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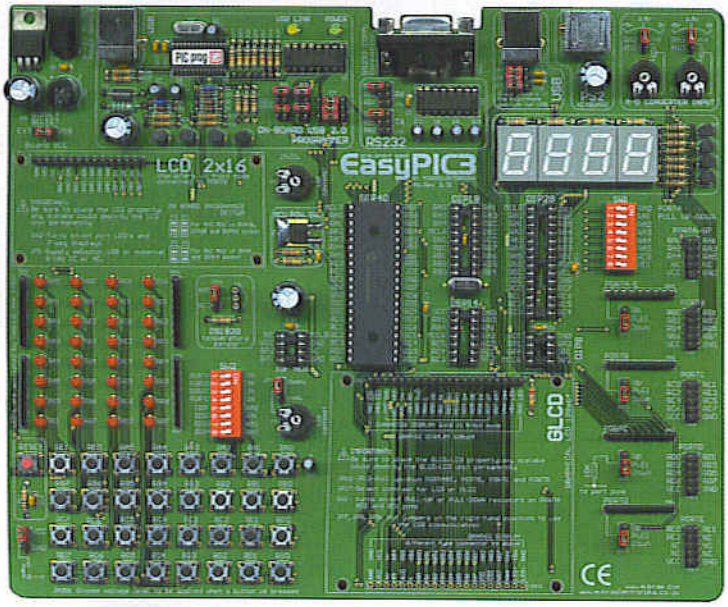

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A word or two in the Inbox

It's great to see that our website at www.elektor-electronics.co.uk is maturing and drawing more and more visitors every month. If I am not mistaken it is the fourth major version of Elektor's Internet presence, the first dating back to about 1998 when we held only a couple of 'who are we' pages on a free CompuServe homepage/email account with dial-up access. I remember many of my colleagues in the subscription, sales, design, commercial, advertising and editorial departments jumping the bandwagon and cheerfully reading and answering emails from a single (!) email account. In the (not so rare) case of just one person 'new to email' having forgotten to tick the 'Leave Mail on Server' box in his/her email client program, a dozen or so Inboxes, including mine, would fall strangely silent all of a sudden. A lot has changed since those early days.

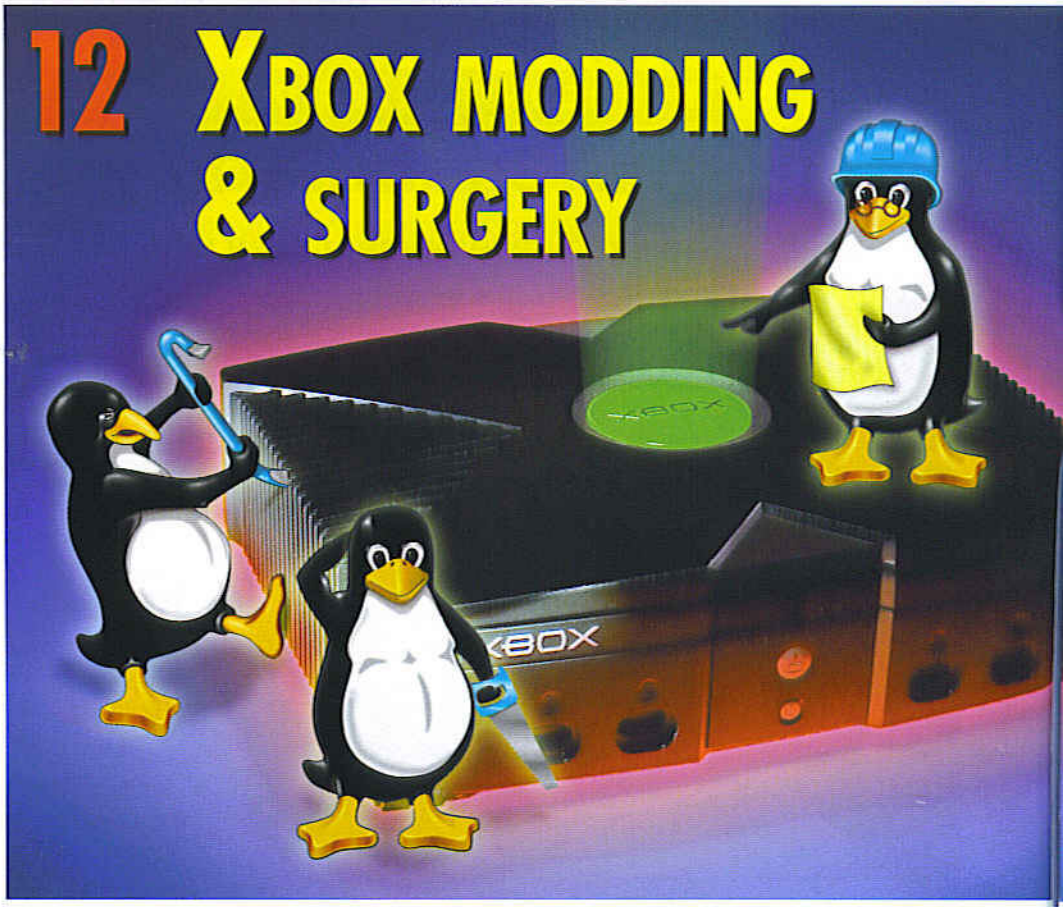
The Forum on our current website has been modified to allow every website visitor to view all messages. However, you need to be logged in to answer and/or create topics. The aim of the Forum is to establish contact between readers, allowing them to solve each other's problems and, in general, exchange ideas. It is not intended for direct correspondence with our design or subscription staff, or myself although I will do my best to post the odd reply. Separate email addresses are available for all departments, guaranteeing a much faster response! Also, the 'Service' page of our website — and in particular the FAQs item — contains information requested in about 6 of every 10 'contact form' emails we get, so please review these pages before emailing us.

Our on-line subscription order form has been updated and is now protected by SSL, as is the checkout from our Shop.

As an experiment hopefully leading up to the availability of an online subscription to Elektor Electronics, the July/August 2005 Double Summer Issue has been available for downloading as a (huge!) pdf file. It may still be available as you read this, so have a look under 'Magazine'. For reasons explained in a recent E-News item (now in the News Archive), having an online Elektor Electronics represents tremendous benefits for our overseas readers suffering from shipping delays, import regulations and outrageous cover price markups at their newsstands.

Finally, the number of subscribers to our E-Newsletter is rising steadily, many readers having discovered that the Newsletter automatically delivered by email every Friday is a relatively small document of less than 50kbytes — nothing towards clogging up your Inbox.

Jan Buiting, Editor



In the past, a lot of space in hobby rooms and work stations was taken up by an instrument in a large case with a small screen, but now many of its functions can be performed using a PC. A small box can transform an ordinary PC into an oscilloscope with extensive functions, in many cases including several extra functions. *Elektor Electronics* subjected eleven of these 'USB oscilloscopes' to an extensive evaluation.

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September 2005
no. 346

The Xbox made by Microsoft is a very popular games console. What many buyers don't know is that the Xbox is really just an ordinary PC running a special (modded?) version of Windows. This leaves the door open to experimenting, for example with Linux. But first you have to get round a couple of modifications, which for many is all part of the fun. So let's get started!

30 ESR/C Meter

The two most important properties of a capacitor are its capacitance and its internal resistance (ESR). You need to know both values in order to judge whether a capacitor is suitable for a particular application. The meter described here combines two popular Elektor Electronics projects to create a convenient new instruments that rightly belongs in every well-equipped electronics lab.

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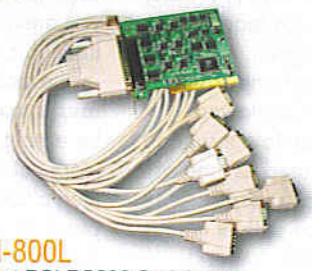

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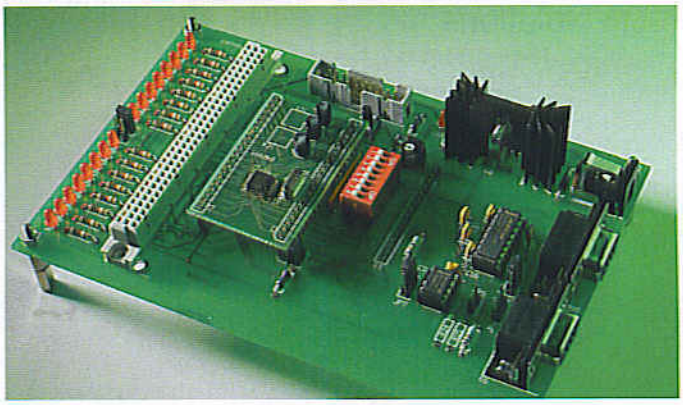
JTAG and the ARMee Board

Dear Elektor staff — on the ARMee board K1 is connected to the primary JTAG pins of the Philips ARM. In order to use the JTAG interface on the ARMee board a few changes are needed. Here are the changes and information on some specific issues you may have when using JTAG on the ARMee board.



1. DBG Signal.
This signal is on pin 6 of K7. It is tied low by R20. In order to enable the primary JTAG pins of the Philips ARM chip, DBG must be high. So you need to fit a switch or jumper between the DBG pin and 3.3V.

2. nTRST Signal.
This signal is on pin 3 of K1. Philips have been a bit confusing about this signal. In their data sheet it is called TRST or nTRST in different places. The JTAG standard name is nTRST because it is active low. ARM specifies this signal as driven by an open collector output. So it requires a pullup resistor. Philips say there is a weak pullup in the device but this is not generally sufficient in an electrically noisy environment. Therefore it is recommended you fit a 4k7 resistor between pins 1 and 3 of K1.

3. RTCK Signal.
This signal is on pin 11 of K1. Philips say that RTCK must be high at reset to enable debug. However this pin is normally an output so this can only be done with a pullup resistor. Whether you need this resistor depends on the ICE you use. Some ICEs do not use RTCK. Others have an internal pullup. If you have problems debugging, this may be something to look at. ICEs that do not support RTCK may have problems interfacing to the ARM7TDMI-S at low clock speeds. The function of RTCK is to stop the ICE sending data to the ARM faster than the ARM can read it (it is a handshake signal). At low CPU clock speeds the JTAG clock rate must be slowed down. ICEs that do not support RTCK may be used as long as their JTAG clock speed is set slower than one sixth of the CPU clock speed.

4. ICE Power.
Some ICEs use pin 2 of K1 for their power (pin 2 is specified for that purpose). On ARMee the 3.3V supply is provided by the regulator on the back of the processor board. It doesn't have a heatsink so care must be take to ensure the regulator doesn't overheat. The simplest thing to do is plug in your ICE and feel how hot the board gets — when it is too hot to touch, you know that ICE is unsuitable for use with the ARMee board.

5. Stepping through code in Flash.
The ARM7TDMI-S core has two hardware breakpoint units so debug software can set two breakpoints in code at any one time. Typically more than two are required so one of the breakpoint units is set up to catch a specific data value rather than a particular address and this special data value is used to replace the breakpointed instructions. When the ARM fetches the instruction, the breakpoint unit recognises it and halts the core. These are called soft breakpoints and there is no limit to the amount that can be used. However to use this technique in Flash, the debugger has to know how to write the Flash. Typically it cannot. The result of this is you can only place two breakpoints in Flash (because there are two hardware breakpoint units). By default most debuggers place breakpoints on a number of exception vectors to catch things like data aborts. Therefore you need to remove these 'vector catches' before there are any breakpoints left for your code. How you do this depends on which debugger you are using. Also stepping through code uses breakpoints — the technique the debugger uses is to read the instruction to be executed, decode it and work out the next PC value, then place a breakpoint on that place. In short, if you want to step through your code to debug it, then either load it into RAM or load it into Flash and disable the debugger's vector catch breakpoints.

Hope this helps everyone out there.
Dave (on Elektor Forum)

Chip Tuning for cars

Dear Editor — I was very disturbed to read your article on Car Chip Tuning (July/August 2005). To even mention the word "do-it-yourself" in the article is highly irresponsible. Vehicle manufacturers configure their Engine Management Systems to ensure the engine components work within safe operating limits. It's one thing a well meaning amateur paying the price of 'over-clocking' his or her CPU, but quite another when a tamped EMS is sending self-destruction signals to the engine while travelling at high speed down a motorway or autobahn!
David A Jack (UK)

We appreciate David's cautionary advice. Personally I am a slow and careful driver and I would not dream of ever messing with the electronics in my own car (A 1997 Vauxhall Astra estate). However, as far as we know, there are legal limits to vehicle speed on public roads — not to torque and acceleration. MOT has the final word in respect of vehicle safety while complying with speed limits in any country is the car driver's own responsibility, as is the decision to have a peek at a car's CPU system, if only on paper or for academic interest.

Corrections & Updates

8958252 Flash Microcontroller Board

December 2001, p. 54, 010208-1

In general, it is best to no longer use the MicroFlash utility for programming. AtmelISP is updated regularly and also works under Windows XP. The configuration required for the Elektor Flash Micro board is set up by selecting the option 'DK7JD' in the opening menu.

Simple Infrared Control Extender

July/August 2004, p. 56, 030103-1

In the schematic diagram, transistor T1 should be a type BD239, not a BD240. The circuit symbol is correct.

LPC210x ARMee Development System

April 2005, p. 20, 040444-2.

Guidance on the values of R24 and R25 settings of jumpers JP4-JP7 was unfortunately omitted from the article. R24 and R25 are pull-up and pull-down resistors taking a typical value of 390 Ω. JP5 is used to determine the effective resistance of terminator resistor R25 in the RS485 interface. The resistor may be left in circuit without problems.
The jumper settings are as follows;
Two RS232 ports: JP4 = 2-3; JP5 = open; JP6 = 1-2; J7 = 1-2.
One RS232 and one RS485 port: JP4 = 1-2; JP5 = closed; jp6 = 2-3; JP7 = 2-3,
With J4, JP6 and JP7, pin 1 is marked by the bevelled edge.
There's more information on the ARMee board in our online Forum.

Thanks for that, Dave, we are sure the ARMee system gets even more powerful by the additions and extensions you have mentioned. The project has generated a lot of interest not in the least by Tony Dixon's excellent support for it in our Forum and the fact that the plug-on CPU module is available ready made through the Elektor SHOP. We now call on our readers to send us their practical applications for the ARMee board and so help to make the project even more successful!

Delving into Delphi

Dear Jan — the articles 'Delphi for Electronics Engineers' look brilliant and I'm sure Delphi is wonderful but at the college where I teach (North Sydney College of Technical and Further Education) we switched from Pascal to C quite a few years ago and I can't get motivated to delve into Delphi.
Would it be possible to re-write the articles to use Borland C Builder or Microsoft Visual C?
If that's too big a job perhaps you could provide some shorter articles on getting started with C Builder. We don't use C Builder in our electronics courses at the moment but it would be good to introduce it.
(Most of our C programming is for microcontrollers and we find the SDCC compiler to be excellent.)

To motivate myself to learn Turbo Pascal graphics I wrote a program to design loudspeaker enclosures and equalisers. Interested users may download it from my web site:
http://members.optusnet.com.au/rwillson/
Thanks for a terrific magazine.
Ross Willson
(Sydney, Australia)

Thanks Ross for the feedback. We're currently negotiating with an team of authors to stage a course in C+ programming for microcontrollers. The Delphi course should be finished by the November 2005 issue. Detlef Overbeek and his fellow course writers have informed us that over 2,000 CD-ROMs have been sent to Elektor readers all over the world.

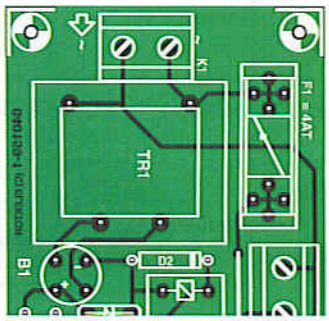
Elusive Phosphor-Bronze

Dear Editor — in the July/August 2005 issue, on page 72 (item 047), I read that "(phosphor bronze)...can be obtained from Conrad among other sources, in the form of small sheets...".
I have searched Conrad's UK website in vain for this material, please can you tell me the entry you are referring to? I would dearly love to find a source of PB sheet for all kinds of jobs, I have been trying for ages!!
Richard Barnes (UK)

Unfortunately the stock reached by way of Conrad UK's website is not (yet) as extensive as that of the German mother company. The matter has been brought to the attention of Conrad on several occasions but with little success so far. The same problem exists in two other countries Elektor is published in: The Netherlands and France.
For now, the parent company's website at www.conrad.de lists phosphor bronze sheet material as item nos 220659-LN and 220658-LN.

Thin PCB tracks

Dearest Friends — I'm sitting with the new magazine (issue 7-8 2005) and cannot put it away :-).
But one thing caught my eye. The Energy-saving Switch on page 38 uses a 4-A fuse, but the PCB tracks are very small (thin). Maybe they will survive, but I would prefer copper tracks of two or three times the width you have designed.
Klavs Rommedahl
(Denmark)



Absolutely right, Klavs, these PCB tracks should be strengthened to about double the width we've shown. This is easiest done by shunting them with pieces of solid, insulated hookup wire.

MailBox Terms

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editor@elektor-electronics.co.uk or Elektor Electronics, The Editor, P.O. Box 190, Tunbridge Wells TN5 7WY, England.

Lightning strikes three times

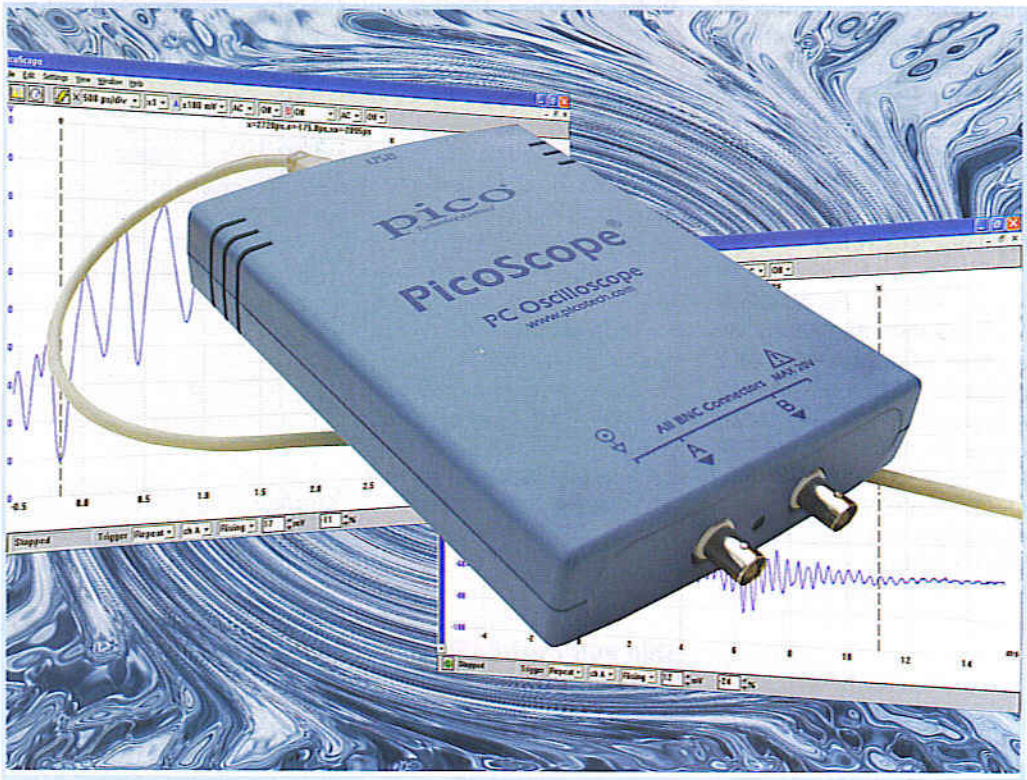
Lascar Electronics Ltd. has added the EL-USB-3 to its popular EL-USB range of standalone data loggers. The unit has a 0-30V d.c. measurement range which enables users to measure and record outputs from a wide variety of sensors such as pressure, flow, pH, load and temperature. The unit is supplied with Windows compatible software which is used for configuration of the unit as well as download and graphing of the data. With the logger connected to a USB port, the software enables the user to set the required sampling rate (from 1 second), custom calibration, high and low alarms, and the logger start time. Once configured, the EL-USB-3 is removed from the computer, the cap is replaced, and the voltage to be measured connected to the logger via two screw terminals. At this point logging can commence.

Two LEDs indicate when the unit is logging, when an alarm level has been reached, when the battery needs replacing or when the device has reached full memory capacity (32,000 readings). To download data, the user reconnects the unit to the USB port. The supplied software is then used to download and graph the data from the unit. Data, saved in .txt format, can be imported to many industry standard spreadsheet packages for more detailed analysis.

The EL-USB-3 is available immediately from Lascar Electronics at a price of £39.00 (£23.40 in OEM quantities of 250+). To order now, call +44 (0)1794 884567 or order online at www.lascarelectronics.com.

(057131-1)

Low-cost Picoscope 2202



Pico Technology has announced the immediate availability of the PicoScope 2202 PC Oscilloscope. Connected to your PC and powered by its USB 2.0 port, the dual-channel PicoScope 2202 is a PC Oscilloscope with 8-bit resolution, 20 MS/s sampling rate and a 32kB memory depth. In combination with the PicoScope and PicoLog software included, the unit acts as an oscilloscope, spectrum analyser, multimeter and data logger.

Using the latest advances in measurement technology, Pico Technology has designed the low-cost PicoScope 2202 with hobbyist and educational markets in mind. With its high sampling rate, the oscilloscope is useful in a variety of electronic applications including audio amplifiers, switched-mode power supplies and microcontrollers, and for displaying waveforms obtained from laboratory experiments. The USB 2.0 port makes the device easy to use with all standard desktop and laptop PC's and removes the need to configure printer ports. There is no need for an external power supply, as the unit takes its power from the USB port.

The PicoScope 2202 is supported by the PicoScope and PicoLog software included with each unit. PicoScope provides oscilloscope, spectrum analyser and multimeter functions, with the ability to save and print waveforms. PicoLog turns your system into a powerful data logger that can export data to a spreadsheet or display it as a graph, both in real time or using recorded data. These programs are easy for the novice to operate, but also contain a full range of advanced features for expert users. Software updates are available free of charge from the Pico Technology website.

The PicoScope 2202 PC Oscilloscope is available immediately direct from Pico Technology or from one of our authorised distributors at a cost of £199 + VAT.

You can obtain further information from the Pico Technology website at www.picotech.com or by calling +44 (0) 1480 396 395.

(057131-2)

Handheld through-wall radar

Cambridge Consultants is previewing the second generation of its through-wall radar technology, which is expected to break new ground in quality of imaging and ease of use. Providing 3D feedback on the location and movement of people inside buildings, the system is being reengineered as a standalone handheld unit, and will be offered in a slimline case with its own colour display.

The new version of the radar, Prism 200, is hoped to eliminates the need for an external controller and man-machine interface. This is achieved by integrating a VideoCore processor which combines high-performance digital signal processing capabilities with a versatile display driver. Results are presented instantly on the unit's built-in 6.4-inch colour display - or, alternatively, transmitted to a remote laptop.

Building on the success of the first-generation Prism 100 radar, the new radar will offer features that will enhance the efficiency and safety of military and emergency service personnel in situations such as hostage taking, search and rescue.

Held against a wall or mounted on a tripod up to 2 metres away, Prism 200 transmits low frequency ultra-wideband (UWB) radar pulses that pass through building materials over 40 cm thick, to detect activity over a range of up to 15 metres.

A unique feature of the new intelligent radar core is an array of antennas which gives it a large field of vision — at least 140 degrees in both vertical and horizontal planes — combined with 3D object location and motion tracking. Operators can use the 3D capability to decide whether people are standing, sitting or lying, or whether the object detected is human or an animal.

Prism 200 will be able to provide plan and elevation views. The onboard signal processing may also be customised to suit a wide range of target applications. Programmable parameters include range, scan rate and target permanence, and the display can be adapted for optimised presentation of the data for specific uses.

The system identifies an individual person as a cluster of targets of the same colour to give a clear representation of the movement of each person in the space being monitored. However, much more is possible, including the ability to focus on living/moving targets to give a tracking history of individuals and to build up a picture of the static objects in the room.

Cambridge Consultants is now at an advanced stage of development with the radar core, and is designing a tough weatherproof case to house the system. The finished product is expected to weigh around 3 kg, including a lithium-ion battery pack that will store enough power for around two hours of continuous use. Featuring a slimline shape with hand grips, the unit will be easily portable by a soldier or emergency service worker. And, it can be put into use almost instantly: all that's required to start monitoring is a single push of a button, with the embedded system displaying results within 2 seconds.

Cambridge Consultants Ltd, Science Park, Milton Road, Cambridge, CB4 0DW, UK.
Tel: +44 (0)1223 420024; Fax: +44 (0)1223 423373;
www.cambridgeconsultants.com

(057131-3)

UltraCMOS technology tops 13 GHz

Peregrine Semiconductor Corporation, a supplier of the industry's most advanced RF CMOS and mixed-signal communications ICs, recently announced that it's leading-edge UltraCMOS™ process technology is producing products that now reach 13.2 GHz, a speed level never-before attained by traditional CMOS processes.

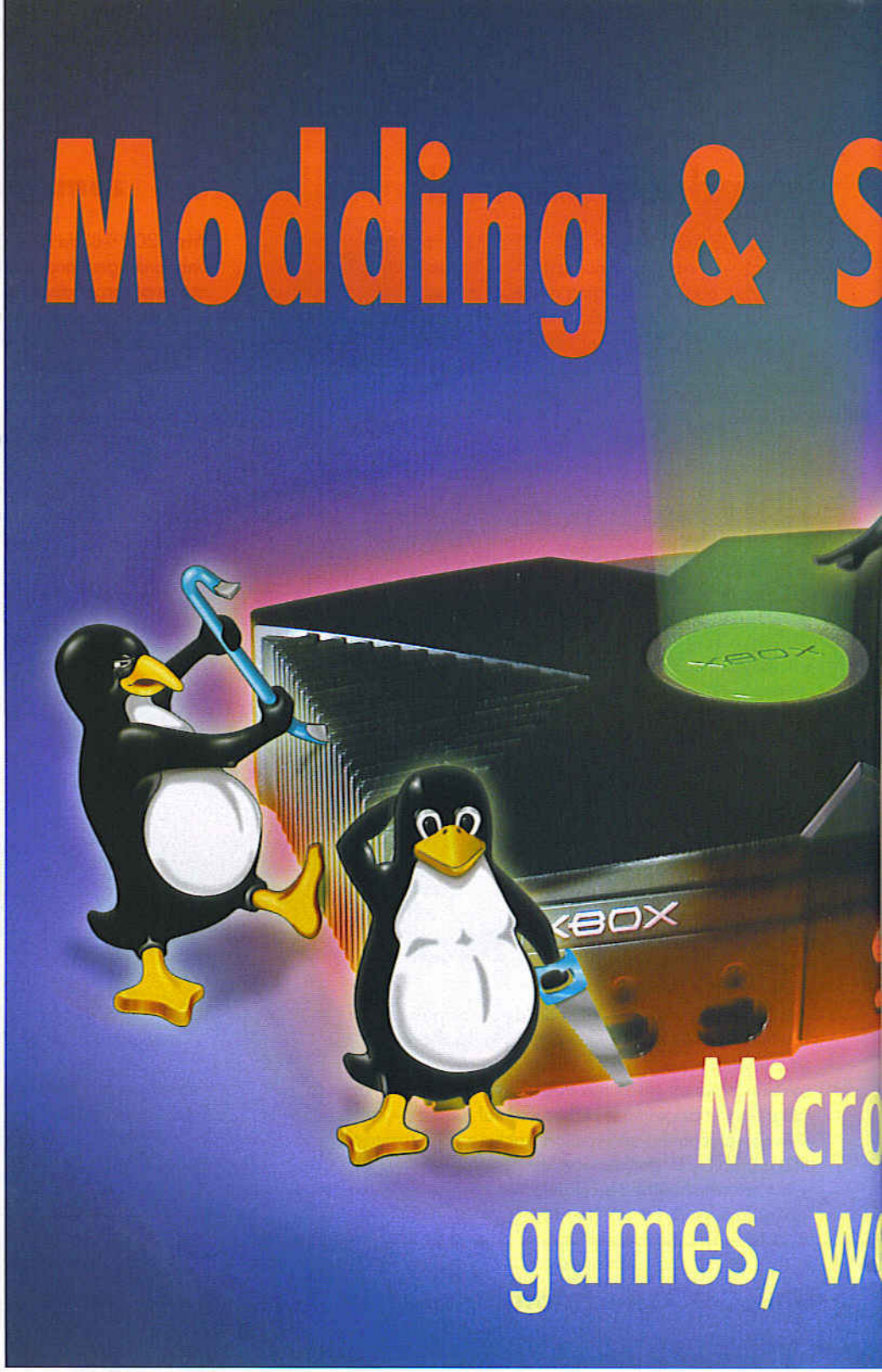
The PE9308 Rad-hard Prescaler, designed for space, high-performance military and infrastructure applications, is the first CMOS device to operate in X and Ku Band, showcasing the UltraCMOS speed advantage. This new Peregrine Prescaler is claimed to deliver industry-leading RF performance at X or Ku Band on CMOS.

