.

Note that the assembly language *source code* is shown in the upper window whilst the *assembled code* (in hexadecimal) is shown in the lower window. Note also how some brief comments have been added to the source code in order to explain the action of the program. These comments can be extremely useful – particularly in larger and more complex programs – when it comes to modifying or “debugging” a program!

Unfortunately, programs written in assembly language will generally only work with a particular microprocessor family. A more “portable” solution is the use of a high-level language such as C or BASIC. These languages are relatively easy to learn and programs written in them can usually easily be transported from one type of microprocessor to another. The conversion process, from high-level language code to machine code is a task that is easily handled by a piece of software called a *compiler*.

Input and Output

The transfer of data within a microprocessor system involves moving groups of 8, 16 or 32-bits using the bus architecture that we described earlier. Consequently it is a relatively simple

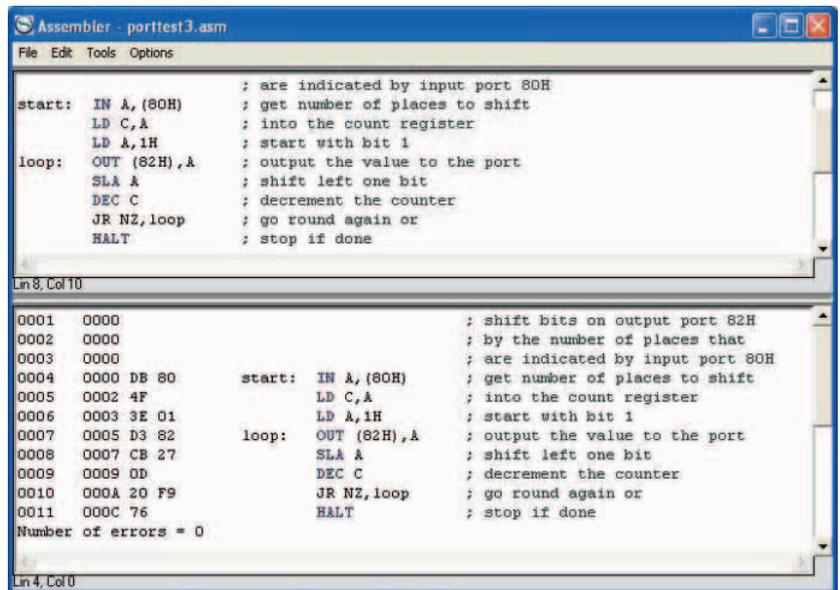


Fig.9.13. A simple Z80 assembly language program

matter to transfer data into and out of the system in parallel form. This process is further simplified by using a Programmable Parallel I/O device which provides registers that can be used for the temporary storage of data being transferred onto and out of the data bus.

Parallel data transfer is primarily suited to high-speed operation over relatively short distances, a typical example being the linking of a microcomputer to a local printer.

There are, however, applications in which parallel data transfer is inappropriate, the most common example being data communication with other microcomputer systems. In such cases data must be sent serially (one bit after another) rather than in parallel form.

To transmit data in serial form, the parallel data from the microprocessor must be reorganized into a stream of bits. This task is greatly simplified by using an LSI interface device that contains a shift register that is loaded with parallel

data from the data bus. This data is then read out as a serial bit-stream by successive shifting.

The reverse process, serial-to-parallel conversion, also uses a shift register. Here data is loaded in serial form, each bit shifting further into the register until it becomes full. Data is then placed simultaneously on the parallel output lines. The basic principles of parallel-to-serial and serial-to-parallel data conversion are illustrated in Fig.9.14.

Interrupts

In most practical microprocessor systems we want to be able to interrupt the normal sequence of program flow in order to alert the microprocessor to the need to do something. We can do this with a signal known as an *interrupt*. There are two types of interrupt; maskable and non-maskable.

When a non-maskable interrupt input is asserted, the processor must suspend execution of the current instruction and respond immediately to the interrupt. In the case of a maskable interrupt, the processor's response will depend upon whether interrupts are currently enabled or disabled (when enabled, the CPU will suspend its current task and carry out the requisite interrupt service routine). The response to interrupts can be enabled or disabled by means of appropriate program instructions.

In practice, interrupt signals may be generated from a number of sources and since each will require its own customised response a mechanism must be provided for identifying the source of the interrupt and calling the appropriate interrupt service routine. In order to assist in this task, the microprocessor may use an additional dedicated programmable interrupt controller chip.

A Microcontroller System

Finally, Fig.9.15 shows the arrangement of a typical microcontroller system. The sensed quantities (temperature, position, etc) are converted to corresponding electrical signals by means of a number of

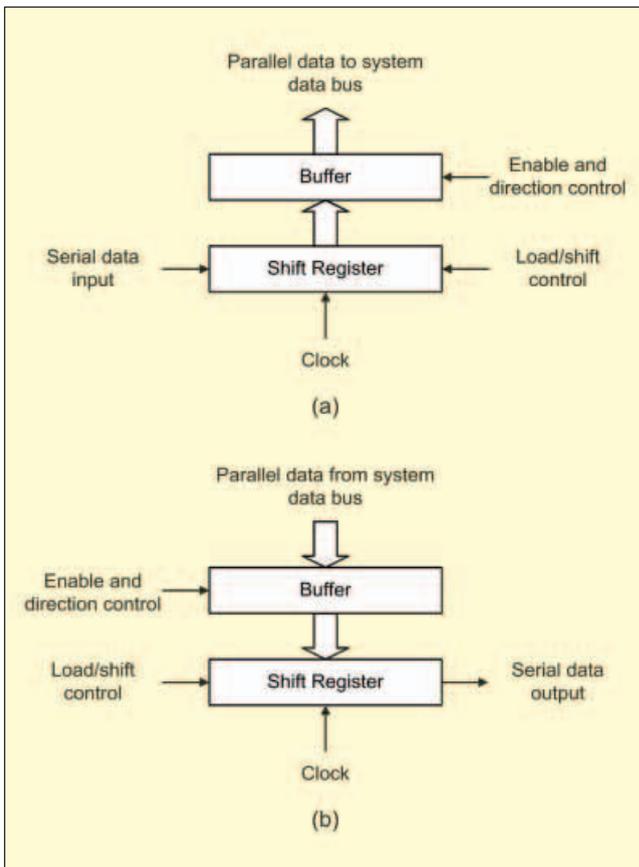


Fig.9.14. (a) Serial-to-parallel and (b) parallel-to-serial data conversion

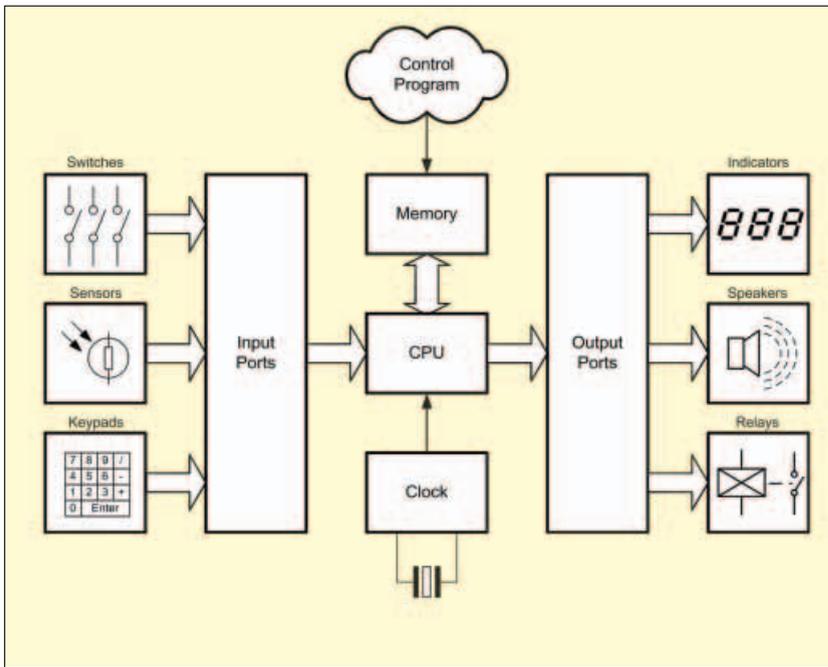


Fig.9.15. A typical microcontroller system

sensors. The outputs from the sensors (in either digital or analogue form) are passed as input signals to the microcontroller. The microcontroller also accepts inputs from the user. These user-set options typically include target values for variables (such as desired room temperature), limit values (such as maximum shaft speed), or time constraints (such as “on” time and “off” time, delay time, etc).

Questions 9.2

Q9.4. Fig.9.16 shows the block diagram of a microprocessor system. Identify each of the blocks.