The PE9308 also reaches an ultra-low-power milestone, operating at 25mA (typ.) @ 2.5V — which is about 1/10th the power of an equivalent GaAs device — yet delivers decidedly superior rad-hard performance, including fixed divide ratio of 4; low SSB phase noise; immunity to Single Event Latchup (SEL); Single-event Upset (SEU) of less than 10^{-9} errors/bit-day; and tolerance total dose radiation of 100 Krads (Si). Additionally, output frequency can be fed directly into Peregrine's complete line of PLLs, offering a complete frequency synthesis capability, from DC to Ku band, entirely from the Peregrine portfolio. This reduces purchasing and vendor management for all frequency synthesis designs.

Evaluation Kits support development with the devices, and UltraCMOS technology tutorials are available from Peregrine on its website at www.psemi.com. The PE9308 is offered in the 8-lead Formed Flat Pack or die, and is in production now.

(057331-4)

Xbox Modding & S



Paul Goossens

The Xbox made by Microsoft is a very popular games console. What many buyers don't know is that the Xbox is really just an ordinary PC running a special version of Windows. This leaves the door open to experimenting, for example with Linux. But first you have to get round a couple of modifications, which for many is all part of the fun. So let's get started!

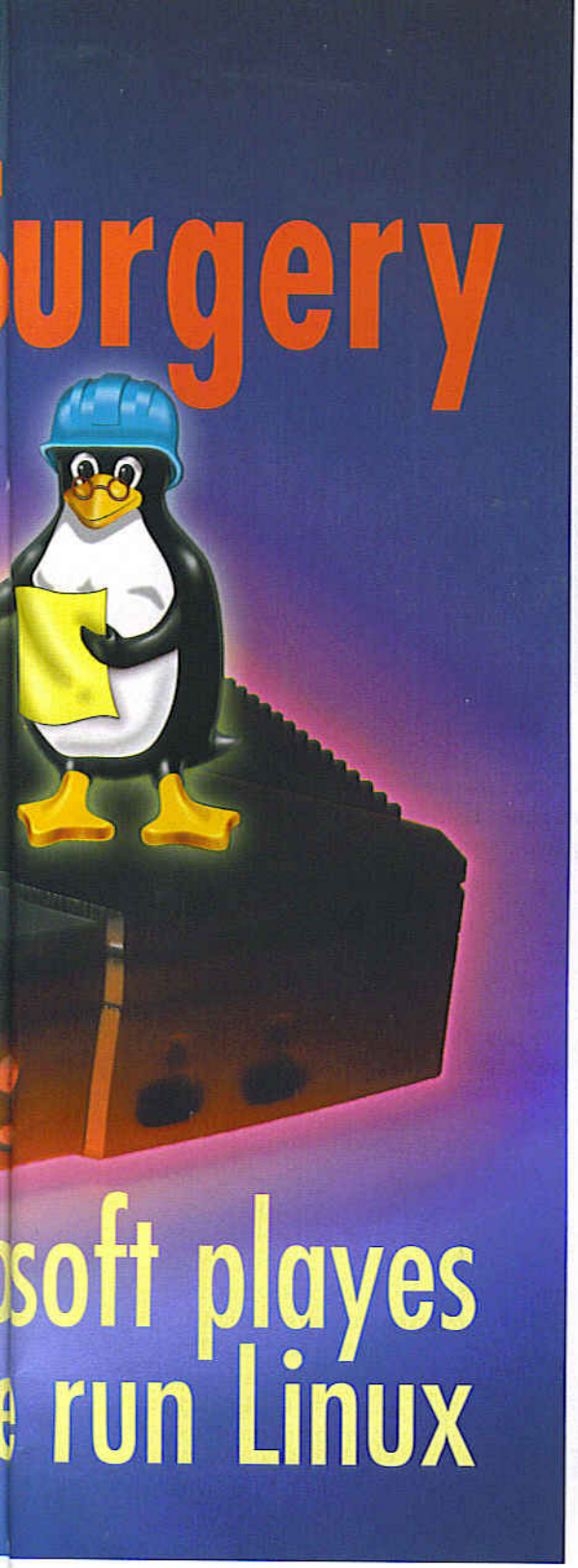
As with most games consoles the Xbox has a built-in protection that prevents the illegal copying of games. A disadvantage for the consumer is that the making of backups of expensive games is not possible or pointless, since the games console refuses to play these copies.
Apart from that, many engineers would like to know how this device works and if it can be used for other purposes. There are always some hobbyists who use their spare time to investigate how to get round this protection.
Microsoft has also included this protection in the Xbox. So there's work to be done...

PC look-alike

When the Xbox was examined it soon became clear that the technology used came straight from the PC. This shouldn't come as much of a surprise, since Microsoft has concentrated on the PC during most of its lifetime.
The CPU, the graphics processor and all other components are the same as those used in a PC. A DVD player, hard drive and network connection are included as well! The idea to run Linux on such a games console is then just a logical conclusion. When you consider that Linux is the biggest competitor of Microsoft, you know that the battle lines are drawn...

Protection

Broadly speaking, the protection in the Xbox consists of two parts. The first



urgery

soft playes
e run Linux

programs. These files now end in .XBE instead of .EXE, as used on the PC. The structure of the file has also been changed, so that a simple renaming of the file is not sufficient.

These days there are many ways in which to get round this protection.

refuses to run programs that haven't been digitally signed by Microsoft. The second protection is that the hard drive is normally 'locked'. Whenever a read or write operation takes place, the drive is momentarily 'unlocked'. This makes it impossible to remove the hard drive and to read or modify its contents from a PC.

To make life even more difficult for the hackers, the files are stored in a different way, called the *xfilesystem*. And finally, there is a new file format for

It's all very different in the Xbox. The BIOS first sets up the hardware, but it also contains the operating system. (This operating system is derived from Windows 2000). There is nothing left of the operating system on the hard disk. The routines that check that the programs are digitally signed by Microsoft

Cromwell BIOS: allows applications without digital signature

Booting up

The biggest difference between the PC and Xbox is the way in which they boot up. The PC contains a BIOS (firmware) that doesn't do much more than set up the hardware and load a boot sector into memory. When this is executed the operating system is loaded.

are also contained in the BIOS, as are the lock and unlock routines for the hard disk.

There are two ways in which to get round these protection systems. One solution is to use a loophole left in the protection by Microsoft. Another is to adapt the BIOS. This also requires a

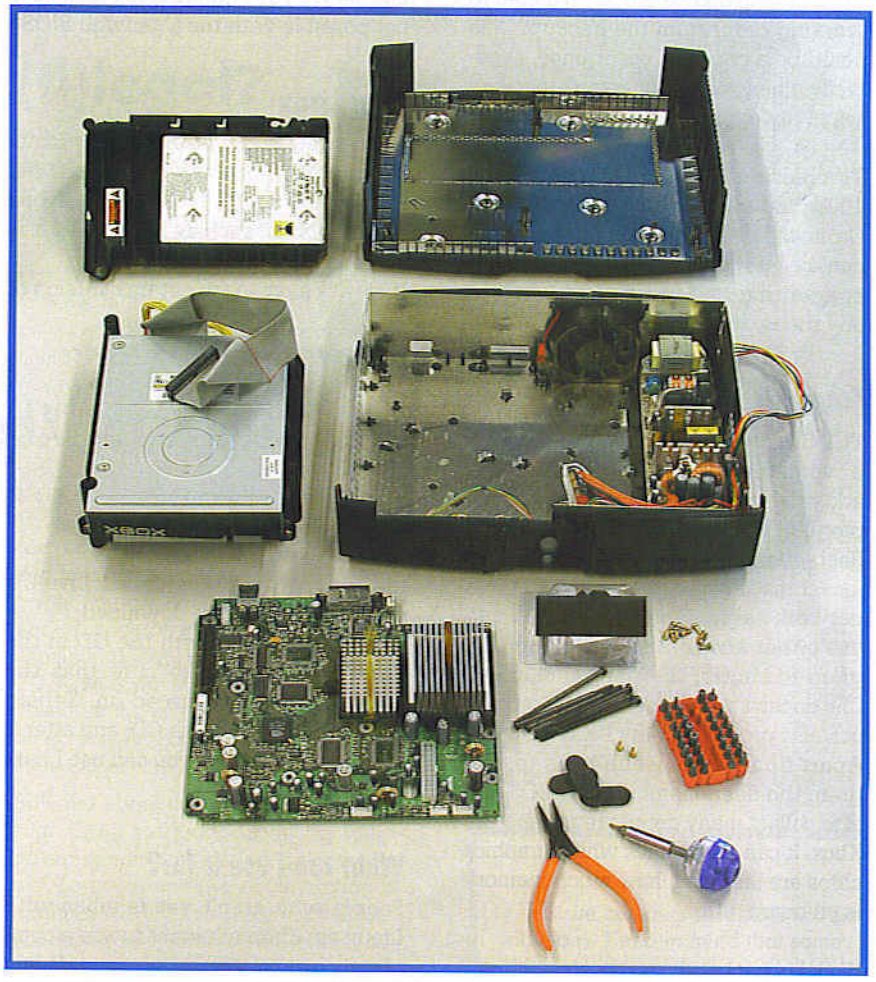


Figure 1. The Xbox in all its glory!

modification to the electronics of the Xbox. As an electronics magazine we obviously looked at the latter option.

Modchip

The BIOS inside the Xbox determines what software is being run and what not. To be able to run Linux, it is necessary to install 'foreign' firmware in the Xbox. This second BIOS is usually added as a separate chip to the existing hardware. There are special 'modchips' available for the purpose. These are small boards with a number of components that change the functionality of the Xbox. All required connectors are usually included. Xbox owners should note that the product warranty is voided when the box is opened!
The hardware itself is quite refined. There are two flash chips, an FPGA and a handful of smaller components. The reason for the two flash chips becomes clear when we look closely at the specifications for the modchip. One of its features is a backup BIOS. The flash chip can be programmed by the user, but if something should go wrong the modchip can be quickly restored to working order from the backup. This could be a common occurrence, especially when you're not completely sure what you're doing.

The BIOS in the backup memory is a 100% open source BIOS (called Cromwell). This part of the memory can be protected via a switch from overwriting and can be turned on at any time.

Cromwell

The Cromwell BIOS is a versatile BIOS. It adds the capability to program the rest of the flash memory of the modchip. This is easily achieved via a network cable. From the PC you can use either a web browser or ftp program to control the programming. If this doesn't work for some reason, you can also program a new BIOS via a CD. Apart from these useful tools to program the flash memory, the BIOS can also collect many details regarding the Xbox. It can report back which graphics chips are installed, how much memory is on board, etc.

We have yet to tell you the most important feature: this BIOS permits the use of programs that don't contain a digital signature from Microsoft!
For those of you who'd like to use this BIOS to play copies of your games, we have bad news: the playing of backups, as well as original Xbox games, is not possible with the Cromwell BIOS.

Modchips: sales illegal — installation legal?

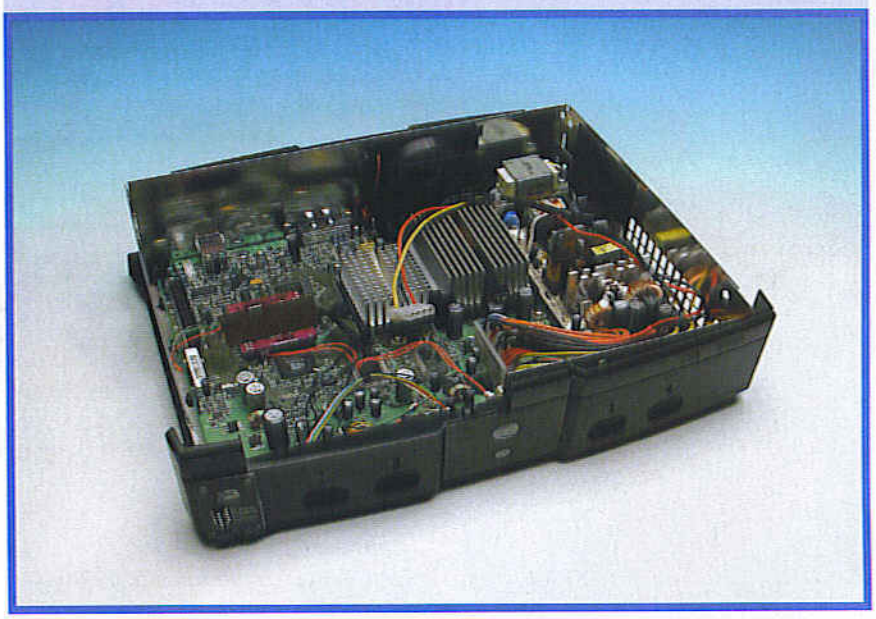


Figure 2. The built-in Xecuter 3 modchip is connected on the left-hand side to a header. At the front on the left-hand side is the accompanying bracket, which is used to install the chip.

Enter Linux

Fortunately it is possible to use Linux in combination with the Cromwell BIOS. This requires a special Xbox Linux version, such as Xebian [1]. It is derived from Debian Linux.
It is very easy to try out this version of the Linux distribution, since a Live-CD is available as a free download.
Turn on the Xbox with the CD in the drive and also make sure that the Cromwell BIOS is turned on. Xebian will then start from the CD, and after it has finished booting you can use Linux straight away.

Xebian: Linux for Xbox

What can I use it for?

People who aren't yet familiar with Linux are often reluctant to use a completely new operating system. It is a wide held belief that Linux is a complex system that can only be operated by computer nerds and Unix experts. Nothing is further from the truth! This is especially so when you use a good distribution (of Live CD), which comes as standard with a graphical user interface (GUI).

The Xbox Linux Live-CD used here is set up round a GUI and has a very intuitive interface. People who are used to Windows won't have many problems to start and use applications. The Live CD already contains a number of programs. A web browser and email program are of course included. There is also an Office suite with a word processor and spreadsheet program. Once Linux has been installed on the hard disk, it becomes possible to install and use all Linux software.
You couldn't be more wrong if you still believe that there is only a limited range of software available for Linux. By now thousands of programs have been written for Linux. It's very likely that all programs you've used so far under Windows will have an equivalent under Linux.

You can configure the Xbox as a multimedia system in the same way. Just add the required software and it will run. It can also be used for many, many other purposes. After all, the Xbox is just like a PC!

(050085-1)

Xbox: cheap multimedia system running Linux

Figure 3. **The modded Xbox in action (running the Live version of Xebian).**

There are other ways

In contrast, the manufacturer SONY has been actively involved in making Linux available for its Playstation. There are Linux distributions for sale for both the Playstation and the Playstation2. The Playstation needed some extra hardware as well, including an interface for the keyboard, a VGA adapter, etc.

The chances that Microsoft will do something similar for the Xbox seem to be very remote...

Xbox 360?

As you may be aware, Microsoft has been busy with the successor to the Xbox, the Xbox 360. When this is released, it's very likely that the 'old' Xbox can be picked up at bargain basement prices. If you are looking for a cheap multimedia system, we suggest you add an 'old' Xbox to the list. An advantage of the Xbox is that it is still a games console, which has a large number of games available for it.

Playing Backups

The Cromwell BIOS is not capable of playing Xbox games, whether they are originals or copies. This can only be done with an illegal BIOS.

These illegal BIOS chips are all copies of the original Microsoft BIOS, the main difference being that the software that checks if a program contains a digital signature from Microsoft has been removed.

(Il)legal?

We asked a lawyer to investigate a few things for us. We wanted to know what is and what isn't permissible. For example, in the US of A you are allowed to make modifications that enhance the functionality of devices. Is this also permissible in Europe? You could look at a similar situation with cars. There are almost no cars that **can't** go faster than 70 mph. In other words, nearly every car is capable of illegal speeds. It is left to you, the user and/or owner, whether you choose to do so. You could reason along the same lines when modding the Xbox. You give it a new function that could be misused (copying). In the UK and most other European countries, as owner you are not allowed to make a backup copy of your software. If, for example, a legal copy of a game on CD-ROM is damaged for some reason, based on the product warranty you may be eligible for a replacement copy from the supplier.

So what about the modchips? The UK High Court has judged that "the sale, advertisement, possession for commercial purposes and use of Playstation modification chips is illegal in the UK" [21 July 2004]. This should apply to the Xbox as well. In the USA, the application of the Digital Millennium Copyright Act in 2003 resulted in five months jail and a 28,500 dollar fine for a trader selling Xbox modchips on the Internet.

Having a modchip installed or commissioning to do so is considered aiding and abetting, or inducing to commit an offence.

According to copyright laws, adding new functionality to software is only allowed if you have obtained written permission from the copyright holder. This also applies to software (firmware) burned into some certain hardware, as is the case with integrated circuits.

Although not strictly mentioned in the UK High Court ruling, fitting an modchip in, say, a Sony Playstation, is likely to be illegal, too, as it allows illegally copied games to be played. This follows a recent verdict of the US Supreme Court that holds makers of peer-to-peer software like Kazaa responsible for possible infringement of copyright by users exchanging illegal music files — although, of course, the same programs also allow perfectly legal files to be shared, too.

However, installing a modchip does not add anything to the existing software. Rather, other software 'also' runs, optionally and in parallel. In other words, no changes are made to the original software. Although selling modchips is illegal, it can be argued that the installation of a modchip in an Xbox by the rightful owner (of the Xbox) is not a violation of the copyrights owned by Microsoft. Based on ownership rights but still observing the bounds of higher legislation you have the right to modify, damage or even destroy the unit to your heart's content. However, if, by accepting Microsoft's Xbox User Conditions, you have promised not to mess with the unit, you may, just in theory, be held liable for contract breach.

Interesting links:

[1] This site contains several Linux distributions. Keep in mind that some downloads exceed 100 MB!

www.Xbox-linux.org

Design and Run a Digital Filter in SECONDS!

Signal Wizard 2: Easy-Use Real-Time Digital Filter and Analyser

Signal Wizard 2 is a unique real-time audio-bandwidth digital filter with infinitely adjustable characteristics – available at the click of a button. It uses a DSP unit that runs the filter and a Windows interface for designing and downloading almost any kind of filter. You don't need to know about maths, DSP or filter design – all you need to know is what filter you want. Signal Wizard designs finite impulse response (FIR), infinite impulse response (IIR) and adaptive filters in seconds. You can even import your own impulse or frequency responses. After you've designed the filter, click a button to download and run. Simple! Its flash memory means it can run filters from start-up, without the need for a PC.

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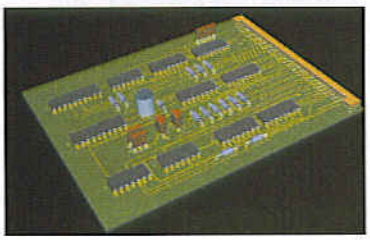

Easy-PC version 9 just gets better

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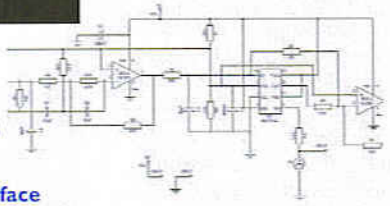

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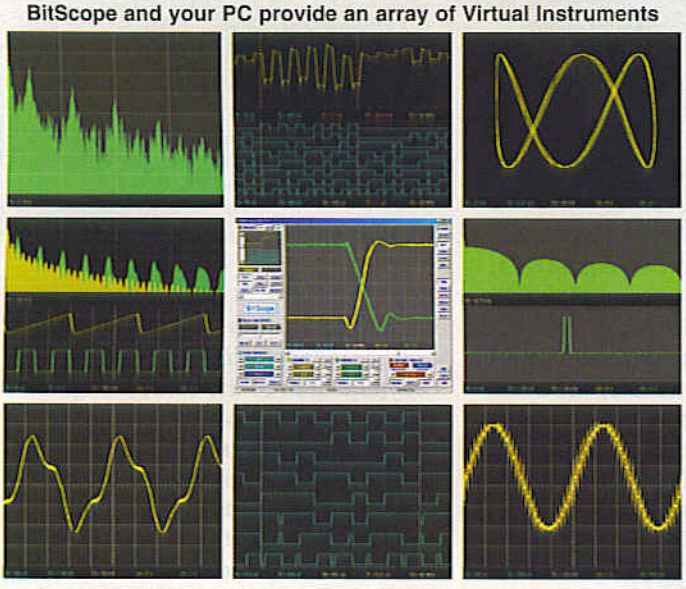

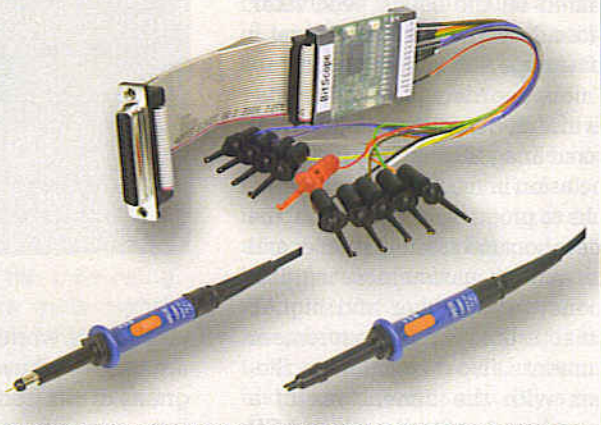

BitScope's integrated design uses standard oscilloscope probes and a growing range of custom probes to provide functionality equal to instruments many times the price.

BitScope plugs into third party software tools and has an open API for user programming and custom data acquisition.

BitScope DSO software for Windows and Linux

www.bitscope.com

USB Oscilloscopes

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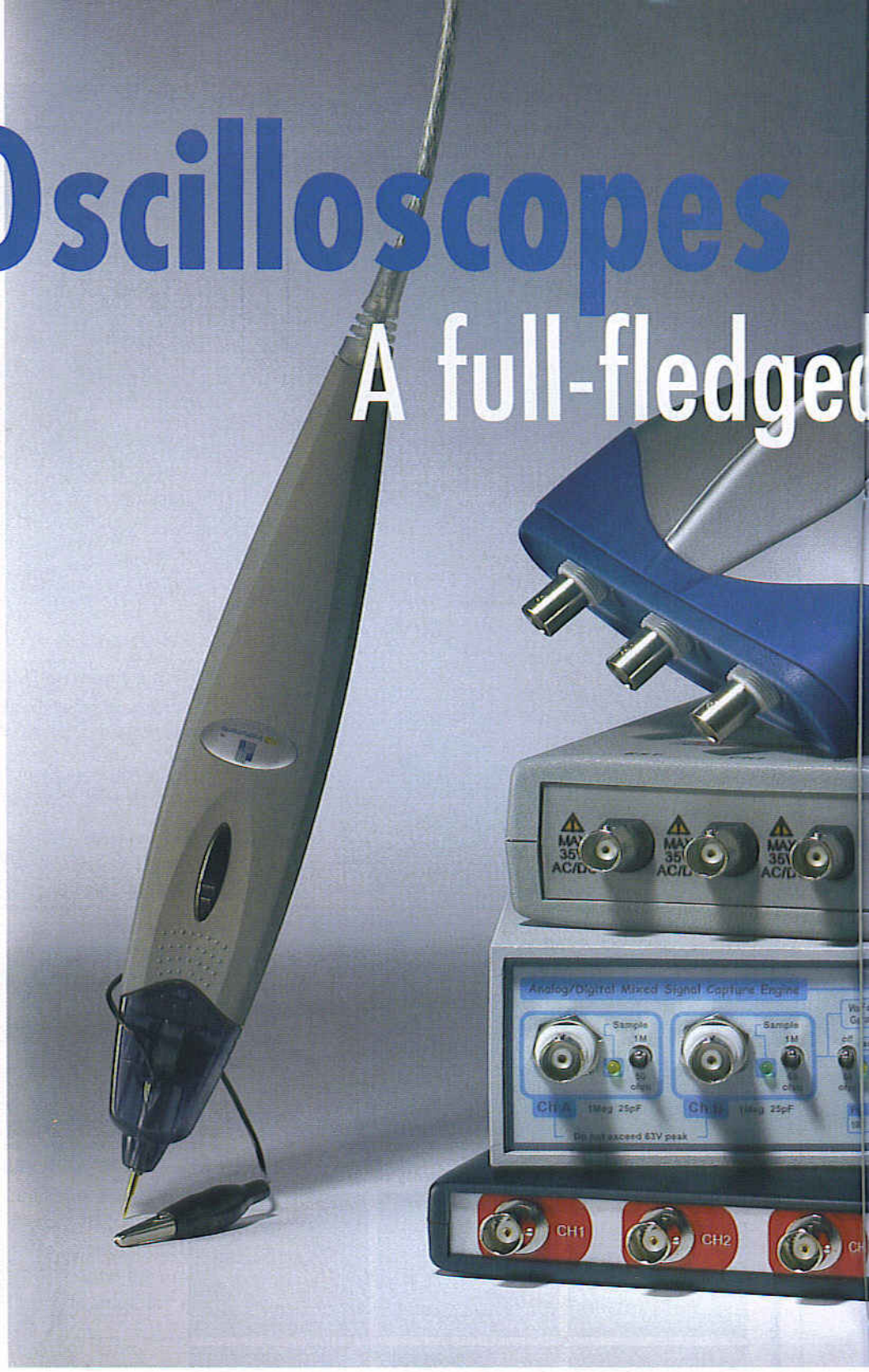


In the past, a lot of space in hobby rooms and work stations was taken up by an instrument in a large case with a small screen, but now many of its functions can be performed using a PC. A small box can transform an ordinary PC into an oscilloscope with extensive functions. *Elektor Electronics* subjected eleven of these 'USB oscilloscopes' to an extensive evaluation.