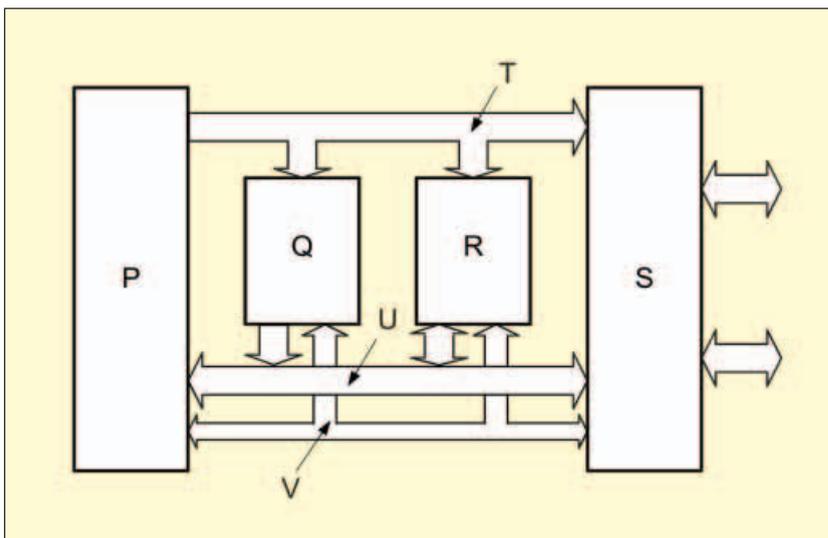


Fig.9.16. See questions 9.2

Answers to Questions (Part 9)

- Q9.1 00101010
 Q9.2 9E (158 decimal)
 Q9.3 c (21 decimal) (10010 binary is 18 decimal)
 Q9.4 P CPU; Q ROM; R RAM; S I/O; T address bus; U data bus; V control bus.

Part 10

In Part 10, next month, we shall be developing our current microcontroller theme into the world of PIC chips and also introducing operational amplifiers (op.amps). In the meantime you might like to see how you get on with our on-line quiz for Part 9. You will find this at: www.miketooley.info/teach-in/quiz9.htm.

Answers to Questions (Part 8)

- Q1. See Fig.9.17
 Q2. See Fig.9.18
 Q3. See Fig.9.19
 Q4. (a) $Y = /A + /B = /(A \cdot B)$. Note that this gate arrangement performs the same logical function as a two-input NAND gate!
 (b) $Y = /A \cdot /B = /(A + B)$. Note that this gate arrangement performs the same logical function as a two-input NOR gate!
 Q5. See Fig.9.20

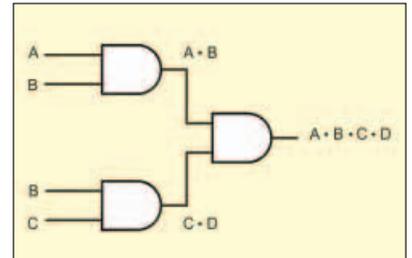


Fig.9.17. See Answers to Questions Part 8

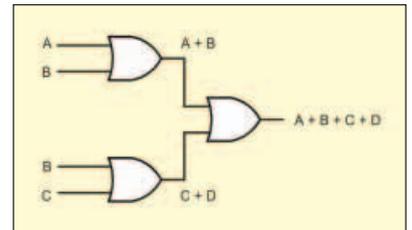


Fig.9.18. See Answers to Questions Part 8

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	0

Fig.9.19. See Answers to Questions Part 8

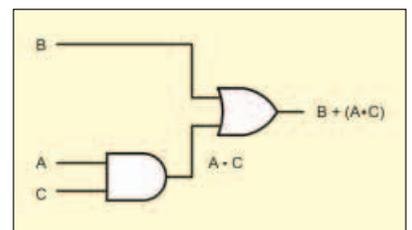
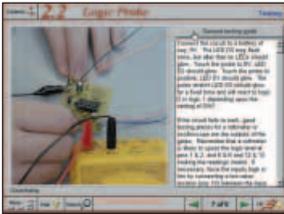


Fig.9.20. See Answers to Questions Part 8

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ELECTRONICS PROJECTS

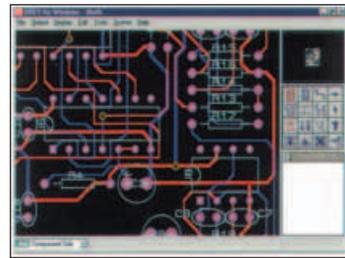


Logic Probe testing

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.

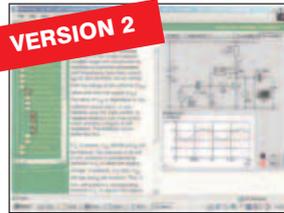
ELECTRONICS CAD PACK



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.

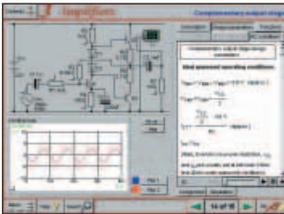
ELECTRONIC CIRCUITS & COMPONENTS V2.0



Circuit simulation screen

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

ANALOGUE ELECTRONICS



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ROBOTICS & MECHATRONICS

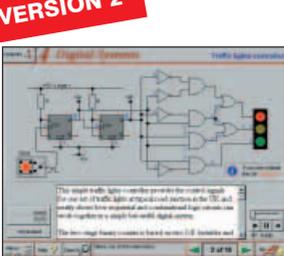


Case study of the Milford Instruments Spider

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

DIGITAL ELECTRONICS V2.0



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.

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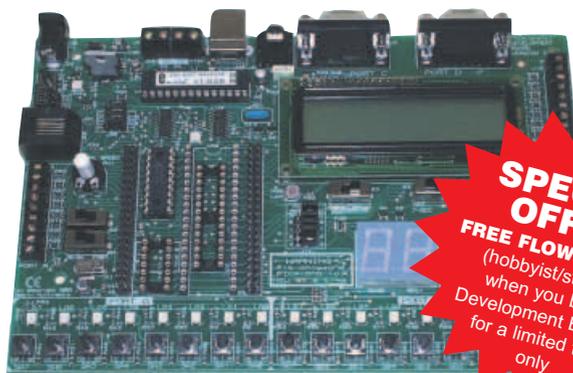
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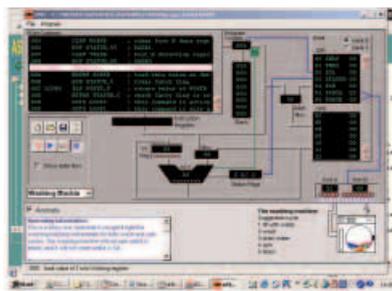
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- Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator
- Tests, exercises and projects covering a wide range of PICmicro MCU applications
- Includes MPLAB assembler
- Visual representation of a PICmicro showing architecture 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.

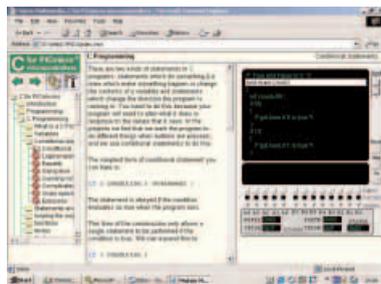


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- Highly interactive course
- Virtual C PICmicro improves understanding
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- Includes full Integrated Development Environment
- Includes MPLAB software
- Compatible with most PICmicro programmers
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Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

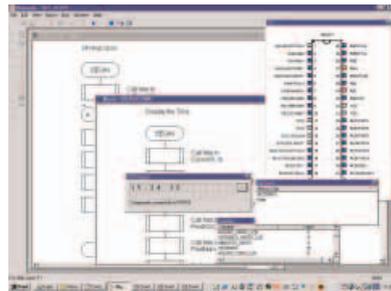
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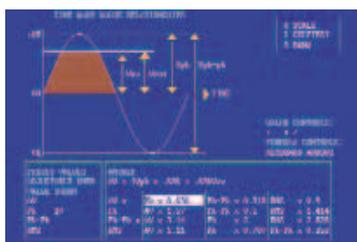
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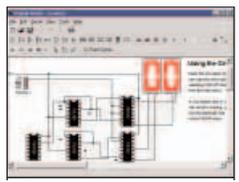
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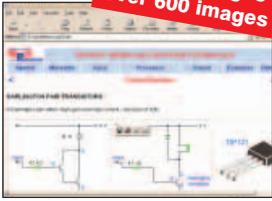
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Last month, we gave the circuit details for our Digital Instrument Display and showed you how to build it. This month, we describe how to connect different sensors to the unit and give the calibration details.

Digital Instrument Display For Cars

Pt.2: By JOHN CLARKE

THE TYPICAL sensor and meter connections that are found a vehicle are shown in Fig.4. Generally, the sensor is grounded and the existing analogue meter connects in series with this to a regulated supply. The other possible configuration is when the meter itself is grounded and the sensor connects to the regulated supply instead.

In either case, you can connect to the junction of the sensor and the meter (marked with an 'x') to obtain a signal to drive the Digital Instrument Display.

Alternatively, the sensor can be rewired as shown in Fig.5, using a fixed resistor (R1) to replace the meter. Note that R1 can be installed on the microcontroller board.

It is important to note that the Digital Instrument Display is designed to accept a signal voltage at its input which is within a certain range. So you will

need to make some measurements to check whether the voltage range from the sensor is suitable. If the signal voltage is outside the limits, it can be tailored using several adjustments at the input to make it suit.

The voltage limits for the Digital Instrument Displays input are as follows:

(1) with R3 out of circuit, the unit can be used with voltages ranging from 0.5 to 4.5V.

(2) with R3 in circuit and VR1 adjusted so that the unit can read down to 0V, the Digital Instrument display can measure up to 2.7V when VR2 is fully clockwise (250k Ω) and up to 3.4V when VR2 is fully anticlockwise (0 Ω).

Attenuating the input voltage

The value of R1 (see Fig.5) needs to be selected so that the voltage across the sensor remains within the allowable range. Typically, R1 would be a

330 Ω (0.25W) resistor and the circuit would be configured with VR2 fully anticlockwise, R3 in circuit and R2 omitted.

However, if the sensor voltage goes above 2.7V, you can adjust VR2 so that signal voltages up to 3.4V can be monitored. Higher input voltages will need to be attenuated by fitting resistor R2.

R2 can be calculated if the maximum input voltage ($V_{in\ max.}$) to be applied to the input is known. The circuit for the attenuator is shown in Fig.6. If VR2 is set at its mid-position, the value for $R2 = 30k\Omega / (V_{in\ max.} - 3)$.

For example if the maximum input voltage is 8V, R2 will be $30k\Omega / 5$ or 6k Ω . A 5-6k Ω resistor would be suitable. VR2 is then used to adjust the range of the signal voltage that can be applied to the circuit.

Trimpot VR1 will require adjustment if resistor R3 is installed. Also,

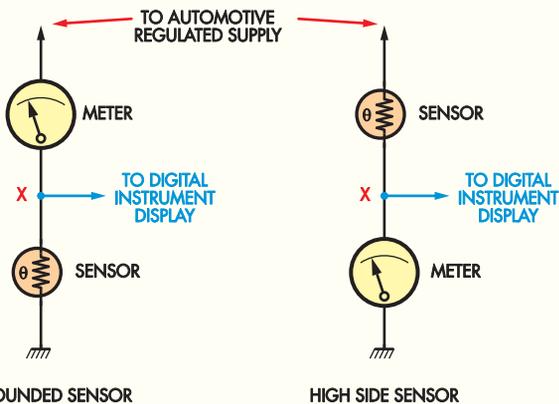


Fig. 4: typical sensor and meter connections as found in a vehicle.

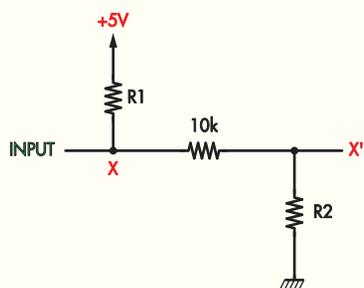


Fig. 6: resistor R2 is necessary only if the signal voltage (ie, from the sensor) goes above 3.4V. Its value is calculated as described in the text.

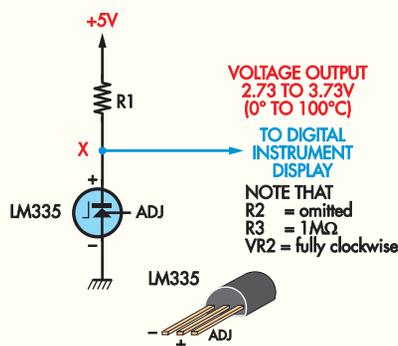


Fig. 7: how to use the Digital Instrument Display with an LM335 temperature sensor (see text).

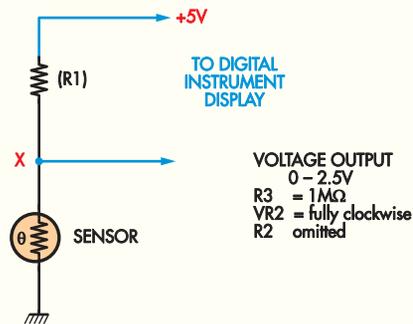


Fig. 5: R1 needs to be selected so that the voltage across the sensor remains within the allowable range. Typically, R1 would be a 330Ω (0.25W) resistor and the circuit would be configured with VR2 fully anticlockwise, R3 in circuit and R2 omitted.

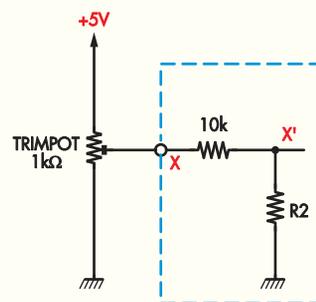


Fig. 8: a 1kΩ trimpot connected between the +5V rail and ground can be used to set input voltages to calibrate the unit.

this adjustment will need to be redone if VR2 is altered. In practice, VR1 is adjusted by connecting the input to the Digital Instrument Display to 0V and selecting the input mode by pressing the Mode switch four times (ie, four times from the normal display position mode).

Note, however, that trimpot VR1 is NOT adjusted for a display reading of 0 (if it does show 0, then trimpot VR1 is too far clockwise). Instead, you have to adjust VR1 so that the display shows a reading between about 97 and 110.

Fig. 7 shows how to use the Digital Instrument Display with an LM335 temperature sensor. Typically, the output from the sensor varies by 10mV/°C, with the output at 2.73V at 0°C.

Calibration

We have already described how the calibration modes are accessed by pressing the Mode switch. As previously stated, calibration is performed

at two different points and the instrument then calculates the readings for the remaining input voltages.

Before starting calibration, you must first decide on the display readings that are required at these two points. For example, for a temperature gauge, you might select 0°C and 100°C for the two calibration points. Alternatively, for a fuel gauge, you could calibrate the unit at 10 litres and 50 litres.

These values are then entered as the first and second calibration numbers.

Note that the first calibration number must correspond to the lower of the two voltages applied to the instrument during calibration. So, taking our first example, if the sensor gives a lower signal voltage at 0°C than at 100°C, then the 0 is entered into the first calibration position and the 100 is entered into the second calibration position.

Alternatively, if the sensor gives a lower voltage at 100°C compared to that at 0°C, the 100 must be entered into the

Installing The Unit In A Vehicle

Use automotive cable and connectors when installing the Digital Instrument Display into a vehicle. The +12V supply connection is derived via the ignition switch and a suitable connection point will usually be found inside the fusebox. Be sure to choose the fused side of the supply rail, so that the existing fuse is in series with the unit.

The ground connection can be made by connecting a lead to the chassis via an eyelet and self-tapping screw.

Similarly, use automotive cable to connect to the chosen vehicle sensor or sender unit.

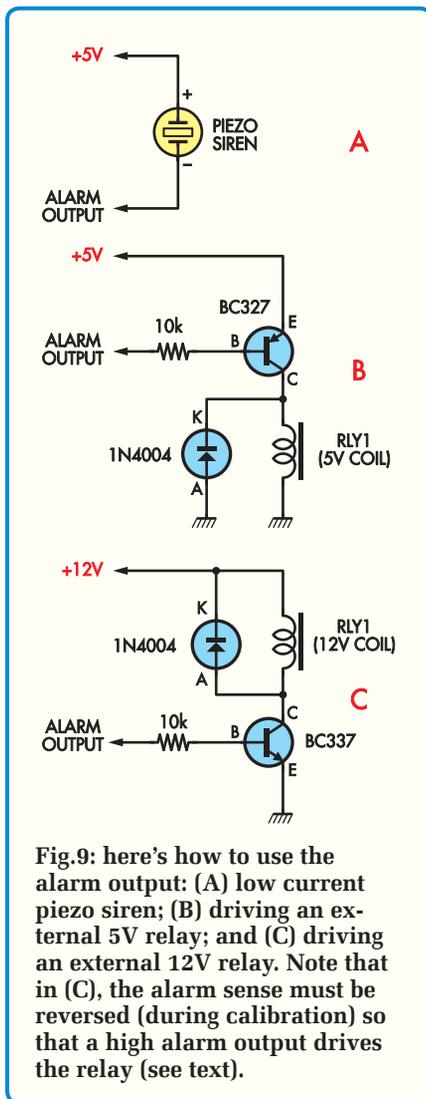


Fig.9: here's how to use the alarm output: (A) low current piezo siren; (B) driving an external 5V relay; and (C) driving an external 12V relay. Note that in (C), the alarm sense must be reversed (during calibration) so that a high alarm output drives the relay (see text).

first calibration position and the 0 into the second calibration position.

The same applies for a fuel gauge or oil pressure gauge – ie, use the figure that gives the lowest signal voltage in the first calibration position and the figure that gives the highest signal voltage in the second position.

Calibration signals

In order to calibrate the unit, you need to feed in a signal voltage that's the same as that provided by the sensor at each calibration point. To do this, you can either use the actual sensor itself or you can use a 1kΩ trimpot connected to the input as shown in Fig.8.

As mentioned before, the two calibration positions are selected using the Mode switch. If the first calibration position is to be calibrated, apply the calibration voltage, then select this

position by pressing the Mode switch once after the “normal” mode.

Now wait for several seconds for the voltage at the input to be measured by the Digital Instrument Display. **Now press the Up switch and then the Down switch, so that the value is the same as before. This needs to be done as calibration can only take place when the calibration value is changed.** Simply selecting the calibration value with the Mode switch will not calibrate the Digital Instrument Display.

The second calibration voltage is then applied and the Mode switch pressed again to show the second calibration number. Wait a few seconds, then press the Up and Down switches to calibrate this value.

Note that there is no need to feed in both calibration values at the same time – calibration can be done for either the first or second position at any time (even weeks apart if that's more convenient).

In fact, if you are calibrating the unit for a fuel sensor, the best approach is to calibrate it for one value when the tank is full and then wait until the tank is almost empty to feed in the other calibration number.

Alternatively, you can do this the other way around – ie, feed in one calibration number when the tank is empty, then fill up and feed in the other calibration number.

Note that the “normal” readings will not be correct until both calibration values have been entered.

Checking signal levels

It's important to check that the voltages applied to the Digital Instrument Display are not beyond its range. This can be done by pressing the Mode switch four times from its normal display mode to select the input reading mode. The display should show a value between about 100 and 940. Values much below 100 will go to “0” and values much above 940 will show “FUL” on the display.

A “0” or “FUL” indicates that the voltage applied to the Digital Instrument Display is out of range and the voltage will need to be altered as previously described using R1, R2, VR1 and VR2.