Jan Steen

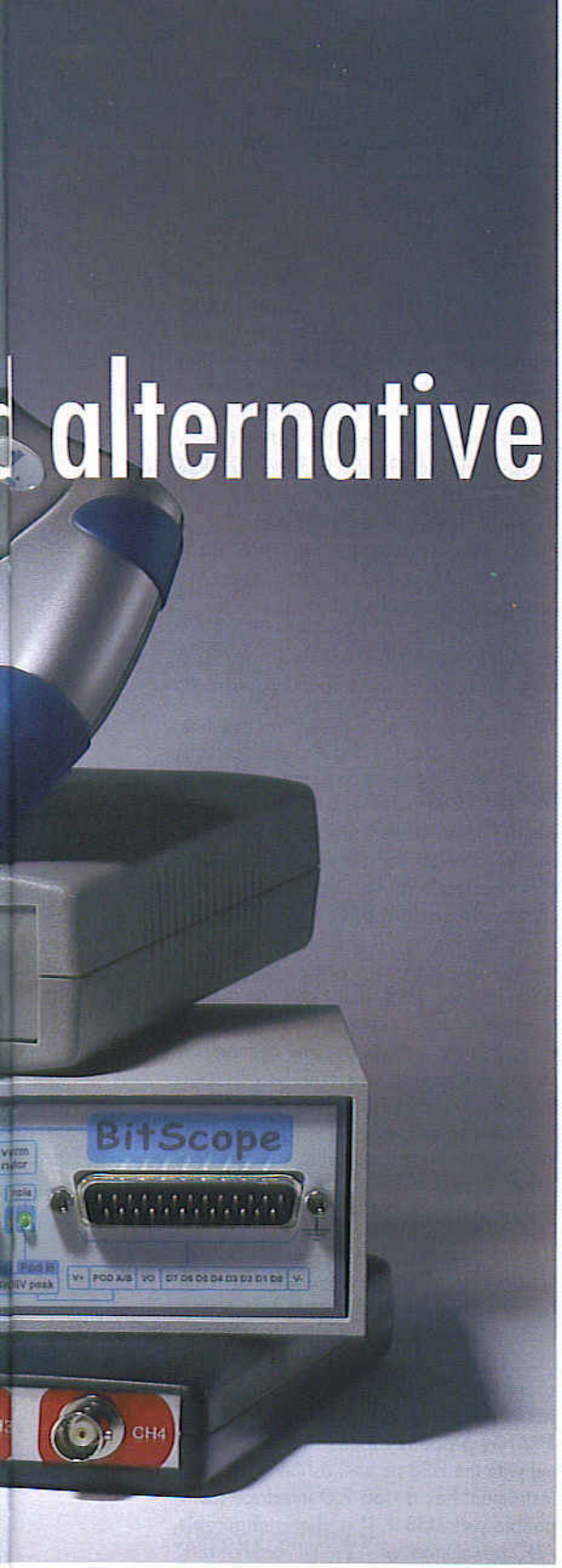
Oscilloscopes have become essential measurement instruments in the electronics world. In the early days, they were simple, massive cabinets with a limited frequency range and a single measurement channel. After that came the multichannel versions. Digital storage oscilloscopes appeared on the scene even later. They made it possible to 'freeze' a certain image and store it in memory. The more luxurious versions sometimes included a small built-in printer so stored images could be printed out for inclusion in measurement reports. Thanks to progress in electronics, the cabinets became steadily smaller and lighter and the maximum measurable frequency rose higher and higher. Manufacturers of measurement instruments also developed oscilloscopes with the dimensions of a hefty multimeter fitted with an LCD screen, which made them suitable for portable use. All of the above-mentioned types are still commonly used.

The PC as 'my man Friday'

PCs have come to be standard features in every house and office. They have also become essential in the electronics world. For instance, PCs are used for drawing schematic diagrams of electronic circuits, simulating circuits, and making PCB designs. They're also very convenient in the lab. An application in which the PC forms part of a measurement system is thus an obvious idea.

USB oscilloscopes

It doesn't take much imagination to think of combining a sort of A/D converter with a PC to observe all sorts of signal waveforms, which practically amounts to the same thing as an oscilloscope. Various types of adapters are available for this purpose, ranging from cheap to expensive. Here we decided to see what was available in this area with a USB interface, because we'd like to keep up with the times and serial ports are becoming increasingly less common in new PCs.
With this sort arrangement, the PC



A bit of nostalgia

I can still remember quite well the impression the oscilloscope made on me as a lower general secondary student during an open-house visit to the intermediate technical school. Various measurement configurations were set up in the electronics lab, and the oscilloscope formed the 'centrepiece'. When I saw it, I thought: 'I'll never learn all of that'. But in practice it turned out to be a lot easier than I expected, because an oscilloscope isn't such a complicated instrument. It basically consists of a cathode-ray tube with horizontal and vertical deflection plates. An internally generated sawtooth signal is usually applied to the horizontal deflection plates. The frequency of the sawtooth signal determines the timebase. That means that when you turn the timebase knob, in principle all you do is change the frequency of the sawtooth signal. The electron beam moves from left to right across the screen. If no signal is applied to the Y input and the timebase is set for a very slow trace, you can see what the sawtooth signal actually does: you see a spot moving from left to right across the screen. If you gradually reduce the timebase (by increasing the sawtooth frequency), the spot moves faster and faster until it finally becomes a line instead of a spot. The connections to the deflection plates are represented on the front panel as the X and Y inputs. The signal to be measured (such as a sine wave voltage) is applied to the Y input. Aside from 'normal' operation with an internal sawtooth signal applied to the X input (internally), it is also possible to apply variable signals to both inputs. That produces fascinating elliptical patterns that constantly move and rotate and give a rather futuristic impression, which are commonly known as Lissajous figures.

actually only serves as a data processing and display system for signals measured using the adapter, which forms the heart of the USB oscilloscope. The adapter contains the components (preamplifiers and attenuators, A/D converters, memory, and USB interface) that process the signals to be measured and forward the measurement data to the PC via the USB port. The associated software processes the received data, and the results are then displayed on the monitor. Here we have a very generously sized display at our disposal, especially compared with previous instruments. The display for the measured signal is complemented by a complete graphic user interface with all the front-panel controls we're used to from a 'real' oscilloscope.

Comparison of selected models

We selected eleven of these 'USB scopes' and subjected them to critical examination for you. The results are reported on the following pages. This does not amount to a thorough study, but instead more of a presentation of the most significant facts and features. We examined aspects such the quality of the construction, the associated software, ease of use, and technical specifications. These are all practical aspects that can help you select a USB oscilloscope for your own use.

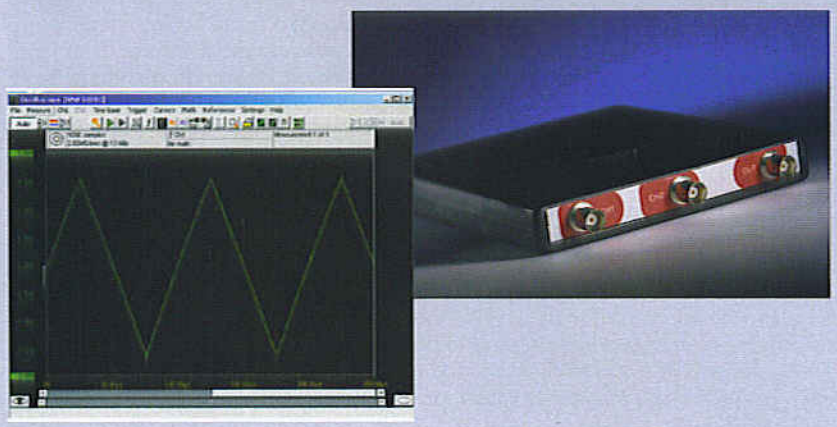
Incidentally, there are also PC oscilloscope adapters that can be used with a parallel or serial port, but we left them aside for the time being. Many PC users are quite rightly enthusiastic about the USB port due to its communication speed (particularly with USB 2.0) and convenient hardware installation.

What are the important characteristics of a USB oscilloscope? For many users, the maximum measurable frequency is an important consideration. However, in the case of digital oscilloscopes (which includes USB oscilloscopes) the actual characteristic is not the maximum frequency, but instead the sampling rate. With an oscilloscope, sampling simply consists of taking measurements a certain number of times per time unit. All sorts of sampling rates are possible, but most devices have a value between 5 MHz and 100 MHz. In theory, sampling yields a series of points. The software joints the points to form a line, such as a sine wave. This is called 'reconstruction'. The maximum measurable frequency is thus not the same as the sampling rate. A rule of thumb that is often used is that the sampling rate must be at least twice the frequency of the input signal to be measured. However, reconstruction of the signal waveform is not possible under these conditions. There are also a number of tricks that can be used, such as oversampling, but that's something we'll come back to further on.

We primarily examined the devices we tested here as USB oscilloscopes. However, some of them can also be used as voltmeters, spectrum analysers or even function generators. 'USB oscilloscope' is thus perhaps not quite the right name. One of the manufacturers, for example, uses the term 'multifunctional PC measuring instrument'. That's actually a better description of the functionality.

A table summarising the principal characteristics of each of the devices is provided at the end of this article. It provides a handy aid for selecting the most suitable solution for a particular measurement situation. But first, let's look at our practical experience with the eleven USB oscilloscopes.

Handyscopes



TiePie Engineering in Sneek, The Netherlands, has specialised in PC measurement instruments for many years already. We received two USB oscilloscopes bearing their brand name for our tests: the two-channel Handyscope HS3 and the four-channel Handyscope HS4. The two instruments have a lot of similarities with regard to construction and software, but they differ in several aspects. Besides the oscilloscope functions, the Handyscope instruments provide voltmeter, transient recorder and spectrum analyser functions. The HS3 also incorporates a function generator. It can generate sine-wave, triangular-wave, square-wave, white noise or arbitrary signals defined by a data file, all up to a maximum frequency of 2 MHz. The output signal can also be swept between two configurable frequencies. Naturally, the amplitude (0–12 V), DC offset and symmetry of the signal are adjustable. We also took a brief look at the spectrum analyser, which computes the frequency components of the input signal and displays them on the screen. A 14-MHz signal from a short-wave receiver was imaged quite nicely.

Installation

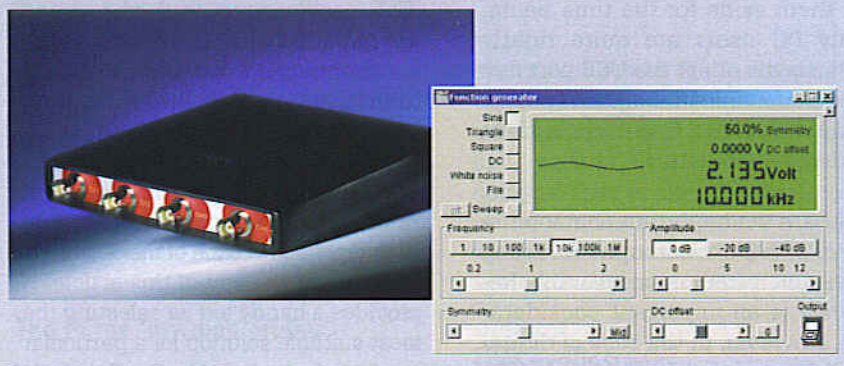
The software is provided on a CD-ROM, along with the user manual, but everything can also be downloaded from the TiePie website.

The first thing we did was to connect the Handyscope to the USB port. We then installed the USB drivers, followed by the application software. After the PC was restarted, everything worked right off the bat.

Oscilloscope

Around 90% of the controls will probably be intuitive for a competent electronics type. The rest require briefly consulting the manual. The image corresponds to the typical display of a digital oscilloscope. The sampling rate and record length, among other things, can be set under the 'Timebase' menu. If the sampling rate and record length are configured properly, outstanding images are displayed. A handy feature is the 'auto setup' function, which automatically configures the input range, sampling rate and trigger level so the measured signal is immediately displayed in an easily viewed form. It probably goes without saying, but the images can be stored and printed. You can also operate the instrument with channels 1 and 2 in sum or differential mode and so on. The ability to use crosshairs cursors is also very handy. They can be used to make measurements between two selected points in the image (time difference, voltage difference, etc.). The results of the crosshair measurement are displayed in a small window.

All in all, the Handyscopes are very complete instruments with matching performance.



Multichannel

Besides the standard software, a 'multichannel' version of the software can also be downloaded from the TiePie website. This software is a beta version, but it is certainly worth mentioning. It allows several instruments to be used a the same time. Several HS3 and/or HS4 units can be linked together, which makes it easy to implement an instrument with 32 parallel channels. If so desired, operations can also be performed on the measurements before they are plotted on the display.

Specifications

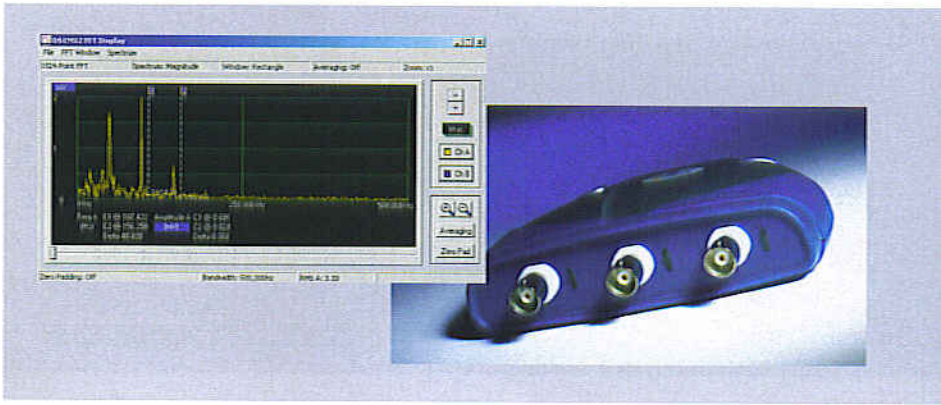
The two instruments are very similar in terms of construction, software and use. The HS3 has two channels and is available in various models with maximum sampling rates of 5, 10, 25, 50, and 100 MS/s. The four-channel HS4 is available with a maximum sampling rate of 5, 10, 25 or 50 MS/s. A 1¥/10¥ probe is supplied for each channel with the HS3 as well as the HS4. Each instrument has a USB 2.0 interface (compatible with USB 1.1) and a configurable ADC resolution of 12, 14 or 16 bits. Besides the two measurement channels, the HS3 includes a function generator, as already mentioned.

Conclusion

It's a pity that lack of space prevents us from listing all the options and features (which is also true for the other USB instruments), but these USB oscilloscopes from TiePie are truly 'top end' and would be a welcome addition to many an electronics bench or hobby room. They are simply outstanding, versatile instruments.

USB Instruments

We tried out two models from this brand. The first one is a 'normal' USB oscilloscope: the DS1M12 Stingray. The second one is a 'pen scope': the PM40M10 Swordfish. In contrast to the two TiePie instruments, these two PC instruments from USB Instruments bear no resemblance to each other. The application programs and graphic user interfaces, on the other hand, are practically the same except for a few details.



Stingray

This might be called a 'starter model'. The Stingray is a good two-channel instrument, but it has major limitations with regard to the maximum measurable frequency. The manufacturer specifies an analogue bandwidth of only 250 kHz. Besides acting as an oscilloscope, it can serve as a data logger and function generator, and it has FFT capability (like the Handyscopes). 'FFT' stands for 'fast Fourier transform', which is a type of spectrum analysis. In an FFT display, frequency is shown on the horizontal axis instead of time. With the shortest timebase setting of 2 ms, the X axis of the analyser extends to 500 kHz.

The Stingray has a sampling rate of only 1 MS/s in normal operating mode, but the ADC resolution is a healthy 12 bits. A sampling rate of 20 MS/s can be achieved by oversampling. However, oversampling can only be used with unvarying (repetitive) input signals. In the oversampling mode, the software measures the input signal at a different time during each cycle and then combines the results. This amounts to a software trick to enhance sampling of a signal that cannot be properly reconstructed using direct sampling. Incidentally, it works quite well.

The Stingray is supplied with a handy carrying case for convenient transportation to where it is to be used.

Stingray software

The software is supplied on a mini CD-ROM. Installation is easy. After the CD is inserted, a menu is displayed to allow various options to be selected. That involves the software for the 'scope, the software for the data logger, the manual, and so on. There are also Linux drivers on the CD-ROM.

The Stingray in practice

The instrument is easy to use, and the manual is actually not even necessary. The graphic user interface looks very much like a normal 'scope. It's amusing to watch the virtual knobs turn when you select the 'autoset' option to automatically search for the best settings for displaying the signal. That allows you to spend less time spinning knobs and more time doing useful work. Of course, you can always adjust the settings (to increase or decrease the number of displayed periods, for example).

Swordfish

This is something quite different. It is a hand-held measurement pen, or 'pen scope'. Although it comes from the same manufacturer, it has completely different construction and specifications. It also comes with a nice carrying case. The Swordfish is a combined oscilloscope and data logger, so it does not have a function generator output. However, it does have a considerably higher sampling rate than the Stingray. The Swordfish has an ADC resolution of 10 bits. The sampling rate is normally 40 MS/s, but that can be boosted to 1 GS/s using oversampling. The analogue bandwidth is 5 MHz. That means you can measure significantly more signals with the Swordfish than with the Stingray.
It also has FFT capability that is tied to the timebase setting. In addition, the Swordfish has a button on the probe that can be used to 'freeze' the image.

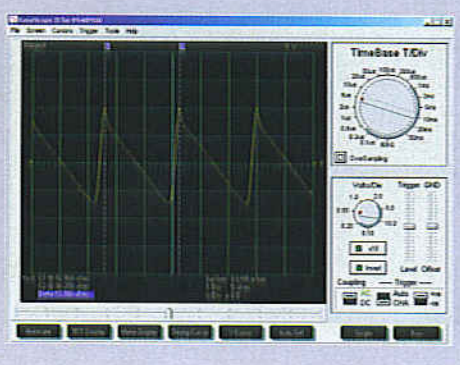
The tip of the Swordfish is attached using a Cinch connector and can easily be removed. A BNC adapter can then be plugged into the Cinch connector to allow a regular probe to be connected.

Swordfish software

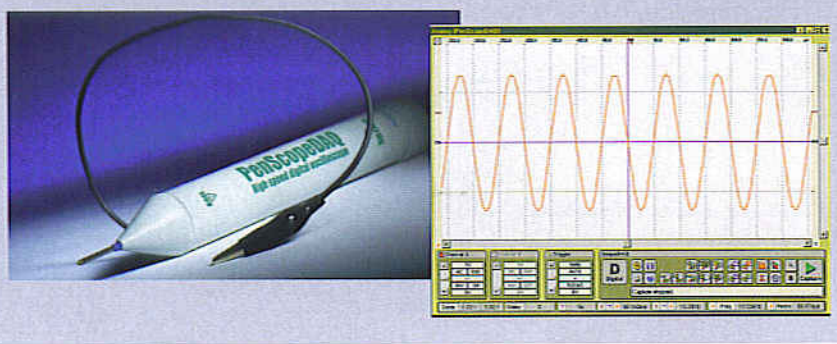
The software for the Swordfish is also supplied on a mini CD-ROM. The installation and menu are practically the same as for the Stingray. The graphic user interface differs slightly from the Stingray interface, but that is because the Swordfish is a single-channel instrument.

Conclusion

These are two different instruments, each with its own specific application area. Both instruments feature a convenient user interface (which unfortunately cannot be resized) and easy-to-use software with Linux support. The screen colours are configurable. The graticule can also be illuminated. All in all, these are fine instruments with matching software.



PenscopeDAQ



The Penscope DAQ from RK Systems has fairly good specifications. Its packaging looks a bit amateurish, but it has a maximum sampling rate of 100 MS/s, an analogue bandwidth of 20 MHz, and a 128-KB data buffer. The 8-bit ADC resolution is somewhat less than that of some other instruments, such as the Handyscopes and the Vego instruments. This instrument also has a voltmeter function and FFT capability. It is actually a probe-type instrument, just like the Swordfish. Unfortunately, in this case the probe head is not removable, so you'll have to improvise if you want to connect a regular probe to it.

Software

Unfortunately, the supplied mini CD-ROM does not start automatically, so you have to open the folder and run the exe file manually. The rest of the installation process is straightforward.

The manual is supplied as a PDF file on a separate CD-ROM, and it is also present on the PC after the software has been installed. In light of the non-intuitive operation of the instrument, the manual is certainly not an unnecessary luxury.

Practical experience

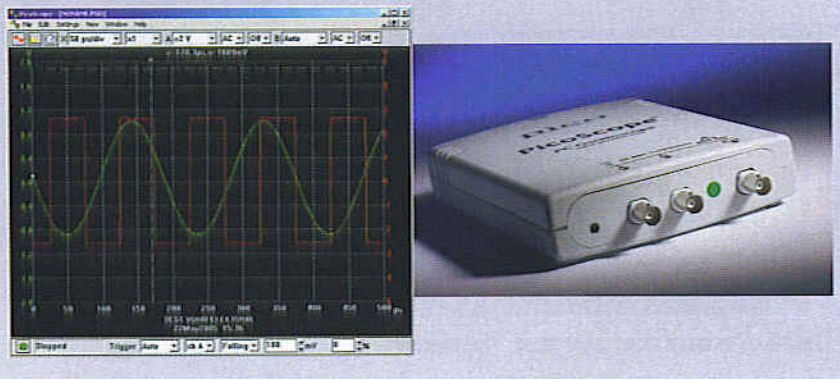
That's a story in itself. The graphic user interface is not particularly easy to understand at first. Although it looks quite professional with regard to presentation, it differs quite a bit from what we're used to from 'normal' oscilloscopes and other USB 'scopes. It thus took a fair amount of time before we started to get the idea. It also takes quite long for the image to be formed, and we found the absence of timebase and input sensitivity knobs a bit inconvenient. Although there are other 'knobs' for this purpose, it's not all that obvious how to use them. We would rather see virtual knobs corresponding to what we're used to from normal oscilloscopes.

Conclusion

The instrument does not have a particularly professional appearance. It also does not allow other measurement accessories to be fitted. That means you have to do everything with the probe tip. Although the graphic user interface has a professional appearance, the non-standard controls frequently make it necessary to puzzle out how to use them before you can make measurements.

PicoScope 3205

Picotech offers a broad range of electronic measurement equipment. The case of the PicoScope 3205 is somewhat larger than what we've seen so far with the other instruments, but it is still a compact device. Besides operating as an oscilloscope, the PicoScope 3205 can be used as a voltmeter, spectrum/FFT analyser, data logger, and signal generator. The specifications are quite respectable. The 3205 is a professional instrument. The 'normal' sampling rate is 100 MS/s, and a rate as high as 5 GS/s can be achieved using oversampling. The analogue bandwidth is 100 MHz (which is actually only usable with oversampling), and the spectrum analyser has a range up to 50 MHz. The 3205 has 8-bit resolution and a 1-MB memory buffer. The signal generator can produce sine-wave, triangular and sawtooth signals up to a maximum frequency of 1 MHz. It can also be operated in swept mode, which nicely rounds out the picture. The unit provides two measurement channels. They can be configured to measure signals and write data in 'alternate' or 'chopped' mode.



Software and user interface

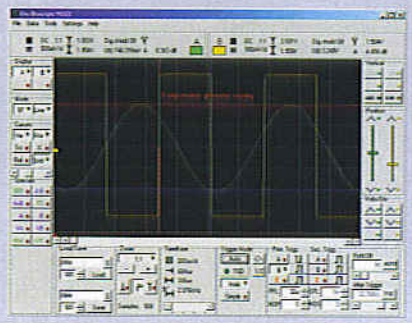
Installation of the software from the supplied CD-ROM is entirely straightforward. Everything works the way it should right off the bat. The user interface does not have virtual knobs, but instead primarily uses pulldown menus. However, everything is very intuitive, and we managed to put the instrument through all its paces in practically no time. An especially nice feature is the ability to display the same signal in a new screen with different settings, such as a different time base or different input sensitivity. The colours can also be freely configured.

Conclusion

We can certainly say that this is one of the better instruments in our selection. We liked everything about the PicoScope 3205: the software, performance, screen images, ease of use, and construction. Just about anyone who works with electronics would be very pleased with this instrument.

ETC M522

The M522 is made by the Slovakian company ETC. The M520 line consists of four models of USB oscilloscopes with the designations M521 through M524. The first two models are 60-MHz versions, while the latter two are 120-MHz versions. The M522 is a two-channel instrument with an additional output for an external trigger or square-wave generator (for probe calibration). Incidentally, most 'scopes also include this feature. Like all of the previously described 'scopes, the unit is compatible with USB 2.0 and USB 1.1, and it has a bandwidth of 60 MHz. The sample rate is 50 MS/s in normal operating mode or 5 GS/s with oversampling. Besides the oscilloscope function, the M522 can operate as a spectrum analyser. According to the specifications, the maximum permissible input voltage (except on the trigger input) is ±200 V at 100 kHz. That's quite a bit. Not all USB oscilloscopes can tolerate such high voltages.



Software and operation

It's beginning to sound a bit boring, but here again there weren't any installation problems. All of the steps are clear, and we could start using the M522 within a few minutes. The 'control panel' appears to be quite a bit more complicated than what we've seen up to now, but it can still be regarded as user-friendly. The graphic user interfaces shows a large number of little knobs and buttons, but you can get quite a ways with a bit of playing around.

Practical experience

As we already said, it takes a bit of getting used to, with an occasional look at the manual. However, operation is still user-friendly, and we always ended up where we wanted to be. The link between the time base and the analyser is a bit inconvenient, because the analyser window disappears every time the time base is adjusted. It's thus better to use the scroll button to adjust the X-axis setting of the analyser. Here again, all of the colours are freely configurable.

Conclusion

A nicely made instrument. Good specifications and performance. Unfortunately, there isn't any built-in function generator (except for a simple square-wave signal). The user interface is very comprehensive and has a professional appearance. If you only need a combined 'scope and spectrum analyser and the signals to be measured lie below the maximum frequency limit, this instrument is certainly a good choice (with the option of choosing the M523 or M523 for greater bandwidth).

DSO-220 USB

This oscilloscope from Voltcraft is one of pair of instruments. Its 'big brother' bears the name DSO-2100 USB, but it was unfortunately not available when we did our testing. The DSO-220 is thus the 'entry model', and in light of its maximum measurable frequency it is perhaps intended primarily for the hobby market. It has a sampling rate of 20 MS/s and 8-bit resolution. We didn't see any mention of oversampling, but there are two forms of signal scanning called 'sampled' scanning and 'linear' scanning. The latter seems to have a certain resemblance to oversampling.

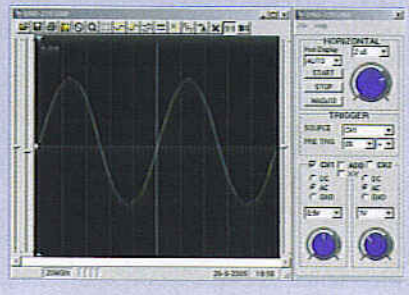
The Y-axis sensitivity setting ranges from 50 mV per division to 50 V per division in seven steps. The timebase can be set from 50 ns to 0.5 s per division. The maximum input voltage is 35 V. A minus point is that the supplied USB cable is rather short. That's a pity, because it hardly makes a difference in the overall cost.
As with many of the tested instruments, here we find an external trigger option.

Software and user interface

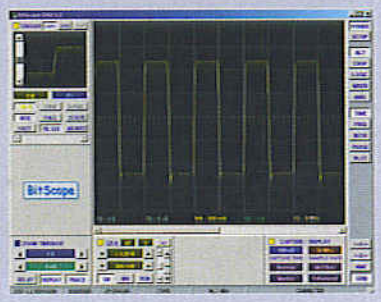
Voltcraft differs from the others in this regard. The user interface consists of three windows, which can be individually positioned on the screen. Naturally, you can also arrange then neatly in a row or column. The advantage of all this is not immediately apparent, but it is an amusing feature. Operation is simple and clear. With the manual at hand for consultation, everything is quite quickly clear.

Conclusion

Not a topper, but a fun and affordable bit of hobby gear with attractive software and a pleasant user interface. A basic oscilloscope without any fuss or bother, with a somewhat limited frequency range. Operation is simple, so even beginners can handle it easily. For higher performance or semi-professional applications, the DSO-2100 would be a better choice.