Measuring sensor voltages

Calibration of the instrument with a fuel or oil pressure sensor

can initially be done by measuring the voltage across the sensor in its standard form when connected to the original analogue meter. You will need to connect your multimeter so that the measurement can be made over the full range of outputs from the sensor during normal running of the car. That way, you will gain a good idea of the voltages that are produced by the sensor.

During this time, record two voltages that correspond to two particular markings on the meter. The further apart the voltages are, the more accurate the calculation for other values will be.

Be sure to check the voltages obtained during this process against the allowable limits. You can attenuate the level using R2 if the voltage range from the sensor is too great. Similarly, if the voltage goes below 0.5V, you will need to install R3 and then adjust VR1 as detailed above.

You can then calibrate the instrument using the voltages found by measurement and by using a 1kΩ trimpot connected as shown in Fig.8. That done, disconnect the car instrument from its sensor and measure the instrument's resistance to determine the value of R1. It's then just a matter of installing R1 on the microcontroller board, as shown in Fig.5.

Temp. sensor calibration

Calibrating the unit for use with a temperature sensor can be done at 0°C and at 100°C. The 0°C calibration is done using freshwater ice which is stirred in a small amount of cold fresh water. Stir the solution with the sensor immersed in it to ensure it reaches the 0°C of the water/ice solution before entering “0” for the first calibration number.

Note that if you connect a multimeter across the sensor, it will stop changing value when it reaches 0°C – ie, it will reach either a minimum or maximum output.

By contrast, the 100°C calibration is done by immersing the sensor in boiling fresh water. Again ensure that the sensor output has stabilised in the boiling water by monitoring its output voltage before entering in the calibration number.

Just remember that the calibration number corresponding to the lowest sensor voltage goes in the first calibration position. So if the sensor voltage

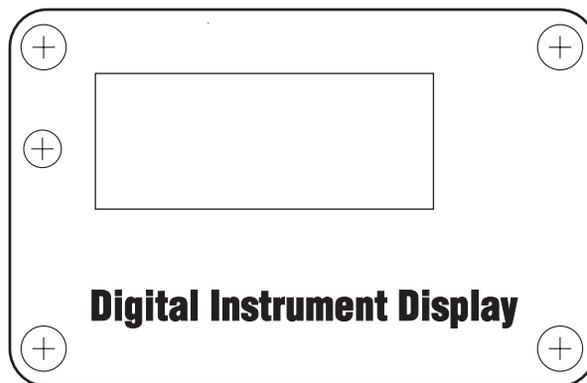
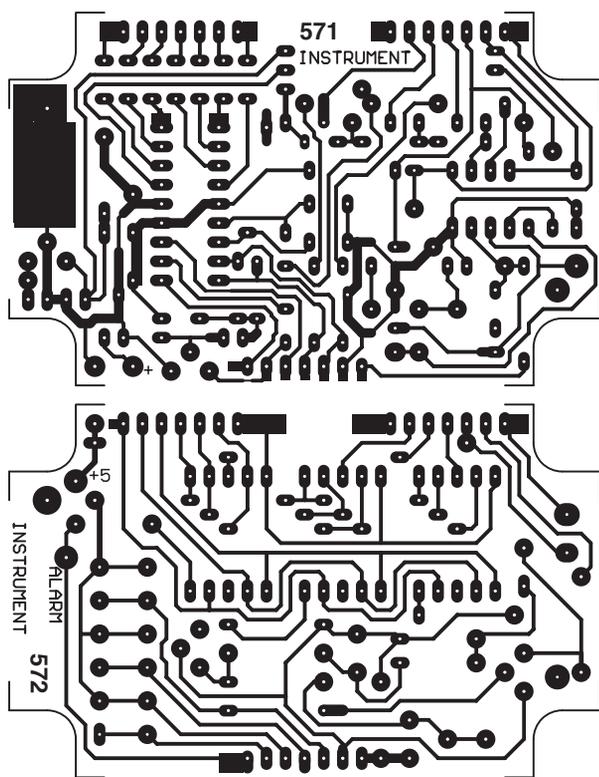


Fig.10: here are the full-size patterns for the two PC boards, together with the full-size front-panel artwork which can be used as a drilling template. Check your PC boards carefully for defects before installing any parts.

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at 0°C is lower than at 100°C, then “0” goes in the first calibration position and vice versa.

Once calibrated the instrument will display values based on a calculation that assumes a straight line (linear) relationship between the two calibration points. It will also calculate the values outside the two calibration points, again assuming a linear relationship.

For example, when connected to a temperature sensor, the display will show temperatures below 0°C when the sensor is colder than this and also above 100°C if the sensor is hotter than this value. In fact, the display can show values between -99 and 999 but, in practice, may be restricted to a range that’s less than this, depending on the signal voltages applied to the unit and the voltage excursion of the sensor.

Using the alarm output

The alarm is set to the required value by first pressing the Mode switch three times from the “normal” mode position. You then set the value using the Up and Down switches and select the sense as described earlier. The latter determines whether the alarm

activates as it goes above or below the calibrated value.

The alarm output goes low under alarm conditions and this lights the alarm decimal point in DISP3. In addition, a low-current piezo siren could be connected between the +5V supply and the alarm output if an audible alarm is required – see Fig.9(a).

External relay

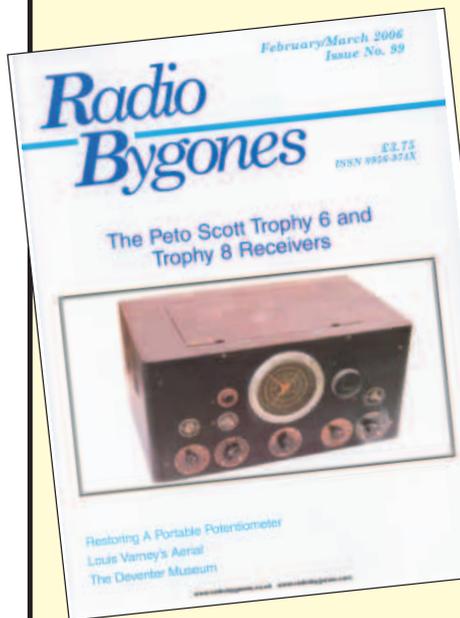
Fig.9(b) shows how to connect an external relay to the alarm output. You need to build up a small circuit consisting of a 10kΩ resistor, a BC327 PNP transistor and a diode. The relay needs to be a 5V or 6V type since it is powered from a 5V supply.

Alternatively, the circuit shown at Fig.9(c) can be built. This circuit can drive a 12V relay but note that the alarm sense will have to be reversed (ie, during calibration), so that a high alarm output drives the relay rather than the normal low output level. In addition, you will have to delete the visual alarm indication, since this will no longer be valid.

This simply involves removing resistor R6 to disable the decimal point indication in display DISP3. **EPE**

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Circuit Surgery

Ian Bell



CHATZONE user **Scott2734** posted the following question recently. "In another thread I asked about breaking a beam between an IR emitter and detector, and running the output through a transistor to a PIC pin. I got that part working, but I get a slow increase or decrease in voltage, or it will hang around one voltage on the lower half without cutting all the way off. I was wondering if anyone knows of a way to have the output from the transistor either on or off all the way without any floating voltages?"

This has been a challenge to me because as you know, if you move something in-between the beam slowly, the voltage goes up slowly, and vice versa. I also built an op amp circuit that acts the same way. Of course that's the way it is supposed to act. Any help would be thankfully received."

Experienced contributors pointed Scott in the correct direction – use of a Schmitt trigger circuit. We will look at this in more depth this month and discuss the selection of component values for the op amp Schmitt trigger circuit.

Switching Requirement

It is a common requirement to take the signal from a sensor, determine when that signal crosses a certain threshold level and switch a digital value cleanly between 0 and 1 to indicate above or below the threshold. A logic gate may do this if the required threshold corresponds to one of the logic levels, more generally an analogue comparator with detect if an input signal is above or below a threshold voltage. The later approach allows the threshold to be specifically set; otherwise we have to make do with the fixed threshold of the gate.

We might need this threshold switching to detect when a certain parameter (e.g. temperature) has reached a level at which some action needs to be taken, or it might simply be to detect the presence of a signal against a varying background value. The latter case is applicable to Scott's enquiry, but we shall consider both situations.

As previously implied, a simple approach to achieving threshold switching might be to amplify the sensor signal by the amount which causes the threshold level to be just above the logic 1 level of a digital input (e.g. on a logic gate or microcontroller). This is probably the approach Scott used. His circuit

Schmitt Trigger Circuits

is shown in Fig.1 – it is a non-inverting op amp amplifier.

Problems

There are a couple of problems with this approach. Firstly, the output from the sensor may take any value, so if it is connected directly to a digital input (either directly or after amplification) it may sit within the logic input's indeterminate voltage range. For more details on the voltage characteristics of basic logic inputs see Part 8 of Mike Tooley's *Teach-In 2006* series last month. Intermediate level inputs may result in unpredictable behaviour from

digital chips and undesirable effects such as increased power consumption. Any input to which a continuously varying analogue signal is connected should be capable of handling such a signal.

A second potential problem is that the logic may switch states many times as a noisy, slowly changing input crosses the threshold. This is often undesirable, for example if the number of threshold-crossings is to be counted. Fig.2 illustrates this problem.