Bitscope



Bitscope is a company that is not especially well known in Europe. However, it already has many years of experience in designing and selling several types of PC oscilloscopes with a variety of interfaces. Besides versions with RS232 and USB ports, there is also a network version available with an Ethernet interface. That makes it easy to couple several 'scopes with each other and a PC, and it dramatically increases the data transfer rate.

The products are sold exclusively by means of direct sale via the Bitscope website.

Bitscope BS-50

What a little jewel! It's scarcely larger than a pack of cigarettes, but its performance is not small at all. The Bitscope BS-50 is a very good instrument. Unfortunately, it has only one BNC connector. However, a wide range of signals can be input via the 26-way POD connector next to the BNC input. The BNC input also has an unusual feature. The normal input impedance is 1 MΩ in parallel with 20 pF. However, when you use the FFT mode the signal source is quite often a transmitter output (but with the signal attenuated by a considerable number of dBs, since the input naturally can't handle high power levels). Transmitter outputs typically have an impedance of 50 Ω, and the Bitscope allows the input impedance of the BNC input to be switched to 50 Ω.
The BS-50 has nice specifications for an oscilloscope. The analogue bandwidth is 100 MHz. The sampling rate can be configured over the range of 4–40 MS/s in fast mode. Other modes are also available (in combination with other measurement data, for example), with a maximum sampling rate of 20 MS/s. And then there is also a 'slow' mode. Various types of signals can be connected to the POD connector, and it also provides the function generator output (AWG), a serial I/O port, and two supply voltages. The BS-50 can be powered externally, but like all USB 'scopes it is normally powered from the USB port.

Bitscope BS-310

This unit is a good deal larger than the BS-50, but it has the same professional appearance. Here we find two BNC connectors and a 26-way POD connector. The BS-310 is distinguished from the other instruments by having switches on the front panel. They serve to switch the input impedance from 1 MΩ to 50 Ω. We already explained what that's about in the description of the BS-50, but in that case the switching is performed via software.

The specifications of the two Bitscope models are the same except for a few details. One of the differences involves the size of the memory buffer, which Bitscope calls the 'channel buffer depth'. In the BS-50, it is 32 K samples (15 KS in mixed mode). For the BS-310, the value is 128 KS. Both instruments have the same bandwidth and sampling rate.

Software and operation

This was actually not a problem with any of the USB 'scopes, and thus not with the Bitscopes. The Bitscope instruments belong to the small minority of instruments in our test selection with Linux support.
After the software has been installed and the application has been started, the screen initially displays a Lissajous figure with 'www.bitscope.com' at the edge of the figure. That's yet again something different. The user interfaces of the BS-50 and the BS-310 are absolutely identical.

Practical experience

The graphic user interface comes to life when you click on the 'Power' button at the upper left. The screen that appears after this is especially handsome. We had to stop and admire it for a while. Although we looked long and hard for an auto-setup function, we couldn't find any. That's a pity. If the function is there, it is well hidden, both in the manual and in the user interface. The manual is truly necessary if you want to take full advantage of what the instrument has to offer, but the Bitscopes are naturally not toys. Besides various sampling modes, they also offer combined display modes.

Conclusion

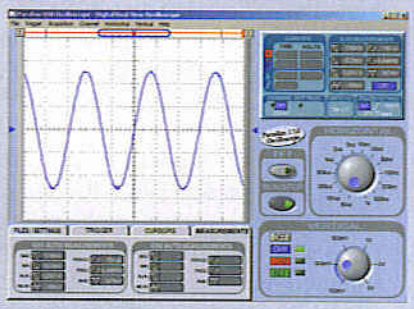
These instruments combine high quality and performance with compact dimensions. Their specifications are nearly the same except for a few details. The choice will thus primarily be determined by questions such as whether you want to have a second BNC input.

Other than that, they are splendid instruments and definitely suitable for professional use. The BS-50 is supplied with a set of test leads that can be connected to the POD connector, in addition to the USB cable (which is supplied with every instrument). The BS-310 is supplied with a more complete set of accessories. Besides the test leads, it comes with two probes, an AC adapter and mains cable for external power, and a flat cable with a POD connector.

Parallax

This USB oscilloscope actually cannot be compared with the rest of the tested instruments. The Parallax is a low-budget 'scope with clear limitations, and it is specifically marketed for educational and hobby purposes. Its price is also considerably lower than that of the other instruments, and its case is correspondingly simple. There are three connectors on the front panel, which resemble power plugs for AC adapters or chargers. It does not come with any probes, but instead has test leads with clips.

The package also includes a small servo motor, a test circuit board and a few electronics components (although it is also available without the accessories).
The specifications are quite basic. The sampling rate is 1 MS/s for single-channel operation or 500 KS/s for two-channel operation. The bandwidth is 200 kHz, and the resolution is 8 bits.



Software

We had a few problems at first, but that came from our cocky assumption that real technical boffins never read the manual before getting started. That was obviously a mistake, and we can only recommend that you simply read what you have to do, and then the installation will be nice and easy. However, a reproducible problem did occur during our test. If we left everything connected and switched off the PC, the familiar blue Windows XP error message screen appeared when the PC was started up again. The remedy was to disconnect the equipment, restart, and then reconnect it. Unfortunately, we didn't have enough time to test this on a different PC.

Practical experience

The graphic user interface is clear and does not generate any questions. Several tabs at the bottom of the screen can be clicked open to make settings or make measurements, with or without using cursors. Here again we were unable to find an auto-setup function. Other than that, there's nothing special to report about the Parallax. It displays simple signals quite nicely, and the measured signals can be exported in the form of images or data.

Conclusion

This is quite obviously an educational instrument for learning how to use an oscilloscope by direct experimentation. The specifications and features are limited, but that is compensated by the fact that this is the least expensive instrument in the test.

Manufacturer	Model	Manufacturer's Internet address	UK distributor(s)
Bitscope	BS-50U BS-310U	www.bitscope.com	Order exclusively via the Internet
Conrad	DSO-220USB	www.conrad.de	Conrad International www.conrad.com
ETC	M522	www.etcsk.com	Directly from manufacturer
Parallax	USB Oscilloscope	www.parallax.com	Milford Instruments www.milinst.com
Picotech	Picoscope 3205	www.picotech.com	CPC Plc www.cpc.co.uk Farnell Electronics Components uk.farnell.com IMEX www.imex.co.uk Rapid Electronics www.rapidelectronics.co.uk Kalestead www.kalestead.co.uk RS Components rswww.com
RK-system	PenscopeDAQ	www.rk-system.com.pl	via DDS Scope Trading www.oscilloscoop.nl or Demotech Denmark www.demotech.dk
Tiepie Engineering	Handyscope HS3-100 Handyscope HS4-50	www.tiepie.nl	Tiepie UK sales office www.tiepie.nl/uk/home
USB Instruments	Stingray DS1M12 Swordfish PS40M10	www.usb-instruments.com	Easysync www.easysync.co.uk

Final conclusions

Time for a summary. Testing this set of USB oscilloscopes was a very interesting project. PCs are increasingly being used as tools to help people do their jobs. In addition, USB oscilloscopes provide an excellent opportunity to combine certain aspects of an electronics workstation, such as technical support (databases), measurements, record-keeping, and exporting measurement reports to Word or Excel. In principle, a USB oscilloscope can be just as good as a 'real' one. Actually, that isn't right way to say it. A USB oscilloscope does the same job as a traditional 'scope, but it simply operates in a different manner.

The range of variation in the features and capabilities of the eleven instruments selected for the test is quite large. They include very simple instruments such as the Parallax, which is actually only intended to be used as a learning aid. Perhaps hobbyists who do the odd bit of puttering will also find it useful, but that's just about the limit of its utility. The Stingray is also fairly basic with its limited specifications, but it is quite a bit better than the Parallax and has a much nicer design. In any case, both instruments are worth what whey cost.

We were not especially satisfied with the Penscope DAQ. Its design also leaves something to be desired. The user interface is clumsy, although the specifications are quite decent. However, it wouldn't be our personal choice of instrument.

The DSO-220USB from Conrad Electronics has a good price/performance ratio. It has reasonably good specifications and a very reasonable price. If you want something more, there is also the DSO-2100.

The Handyscopes from TiePie are especially attractive instruments. They are available with different sampling rates for each model, with prices in proportion. We have listed the specifications and prices of the two 'top-end' units. They clearly fall

Ten common misto

Guido Wolf – Marketing Manager, LeCroy Europe

- Not taking enough time to study the capabilities, features and operation of the instrument, with the result that several functions remain unused.

Read the manual!

- Failure to take possible error sources in the measurement setup into account, or not giving sufficient consideration to such error sources, which can collectively generate a relatively large error.
- Failure to exploit the available resolution of the oscilloscope. An 8-bit measurement is approximately five times as precise as a 'eyeball' estimate.
- Restricting measurements to visual examination of signal waveforms using the oscilloscope function without using other functions, such as histogramming, trend analysis or FFT, to fully investigate the characteristics of the signal.
- Undersampling the signal due to an inadequately sized memory buffer in the instrument.
- Using a passive probe to make high-frequency measurements or measurements on very sensitive circuits.
- Viewing the signal over time span that is too short, with the result that problems and their consequences are often not recognised.
- Viewing too many waveforms at the same time in

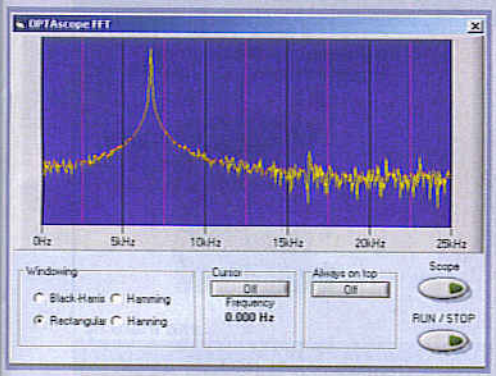
Model	Analogue/digital inputs	Resolution	Max. sampling rate	Input range min/max	Internal memory
Handyscope HS4-50	4 x BNC	12/14/16 bits (configurable)	50 MS/s	50 mV / 20 V/div	128 KB
Handyscope HS3-100	2 x BNC	12/14/16 bits (configurable)	100 MS/s	50 mV / 20 V/div	128 KB
Picoscope 3205	2 x BNC	8 bits	100 MS/s	10 mV / 2 V/div	512 KB
Bitscope BS-310U	2 x BNC 2 x POD	8 bits	40 MS/s	513 mV 10,8 V	128 KB
ETC M522	2 x BNC	8 bits	50 MS/s	10 mV / 5 V/div	not stated
PenscopeDAQ	1 x BNC	8 bits	100 MS/s	20 mV / 25 V/div	128 KB
Bitscope BS-50U	1 x BNC 2 x POD	8 bits	40 MS/s	513 mV / 10,8 V	32 KB
Swordfish PS40M10	1 x BNC	10 bits	40 MS/s	100 mV / 10 V/div	not stated
Stingray DS1M12	2 x BNC	12 bits	1 MS/s	10 mV / 5 V/div	32 KB
Conrad DSO-220 USB	2 x BNC	8 bits	20 MS/s	50 mV / 5 V/div	32 KB
Parallax USB Oscilloscope	2 x power plug	8 bits	1 MS/s	100 mV / 5 V/div	not stated

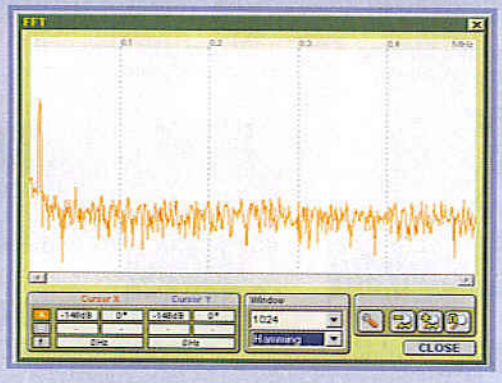
* Beta version of multichannel software available on website
** Price without instruction manual and test material

xes in using digital oscilloscopes

a single window. That reduces the resolution, so the signals cannot be portrayed with sufficient accuracy.

- Failure to exchange practical experience with other electronics technicians and engineers who use the same type or model of measurement equipment. Exchanging experience and information about setups can be very useful and can save time and trouble.
- When purchasing an oscilloscope, buying the top-ranked model or the cheapest model. Carefully examine the full range of available models and select an instrument that does what you need.





in a different price class, but they are professional instruments. They might not be your first choice as a hobbyist, but you might want to compare the price with that of a comparable conventional oscilloscope. For a demanding electronics technician or engineer, the Handyscopes are definitely worthwhile.

The ETC M522 is a nice midrange model, as are the Bitscopes and the PicoScope. All three of these instruments offer a lot for what they cost and provide substantial performance. Based on the test results, you can decide for yourself which model meets your wishes and whether it fits within your budget.

Finally, we would like to draw a bit of attention to the software that comes with the instruments. A couple of the models have Linux support, but none of them has Mac software. Maybe that's something the manufacturers should turn their attention to.

(050130-1)

Supplied probes	Software	Power supply (external/via USB)	Extras	AWG/FFT	RRP (ex VAT)
4	98, ME, 2000 & XP	USB	*	FFT	€1380 (£960)
2	98, ME, 2000 & XP	USB	*	AWG/FFT	€1108 (£765)
-	98 SE, ME, 2000 & XP	USB	-	AWG/FFT	£599 (€869)
2	98, ME, 2000, XP & Linux	USB/external	AC power supply with adapter	AWG/FFT	$495
-	98 SE, ME, 2000 & XP	USB	-	FFT	€487 (£335)
n/a	not stated, tested using XP	USB	-	FFT	€272 (£187)
-	98, ME, 2000, XP & Linux	USB/external	-	AWG/FFT	$295
n/a	2000, XP & Linux	USB	case	FFT	€245 (£169)
-	98, ME, 2000, XP & Linux	USB	case	AWG/FFT	€221 (£152)
-	98 SE, ME, 2000 & XP	USB	-	FFT	€169 (£117)
3 test leads	98, ME, 2000 & XP	USB	instruction manual and test material	FFT	€134 (£93) (€ 116) (£80) **

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RD Research

ESR/C Meter

A versatile meter for capacitors

Flemming Jensen

The two most important properties of a capacitor are its capacitance and its internal resistance (ESR). You need to know both values in order to judge whether a capacitor is suitable for a particular application. The meter described here combines two popular *Elektor Electronics* projects to create a convenient new instruments that rightly belongs in every well-equipped electronics lab.

Digital capacitance meters have become fairly inexpensive. Most commercial capacitance meters have a measurement range of a few picofarads to 2,000 mF. Some can even go as far as 20 mF, but that's where it stops. Large capacitors with values of several hundred millifarads, which are often used in power supplies, printers and photocopiers, cannot be measured using such meters. That means you will need a different (and more advanced) type of meter.

There's another important property of a capacitor that cannot be measured using a normal capacitance meter: its equivalent series resistance (ESR). Beside the capacitance, it is one of the most important properties of a capacitor. An ideal capacitor is a purely reactive component, with a 90-degree phase shift between voltage and current. However, practical capacitors also have a non-zero resistance in series with the 'ideal' capacitance (see **Figure 1**). The resistance represents the losses inside the component, and it largely corresponds to the quality of the capacitor.

Electrolytic capacitors tend to dry out after a long time, which causes their ESR to increase. A pure reactance cannot generate any heat, due to the phase shift of exactly 90 degrees between voltage and current, but a resistance can generate heat. The heat

dissipated in a capacitor due to its ESR increases in a switch-mode circuit, which causes its quality to deteriorate even more. With an aged electrolytic capacitor, it is not uncommon to find that although the capacitance has decreased by only a few percent, the ESR is more than 100 Ω. An ESR of this magnitude makes a capacitor completely unusable in switch-mode circuits and hardly usable for any other type of application.

Why a combined meter?

An ESR meter and a capacitance meter measure two different things. They complement each other. That's why it's convenient to combine the two measurements in a single instrument. For this purpose, the author has merged the especially popular ESR Tester published in the September 2002 issue with the Autoranging Capacitance Meter published in February 2003 (and also designed by the author). The result is a handy instrument with a dual function and outstanding characteristics.

The new instrument also has a considerably more up-to-date design than the original versions. The design of the original ESR meter was based on a voltmeter IC, but new design is built around a type 16F877 PIC microcontroller. The advantage of this is that some new features can be added, while there is also enough room for the program for the capacitance meter.

The following capabilities have been added to the ESR meter:

- AC resistance (ESR) and DC resistance are displayed simultaneously. In the old design, you had to select one or the other by pressing a switch. The DC resistance indicates whether the capacitor is internally shorted (and thus simply 'kaput').
- The new design asks the user to short the probes together when the meter is switched on, so the offset can be measured. With the old design, this had to be handled mechanically.
- An audio function is built in to avoid having to always keep an eye on the meter. That's primarily helpful when you're making measurements on capacitors deep inside a device. The rounded-off ESR value is indicated by beeps. If the measured ESR is in the range of 3.1–4.1 Ω, for instance, four beeps are emitted. The meter also generates a warning signal if the DC resistance is less than 10 Ω. No beeps are emitted if the measured ESR is greater than 10 Ω, since a capacitor with such a high ESR value probably should be replaced. If no signal is emitted, you should briefly check the display to see what's wrong.

No new functions have been added to the capacitance meter. Here the major change consists of rewriting the code for the PIC16F877.

Measurement principle of the capacitance meter

The complete schematic diagram is shown in **Figure 2**. The circuit of the capacitance meter is based on a CMOS version of the well-known 555 timer IC, which is used here as a monostable multivibrator. The PIC provides the reset signal, controls the trigger input, and monitors the output of the 555. The larger the value of the capacitor to be measured, the longer the output of the 555 remains high. A counter in the PIC counts up as long as the output remains high. The count is read when the output goes low.

The PIC automatically switches between the various measurement ranges. The meter has three ranges: 1–9999 pF, 10–9999 nF, and >10 µF. To make the measurement easy to read, a value of 1000 pF or 1000 nF is shown as 1.00 nF or 1.00 µF, respectively.

The capacitance meter has automatic zero adjustment. After the instrument is switched on, the PIC executes a routine to measure the residual capacitance of the probe leads or other external circuitry. The measured value is subsequently subtracted from every reading to yield the correct value, so the offset resulting from using different probe leads does not affect the reading. It's thus important to ensure that the meter is not connected to a capacitor when it is switched on, although this actually only applies to the picofarad range.

For capacitance measurements in the other ranges, no problem will result if the capacitor is already connected before the meter is switched on. Immediately after the automatic zero adjustment, the meter starts measuring in the picofarad range. If the capacitance is too large, a counter overflow occurs and the PIC selects the nanofarad range. A lower charging resistance is selected for this range (R17–R19 and P2–P4), so the charging current is higher. If the capacitance is still too large, the PIC switches to the microfarad range and completes the measurement in that range, regardless of the charging time. The results are displayed on a two-line alphanumeric LCD module.

Hum interference

The input impedance is very high in the picofarad range. In that range, the capacitor is charged via a resistance of 5–6 MΩ. As a result, the meter is quite sensitive to AC mains interference (hum) in the picofarad range. You should keep the meter well away from transformers and similar components when making measurements in the picofarad range, since otherwise the displayed value may fluctuate.

In order to suppress the effects of possible hum, the measurement is made twice in the picofarad range at an interval of 10 ms. The average value of the two measurements is calculated and displayed. That makes the measured value more stable. The impedance is relatively low in the two other ranges, so no special measures are taken. The measurements on those ranges are thus single measurements without any averaging.

Large capacitances

Capacitors with values less than 10 mF are continuously measured. The measurement cycle is repeated periodically starting with the picofarad range, followed by the nanofarad range and then the microfarad range. Capacitors with values greater than

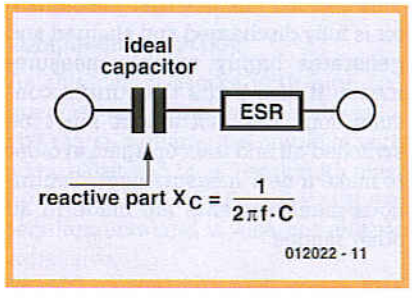


Figure 1. The most important property of a capacitor is its capacitance. The second most important property is its equivalent series resistance (ESR).

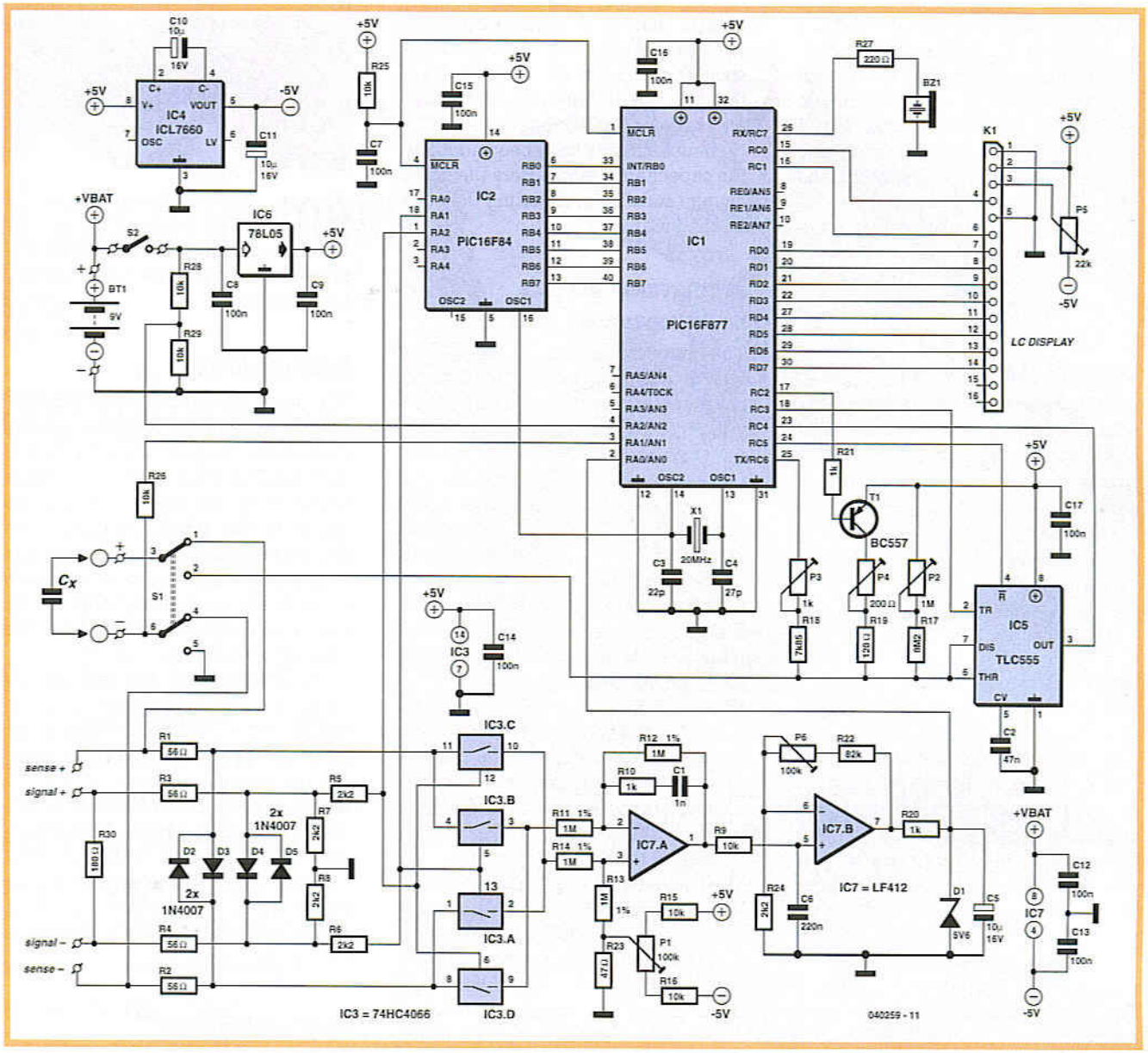


Figure 2. The complete schematic diagram of the capacitance/ESR meter.

10 mF (milli-farad) are not measured continuously. Instead, a series of four measurements are made and the results are then averaged.

This method ensures that the capacitor is fully discharged and charged and generates highly reliable measurements. It also limits the current consumption. The instrument must be switched off and then on again in order to make a new measurement. Continuous measurements are made in all other ranges.

Measurement principle of the ESR meter

A 100-kHz square-wave signal that supplies a constant current is applied to the capacitor being tested (the 'capacitor under test' or C.u.T.). The value of the ESR can be determined by measuring the AC voltage across the capacitor. If the capacitance is sufficiently high relative to the frequency, the voltage drop due to the reactive impedance is negligible, so the voltage across the capacitor is entirely caused by the ESR. This voltage is rectified and fed to the voltmeter.

The operating principle is illustrated in **Figure 3**. Here it is assumed that the C.u.T. is rated at 100 µF and has an ESR of 10 Ω. The reactive impedance (X_C) is equal to $0.5\pi fC$ or approximately 0.0159 Ω, which is negligible relative to the ESR value of 10 Ω. The voltage measured across the C.u.T. is thus the voltage across the ESR. As the two electronic switches are actuated synchronously at the same frequency, a constant differential voltage is present at the input to the opamp. The opamp passes the differential voltage (in this case 11 mV) to its output, so the voltage at the output of the opamp is proportional to the ESR value.

Figure 4 shows a different example, with a test capacitor rated at 0.1 µF and having an ESR of zero ohms. As already noted, a fairly high frequency is used to keep the effect of the reactive impedance as small as possible so that even small electrolytic capacitors with values as low as around 0.1 µF can be measured. That makes it necessary to further reduce the effect of the initial

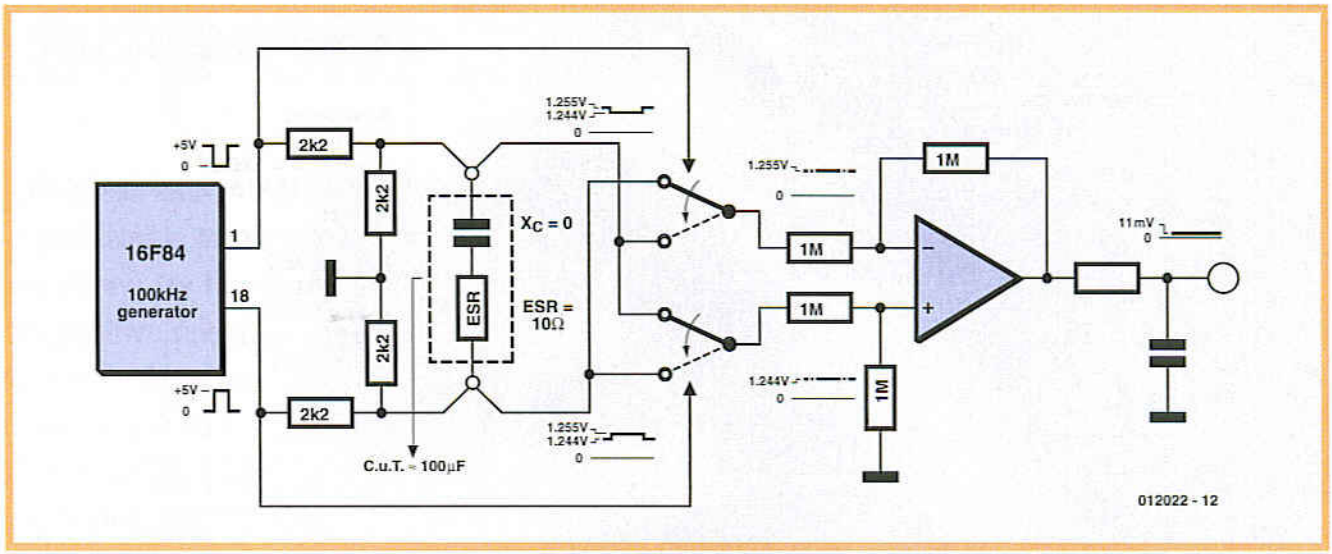


Figure 3. With a capacitor rated at 100 µF and having an ESR of 10 Ω, the reactive impedance is negligible and the ESR (which is purely resistive) determines the output voltage of the opamp.

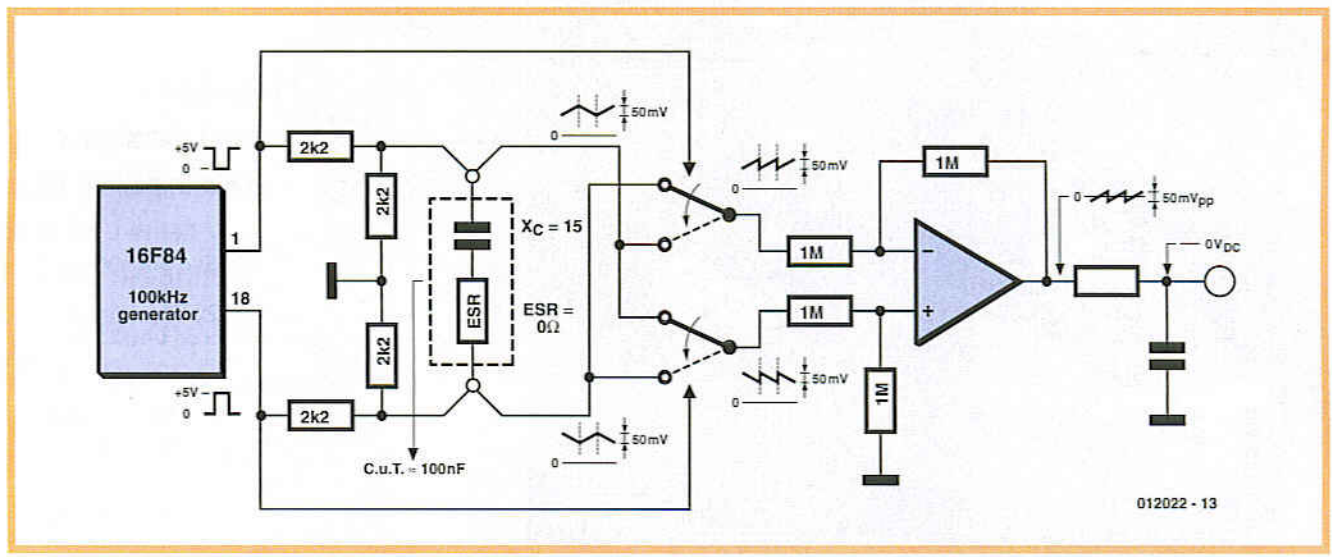


Figure 4. The situation with a capacitor rated at 0.1 µF and having an ESR of 0 Ω. Here the average output voltage of the opamp is 0 V.

integration of the voltage waveform. Here the ESR is zero and the reactive impedance is $0.5\pi fC$, or approximately 16 Ω. As can be seen, the differential configuration of the opamp causes the sawtooth integration waveform on the inputs to be summed to yield a sawtooth voltage on the output with an average value of 0 V. The resulting voltage after integration by the subsequent *RC* network is 0 V, and this value is applied to the input of the voltmeter. If the capacitor had an ESR of 10 Ω, the sawtooth voltage on the output would still have the same form, but it would be superimposed on a DC component due to the ESR. After the sawtooth was filtered out by integration, the remaining voltage would correspond to the actual ESR value of 10 Ω, while the effect of the reactive impedance of 16 Ω would have been eliminated.

Multiple PICs

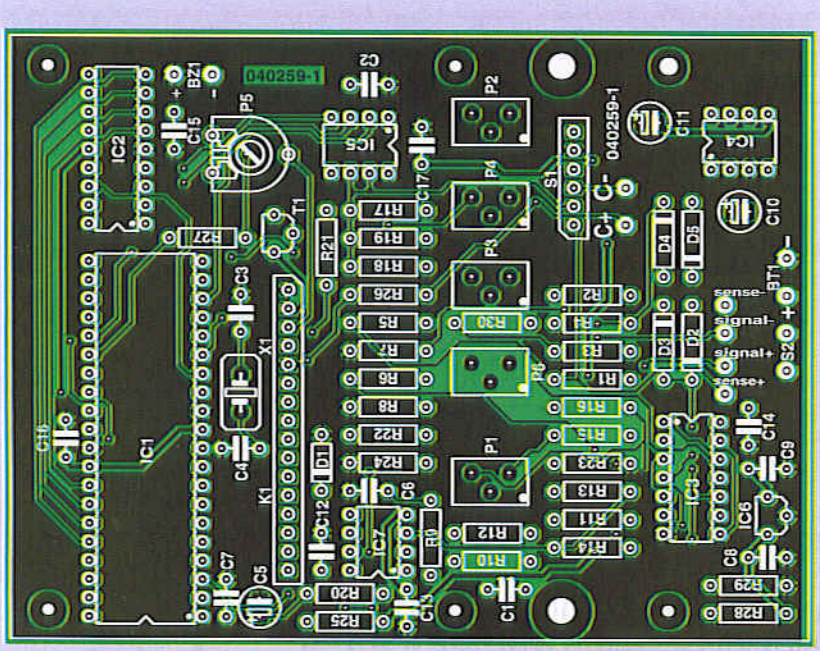
The frequency generator in the circuit of the original design has been replaced by a PIC (type 16F84). The 16F877 cannot be used for this purpose because the signal cannot be interrupted unless a DC tests is being made. The 16F84 uses the same clock oscillator as the 16F877. The advantage of using a second PIC is that it makes it unnecessary to align the 100-kHz generator frequency. It also allows the generator to be easily switched between AC and DC measurements. These modes are controlled by the 16F877, which uses interrupt routines to determine what the 16F84 has to do.

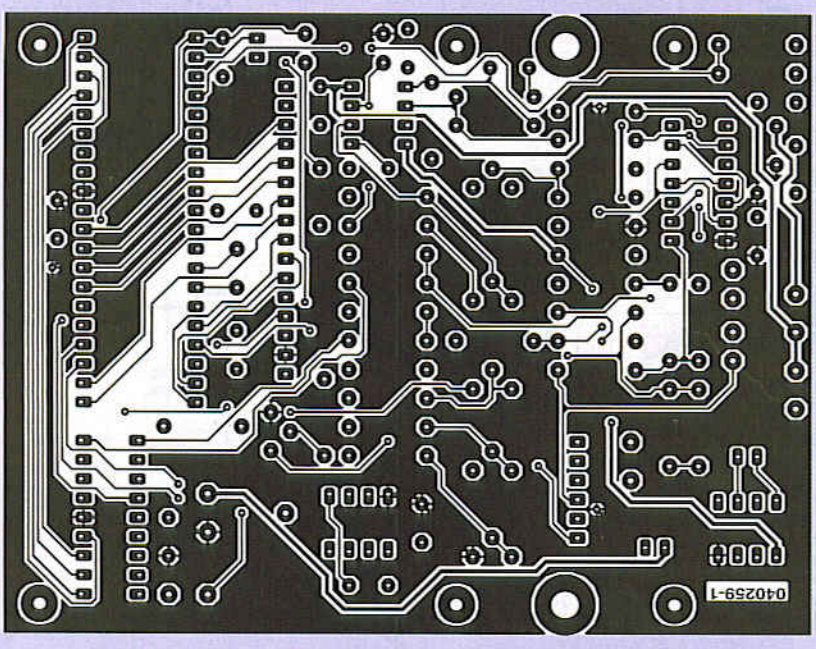
Component selection

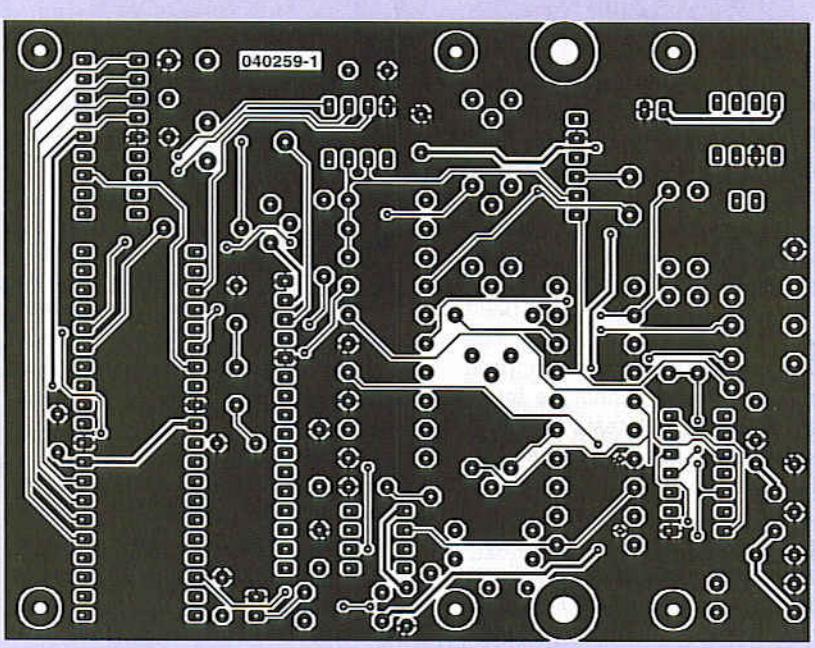
As this circuit works with high frequencies and signal levels in the millivolt range, a differential amplifier with a low offset and large bandwidth must be used. The LF412 meets these requirements and is also not all that expensive.

The HC version of the well-known 4066 quad electronic switch IC provides fast switching times, which reduces the effect of the undesirable reactance by a factor of 2.

The best results will be obtained if the







COMPONENTS LIST

Resistors:
R1-R4 = 56Ω
R5-R8,R24 = 2kΩ2
R9,R10,R15,R16,R25,R26,R28,R29 = 10kΩ
R11-R14 = 1MΩ 1%
R17 = 8MΩ2
R18 = 7kΩ85
R19 = 120Ω
R20,R21 = 1kΩ
R22 = 82kΩ
R23 = 47Ω
R27 = 220Ω
R30 = 180Ω
P1 = 100kΩ 10-turn preset
P2 = 1MΩ 10-turn preset
P3 = 1kΩ 10-turn preset
P4 = 200Ω 10-turn preset
P5 = 25kΩ preset
P6 = 100kΩ 10-turn preset

Capacitors:
C1 = 1nF
C2 = 47nF
C3 = 22pF
C4 = 27pF
C5 = 10µF 16V radial
C6 = 220nF
C7,C8,C9,C12-C17 = 100nF, lead pitch 5mm
C10,C11 = 10µF 16V radial

Semiconductors:
D1 = zener diode 5V6 500mW
D2-D5 = 1N4007
IC1 = PIC16F877-20/P, programmed, Publishers order code **040259-41***
IC2 = PIC16F84A-20/P, programmed, Publishers order code **040259-42***
IC3 = 74HC4066
IC4 = ICL7660
IC5 = TLC555
IC6 = 78L05
IC7 = LF412CP
T1 = BC557

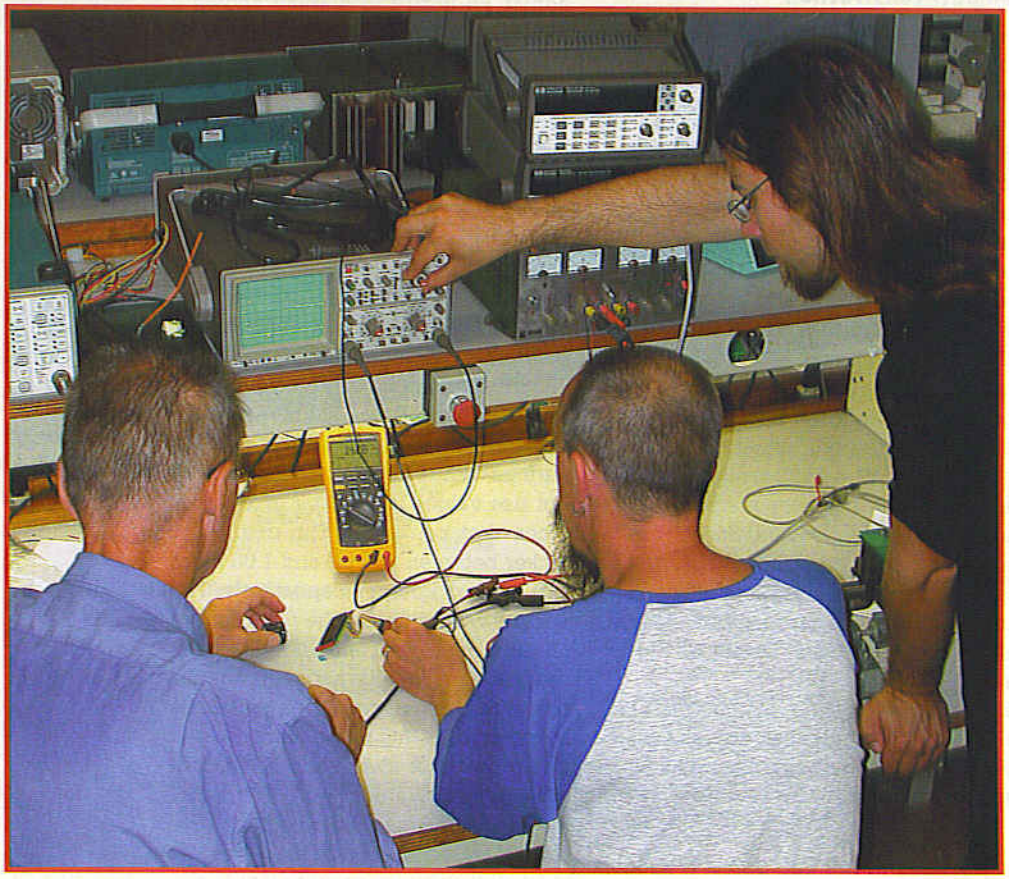
Miscellaneous:
Bz1 = AC (passive) piezo buzzer
S1 = switch, 2 changeover contacts
S2 = switch, 1 make contact
K1 = LCD module, 2x16 characters (e.g., Digikey # 153-1078-ND)
X1 = 20MHz quartz crystal
2 wander sockets for banana plug
Measurement cable
Enclosure, e.g., SERPAC H75 (Digikey # SRH75-9VB-BD)
PCB, Publishers order code **040259-1***
Disk, source- and hex-code files, Publishers order code **040259-11*** or **Free Download**

* see Elektor SHOP page or www.elektor-electronics.co.uk

Figure 5. Double-sided circuit board layout and component layout for the ESR/capacitance meter.

Keep smiling

Even if we run into major problems in our lab we always try to see the positive side of things — if only to convince ourselves that a troublefree life would be boring. Engineering Flemming Jensen's ESR/C Meter from blueprint right up to publication in print was a far from smooth process and with hindsight we have to admit having made an error or two when assembling the prototype. Nothing too serious of course, but still...



Karel Walraven

The first life signs of the circuit were hopeful. The display produced legible texts, so at least the microprocessor is running its program. Then came the problems. Measuring capacitors was troublesome if not impossible — usually, the display remained stuck at one firm '0' and that's no incentive to build an ESR/C Meter. So we ran the usual checks on the board. Always start by measuring the supply voltage directly on the IC pins — both the +5 V and ground rails should be inspected. Next up is the microprocessor clock and *bingo* there we got 6.66 MHz instead of the desired 20 MHz – the quartz crystal was cheerfully resonating at its fundamental frequency instead of the third overtone. Sometimes this is a false reading however, the 50-pF scope probe capacitance wreaking havoc at the oscillator input. However, a rock solid 6.66 MHz was measured at the oscillator *output* and we were using a 1:10 probe so extra capacitive loading would be small. This leaves several other fault factors to be considered: the PIC may have been programmed for 'standard crystal' instead of 'high speed crystal', or the two xtal loading capacitors may be too large. Also, the crystal itself may be at fault, some will simply refuse to switch to overtone resonance. In our case, it turned out that the PIC was incorrectly programmed and the problem was solved quickly. Alas... the display now greeted us with total gobbledygook. Strange, but still reassuring to know at this point that there were no display wiring errors — after all, the display had worked just fine we corrected the clock frequency. A timing error? LC displays may not be driven too fast. For example, the datasheet tells us to observe a minimum length of 450 ns for the enable pulse. Internally, a PIC operates at the xtal frequency divided by four, so in theory, at 20 MHz, it is able to supply new data on its I/O pins every 200 ns. That looked like a plausible explanation of the phenomenon we were faced with. This kind of error easily creeps into a design. The test circuit runs fine at a lower clock speed, *hooray*, the design is 'quickly optimised' while drawing the schematic and then... a final check of the pulse timing is forgotten. However, it could also be an undiscovered error — some LCDs have no problems with 200-ns pulses, while others from a different series or manufacturer will hang.

We cast a critical eye on the LCD driver routine, created a longer enable pulse and reprogrammed the PIC. The LCD then worked as desired. By itself, that is, because after all this hard work, the readout was still meaningless. We quickly found out that the measured values were invariably negative instead of positive, and the microprocessor programs was known to turn any negative value into a solid zero. In theory, this can happen if the phase of the synchronous detector has been swapped over. After a lot of searching and debating, we agreed that that was not the case. Wild theories were heard then in the lab, until it transpired that the switch selecting between capacitance and ESR measurement was incorrectly wired, causing a mighty offset in the detector. Nobody had thought of such a simple exchange of two wires!

The moral of the story: always check obvious matters first. Do not fear the worst and certainly do not dig deeper than necessary!

recommended components are used. However, the performance is still acceptable with a normal 4066.

Compact construction

Thanks to the use of two microcontrollers, the size of the overall circuit remains relatively small, so the printed circuit board designed for the circuit (**Figure 5**) has quite modest dimensions.

There are only a few components that have to be connected to the circuit board via short leads. The LCD module is connected to K1. Switch S1, which is used to select either capacitance or ESR measuring mode, is wired to connector S1 on the circuit board using six short leads. Points C+ and C– are connected to two measurement terminals or sockets located on the front side of the enclosure. The pins marked Signal+, Signal–, Sense+ and Sense– are for connecting the additional ESR test leads with their separate sense lines in order to measure capacitors while they are still connected in a circuit (see **Figure 6**).

The battery and power switch S2 (BT1 and S2, respectively) must also be connected to the circuit board, as well as the beeper (BZ1).

Test probes

Four-wire measurement is used here to compensate for the voltage drop in the test leads. Each of the test leads has two screened conductors, consisting of a signal lead and a sense lead (see **Figure 6**). This prevents the measurement from being corrupted by hum, noise or ESD interference and allows a stable zero calibration to be implemented.

Calibrating the ESR meter

The offset is set to 40 mV instead of 0 V because the ADC cannot handle negative voltages. Short the test probes together and connect a voltmeter to pin 7 of the LF412 (IC7). Then adjust P1 for an offset voltage of 40 mV. The resulting offset can then be compensated by the software. However, that requires shorting the probes together when the meter is switched on in the ESR mode. The offset voltage is converted by the ADC. The resulting value is stored in an EEPROM and subtracted from the measured ESR value when a measurement is made.

Switch the meter to the ESR mode and switch on the power. You can use P5 to adjust the contrast of the LCD module. Short the probes together when you are requested to do so. Now connect the probes to a 10-Ω resistor and adjust P6 until the display shows a value of 10 Ω. Connect the meter to several working capacitors in turn, without and without a 10-Ω resistor in series, to verify that the meter is working properly.

Calibrating the capacitance meter

You need a pair of precision capacitors to calibrate the capacitance meter. A value of 470 pF / 1% is suitable for the picofarad range, and a value of 220 nF / 1% can be used for the nanofarad range. Both values can be obtained at a reasonable price from various vendors, such as Farnell. Do not use values of 1000 pF or 1000 nF, since that can cause the display to flicker between 999 pF and 1.00 nF or 999 nF and 1.00 µF, respectively. The easiest way to adjust the range above 10 µF is to use a commercial capacitance meter. An alternative method is to use the formula $t = RC$ and a simple stopwatch.

Keep the meter away from transformers and strong 50- (60-) Hz fields. Switch on the meter, connect it to the 470-pF capacitor, and use P2 to adjust the value on the display to match the value of the capacitor. Next, connect the meter to the 220-nF capacitor and use P3 to adjust it to the right value. Finally, you can use P4 to set the right value for your reference electrolytic capacitor.

After that the meter is ready for use. From now own, no capacitor new, old or NOS (new old stock) will hold any secrets for you.

(040259-1)

Things to pay attention to

- Always discharge the capacitor before connecting the meter to it.
- Switch on the meter before connecting it to the capacitor to be measured.
- Four measurements are made on capacitors with values greater than 10 mF. After that, the meter displays 'Ready', and it must be switched off and back on to make a new measurement.
- Be patient when measuring capacitors with very large values. It takes approximately 10 minutes to measure a 370-mF capacitor.

Warning

Although the inputs of the meter are protected by diodes, it is good idea to discharge large capacitors before measuring them. The risk of burning out the protection diodes is particularly high with filter/buffer capacitors used in power supply circuits.

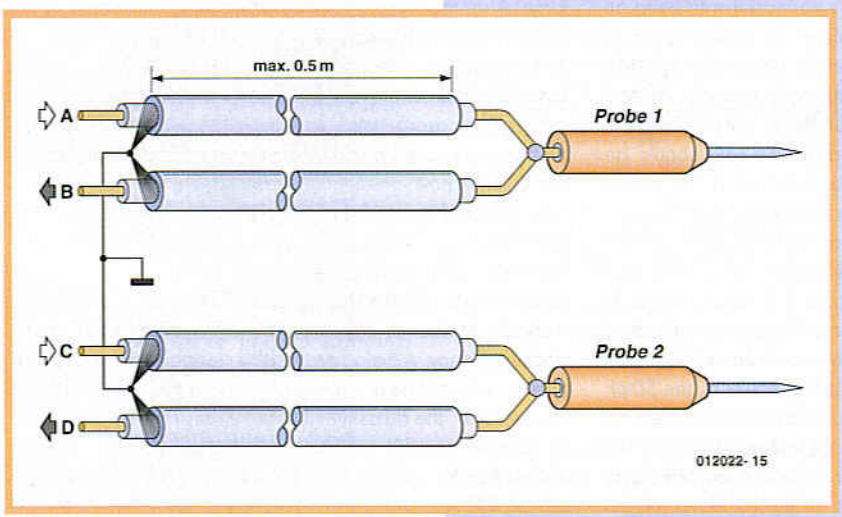


Figure 6. How to build the two dual shielded measurement leads that connect the probes to the actual instrument.

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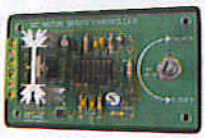

Control the speed of almost any common DC motor rated up to 100V/5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15VDC. Box supplied. Dimensions (mm): 60Wx100Lx60H.
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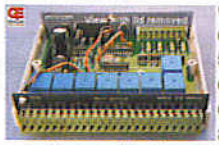

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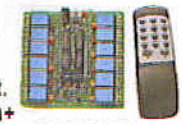

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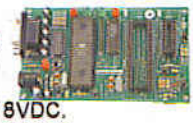

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USB-to-RS232 Hu

adaptor problems and tuning tips

Burkhard Kainka

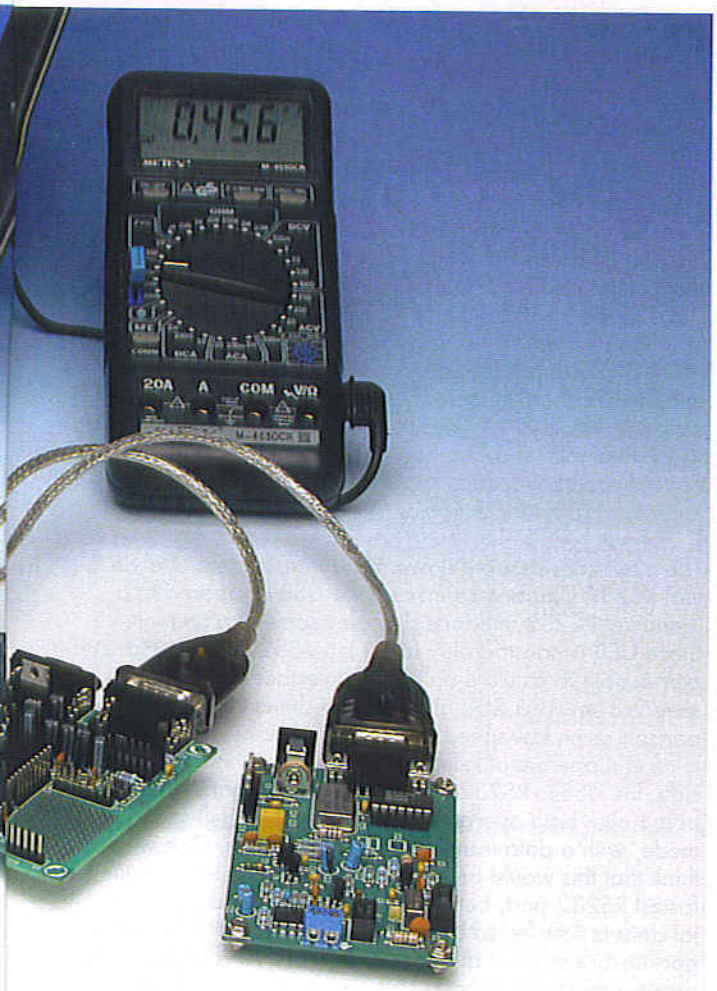
The comparatively slow RS232 interface is getting rather long in the tooth now and is steadily being replaced by the USB interface on modern notebooks and PCs. If an RS232 interface is essential, for example when programming microcontrollers, there are commercial adaptors available to bridge the gap between RS232 and USB. However, things do not always go as smoothly as one might like...

The RS232 serial interface will continue to live on for as long as there are peripherals that use the interface. Adaptor manufacturers recognise this, and so there is a range of USB-to-RS232 interface converters available for notebook, laptop and desktop computers that are not fitted with an RS232 interface. Experience with these adaptors shows that the conversion between USB and RS232 does not always proceed as smoothly as one might wish. We have taken a closer look at two adaptors and tried to determine where the problems lie and what can be done to overcome them. As example practical applications for a USB-to-RS232 adaptor we have taken the 89S8252 Flash Microcontroller Board (*Elektor Electronics* December 2001), the DRM Receiver (March 2004) and the Serially Programmable Crystal Oscillator (March 2005). A further product of our research is a handy PC program to test both real and virtual RS232 interfaces. The program is available for free download from the *Elektor Electronics* website.