The multiple-switching problem may be overcome by using two thresholds, e.g. V_{TH} and V_{TL} . The difference between V_{TH}

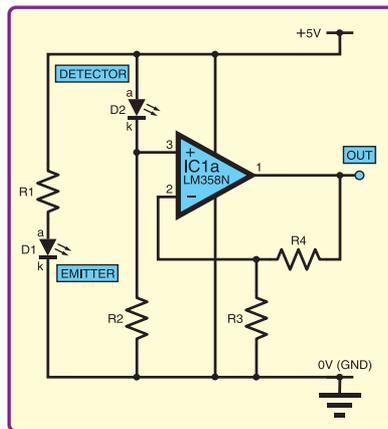


Fig.1. Scott's circuit

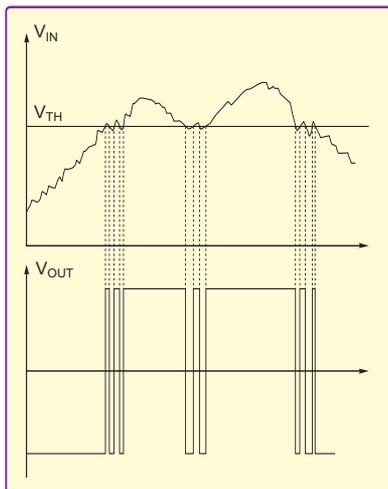


Fig.2. Threshold switching problem

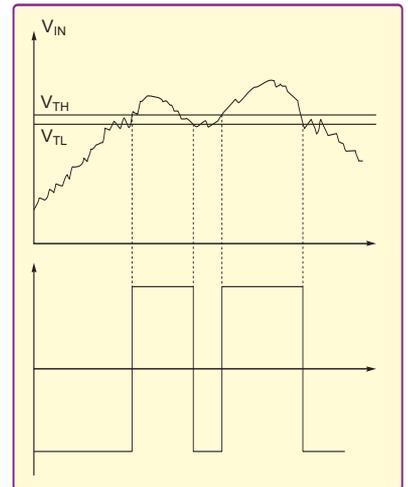


Fig.3. Using different thresholds depending on the direction of change provides clean switching

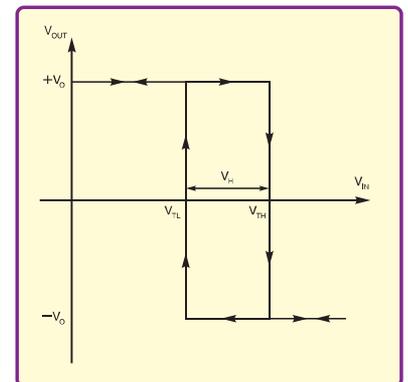


Fig.4. Switching characteristic of circuit with hysteresis

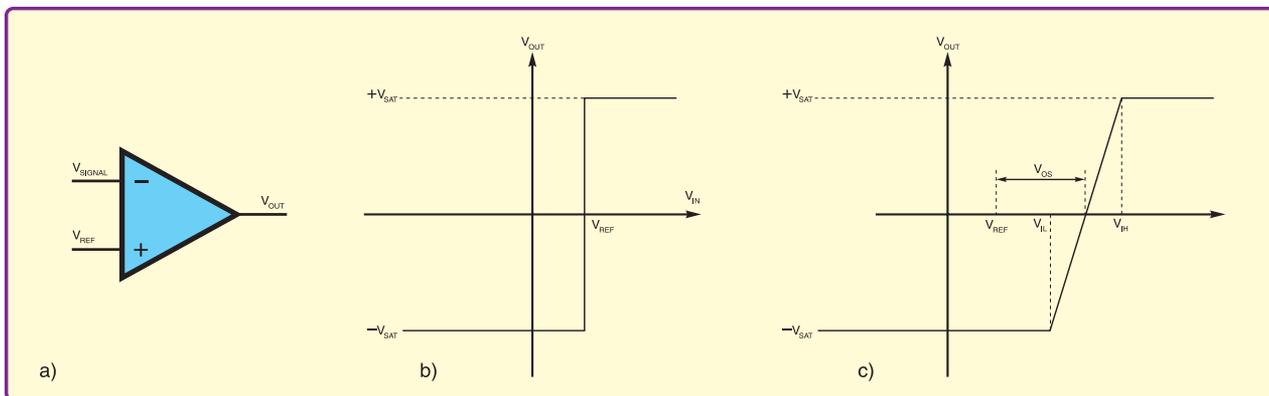


Fig.5. Comparator Input-Output characteristic. (a) schematic, (b) ideal response, and (c) realistic response

and \$V_{TL}\$ is called the *hysteresis*. When the input *increases* past \$V_{TH}\$, the comparator switches, but it does not switch if the input *decreases* past \$V_{TH}\$. Instead, the input must decrease past a lower threshold, \$V_{TL}\$ before the comparator switches again. This is illustrated in Fig.3 and Fig.4.

Schmitt Triggers

Comparators or logic inputs with hysteresis are known as *Schmitt Triggers*. If the PIC or other microcontroller has Schmitt inputs it may not be necessary to use an external Schmitt Trigger, but you will need to check the datasheet for the device you are using to get the details. For example, on PIC18FXX2 devices PORTC, PORTD and PORTE in I/O mode, RA4/T0CKI and RB0/INT0 when configured as an interrupt have Schmitt Trigger input buffers. An external Schmitt logic gate, such as a 4093 (quad NAND) or 40106 (hex inverter) may also be used.

Use of a logic gate or microcontroller Schmitt trigger input does not provide much control over the switching characteristics. Use of a circuit based on an op amp or comparator IC allows far more control over the switching behaviour.

An op amp used without negative feedback has very high gain, thus for all but a small range of input voltage differences the output will be saturated. These two voltages (e.g. \$-V_{sat}\$ and \$+V_{sat}\$) may represent logic 0 and 1 and will indicate which of the two inputs is at the higher voltage (see Fig.5). An op amp used in this way is known as a *comparator*.

One input of the comparator is usually connected to a fixed reference or threshold level (\$V_{REF}\$ in Fig.5) and other input is connected to the signal of interest (e.g. from the sensor). A real op amp may not switch when the input is at exactly \$V_{REF}\$ due to offsets. Furthermore, for a range of input voltages the op amp will be in normal "linear" mode and will output intermediate voltages (see Fig.5.1c). This range of inputs is very small, however, and the

situation is much better using an op amp than say a single transistor.

Comparator Ideals

An ideal comparator would switch instantaneously when the input signals crossed the comparison threshold. A real comparator takes a finite time before it reacts; this time is known as the *propagation delay*. The rate of change of the comparator's output voltage as it switches is known as its *slew rate*.

Any op amp may be used as a comparator, but the best performance is obtained by using devices that have been specifically designed as comparators.

A comparator with hysteresis (Schmitt trigger) can be made using an op amp or single-threshold comparator by setting the threshold depending on the current output state. The comparator has two output states so these can be used to set the two thresholds as required using positive feedback. If the input noise level is known, the hysteresis can be set slightly larger than this. The comparator will then not switch as a result of the noise.

A Schmitt trigger can be made using an op amp with positive feedback as shown in Fig.6. The comparator's switching point, \$V_{comp}\$ depends on \$V_{REF}\$ and \$V_{OUT}\$. \$V_{REF}\$ will usually be fixed but \$V_{OUT}\$ depends on the current state of the comparator. \$V_O\$ can take one of two values, basically the op amp positive and negative saturation voltages, which for simplicity we will assume to have the same magnitude and opposite sign, that is \$\pm V_{OUT}\$. This assumes a dual supply circuit. For a single supply circuit the formulae for the thresholds will be slightly different.

To follow the operation of the circuit start by assuming that \$V_{in}\$ is less than \$V_{comp}\$ so \$V_{out} = +V_O\$. As \$V_{in}\$ is slowly increased this condition remains until \$V_{in} = V_{comp}\$

= \$V_{TH}\$ (upper threshold), where

$$V_{TH} = \left[\frac{R2}{R1 + R2} \right] V_{ref} + \left[\frac{R1}{R1 + R2} \right] V_O$$

On switching at \$V_{comp} = V_{TH}\$ the output changes to \$V_{out} = -V_O\$, changing the threshold to a new value, \$V_{comp} = V_{TL}\$ (lower threshold), where

$$V_{TL} = \left[\frac{R2}{R1 + R2} \right] V_{ref} - \left[\frac{R1}{R1 + R2} \right] V_O$$

\$V_{OUT}\$ will now stay at \$-V_O\$ until the input falls below \$V_{comp}\$ again. The difference in the switching points, i.e. the hysteresis, \$V_H\$, is

$$V_H = V_{TH} - V_{TL} = \left[\frac{2R1}{R1 + R2} \right] V_O$$

\$V_{REF}\$ can be obtained from a potential divider connected to the supplies as shown in Fig.7. Ideally, in order to prevent the feedback network from loading the divider, the larger of \$R3\$ and \$R4\$ should be at least 10 times smaller than value of \$R1 + R2\$.

Fig.6 and Fig.7 show inverting versions of the Schmitt trigger circuit. A non-inverting version can also be made, as shown in Fig.8. The equations are slightly different, but the fundamental operation of the circuit is the same. However, if the input is not connected to a low impedance source the source impedance may affect the switching points.

For the non-inverting circuit, with the output switching between \$+V_O\$ and \$-V_O\$, the thresholds are.

$$\left[1 + \frac{R1}{R2} \right] V_{ref} + \left[\frac{R1}{R2} \right] V_O$$

$$\text{and} \left[1 + \frac{R1}{R2} \right] V_{ref} - \left[\frac{R1}{R2} \right] V_O$$

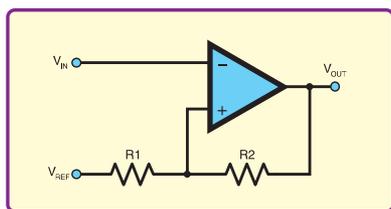


Fig.6. Inverting Schmitt trigger

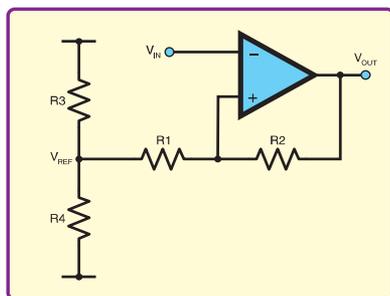


Fig.7. A potential divider can be used for the reference voltage

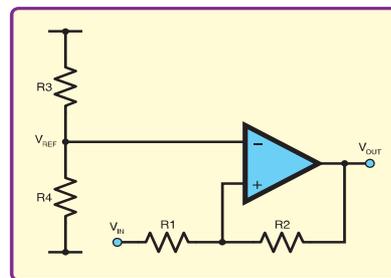


Fig.8. Non-inverting Schmitt trigger with potential divider reference voltage

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

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The Atlas LCR automatically measures inductance from $1\mu\text{H}$ to 10H , capacitance from 1pF to $10,000\mu\text{F}$ and resistance from 1Ω to $2\text{M}\Omega$ with a basic accuracy of 1%.
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★ LETTER OF THE MONTH ★

ADC and PICs

Dear EPE,

When dealing with 10-bit ADC inputs such as those provided on PICs, you often want values in volts – a range of 0 to 1023 is not very helpful for most calculations. A range of 0 to 999 would be more useful (and a right-shift by one step would change that to 0 to 499 which gives you a value in hundredths of a volt). But how to do this on a PIC which doesn't have multiply or divide instructions? Obviously you could use Microchip's maths libraries if you wanted, but they're very slow. Here's how to do the job a lot faster.

Obviously, 1023 is very close to 999. As you count up 0, 1, 2, 3, ... 1023, then the other side should count up 0, 0-977, 1-953, 2-930, ... 999 if we were using floating-point numbers. But our processors use integers, so we're actually going to start counting up with 0, 1, 2, 3 and so on, and the rounding error gets increasingly large at each step. Every now and again, the rounding error will get large enough to be significant (i.e. more than half a bit of error), and the "0 to 999" side will stay on the same value when the "0 to 1023" side increments by one. This means that if we can work out where the rounding error will catch up (or a good approximation of it), then

we can do this scaling simply by subtracting the total rounding error so far from the original value, without having to go through all the hassle of multiplies and divides. The total rounding error is proportional to the value, so we can use the value itself to calculate the total rounding error.

The difference between 1023 and 999 is 24, which isn't totally convenient. However, $24 = 32 - 8$ and both of those are powers of 2, which are easy for integer arithmetic because we can use right-shifts to do division. For those who don't know, shifting the bits of a number right by one will divide the number by 2, and shifting left will multiply by 2 (try it for yourself to see). If we divide 1023 by 32 then we get 31 and if we divide 1023 by 128 then we get 7 (allowing for integer division rounding down), which gets us to a total of 998. This is accurate enough since we're going to be dividing by 2 at the end anyway to get a scaling of 0 to 499. So, our calculation to scale an ADC value (0 to 1023) into hundredths of a volt (0 to 499) is: Scaled value = $((\text{ADC value} - (\text{ADC value}/32)) - (\text{ADC value}/128))/2$.

We can implement this with the following pseudocode:

A = ADC value (0-1023)
B = A right-shifted by 5 (i.e. divide by 32)

C = B right-shifted by 2 (i.e. divide by 4)
B = B - C
A = A - B
A = A right-shifted by 1 (i.e. divide by 2)
Scaled value (0 to 499) = A

This calculation isn't entirely perfect, but it's accurate to less than 1 bit, so you'll get more error from the ADC noise and resistor tolerances than from this conversion. It's very much faster for processors that don't have multiply or divide instructions, and may well even be faster even for processors that do – since the scaling relies on maths rather than processor instructions, you can use this trick on any processor you like.

Graham Bartlett, via email

Graham, (or should I call you "Grab" as you use on our Chat Zone?), thanks for this. It's an interesting solution, but there is a simpler more accurate way of doing it for those who have Peter Hemsley's excellent maths suite of PIC progs, as published in EPE a while back (available via our Downloads site – access via www.epemag.co.uk). I have used Peter's codes in many applications and find them highly useful. The codes don't do what you want as an actual routine, but writing a specific routine using them would be very straightforward.

Banks and Pages

Dear EPE,

The correspondence in *Readout* on C has persuaded me that I should try harder. Like Jack Botner, *EPE* Mar '06, I spend a lot of time sorting out PIC banks and pages. If I can keep my program smaller than one bank and one page, it is manageable, but once it grows beyond that, it more or less spontaneously explodes to lots of banks and lots of pages as I insert banksel and pagesel statements trying to keep it working.

I was very disappointed with the C system I bought a couple of years ago, but Jack seems happy with the system he bought, and other readers seem also to have discovered good systems. Jack might value his privacy and might not want me to pester him, but you might be able to contact him and ask him to contact me to tell me what system he bought.

You might even want to tell all readers. Although suppliers become upset when

we make bad remarks about their product, few are upset when we report that their product is terrific.

Keith Anderson, Tasmania, Australia

Keith, the PIC18F series make bank and page handling somewhat easier. Jack replied:

I have been using the SourceBoost BoostC compiler from www.sourceboost.com/Products/BoostC/Overview.html. I have been very happy with it, since they provide a single-user non-commercial license at a very reasonable price.

I have programmed PIC16F84/84A, 684/685, and 877 PICs and seen no glitches.

My only complaint is that their function library is thin, I had to provide my own itoa function. They need a printf/sprintf but I realize that these functions are big and not well suited to small PICs. They do support long inte-

gers which is badly needed and have support for standard LCD displays. Good luck Keith!

Jack Botner, via email

VB6 Sorting

Dear EPE,

I need a quick method of converting a string into its alphabetical equivalent. Power Basic for DOS has a function called Array Sort, so if you input the string "BASIC" you get "ABCIS". I have searched through various help files but found nothing of any relevance. Perhaps VB6 has a similar function with a completely different name?

Craig Patterson, via email

No Craig, I've not come across the facility, but it's only a matter of sorting the individual letters into sequence, a routine it should not take too long to write! Readers, do you know of anything that can help Craig?

Web Downloads, plus TK3

Dear EPE,

I have been reading *EPE* for the past many years, I now use the on-line version. I have some concerns and some disappointments with the new style, for one thing, all the fancy colours have only managed to increase the size of the file, now the download time has doubled. The biggest disappointment comes when you find there are no PCB patterns for some circuits, I wanted to build the Audio-Video amplifier and the active crossover, there were no PCB patterns. For those of us outside the UK and who are capable of fabricating our own PCBs, a download area should be created on your website, from where good quality, EPS and PDF images can be downloaded.

I also have something to say about the *TK3* software. Good software like *TK3* should include as many PIC types as possible, even the older C versions should be there. As an example, I wanted to build the *PIC LCF Meter* by John Becker, but the PIC16F628 it uses is just not available here, only the "A" version is available and *TK3* has no support for it. I finally managed to program it using the excellent, ICcprog 105c-a, freely available on the internet.

Finally, it will be unjust not to appreciate the quality of electronics related material *EPE* provides. I think more useful circuits are needed, test gear such as a wide range signal generator, PIC and LCD based multifunction counter/frequency meter etc.

Humayun Ali Mirza, via email

Editor Mike first replied to Ali:

Thanks for your comments. We have already instigated a PCB Master download area which has been up and running for a couple of months now. See my Editorial in the May issue – we did foresee the problems. I have passed your email to John for his comments on *TK3*.

I replied to Ali: I have in fact asked someone else to arrange for the 628A facilities to be added sometime. You will appreciate that TK3 is mine and basically I've only designed it for those chips I use. But I'm quite happy if others update it for other chips under my supervision if they offer. But there's no way in which it will ever cover all PICs. Commercial software/hardware is needed for those.

Digital TV Again

Dear EPE,

There is some hope for Ken Wood's acquaintances (*Digital Terrestrial TV – Readout* April), but still complex and not good value for money if needing to cover all five channels. CPC sell AV10363, an RF modulator to convert SCART audio/video to Channel 36 (it doesn't say if Ken could get inside the box and retune the actual output channel). Needs mains power. Currently on offer at £8.86 plus VAT each. Of course, if the power fails, each of the five digiboxes will need

re-setting to select their appropriate off-air channel once service resumes.

As an aside, I've just bought a digibox and must say that the quality is rather capricious. I haven't had the experience where the signal drops out and blanks the screen, but whether you get colour or monochrome seems to be a lottery. Sometimes it forgets its channels and has to re-acquire them. Consumer electronics, at the price we pay for such, is designed to make a profit. Who said it would work reliably? Probably also contains unleaded unreliable unsolder! They also say that every existing receiver in the land will be blacked out by the threatened move from MPEG 2 to version 4 compression encoding. More profits when they sell millions of new boxes, unless the "off-air software update" function copes with the change. I'm in the wrong business!

**Godfrey G4GLM, Edgware, Middx,
via email**

Thank you for that Godfrey, But I wonder if you might get a few readers commenting on your latter somewhat cynical view of the world?!

Light Detection And Ranging

Dear EPE,

Is it too late to comment on a letter titled *Laser Radar in Readout*, August '05?