Manhattan

The Taiwanese manufacturer Manhattan produces an adaptor in the form of a short cable (**Figure 1**). At one end is a USB plug and at the other is a nine-pin sub-D connector. The sub-D connector housing is a moulding which contains the adaptor electronics. When first connected to the USB port of a PC the Windows Device Manager recognises a new USB device and searches for a driver. The necessary driver is provided on the CD that accompanies the product; the new USB device has the name 'Prolific USB-to-Serial Bridge'. Windows warns that the 'Windows Logo Test' has not been passed, but this can be ignored: it simply means that the device has not been tested for compatibility with Microsoft Windows XP. The new virtual COM port will appear in the device manager under 'Ports', and a free COM port number is allocated to it. If the allocated COM port number is greater than COM4 (for example,

rdle Race



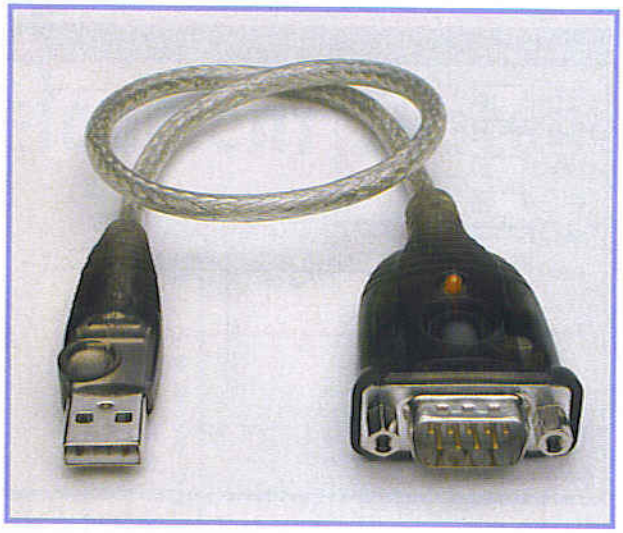


Figure 1.
The adaptor made by the Taiwanese company Manhattan. The electronics are built into the sub-D connector.

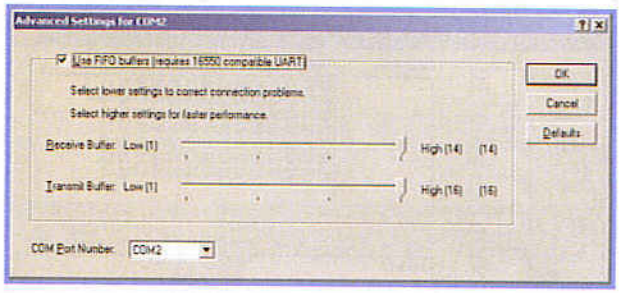


Figure 2.
'Advanced settings' for the new COM port in Windows XP.

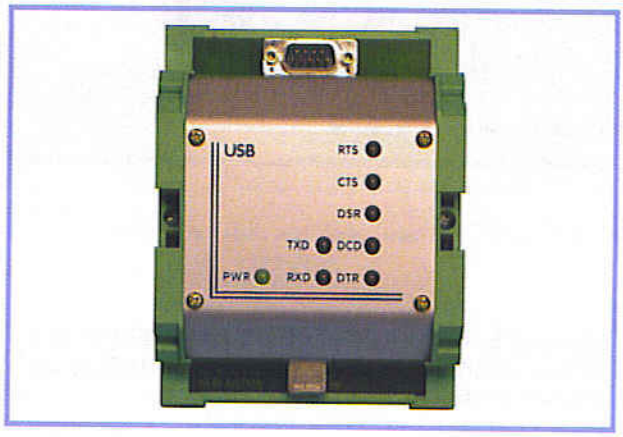


Figure 3.
The Kolter adaptor, designed for mounting on a DIN rail, uses the FTDI FT8U232AM.

COM6) the setting may need to be changed manually. This is advisable, since many programs can only work with ports COM1 to COM4. To change the COM port number, click on the new interface under 'Ports' in the Device Manager, so that the properties window appears. Under 'Port Settings' select 'Advanced' (**Figure 2**). Here a new COM port number can be chosen for the device, and the characteristics of the FIFO buffer can also be modified. Sometimes problems communicating with external devices can be solved by disabling the FIFO buffer.

Kolter

The USB-to-RS232 adaptor from Kolter Electronic (**Figure 3**) is designed for mounting on a DIN rail for use in switching cabinets or fuse boxes. A feature of this module is that the USB and RS232 interfaces are galvanically isolated from each other using an internal optocoupler. Eight LEDs are visible from the outside, which show the state of the unit and the levels on the RS232 signal lines. The adaptor uses the FTDI FT8U232AM: the driver for this device is available from the manufacturer. In the Windows Device Manager the adaptor appears as 'USB Serial Port'. As before, the COM port number should be between COM1 and COM4. If Windows chooses a higher number when the adaptor is installed, the port number can be changed using the same procedure as for the Manhattan adaptor.

Test program

The program called 'RS232 terminal' (filename: terminal.exe) was originally written to carry out simple tests on devices connected to a serial port. For our examination of USB-to-RS232 adaptors it was extended to include two functions for measuring communication speed. The pro-

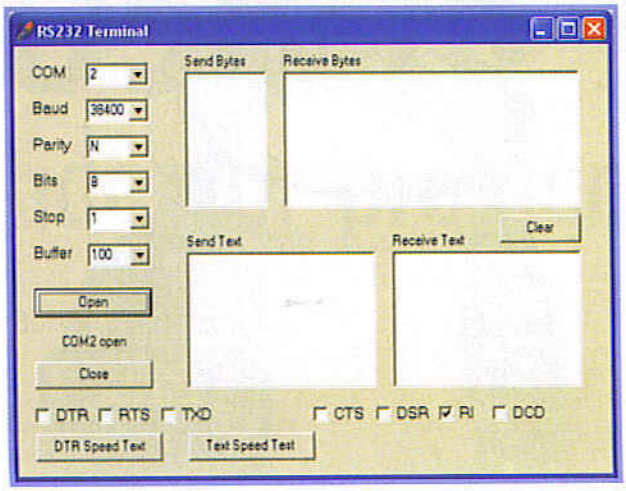


Figure 4. The 'RS232 Terminal' test program shown immediately after launch.

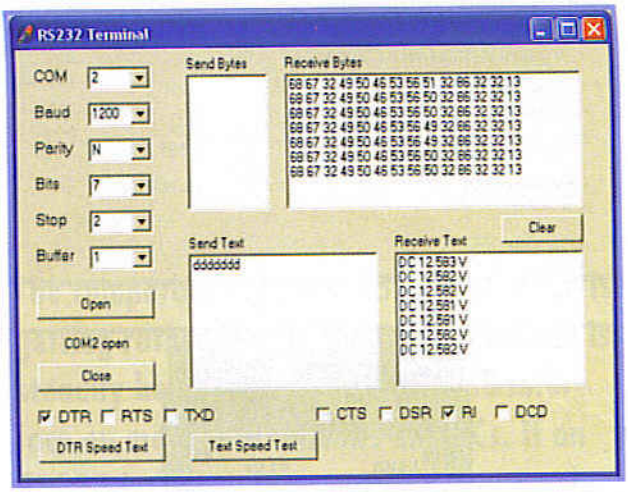


Figure 5. The receive window of the test program shows data read from a multimeter.

gram can be downloaded for free from the *Elektor Electronics* website at http://www.elektor-electronics.co.uk. File number: **050071-11.zip**.

The window which appears when the program is started is shown in **Figure 4**. When the COM port allocated to the USB-to-RS232 adaptor is opened a check is made to see if the RI (ring indicator) signal is active. In both of the USB-to-RS232 adaptors tested here the RS232 input is internally wired in such a way that the RI signal is always active. It is for this reason that there is no indicator LED for the RI signal on the Kolter adaptor.
In the terminal program window the TXD, DTR and RTS output signals can be activated and deactivated at will. When it is connected to a PC the LEDs on the Kolter adaptor give a visual indication of the state of the signals, and a voltmeter can also be used to examine the voltage changes on the interface pins.

Simple USB-to-RS232 adaptors like the Manhattan cable often generate the RS232 output signals with reduced voltages to represent the logic levels: the voltages are around +6 V and –6 V. In contrast the Kolter adaptor produces the standard output voltages of +12 V and –12 V, which are the signal levels expected from a proper serial interface. Conformance to the RS232 standard voltage levels can be important, for example when connecting devices to the interface that do not have their own power supply, but which steal power instead from the interface itself.
The galvanic isolation offered by the Kolter adaptor is particularly useful in harsh industrial environments. It helps to reduce the impact of interference by effectively decoupling the driver stages from the control electronics.

Start-stop

Once the USB-to-RS232 adaptor is installed, the PC or laptop effectively sports an extra virtual COM port. However, this port can behave in ways rather different from a real RS232 interface. The difficulty can be due to the reduced signal voltage levels on the outputs, or, more problematically, it can often be due to a difference in timing. Furthermore, older programs, for example those from the DOS era, will of course not work if they directly access registers that control the RS232 port. On the other hand, all Windows programs that indirectly access the port using the Windows API will, at least in theory, be able to use a virtual COM port without problems. In all cases it is possible that, despite the considerably higher data transfer rate possible over the USB interface, communication is slower than usual. Examples showing how to program the interface correctly can be found in part 3 of 'Delphi for Electronic Engineers' (*Elektor Electronics* March 2005).

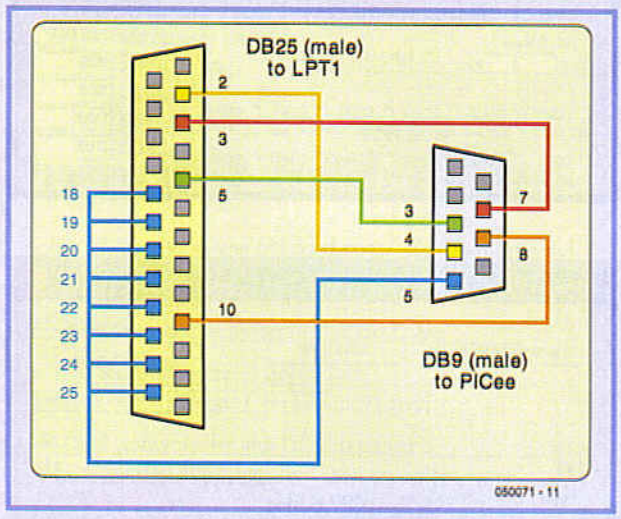
The often considerably slower data transfer rate of a virtual RS232 interface connected via USB compared to a 'genuine' RS232 interface deserves some explanation. Since USB is considerably faster than RS232, it should be possible to emulate an RS232 interface running at a speed of say 115,200 bit/s without difficulty: by comparison, even low-speed USB devices like keyboards and mice can operate at rates of 1.5 Mbit/s. On the USB side, the USB-to-RS232 adaptors from Manhattan and from Kolter both operate in USB version 1.1 full speed mode, with a data transfer rate of 12 Mbit/s. One would think that this would be more than enough to emulate the fastest RS232 port, but unfortunately there is a snag. Serial data is transferred over USB in data packets. The data packets are sent out at one millisecond intervals. The receiver must check that a complete and correct data packet has been received and send back acknowledgement data. The shortest possible turn-around time for sending a single byte over USB is three milliseconds. As long as the data packets are sufficiently long, continuous communication at a speed of 9600 bit/s is feasible over the virtual RS232 port. This in any case presupposes that large amounts of data are to be transmitted, for example for driving a printer or modem. The RS232 terminal test program shows the maximum communication speed of a connected USB-to-RS232 adaptor when the 'Text Speed Test' button is clicked on. The TXD and RXD signals on the RS232 side must be connected together before this test is run. The program sends sixty characters of text to the adaptor, and they are almost immediately returned via the looped-back TXD and RXD connections. Comparing the speeds of virtual and real RS232 ports shows that the USB-to-RS232 adaptor can guarantee to match the speed of the real port up to about 9600 bit/s. At higher communication speeds it starts to fall behind, since each byte must be sent individually on the one millisecond timebase. The transfer in this case will thus take exactly 60 ms for the 60 bytes.

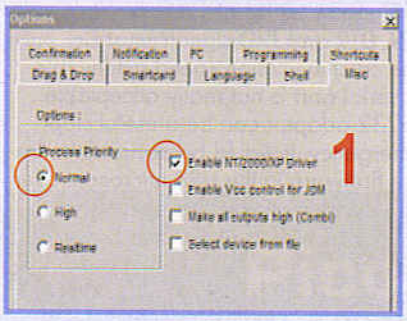
RS232 replacement for the PICee Development System

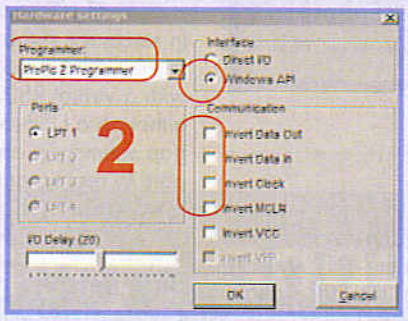
Reinhardt Weber

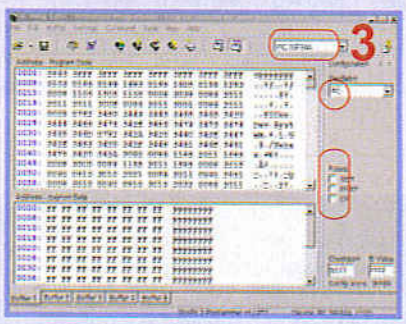
The 'PICee Development System' published in February 2002 will not work with newer laptops not fitted with an RS232 interface. The author has developed an alternative, which consists of a simple adaptor cable to allow the PICee system to be connected to the parallel port (printer interface). The adaptor cable has the advantage that it is inexpensive and DIY construction is possible. The figure shows how the adaptor cable is wired.

The adaptor cable is designed to be used with the ICPROG programming tool (filename: icprog.exe). Under Windows XP the driver icprog.sys must be installed, located in the same directory as the program itself. The necessary steps to achieve this are shown in the following figures. Simply changing the compatibility mode in which the program runs is not enough!









The behaviour described above was observed under Windows XP for both the adaptors tested. In comparison, a genuine RS232 interface running at 115200 bit/s will transfer 60 bytes in approximately 5 ms; the USB-to-RS232 adaptor takes twelve times as long!

Things take even longer when relatively small quantities of data need to be transferred back and forth alternately. For example, in a microcontroller system a series of command bytes may need to be transmitted and the microcontroller may need to reply to each byte received: the USB protocol will now bring the system grinding practically to a halt. Irrespective of the direction of transfer, each byte will take three milliseconds to send and hence the effective data transfer rate will be just 167 bytes per second.

This example also shows that the data transfer rate will increase if it is not sent one byte at a time, but rather in groups of bytes. Digital multimeters that have a serial port often behave like this. As an experiment, we connected a Metex model M-4650CR multimeter to a USB-to-RS232 adaptor. For this model it is necessary to set the PC's serial interface to 1200 bit/s and 7 data bits in the terminal program. DTR must also be set active as this provides the multimeter's interface with power. The test program allows any desired character to be sent to the multimeter. The reply is a text string 14 characters long which contains the value currently displayed on the meter. If the meter is connected to a real RS232 interface the data transfer is fairly slow as the data rate is only 1200 bit/s. If a USB-to-RS232 adaptor is used instead, there is no further loss in speed, and in this case the adaptor properly emulates a real serial interface. **Figure 5** shows the terminal program displaying data read out of the multimeter. Similar results were obtained from experiments with an MCS-52 BASIC microcontroller system based on the 89S8252 Flash Microcontroller Board (published in December 2001), with the microcontroller's serial interface being set to 9600 bit/s. The data transfer rate was measured in both directions. Measurements were carried out using a real serial interface and using a virtual one, via a USB-to-RS232 adaptor emulating a serial port. No difference in data transfer performance was observed.

Control signals

Controlling the handshake signals DTR and RTS as well as entering and leaving the 'break condition' on the TXD line is generally slower than transferring serial data on a virtual RS232 interface, since each action takes at least the

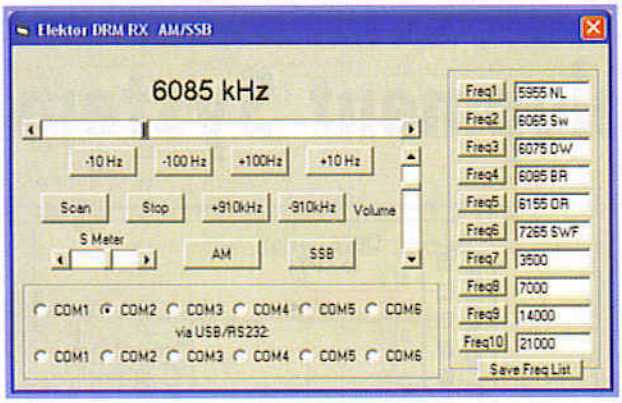


Figure 6. Tuning the DRM receiver.

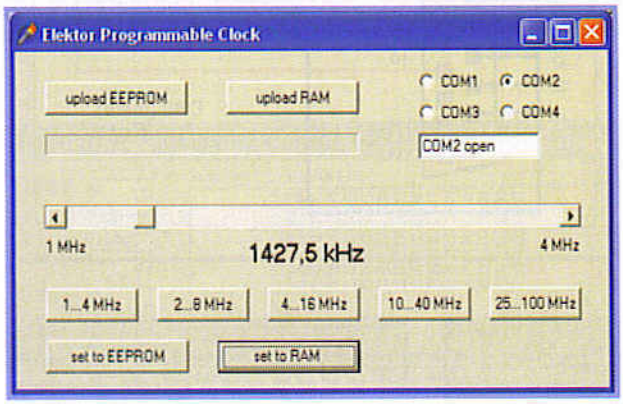


Figure 7. Setting the frequency of the programmable crystal oscillator.

basic three millisecond period. The same goes for reading the state of the CTS and DTR signals. You can confirm this using the terminal program by clicking on the 'DTR speed test' button. The terminal program switches the DTR signal on and off 1000 times at the highest possible speed. Running this test using a real RS232 interface under Windows XP results in a measured frequency of 40 kHz on the DTR line, with 1000 cycles completing in 25 milliseconds. Using a USB-to-RS232 adaptor providing an emulated interface the same process takes 6000 milliseconds, corresponding to a signal frequency of 167 Hz.
This test also shows that the various versions of Windows behave differently. Under Windows 98 and Windows ME signal transitions are lost when they follow in succession too quickly, whereas under Windows XP this problem no longer occurs: instead, when the command to switch a handshake signal is issued program execution is suspended until the signal actually changes state. It is no longer necessary to take steps in software to ensure that the DTR signal is correctly set; but unfortunately the program runs slightly slower under Windows XP.

89S8252 Flash Microcontroller Board

The 89S8252 Flash Microcontroller Board we published in December 2001 has two RS232 interfaces. The first RS232 interface is intended to be used for communicating with the outside world during normal operation. If, for example, MCS-52 BASIC is loaded, it provides the interface between the interpreter and a PC running a terminal emulator program. As we have already discussed, communication with a PC via a USB-to-RS232 adaptor at a speed of 9600 bit/s does not cause any problems.
The second serial interface on the board is used for programming the flash memory of the microcontroller over its SPI interface. This is achieved by the PC taking direct control of the RTS (clock), TXD (data) and DTR (reset) signals. If the board is connected to a real RS232 interface, programming over the SPI interface is a quick operation. Connect to the PC using a USB-to-RS232 adaptor, however, and the same process takes considerably longer. The programs 'MicroFlash' and 'TASMEdit' were developed for use alongside the 'Microcontroller Basics Course' published in *Elektor Electronics* between January and September 2002 to allow data to be downloaded into the microcontroller. Since then, a software update has been necessary since timing problems have been encountered when using the board under Windows XP connected via a real RS232 interface. The new versions of the programs work without problems under Windows XP, even when the board is connected to the PC via a virtual RS232 serial interface. The same comments apply to the 'Atmelisp' program by Ulrich Bangert. In any case, when using a USB-to-RS232 adaptor communication speed is very slow, at only around four bytes per second. At this speed downloading small assembler programs is reasonable, but downloading longer programs will demand a lot of patience. Downloading MCS-52 BASIC (8 kBytes) will take about half an hour, although if you wish to continue to use MCS-52 BASIC you will only have to download it once.

In summary, if the RTS, DTR and TXD signals must be switched by hand, the communication speed achievable with a virtual RS232 serial port is not really acceptable, although a USB-to-RS232 adaptor can be a useful stopgap solution in an emergency. It would be desirable to be able to reprogram the firmware in the USB microcontroller to accept a byte and process it as eight individual bits.

DRM Receiver

The DRM Receiver is a project which was published in March 2004. First the good news: the DRM receiver can be tuned directly using the 'DREAM' program under Windows XP using a USB-to-RS232 adaptor (see **Figure 6**). The DDS oscillator in the receiver is clocked serially, with TXD in this case being the clock signal and RTS the data signal. On the oscilloscope we can see that the clock pulses occur at 9 ms intervals for a clock rate of 110 Hz. Three state changes are required: first set the RTS data signal appropriately, activate TXD, and finally deactivate TXD. During tuning several bytes are transmitted, and the process lasts about a second. Since this delay only occurs when switching between DRM stations it causes hardly any inconvenience. However, tuning randomly in AM mode is rather more tiresome. In comparison, using a real RS232 interface the software manages a clock frequency of 10 kHz, and a tuning adjustment can be carried out in about 14 ms.

The original tuning programs, written in Visual BASIC and Delphi, work equally well with a USB-to-RS232 adaptor emulating a serial port, although they run somewhat slower. The 'AM/SSB' program available on the ELEXS server can be configured to use any port from COM1 to COM6. The COM1 to COM6 options 'via USB/RS232' cause extra delay instructions to be added to ensure correct operation of the program under Windows 98 and Windows ME. Under Windows XP the normal (real) COM port buttons can be used. The program has also been extended to include a search function,

which can only be used in conjunction with a real RS232 interface. Fine tuning, in steps of 100 Hz or 10 Hz (especially useful for SSB operation) is also a tedious process when using a USB-to-RS232 adaptor.
The USB-to-RS232 adaptors from Manhattan and Kolter behave differently when used with the DRM receiver. The explanation lies in the galvanic isolation between the USB and RS232 sides of the Kolter adaptor. One might think that the galvanic isolation would improve the quality of reception, as it would help to keep interference from the PC away from the receiver. Unfortunately, however, the isolated DC-to-DC converter in the Kolter adaptor generates interference on the ground connection at frequencies up to 10 MHz. The Manhattan adaptor is thus better suited to use with the DRM receiver.

Serially Programmable Crystal Oscillator

The Serially Programmable Crystal Oscillator module, published in March 2005, is configured over an I²C bus implemented using the signals of an RS232 interface. For direct connection to a PC's USB port, the starter kits from Cypress (the so-called 'candy boards') are a possibility, since they are already equipped with their own USB interface. Alternatively, the module published in *Elektor Electronics* will work, taking the roundabout route via the RS232 interface. A simple program has been written to allow the frequency to be set easily (**Figure 7**). The software works without problems under Windows XP when the module is connected to the PC via a USB-to-RS232 adaptor. Downloading the basic settings, which occupy 256 bytes, takes about 30 seconds. This procedure is only required once, when initialising the unit. When changing the frequency using the above program only a few bytes are transferred, the process taking approximately half a second. Compared to the time it takes for a custom-cut quartz crystal to be ordered and delivered, this is phenomenally quick!

(050071-1)

Internet addresses

Kolter Electronic: www.pci-card.com/ (in German only)

FTDI: www.ftdichip.com/

Manhattan: www.manhattan-support.com/

Source for USB-to-serial adaptors: www.ak-modul-bus.de/ (in German only)

AM/SSB software for the DRM receiver: www.elexs.de/drm5.htm (in German only)

Download software update for the 89S8252 Flash Microcontroller Board: www.b-kainka.de/basismifaq.htm (in German only)

Advertisement

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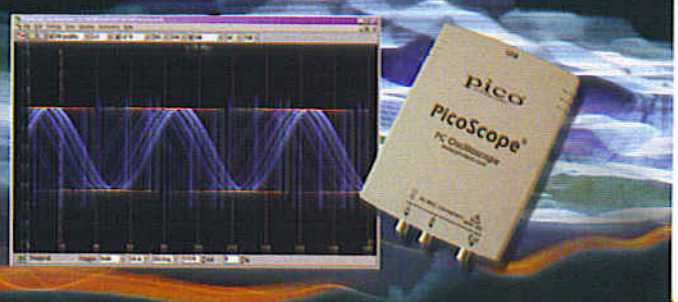

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Hitting the High

Günter Koch

Lengths and distances are usually measured using a yardstick or measuring tape. For inaccessible locations, and especially for measuring the level of a liquid in a container, using an ultrasonic device to measure distance is an attractive alternative.

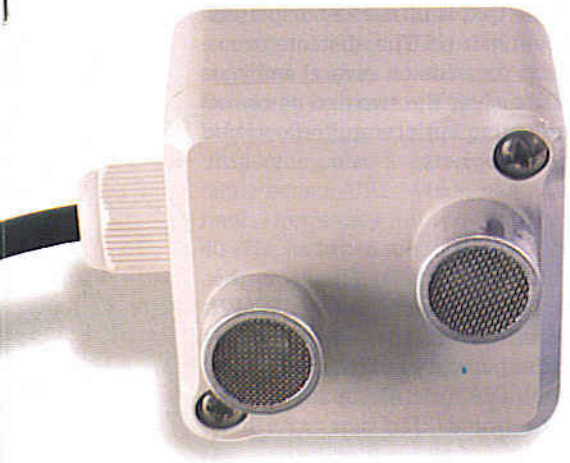
Notes

An ultrasonic distance meter & liquid-level gauge

Ultrasonic distance measurement involves using pulses of ultrasonic energy that are emitted by a transmitter and sensed by a receiver. The time required for the acoustic pulse to travel from the transmitter to the receiver is proportional to the distance, and this time can easily be converted into distance. In addition to making 'direct' measurements of the distance between the transmitter and the receiver, this technique can also be used to make a 'indirect' measurements using the reflection method, with the transmitter and receiver located together in the instrument. In the reflection method, the acoustic wave is directed at a 90-degree angle toward a sufficiently large object having a surface that is as flat as possible, which reflects the acoustic pulse back to the instrument. In this situation, the acoustic wave naturally travels twice the distance to be measured.

Most commercial instruments use a combined transmitter and receiver unit. Although this is a practical, compact and inexpensive solution, it does not allow very short distances to be measured, due to the transit time of the pulse. The instrument described here overcomes this difficulty. Although it also measures using the reflection principle, it has separate transmitter and receiver modules. This allows it to measure even very short distances.

The instrument is designed as a stationary device, since the author mainly uses it for measuring the level of a liquid in a container. The transmitter and receiver are housed in a separate sensor enclosure, so they can be positioned independently of the main portion of the instrument.



Measurement principle

Measurements are made continuously. A new measurement cycle is started every 200 ms. At time t_0 of each cycle, the transmitter module initiates a 40-kHz pulse with a duration of 250 μs. The received signal is amplified as necessary and repeatedly sampled by the analogue-to-digital converter of a microcontroller, which initially stores the measured values in its memory. Sampling also starts at the initial time t_0 and continues for 35 ms. After this, the software compares each of the stored 8-bit measurements of the received signal with a threshold value.

As the level of the received signal decreases markedly with increasing distance, the threshold value is correspondingly reduced as the sampling time increases. It must also be borne in mind that a rather strong signal is received while the transmitted pulse is being emitted and for a short time afterwards, due to direct crosstalk from the transmitter to the receiver and signal artefacts. **Figure 1** shows an example of a plotted set of signal measurements and the curve of the threshold value.

The evaluation software first determines the maximum point of the sampled values, which is the sample that lies the furthest above its associated threshold. However, a strong reflection (at a short distance) will overload the receiver and the A/D converter. As the actual maximum level of the signal will exceed the measurement range of the converter in such cases, the first measurement after the initial time that exceeds a predefined overload level is taken to be the maximum point. The interval between the initial time and point where the two curves intersect *before* the maximum is then the transit time for the pulse, which is used to calculate the distance. To increase the accuracy of the measurement, the exact intersection point is determined using linear interpolation.

Unfortunately, the speed of sound

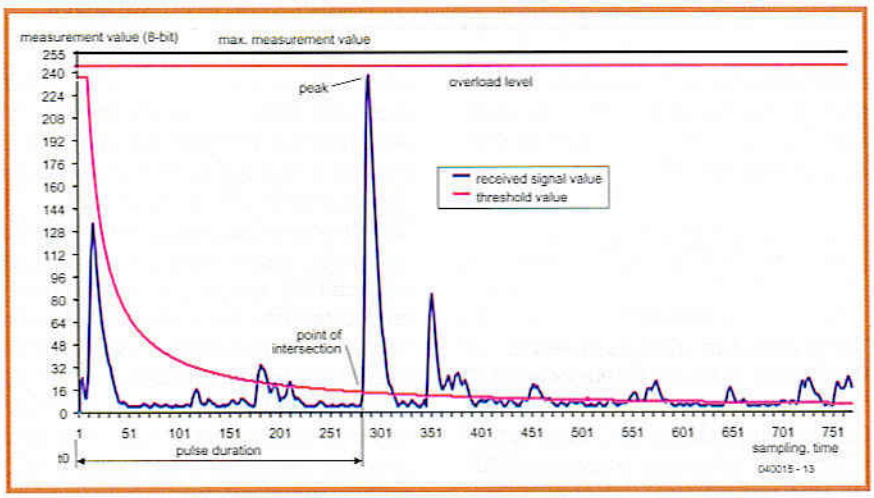


Figure 1. Sample plot of signal measurements with threshold curve and overload level.

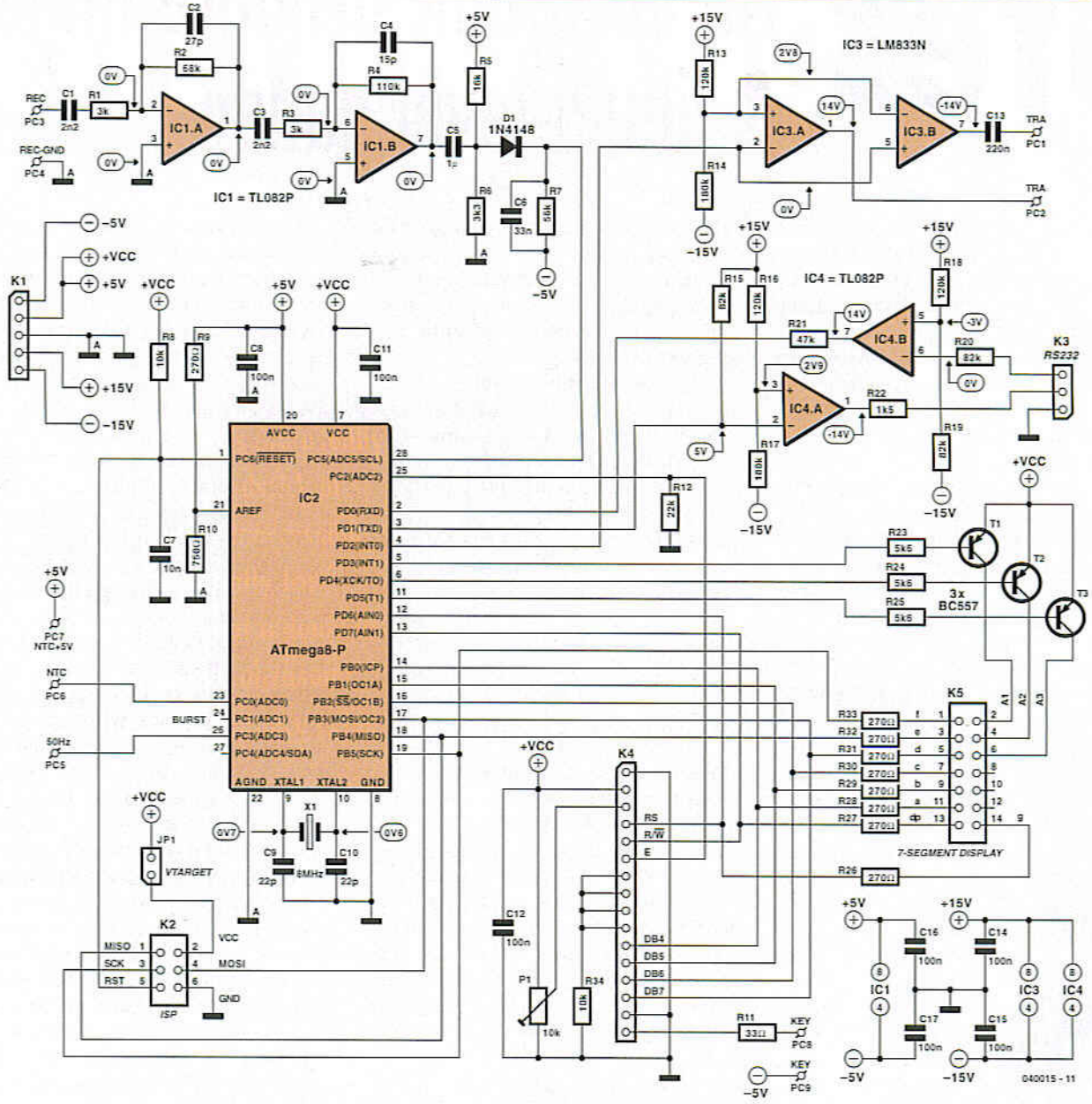


Figure 2. The circuitry of the ultrasound distance measurement device, which is based on an ATmega8 microcontroller, is divided among three circuit boards.

depends on temperature, and more so than you might think. At 0 °C it is approximately 331 m/s, and at 40 °C it already reaches 345 m/s.

$$V_T = 331\sqrt{\frac{T}{273}}[m/s]$$

where:
T = temperature in degrees Kelvin
V_T = speed of sound at temperature T

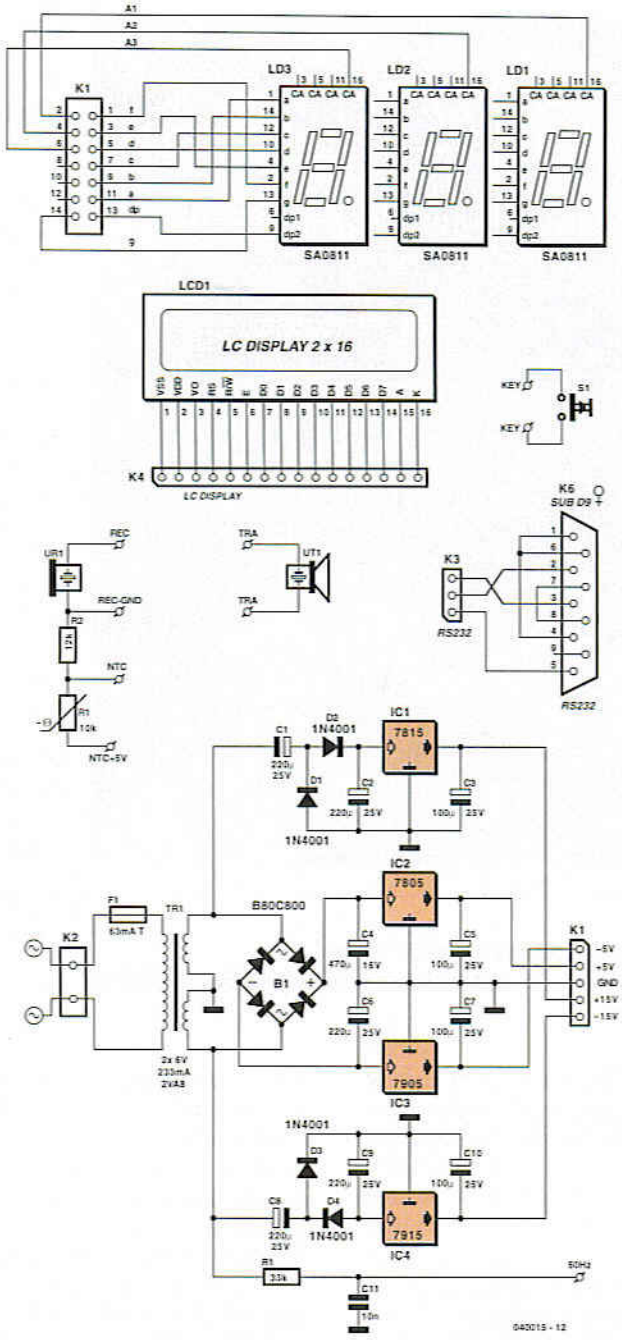
Consequently, the temperature in the sensor head is measured using an NTC resistor, and the result is taken into account in calculating the distance. The temperature-dependent voltage drop is measured using an A/D converter in the microcontroller, in this case with 10-bit accuracy. The temperature range that can be measured in this manner is approximately –35 °C to +44 °C.

The distance determined during each individual measurement cycle is not immediately displayed, but instead first compared with the results of previous measurement cycles. No value is displayed unless the majority of the ten most recently calculated values lie approximately within the same range, in which case an average value is calculated and displayed. This makes the displayed value immune to isolated spurious measurements.

Although the values are processed internally with a precision of 1/16 cm, the value that is ultimately displayed is in centimetres. The absolute accuracy also depends on several ambient factors, such as the size and nature of the reflecting surface and reflections from other objects.

Circuit description

As can be seen from **Figure 2**, the instrument is controlled by an AVR ATmega8 microcontroller. The microcontroller generates the measurement pulse on PD2 (pin 4). Opamps IC3a (inverting) and IC3b (non-inverting)



raise the voltage of the logic-level output signal to approximately 55 V_{pp}, which is the level required by the ultrasonic transmitter (UT1). This level is obtained using a voltage doubler formed by connecting IC3a and IC3b in bridge configuration. The reflected ultrasonic pulse is received by ultrasonic sensor UR1, which has a resonant frequency of approximately 40 kHz, and then amplified by a factor of approximately 500 by opamps IC1a and IC1b. A bandpass filter with a centre frequency at approximately 40 kHz is incorporated in the amplifier stage to suppress any external interference signals that may be present.

The ac portion of the output signal from IC1b is coupled to rectifier diode D1 via coupling capacitor C5. The rectifier diode is biased by voltage divider R5/R6. The positive half cycles passed by D1 charge smoothing capacitor C6 such that the voltage across C6 is proportional to the level of the input signal. The capacitor is discharged by R7, and the time constant of the RC network (C6/R7) is chosen such that the ripple voltage on the smoothed measurement signal is adequately suppressed, while still ensuring that the measurement signal decays within the shortest possible time. To improve the discharge characteristics, the discharge resistor is connected to –5 V instead of ground. At the maximum signal level, the resulting voltage at the input to the A/D converter in the microcontroller (PC5 on pin 28) has a maximum value of approximately 3.7 V. This makes the measurement signal compatible with the converter in the microcontroller. The temperature dependence of the diode threshold voltage is corrected by the software by means of periodic zero-point adjustment. This involves measuring the voltage at the converter input when no output signal is present on PD2, so that no signal is received by the ultrasonic receiver. All that remains to be ensured is that the zero level of the measurement signal does not drop below 0 V, even at the lowest operating temperature (which is taken to be –25 °C for calculation purposes). At temperatures above this, the zero level is slightly above 0 V (approximately 150 mV at +45 °C).

The reference voltage for the A/D converter on the AREF lead (pin 21), which is equal to the maximum voltage of the measurement signal (3.7 V), is provided by the microcontroller via voltage divider R9/R10. The conversion is made using 8-bit resolution, which is fully adequate for this purpose. This allows the sampling rate to be set to the relatively high value of slightly less than 20 kHz (one measurement every 52 µs).

The temperature is measured using NTC resistor R1 in the sensor head. The voltage drop across series resistor R2, which is proportional to the temperature, is measured using converter PC0 in the microcontroller (ADC0 on pin 23) and included the distance calculation. The accuracy of the measurement also depends on the accuracy of the microcontroller clock. Consequently, the ATmega8 is operated using an external crystal instead of its internal RC clock oscillator.

Display

The computed distance in centimetres is shown using a time-multiplexed, three-digit seven-segment display (with common-anode display modules). The three seven-segment display modules are fitted to a circuit board that is connected to K5 on the main circuit board via K1. The decimal points of the display modules are not used by the current software, but for the sake of completeness, the hardware does allow them to be driven.

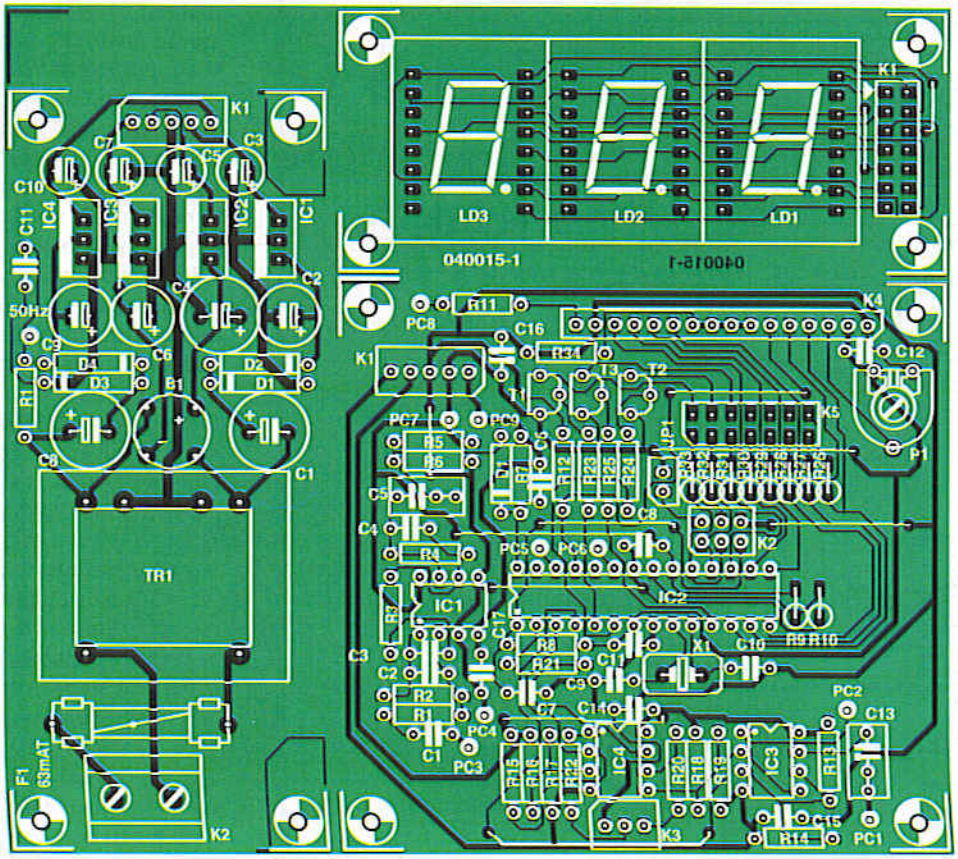


Figure 3. There are nine wire bridges on the main circuit board, two more on the display board and one on the power supply board (next to IC3). (copper layout available from our website)

Alternatively, a 2 × 16 LCD module can be connected. This display is driven in 4-bit mode. As the seven-segment display and the LCD module share several port leads, a multiplex mechanism in the software allows both types of display to be used at the same time. In a manner of speaking, the LCD drive signals are interleaved with the drive signals for the seven-segment display. Trimpot P1 is the usual contrast adjustment trimpot for the LCD module. An optional backlight for the LCD can be keyed by a pushbutton switch in series with R11.

A 50-Hz signal tapped off from the unrectified supply voltage and fed to the microcontroller via lead PC5 provides a time reference for updating the date and time of day. The date and time are shown alternately on the LCD module.

Interfaces

An RS232 interface is essential for configuring the instrument settings or receiving periodic measurement data outputs. As ±15 V voltages are already present, we can do without the usual interface converter and use opamps IC4a and IC4b as drivers. The port lines are protected by internal diodes, so voltages greater than 5 V or less than 0 V can be applied to them without causing any problems if suitable current limiting is provided (by R21).

The six-way ISP connector (K2), which is an Atmel STK500-compatible ISP6PIN connector, is provided to allow a programming unit to be connected for in-system software programming. This allows the circuit to be used as an ATmega8 development board, independent of its actual intended use.

Jumper JP1 (VTARGET) should only be fitted if the programming unit does not have its own power supply and thus must take its supply voltage from the circuit it is connected to. **JP1** should normally be left **open**.

While programming is underway, the Reset line of the microcontroller is pulled Low. This causes all port leads that are not involved in serial programming to assume the high-impedance state (tri-state). To prevent the LCD module from placing data on the serial programming lines as the result of an undesired read operation, the Enable line (E) of the LCD module is held Low via R12.

The ±5-V supply voltages are generated on the power supply circuit board using 7805 and 7905 voltage regulators. Each of the necessary unregulated ±15-V supply voltages is obtained using a voltage-doubler stage consisting of charge pump C1, C2, D1 and D2 or C8, C9, D3 and D4, respectively. The load on each of these supply voltages is less than 20 mA.

Construction and operation

The circuitry for the distance meter is divided among three printed circuit boards and the sensor head. The sensor head contains the ultrasonic transmitter and receiver and the NTC resistor, all of which are wired point-to-point. Besides the main circuit board, which holds the microcontroller and the opamps for signal conditioning, the

printed circuit board has separate sections for the power supply and the seven-segment display. Before any components are fitted, the printed circuit board must be separated into the individual sections.

Start fitting the components with the **wire bridges**. There are **nine** on the **main circuit board**, **two** on the **display board** and **one** on the **power supply board**. As you can see, the wire bridges are the price that must be paid for using a single-sided circuit board with a compact component layout and correspondingly tight track routing. This makes it worthwhile to fit the wire bridges on the copper side using insulated wire. After this, the resistors, capacitors and IC sockets, and finally the solder pins and the various connectors (headers, ISP connector and other connectors) can be fitted (on the component side, of course) and soldered using a soldering iron with a fine tip. Be careful to avoid creating any solder bridges.

Fitting the components to the display board should not present any problems. The display modules are not directly soldered to the board, but instead fitted in sockets so they protrude through the cover of the enclosure and stand higher than K1 together with its attached flat-cable connector. LCD modules come already assembled, so all you have to do is solder a flat cable to the module and plug it into K4 (or solder it directly to the board). A 13-way flat cable can be used, with every second lead being left open.

The power supply board can also be put together quickly and easily. Here you only have to pay attention to the orientation of the components, since almost all of them must be fitted with the proper 'polarity'. Given the low current consumption of the circuit, there's no need to fit additional heat sinks to the voltage regulators. The 50-Hz link is provided by a single solder pin (50 Hz) next to C9 on the power supply circuit board and a matching solder pin (PC5) on the main circuit board, close to IC2.

The connection between the sensor head and the main circuit board must without exception be made using a single, screened four-way cable (a microphone cable or a quad cable for satellite TV). The connections for the two ultrasonic modules are distributed over several solder pins (PC1–PC4) on the main circuit board. The screens for the PC1–PC3 leads are twisted

COMPONENTS LIST

Power supply board

Resistor:
R1 = 33kΩ

Capacitors*:
C1,C2,C6,C8,C9 = 220µF 25V radial
C3,C5,C7,C10 = 100µF 25V radial
C4 = 470µF 16V radial
C11 = 10nF

Semiconductors:
B1 = bridge rectifier 80V (or 40V), 0.8 A
D1-D4 = 1N4001
IC1 = 7815
IC2 = 7805
IC3 = 7905
IC4 = 7915

Miscellaneous:
K1 = 5-way SIL header
K2 = 2-way PCB terminal block, lead pitch 7.5mm
Tr1 = mains transformer 2 x 6V @ 2 x 233mA (e.g., ERA BV030-7590.0U)
F1 = fuse, 63mAT (time lag), with PCB mount holder (lead pitch 22.5mm) (not required if a short-circuit resistant transformer is used)

Main circuit board

Resistors:
R1,R3 = 3kΩ
R2 = 68kΩ
R4 = 110kΩ
R5 = 16kΩ
R6 = 3kΩ3
R7 = 56kΩ
R8 = 10kΩ
R9 = 270Ω, 1%
R10 = 750Ω, 1%
R11 = 33Ω
R12 = 22kΩ
R13,R16,R18 = 120kΩ
R14,R17 = 180kΩ
R15,R19,R20 = 82kΩ
R21 = 47kΩ
R22 = 1kΩ5
R23,R24,R25 = 5kΩ6
R26-R33 = 270Ω
P1 = 10kΩ preset, H

Capacitors*:
C1,C3 = 2nF2
C2 = 27pF
C4 = 15pF
C5 = 1µF, lead pitch 5mm or 7.5mm
C6 = 33nF
C7 = 10nF
C8,C11,C12,C14, C15,C16,C17 = 100nF
C9,C10 = 22pF
C13 = 220nF, lead pitch 5mm or 7.5mm

Semiconductors:
D1 = 1N4148
T1,T2,T3 = BC557A
IC1,IC4 = TL082P
IC2 = ATmega8-16PC, programmed, order code **040015-41**
IC3 = LM833N

Miscellaneous:
X1 = 8MHz quartz crystal
K1 = 5-way pinheader and mating socket
K2 = 6-way pinheader (2x3 block)
K3 = 3-way pinheader, straight
K4 = 16-way pinheader, straight
K5 = 14-way (2x7) pinheader, straight
K6 = 9-way D subminiature socket (female)
Solder pins
1 off 28-way IC socket, narrow-DIL
3 off 8-way IC socket
S1 = pushbutton, 1 make contact
LCD module with 44780 controller; 2x16 characters (optionally: with backlight; Display Tech 162)
ABS case, min. inside dimensions 125 x 102mm (splashproof; approved for damp room / outdoor use)

Display board

LD1,LD2,LD3 = 7-segment display, common anode, 20mm high (Kingbright SA08-11 SRWA)
K1 = 14-way (2x7) pinheader

Sensor head

R1 = NTC, 10kΩ
R2 = 12kΩ, 1%
UT1 = ultrasonic emitter (36-40 kHz)
UR1 = ultrasonic receiver (36-40 kHz)
5-way cable with individual screening (e.g., microphone cable); see text
Splashproof ABS case with strain relief grommet and locking nut (Bopla ET205, BF7, GM7)

*All capacitors 5mm lead pitch unless otherwise indicated

Ultrasonic transmitter and receiver

Suggested sources and order numbers:

www.maplin.co.uk
HY12N (receiver/transmitter pair)

www.conrad.de

400ST160/MA40-S	182273-12
400ST160/MA40-R	182281-12

www.reichelt.de

400ST160/UST-40T	UST-40T
400SR160/UST-40R	UST-40R

www.segor.de

UST-40 T	UST-40 T
UST-40 R	UST-40 R

www.simons-elektronik.de

UST-40T	UST-40T
UST-40R	UST-40R

Table 1 Information shown on the LCD module

A. If no maximum liquid level has been configured (and during initial operation):

B. If the maximum liquid level has been configured using the RS232 interface:

rrr	measured distance in cm
rr1,rr2,rr3	previous distance measurements, which shift to the right every minute
ttt.t	current temperature in degrees Celsius
ddddd	date (day.month) and time of day (hours:minutes), shown alternately
fff	measured liquid level, computed by subtracting the measured distance from the maximum liquid level
ff1,ff2	previous liquid level measurements, which shift to the right every minute.
hhh	currently configured maximum liquid level
pp	liquid level in per cent (measured liquid level divided by maximum liquid level × 100)

together and connected to solder pin PC4 (REC GND), where they also provide the ground connection. Although the NTC connection via solder pins PC6 and PC7 is not sensitive to interference, it's practical to use the remaining free leads (and associated screen) for this connection. It doesn't matter where this screen is soldered. Naturally, it should be prevented from coming in contact with the other screen braids. This technique will only work if the individual screens in the cable are actually insulated from each other. With cables that don't meet this requirement, a five-way cable must be used instead.

The sensor head can be constructed using any desired enclosure that is suitable for the intended application. Naturally, there's no reason why the ultrasonic transmitter and receiver cannot be fitted a few centimetres apart in an enclosure, along with the NTC resistor and the other circuitry. The two ultrasonic modules should be arranged such that they are as nearly possible parallel to each other.

Don't overlook the lead for the 50-Hz signal between the power supply board and the main circuit board, since otherwise you won't see the time and date on the display. For the RS232 interface, three leads are run from K3 to the RS232 chassis-mount socked, while the remaining connections are made directly to the socket.

Table 2. Configuration commands

```
Command Menu:
  d - date
  t - time
  h - high level water mark
  v - voltage to temperature table
  p - temperature voltage logging
  c - distance calibration table
  q - quit command mode
udm>
```

Initial operation

If you initially operate the distance meter before it has been fitted in an enclosure, don't forget that mains voltage is present on the power supply board. The best solution is to operate it using an isolation transformer.

After the unit is switched on, the underline segments of the seven-segment display will be lit for a short time before the actual measurement process starts up. You can hear the transmission of the ultrasonic signals, although what you hear is of course not the 40-kHz oscillations, but instead the switch-on and switch-off noises the acoustic transducer produces when it's driven by a pulsed waveform. If a minus sign (–) is shown on the seven-segment display, it means that no valid measurement value could be determined. This error indication should disappear within a few seconds after the unit is switched on, and you should then see the measured value in centimetres. The information displayed on the LCD module is described in **Table 1**.

Following these initial tests, you should check the indicated temperature. As the value of an NTC resistor can differ from its nominal value by a relatively large amount (and usually does), the deviation must be compensated. A simple way to do this is to suitably adjust the value of series resistor R2 in the sensor head, or possibly replace it by a multi-turn trimpot. If the displayed temperature is too high, the series resistance must be reduced. If you want to obtain accurate temperature or distance measurements over a relatively wide range of temperatures, you should use the RS232 interface to modify the *Voltage to Temperature* table.

When the instrument is used continuously, you should avoid exposing yourself and other creatures to the ultrasound energy for too long, even though people cannot hear the ultrasonic waves.

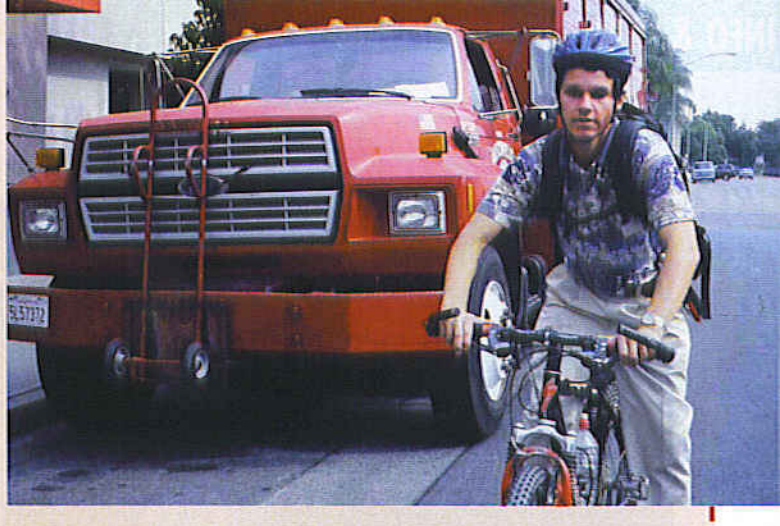
Configuration

To configure the meter via the RS232 interface, you must connect it to a PC using a 1:1 cable (**not** a null-modem cable). In the terminal emulator program, set the baud rate to 57,600 (or 56,000) and configure the other parameters as usual: 8 data bits, no parity, and 1 stop bit.

After the meter is switched on, it issues a welcome message via the RS232 interface. After this, the date, time of day, temperature, distance or liquid level, and optionally the liquid level in per cent, are periodically output every minute.

Pressing the Return key on the PC keyboard switches you into the command mode, which provides the following options as described in **Table 2**:

Learning from bats



The American Daniel Kish, who is now 38 years old, has been blind since the age of two. Despite this, he can orient himself in his surroundings almost as well as a sighted person. When he is in an unfamiliar area, he makes a rapid series of clicking noises and orients himself using the echoes returned by obstacles. Dan Kish, who is called 'Batman' by his friends, has refined this form of echo orientation to the point that he can reliably distinguish the size, distance, and even the shape and spatial form of a large variety of objects, and he can even ride around on a mountain bike.