Your correspondent, George Chatley, was bravely suggesting an improvement to the *PIC Ultrasonic Radar* (June '05), by substituting an infra-red LED circuit in place of the ultrasonic original.

Your reply was "I've thought about such techniques many times George, but it's timing the return echo that is beyond me. Light travels at 186,000 miles a second. What sort of frequency would be needed to time an echo across say three metres? Beyond my calculator at this moment! And certainly beyond the scope of timing electronics on the hobbyist scene."

I thought of making a reply, suggesting that some kind of phase shift detector might be possible (i.e. let the light beam itself do the tricky work – I remember as a schoolboy one hundred years ago using interferometry to make tiny distance measurements, and we then had only stopwatches and 300mm rulers with which to measure), and the observation that these days 1ns is quite a long time, and the direct approach might now be possible. (Clock frequencies greater than 1GHz now being nothing special, all over the place in PCs for example.)

However, both these points were more or less covered in *Readout*, Nov '05, by John Waller, USA, and George Martin, Texas, so I kept quiet.

Now, as you know, I am a very loyal reader, and I conscientiously retain all my back issues, so I immediately thought of you and looked these up when I received some information in my profession as an engineer, from the semiconductor company National Semiconductors. It was a document entitled "LIDAR (Light Detection And Ranging) System Design for Automotive/Industrial/

Military Applications", and gave practical details of how the required task may be accomplished.

I can take no credit for this information, other than having had the sense to keep my eyes and ears open, and I can do no better than refer you to that document, entitled "national_sp_designer105.pdf" from www.national.com.

Your original answer was correct insofar as the detection is sadly not performed using a cheap microprocessor running at a few Megahertz, but the new information should remind us in our trade that we should "Never say Never".

**David M Parkins, Greenbank
Electronics, via email**

Thank you David, that pdf does look interesting, and could well inspire me to look at the problem again sometime.

Mains Safety

Would you please advise me of the type of relay suitable for the *IU Dog Alert* of March '06.

J.E. Pryor, Hailsham, Sussex

I'm sorry but we don't give constructional guidance in IUs unless the reader quotes them when he sends the IU offering. In this instance, it is likely that the circuit will be used with mains operated devices and we never encourage people to build such unless they can justifiably call themselves competent at dealing with mains requirements, there being too much danger of killing themselves or others.

We strongly recommend that you build something simpler and safer until you feel ready to tackle something potentially more dangerous.

For your interest, relay contacts should be chosen to suit the voltage and amperage ratings, AC or DC, of the equipment being controlled.

Best wishes for your continued enjoyment of electronics, which can be great fun, and safe!

Front Panel Graphics

Dear EPE,

Following on from an article you ran about making front panels in the March issue, I recently had a couple of projects that needed some basic text overlay and some numbering along side an LCD display. I found a web site at www.crafty-computerpaper.co.uk and one of the papers enables you to create "dry rub off decals" with a laser or inkjet printer with either a clear or white background.

The process is fairly straightforward but it's best to follow their instructions exactly. Once you have created your design it can be "rubbed" directly on to the project case, where after a while it then hardens. This leaves you with a design without any edges that can lift. I then sealed it with clear acrylic spray, which probably wasn't necessary, but does make it more durable.

Roger Gibbs, via email

Thank you Roger, that sounds useful.

C – A Final Word

Dear EPE,

In response to *Readout* May '06 – Although a professional engineer (and therefore not supposed to admit I read the same magazines as hobbyists), I am delighted to inform you that I have been a keen reader of your excellent magazine for thirty or more years; in fact I think right back to the pocket sized issue number one.

But this year particularly I have been eagerly looking forward to each issue with greatly increased anticipation. Why? Is it the shiny new paper, the attractively laid out editorial, the tasteful type-setting and clear graphic design, the wide range of practical articles? Well, although this is all true, the real reason is that my name seems to be in every issue. On page 72 May '06, there I am again: “We’ve received more responses to the letters from David Parkins...”

Usually the vanity press charges for mentioning people’s names like this, but you do it for free. Check with your subscription department – I’ve just signed up for the maximum three year subscription.

What did I write though, that has struck such a chord? I fear I do not deserve these mentions, because I have been slightly misrepresented. It sounds like I (and your other contributor Dr Jim Arlow) have become the new messiahs: the chosen ones who have brought forth the gift of C for you and your troubled masses.

I think I had better stand down and let Dr Arlow be the one appointed as the leader of this new cult, with its creed “C is the one true language, thou shalt worship no other but C”. I’m no pusher of C, I use assembler quite happily. What I want is a wide ranging educational interesting and informative magazine. Sometimes I like a polycarbonate capacitor, sometimes polystyrene, but I’m not going to join a gang that wants to ram one particular type down another’s throat. You use 5k6 resistors, you cad; I demand you use 4k7, else you are nought but a fool. What is there to get so excited about? Sometimes one approach is best sometimes another, and I look to a magazine like *EPE* to educate us about all points of view.

I am shocked at the fervour shown by the warring factions (the ancient “assemblers” and the young upstart “Cs”). Please, calm down lads, they’re only computer languages; there’s no need to start a war. (Tell you what though Mr Editor, I’ll bet you’re delighted – while competing magazines are stagnating and dying, yours seems alive with activity and excitement.)

If I recall correctly, my original letter was a bit of a liverish reprimand to you at the way I thought you had patronised one of your Australian correspondents, John O’Hagan (Nov '05), by telling him he was out of order for having the temerity to ask for a change from the regular diet of PIC and assembler. In reply you treated me so courteously and in such a friendly manner, that I realise that I was

committing the very same sin as that of which I was accusing you, and I am sorry that I put my points so impolitely.

Your correspondents, those who are so passionate “for”, and the others who are equally passionate “against”, are justifiably proud of being self-educated, and, because the knowledge was so hard-won they clearly find it very hard to let it go. One very wise self-educated man (Benjamin Franklin) recognised the dangers when he cautioned: “He that teaches himself hath a fool for his master”.

I don’t know what the Editor’s position is (although I can guess), but if he has any prejudices he is clearly putting them aside, and is generously allowing an even handed debate in the letters pages, and it sounds like he has commissioned some articles discussing the contentious topics. It would be a braver man than I who would declare he has nothing further to learn, so I for one will be eagerly looking forward to the future issues of this excellent magazine.

**A lifelong fan – David M Parkins,
B Eng (Hons), C Eng, MIEE,
Greenbank Electronics, Birkenhead**

Thank you David for those insights, and for sparking off what has been a long and interesting debate. There I think we leave this topic now, thank you all who have contributed, and apologies to those whose emails and letters I have not had space to include. By the way, lots of professionals read us – thank goodness!

PIC Code Protect

Dear EPE,

As always, thanks for the fine articles in *EPE*.

I have a Magenta *PIC Toolkit 3* board and a *TK3* program. My problem is how to erase the Code Protect bit from the chip (in my case PIC16F876/877) once the program has been burnt into the chip. I have read and re-read the procedure but it doesn’t seem to work. Is there a sure fire method of doing this?

When I try to reprogram the microcontroller I get an error message stating that the Code Protect has been set. I am not setting the Code Protect bit ON in my programs as I rewrite to them quite often when debugging my programs. Somehow the Code Protect bit gets turned ON and I can’t get it OFF to reprogram the microcontroller.

Could you describe to me (and maybe others) a simple way of doing this as I might be doing it wrong.

Dick Gurske, via email

Thanks for your kind comments, Dick. I have had similar problems and have usually cured them by simply using the TK3 Config option, via the Clear CP button. It’s a curious situation and I don’t know why it arises. Perhaps Mike Hibbett’s PIC n’ Mix in May issue provided the answer, external conditions altering bit values for no obvious reason, except for local electrical fields.

I did once have a chip in which a program area of memory could not be changed from a 1 in a particular bit. That I put down to a manufacturing fault. TK3 can also say CP is set if it does not read data back cleanly from a PIC, indicating a fault at the TK3 board end, or on a prototype development board connected to TK3 for programming. I frequently reprogram chips when I’m developing something, usually preferring to test code live rather than by simulation.

I wonder what others may have to say?

Murphy’s Uncle

Dear EPE,

I know that John is also interested in the quirks of hardware and software and I have have come across another interesting case. I have been doing some work on a graphics LCD and following his article in *EPE* Feb '01, which, by the way, is excellent. In the source for Gepe456.asm I noticed what I think is an error. The appropriate portions of code are reproduced below:

```
PAUSIT: movlw 5 ; pause rou-
tine, 1/5th sec
```

```
movwf CLKCNT
clrf INTCON
```

```
PAUSE: btfss INTCON,2
goto PAUSE
bcf INTCON,2
decfsz CLKCNT,F
goto PAUSE
return
```

```
PAUSE2: movlw 1 ; pause rou-
tine, 1/25th sec
```

```
movwf CLKCNT
clrf INTCON
```

```
PAUS2: btfss INTCON,2
goto PAUSE ;** I think this
should be GOTO PAUS2
bcf INTCON,2
decfsz CLKCNT,F
goto PAUS2
return
```

Now in fact this does not matter as the code at PAUSE does the same thing and CLKCNT is decremented correctly. The program functions correctly.

I have come across similar cases before, when maintaining programs, where you change a subroutine in one part of the program and another part in a completely different area stops working. I have a theory about this. I think it is due to Murphy’s uncle. We all know how Murphy goes around messing things up when he can and I think that Murphy’s uncle goes after him to try and ameliorate the situation by letting things work which really shouldn’t. What do you think?

Peter, via email

A wry smile on my face at this one Peter!

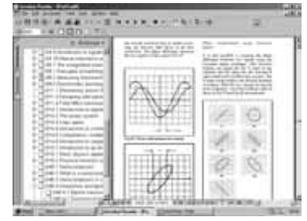
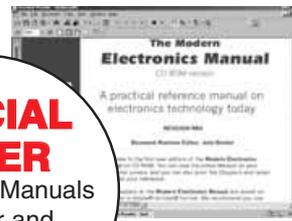
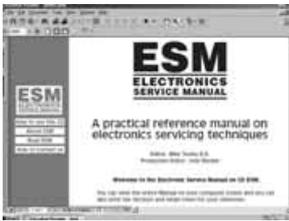
You’re absolutely right on the code, but it works for the reason you say. Funny I’d not noticed before. I have used that routine several times.

I wonder if Murphy does indeed have a benign relative? So I’ll ask readers ...

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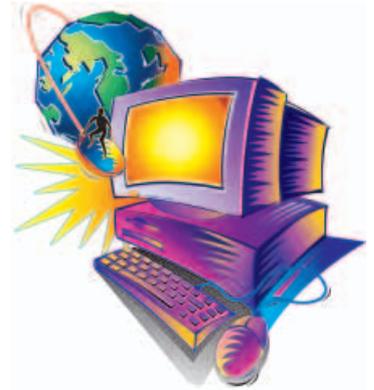
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Net Work



Alan Winstanley

WELCOME to *Net Work* – our Internet column to help readers get the most out of their hours spent online. Regular readers will be aware of our popular web site at www.epemag.co.uk, which is intended to support the magazine in a number of ways.

For constructors seeking our PIC source codes, our Download page is at www.epemag.wimborne.co.uk/downloads.html which offers a web-browser front end to our file area. New additions are highlighted in bold and to access the files, single-click the “+” sign next to each subheading and the navigation tree will open. Then click the desired individual download, and the relevant files will appear in the window (see the screenshot example of the *Digital Instruments for Cars*).

Most users have Microsoft Internet Explorer 6, so the easiest way to fetch the files is to right-click and drag an outline around all the files to highlight them: then use the **Copy to folder...** option in the browser’s right-click menu to save all the files to your disk in one easy session.

A new addition to the Downloads Area in recent weeks is p.c.b. artwork: for the first time *EPE* can offer almost every new printed circuit board copper foil master pattern for free download as a PDF file (for which the free Adobe Reader software is needed from www.adobe.com). Note that clicking on the relevant month in the Download Tree makes a direct link to a .zip file containing all available artwork for that month; there is no need to select individual files.

The “download tree” script works extremely well for almost all users, but if you use traditional FTP software, it should be pointed to our FTP server address at <ftp://ftp.epemag.wimborne.co.uk/pub> – or click the “classic FTP view” link near the top of the Downloads page to see a web folder view of the FTP site.

It is worth reminding all *EPE* readers that it is *not* necessary to own a computer nor a PICmicro programmer in order to enjoy building *EPE*’s PICmicro-based projects. Ready-programmed PIC micro-controllers can be purchased from Magenta Electronics (www.magenta2000.co.uk) who offer a valuable mail order service as well as an online shopping cart for those happy to buy online.

Another useful resource is our *EPE Chat Zone* online forum at www.chatzones.co.uk. Many regulars use the friendly forum to exchange hints, schematics and tips. After creating a unique username and following the registration procedure, users may post messages into the forum. An archive stretches back at least 12 months.

Don’t forget our online Project Index pages, summarising our projects back to at least 1998 (back issues are usually unavailable for issues over five years old). If you are not sure of the issue in which a project was published, try entering some keyphrases into our search engine, which may then point you to the monthly update. From there you can visit our *EPE Online Shop* and buy back issues, printed circuit boards, electronics books and CD ROMs and more beside. There is no minimum order charge and *EPE* delivers worldwide.

The *Net Work* column has its own page of useful links – the “Net Work A-Z Best of the Net” at www.epemag.wimborne.co.uk

[/netwkaz.html](#). In the future I hope to expand this to include a useful “toolbox” of handy online resources, links, software and more.

Lastly, what if you ever need to contact us? The **Contact Info** link on our web site provides the postal details and email addresses of all departments. Please grant a reasonable time for a reply, as “chaser” emails merely add to the workload. Next then, why not click onto our web site and see what is available online?

The Phone Age?

Recently I highlighted Skype (www.skype.com), the voice and video messaging package that enables you to “chat” with other

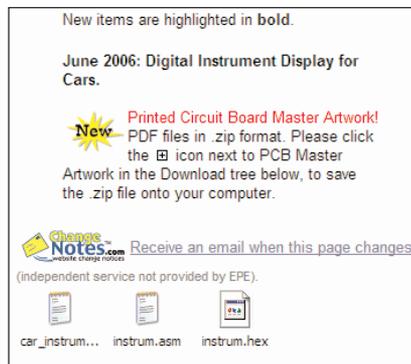
Skype users around the world. Because Skype utilises your existing broadband connection, the calls are essentially free. You can also call landlines (“skype out”) by paying a pre-paid toll.

There is a clear trend towards VoIP (Voice over Internet Protocol) communications that exploits higher speed Internet connections. However, whilst a broadband connection can wire you to the world, if you want to use Skype or similar services then obviously your computer must be running on the network. What about making an ordinary phone call using your broadband line?

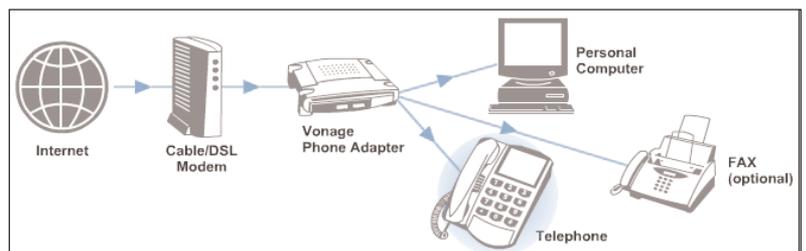
A number of hardwired VoIP solutions are becoming available, including the impressive package from Vonage (www.vonage.com/co.uk). For £7.99 per month for domestic users, a Linksys phone adaptor is supplied that connects a POTS corded or cordless phone via an Ethernet cable to a broadband router, to provide a VoIP telephone line, *without the need for a host computer to be online*. Caller Display, Call Waiting, Call Diversion and more are bundled as well, at no extra charge; add in the fact that a new phone line is supplied with no extra line rental, and this VoIP service adds up to great value: bear in mind their setup and activation charges of £26.97 in the first month though.

Separately, routers with built-in phone adaptors are available: the Linksys RT31P2 avoids the need for some messy wiring. Vonage offers unlimited phone calls to the UK and Ireland, and international rates are attractive: Australia is 3p per minute. If you are keen to get the most mileage from your broadband connection, the commendably-clear Vonage web site is worth spending time visiting.

Next month: another alternative to Skype? I investigate MSN Messenger from Microsoft. You can email the writer at alan@epemag.demon.co.uk



Highlight the required filenames then right-click to save them to your computer



The principle of VoIP from Vonage. A Linksys phone adaptor connects a standard telephone and/or fax machine to a broadband connection (courtesy Vonage)

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For a further selection of books see the next two issues of *EPE*.

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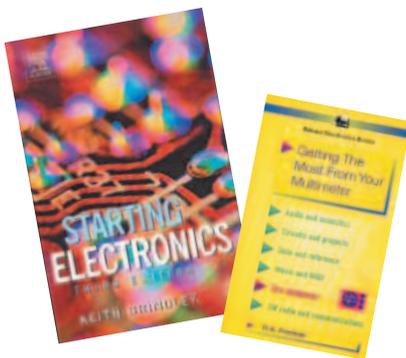
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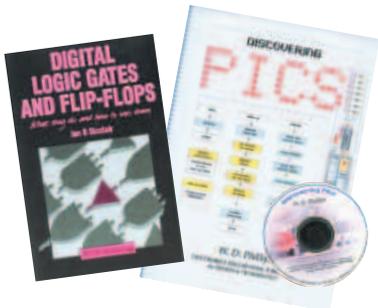
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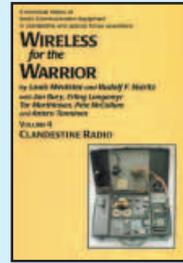
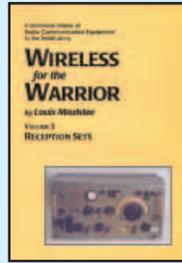
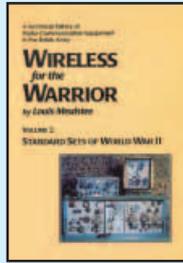
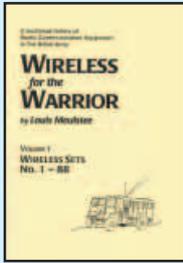
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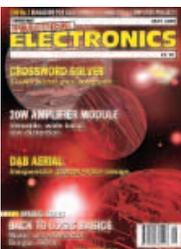
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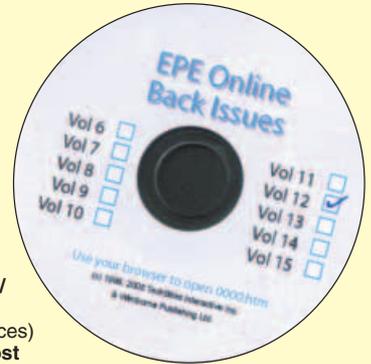
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PC Power Monitor		

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