He has now started teaching his technique to other blind persons (see http://www.worldaccessfortheblind.com/). As persons who are just starting to learn this technique often find it difficult to distinguish the subtleties of the echoes, Kish has developed a device to perfect the snapping sound. This is an 'embedded system' with a loudspeaker that can be fastened on the user's forehead like a miner's lamp. The circuitry produces a selection of clearly defined, consistent clicks, which can also be made rather loud if necessary. The computer-controlled clicking is far superior to the 'home-made' variety, so the echo is up to three times as sharp.

Industrial firms and research organisations have also taken up this idea. Alcon, an international market leader in ophthalmic devices, found the design fascinating. They intend to market the device under the name 'Soundflash'. The next-generation Soundflash units are planned to emit ultrasonic signals in addition to audible signals. The resulting echoes would thus also be satisfactory for bats. The only problem is that the device must feed the manifold details of the echo back into the human ear. The result is no longer an echo, but instead an image of the echo that has essentially been shifted down in frequency, which the blind person must in turn painstakingly translate into a sort of spatial impression. The ability of the brain to 'naturally' perceive spatial qualities is restricted to the real echo in the audible spectrum. For this reason, Kish is now working with technicians and engineers to figure out how to generate a virtual model of the surroundings that the auditory system will intuitively perceive as being consistent.

Scientists associated with the Chair of Sensor Technology of the University of Erlangen in Germany (http://www.lse.uni-erlangen.de/layout.cgi?page=Forschung/Projekt8) are presently working on the individual components of an artificial bat head. They plan to use it to study exactly how signals are transmitted and received by bats. The objective of this study, which forms part of an EU project, is to learn more about object recognition using ultrasound. The potential applications foreseen by the team lie primarily in the area of medical technology as orientation aids for blind persons.
The mouth and ears of the artificial bat head will be able to be moved exactly the same as the mouth and ears of a real bat. 'Rotation of the head and ears is the decisive factor in researching the ultrasound orientation system', explains Reinhard Lerch, a professor at the University of Erlangen. 'We are presently concentrating our efforts on the ears, which pick up the signal, and on the part that generates the emitted signal and receives it.'

The primary problem with this device is its size. 'In order to accurately reproduce the transmission and reception processes, the artificial head must be no larger than the original', says Alexander Streicher, one of Lerch's associates. The scientists are presently still working to overcome another problem: they have not yet succeeded in realistically generating the entire frequency spectrum of a bat (from 20 Hz to 200 kHz).

Besides the characteristics of the ultrasonic transducer, the bat's ears and their various shapes are the decisive factors for reception. To simplify construction, different types of bat ears were scanned using X-ray techniques, and computer models for the simulation and plastic models for making measurements were generated from the scanned-in data. A computer program can then be used to determine the most favourable orientation of the ears, generate a suitable shape, and produce a genetic algorithm.

d Set the date.
t Set the time of day.

h Maximum liquid level (distance from the sensor to the bottom of the monitored liquid container). Enter a value of '0' to display distance.

v Calibrate the temperature measurement by modifying the *Voltage to Temperature* table. This table stores A/D voltages corresponding to specific temperatures (every 5 °C over the range of –30 °C to +45 °C). The entered values must always increase with increasing temperature. A linear interpolation is made between the entered values. An Excel table included in the software for this project can be used to help determine the voltage values.

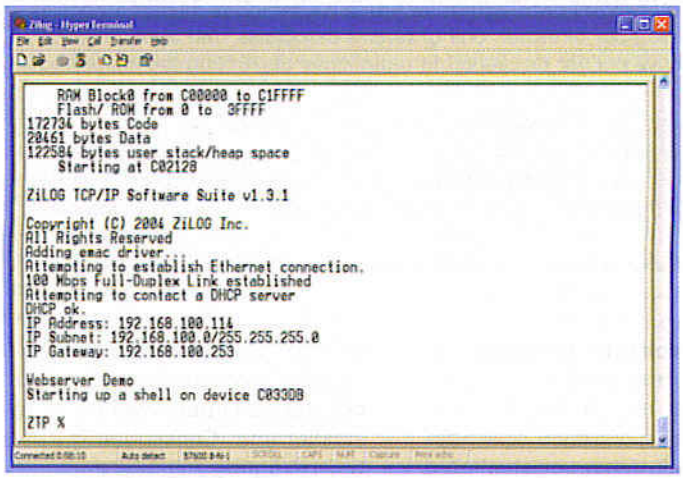
p Continuously display the temperature-sensor voltage measured at ADC0.

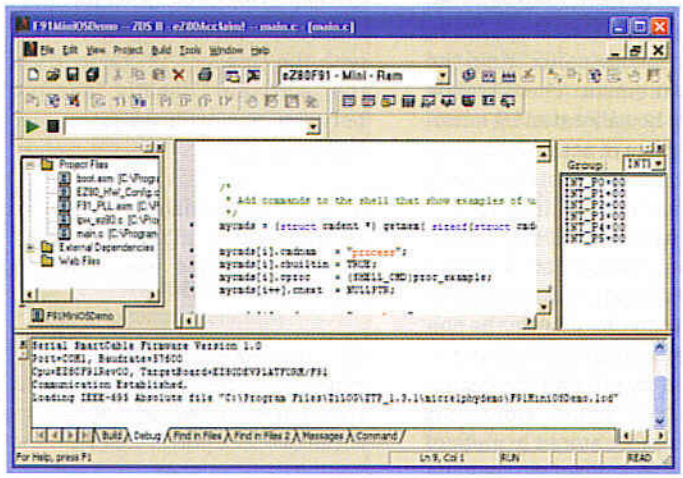
c Calibrate the distance measurement. As the distance calculation depends on the current temperature, it's best to calibrate the temperature measurement before calibrating the distance measurement. The distance calculation can be calibrated by entering up to nine pairs of actual and nominal values. At specific distances covering the entire range of distances to be measured, record the distance displayed by the instrument together with the actual distance. For each calibration point (pair of values in the calibration table), enter the displayed value as the 'in' value and the actual value as the 'out' value. Note that these values must be stated in units of one sixteenth of a centimetre, since the software uses this unit for its internal calculations and the accuracy of the calibration is improved by using the smaller unit. Consequently, the centimetre figures must be multiplied by sixteen. The pairs of values must be entered in increasing order, starting with the smallest 'in' value. As usual, the software linearly interpolates between the values entered for the individual points.

q Exit the command mode and return to the normal mode, in which the measured values are output every minute.

With the exception of the date and time of day, all of the configuration data are stored in EEPROM, so they are not lost in the event of power failure.

(040015-1)





eZ80 Accla

The Z80, used extensively in the past, has been given a new lease of life by Zilog. Having kept a low profile for a while, this manufacturer has returned with a fast, modern controller.

Paul Goossens

One of the remarkable events of the eighties was the growth of the home computer market. The processor (CPU) inside most of these computers was either a 68xx series processor or a Z80. Well-known computers such as the ZX Spectrum and the MSX range used the latter processor. Since then most people have lost interest in these processors (and hence in Zilog). Since that time Zilog has concentrated on a different market, making dedicated processors for a variety of manufacturers. The Gameboy, for example, uses a derivative of the Z80.

eZ80 Acclaim

Zilog has recently returned to the spotlight with the introduction of several general purpose embedded processors. The newest arrival in this range is the eZ80 Acclaim family. This family currently consists of just three processors, one of which has a built-in Ethernet MAC. The inclusion of this goes to show which applications Zilog thinks this will be used for.
A well-designed development kit with an eZ80F91 is available at a reasonable price (around US$ 100).

eZ80F91

This new Z80 with an Ethernet MAC on board has been christened the eZ80F91. Some of its more important features are shown in the inset alongside. It is clear that the development of the Z80 hasn't stood still and that this controller has a wide variety of extras.
One of the more noticeable features is that the system bus is configurable, so that the controller can be used with hardware that was originally designed for use with a different controller. Of the features mentioned, the Ethernet functionality should prove very popular with designers, especially when all the other extras are taken into account!

The kit

For this article we've taken a closer look at the 'eZ80Acclaim Modular Development Kit', which was designed as an introduction to developing software for the eZ80F91.
This development kit contains everything you need (apart from a PC) to get started. We do miss the inclusion of an RS232 cable, which would have been useful although not strictly necessary. Most people will have such a cable lying around somewhere, so it's not a big omission really.
The hardware consists of two parts: a small board with, amongst other things, the processor, 128 KB SRAM, oscillator, Ethernet connector and two headers with all relevant signals. This board has been designed so it can be incorporated into your own circuits as well.

im! A new lease of life for the Z80

The second board contains JTAG, RS232 and programming connectors, along with a 3.3 V power supply. There is also the facility to connect a GSM modem to the module. This board also has all connectors required for it to be used in your own circuit.

Software

Apart from the hardware it's the included software that can make or break a kit. In this case the accompanying software is more than adequate. On the CDROMs are a full development environment including a C compiler and a TCP/IP stack. Several examples are also included on the CDROM, as is a large amount of useful documentation. On top of this, the kit comes with its own operating system based on XINU, which is a multitasking operating system. In this case it has been extended with an API for using various features of the kit. This makes it easy to use the HTTP protocol and other Ether(inter)net functions. The fact that several tasks can apparently run at the same time makes this an appealing system to use and it makes it easier to write reliable software.

Examples

The examples included with the kit highlight the most important features of the new controller. The example that shows how individual tasks can be started and stopped is a very useful introduction to the operating system.
The webserver application will be of particular interest to most users, because it is a perfect example of what the built-in Ethernet module and operating system are capable of.

Expansion modules

Should you feel that the kit doesn't have enough I/O potential, you can always buy Zilog's 'General purpose modular development system'. Many kits made by Zilog (including this one) can be connected to this. This kit adds a 2x16 character LCD, 4x3 keypad, A/D converter, a connector for a GPS module made by Trimble, and much more.

And finally...

The eZ80F91 and its development kit are certainly worth a closer look. Don't be fooled into thinking that this is an old-fashioned processor given a new shine. It is in fact an up to date microcontroller suitable for use in many demanding embedded applications. If you would like to find out more about this controller, go to the manufacturer's website (www.zilog.com) and search for the eZ80F91. You will be rewarded with a large number of application notes, circuits and various other documents.

(040375-1)

Supported protocols

- TFTP
- FTP
- SMTP
- TELNET
- BOOTP
- OHCP
- DNS
- IGMP
- TIMEP

Main specifications for the eZ80F91

- 50 MHz core
- PLL
- 256 Kbyte flash memory
- 8 Kbyte SRAM
- 8 Kbyte buffer for Ethernet MAC
- 10/100 Mbit Ethernet MAC
- Power management
- SPI and I²C interface
- JTAG interface
- 32 I/O pins
- System bus configurable as a Z80, Intel or Motorola bus!
- Watchdog timer
- Real-time clock
- 4 enhanced timers
- 2 UARTS
- IrDA encoder/decoder
- New DMA-like instructions

Contents of the kit

- Processor module (with an eZ80F91) and Ethernet connection
- Expansion board
- Power supply
- A CDROM containing the Development Environment including an ANSI-C compiler, plus circuit diagrams, datasheets and a manual for the compiler
- Quick-start guide
- A CDROM with a complete TCP/IP-stack and documentation
- Programming adapter (for the serial port)

PRECISION BAROMETER / ALTIMETER

With temperature readout

G. Samblancat

Based on the MS5534 pressure sensor made by the Swiss company INTERSEMA (specialized in pressure measurements), with one metre resolution in altitude, this circuit will also give you absolute pressure, temperature, and even the time of day. The microcontroller used in the instrument is the now well established PIC16F876.

Technical Features

- Barometer mode at ±0.1 mbar (from 300 to 1.100 mbar)
- 'Barograph' display of the tendency of the last 4 hours
- Altimeter/level meter mode at ±1 m (from –1,500 m to +9,000 m)
- Low consumption (5 mA or 50 nA in standby mode)
- Thermometer and clock
- Output data to PC COM port at 9,600 bits/s

In this application, the PIC micro is pushed to the limits because measuring pressure, and especially altitude, means a large number of operations, some of which are 'floating point' maths.
Before moving on to the practical side of this superb project, we need to ponder a minimum of theory.

Pressure and the weather

You may have an old aneroid barometer in your home that you may still tap with your finger to make the needle move. The mechanical instrument gives you the approximate pressure and the 'tendency'. The 'weather glass' as sailors of old called it, is not infallible, but generally when the pressure reaches 1,020 mbar (note that 1 mbar = 1 hPa, the latter being the official SI unit) it is often a synonym for high pressure and therefore clear skies. Inversely, below 1,010 mbar, a strong chance exists that there will be a depression and, at 960 mbar, everyone should run for cover!

What meteorologists monitor most is the **tendency**, or the variation in pressure over the last few hours as that is by far the best indicator of the coming weather. In general, they will employ the dP/dt rates (difference in pressure by time interval) as shown in **Table 1**. This is why our circuit retraces, on the right side of the screen, pressure trend over the last four hours — equal to one horizontal bar every 30 minutes (1 bar on the display represents 0.8 mbar).

Table 1. How to become a great weather forecaster

dP/dt >2.5 mbar/h	Clear unstable weather
+0.5 <dP/dt <+2.5 mbar/h	Clear stable weather (high pressure)
–0.5 <dP/dt <+0.5 mbar/h	No change
–2.5 <dP/dt <–0.5 mbar/h	Bad weather, continuous rain
dP/dt <–2.5 mbar/h	Danger! Highly unstable atmosphere

And altitude?

Air pressure at any given location may be seen as the weight of a column of air above a given location. The pressure is therefore directly linked to the altitude, the higher up, the more the pressure decreases, and of course the other way around. Unfortunately, the relationship which links these two measurements (ft/hPa) is not linear (see the graph in **Figure 1**). Even though the French may have had a big influence on initial progress in aeronautics, we still use feet (ft) in the world of aviation. Only the Russians persistently use altimeters calibrated in metres.

The graph includes a function (x ^ y) that forces us to perform scientific calculations using floating point operations (especially EXP and LOG functions).

ALT = (288.15/0.0065) * (1– (PRESS / 1013.25) ^ 0.19)

which is equal to:

ALT = (288.15/0.0065) * (1 – EXP (0.19 * LOG (PRESS / 1013.25)))

In altimeter mode, the software applies this formula to each absolute pressure measurement in order to recalculate the altitude of the location. But, then, you say, if a cloud passes, will the pressure change, and with it the altitude? This confirms the need to

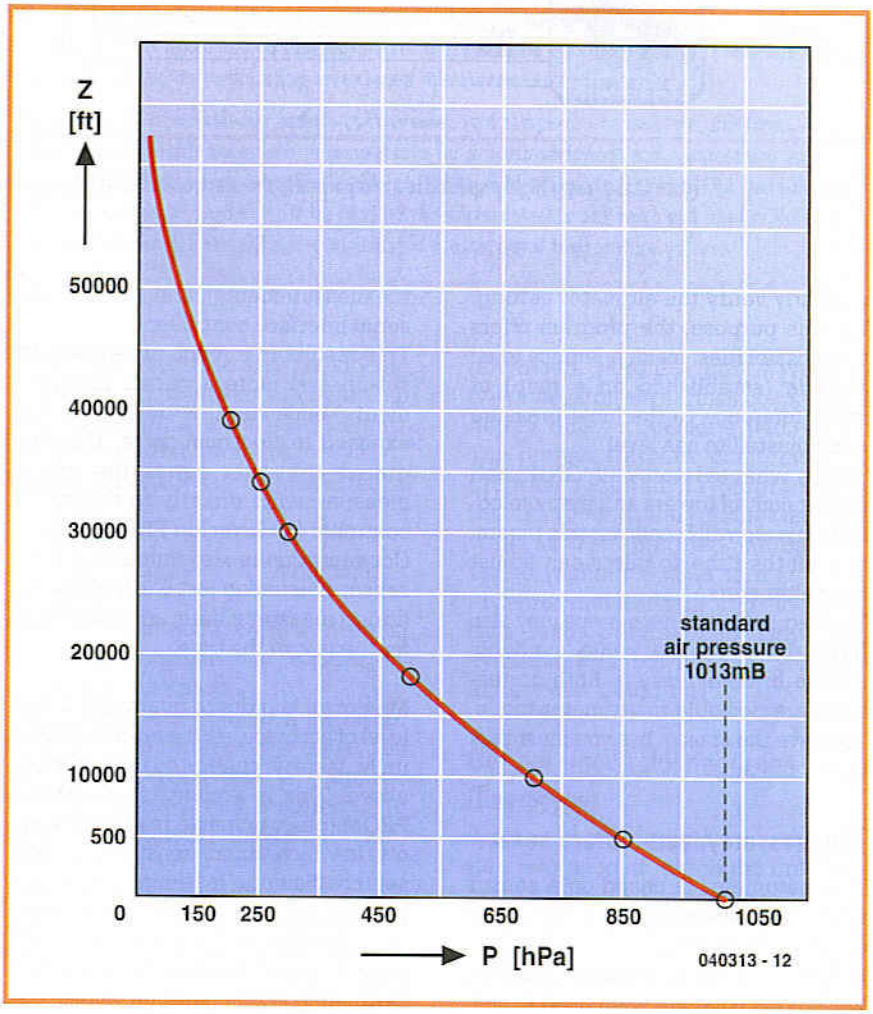


Figure 1. Although the curvature is slight, the relation between pressure and altitude is actually a hyperbolic curve.

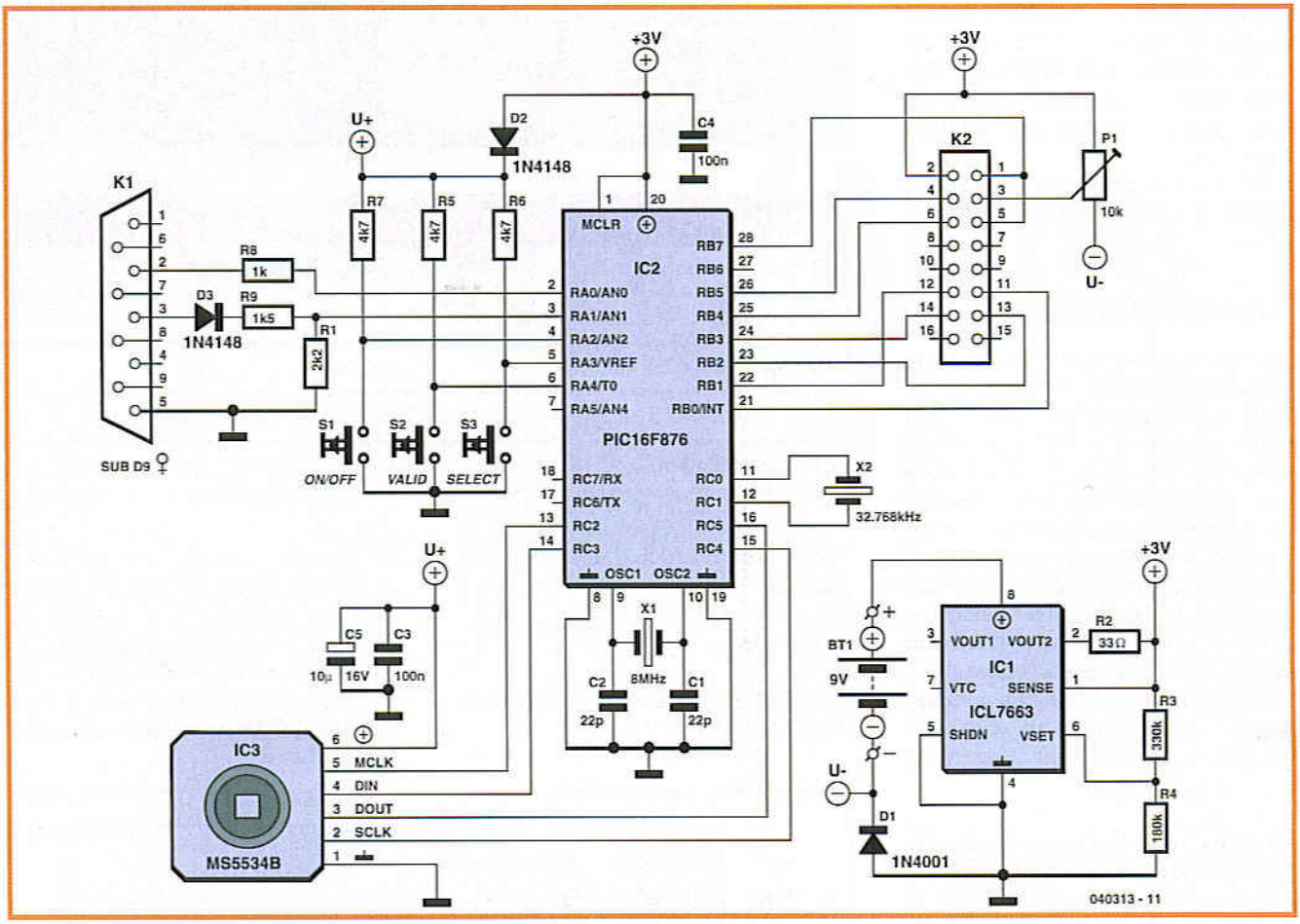


Figure 2. By using highly specialised components, the electronics for the barometer/altimeter remains uncluttered.

regularly verify the altimeter setting. For this purpose, the program offers two possibilities: make reference to an altitude (established on a map) or make reference to the local pressure and adjusted to sea level.

This is what aviators call 'QNH', and airport control towers and meteorological services will broadcast this parameter all the time so pilots can adjust their altimeters.

Your regional weather service may also have the reference value available (online in many cases). Both corrections are possible in altimeter mode. You have the choice, but you must pick one or the other.

The pressure/temperature sensor

This barometer is based on a sensor type MS5534 designed by the Swiss company Intersema.

It offers a level of integration that's well above what we were used to see. In fact, it includes, in one module, a piezo-resistive pressure sensor, an ADC with 15 bit resolution (to perform the measurements), and also a 3-wire serial interface controller.

This results in a much more compact set-up and more accurate measurements because the device is less exposed to electrical noise. The integrated converter sends the digital measurements directly to the microcontroller (a Microchip PIC16F876).

Consumption is also much lower, the sensor consuming just 5 mA maximum during measurements, and only 50 nA for the rest of the time.

Moreover, in order to guarantee a high level of accuracy, each sensor is individually factory calibrated and personalised. This is accomplished using a PROM (programmable read only memory) in which various sensitivity and offset coefficients in temperature and pressure are programmed. These values will be different for each sensor, and must be reread by the software before calculating actual pressure values.

The drawback of the sensor is in the complexity of the associated software and in particular the number of operations required, but you may rest assured that the PIC is very capable.

The microcontroller

With 8 kBytes of flash memory, simplicity of use, and also its excellent reputation, the PIC16F876 has demonstrated that it is perfect for this circuit.

The program object code, which is rather large, easily reaches 4 kBytes of memory (floating point calculation procedures are mainly responsible for that).

This controller also has a special 'clock' timer, and a very useful standby mode, so we can still have a watch function without consuming too much current (50 nA).

We shall also use a second timer to generate the clock of the pressure sensor, and the numerous connections offered by three input/output ports will come in handy.

(**Please note:** there are slight differences between the PIC16F876 and the 16F876A, as well as the programming procedures for their Flash memory. The program supplied is compatible with

both chips but your PIC programmer will need to be compatible as well!)

Circuit diagram

As already mentioned, the microcontroller, IC2, a PIC16F876 occupies the central position in the circuit diagram (**Figure 2**). The clock is driven by quartz crystal X1 ticking at 8 MHz, which makes for sufficiently fast operation, even in altimeter mode. Timer 1 is configured to use its own external oscillator built around X2 (32.768 kHz). The quartz accuracy determines the clock accuracy. A ±20 ppm (20/1,000,000) crystal will cause a typical error of ±1.7 seconds per day.
K1, with only 3 contacts utilized, RxD (2), TxD (3) and Ground (GND, 5), is used to connect the circuit to the PC's serial port (COM) in order to transfer data.

The LC display is a low-power model controlled directly by the microcontroller connected to it on connector K2. If you run into problems with contrast adjustments, try to experiment a little with potentiometer P1.
Regulator IC1, an ICL7663 from Maxim, was also selected for its low consumption (5 µA without load and 4 mA during normal usage). It is also used to obtain an adjustable voltage, economically, with the divider bridge formed by R3 and R4.

The MS5534

The MS5534B is a SMD-hybrid device including a piezo-resistive pressure sensor and an ADC-Interface IC. It provides a 16 Bit data word from a pressure- and temperature-dependent voltage. The module contains 6 readable coefficients for a highly accurate software calibration of the sensor. MS5534B is a low-power, low-voltage device with automatic power down (ON/OFF) switching. A 3-wire interface is used for all communications with a microcontroller. Sensor packaging options are plastic or metal cap.

Compared to the previous version A the temperature range has been improved (–40 to +125 degrees C) as well as the pressure range (measurement down to 10 mbar). Other improvements concern the ESD sensitivity, current consumption and converter accuracy.

The MS5534 consists of a piezo-resistive sensor interface IC. The main function of the MS5534 is to convert the uncompensated analogue output voltage from the piezo-resistive pressure sensor to a 16-bit digital value, as well as providing a 16-bit digital value for the temperature of the sensor (measured pressure, 16 bit = D1, measured temperature, 16 bit = D2).

As the output voltage of a pressures sensor is strongly dependent on temperature and process tolerances, it is necessary to compensate for these effects. This compensation procedure must be performed by software using an external microcontroller.

Every module is individually factory calibrated at two temperatures and two pressures. As a result, 6 coefficients necessary to compensate for process variations and temperature variations are calculated and stored in the 64-bit PROM of each module. These 64-Bit (partitioned into four words of 16-Bit) must be read by the microcontroller software and used in the program converting D1 and D2 into compensated pressure and temperature values.

The software

The first part of the program is the readout of the data supplied by sensor MS5534.
The relevant program code responds to several commands used to access different registers and to launch pressure and temperature measurements. It all has to be done in a specific order. Calibration constants C1 to C6 are first read and stored in RAM, then come the pressure and temperature measurements, and finally, the pressure is calculated in tenths of millibars.
Knowing the exact temperature makes it possible to compensate for the various errors (sensitivity, delay) linked to it. That is the purpose of correction constants C1 to C6, which are measured and stored in each sensor in the factory.
At this point the calculations are performed on 16-bit integers.
The biggest part is the altitude calculation, performed entirely in floating point calculations.

The decimal notation used (Microchip 24-bit format), represents numbers up to $\pm 6.8 * 10^{e}38$, as compared to 'just' ±32768 for a 16-bit integer.
Each number x is then represented in the form:

x = sign * mantissa * 2^exponent.

That is the same principle as decimal scientific notation but completely transposed into base-2.
The exponent is of type 2^n rather than 10^n (n stored in 7 bits). The mantissa represents a number between 1 and 2, and is stored in 16 bits in the following manner:

mantissa = 1 + 2/b0 + 2/b3 ... + 2/b15, where b0, b3 and b15 are the bits with the value of 1 within the mantissa.
The software produced by the author for this project is available in the usual ways, that is, either as a free download from our website (www.elektor-electronics.co.uk) or on floppy disk, order code **040313-11.** The project software comprises the program required for programming the microcontroller (fichier.hex) as well as the program altibar.exe. Those without access to a suitable PIC programmer will care to know that ready-programmed chips are available from our Readers Services under order **040313-41**.

Get out your soldering irons (fine-tipped)

Before actually attempting construction, we need to highlight the celebrated pressure sensor MS5534. It is the most delicate part of this circuit, both at the design stage and in the soldering job.

This is a relatively fragile miniaturized component; it should be stored in dry

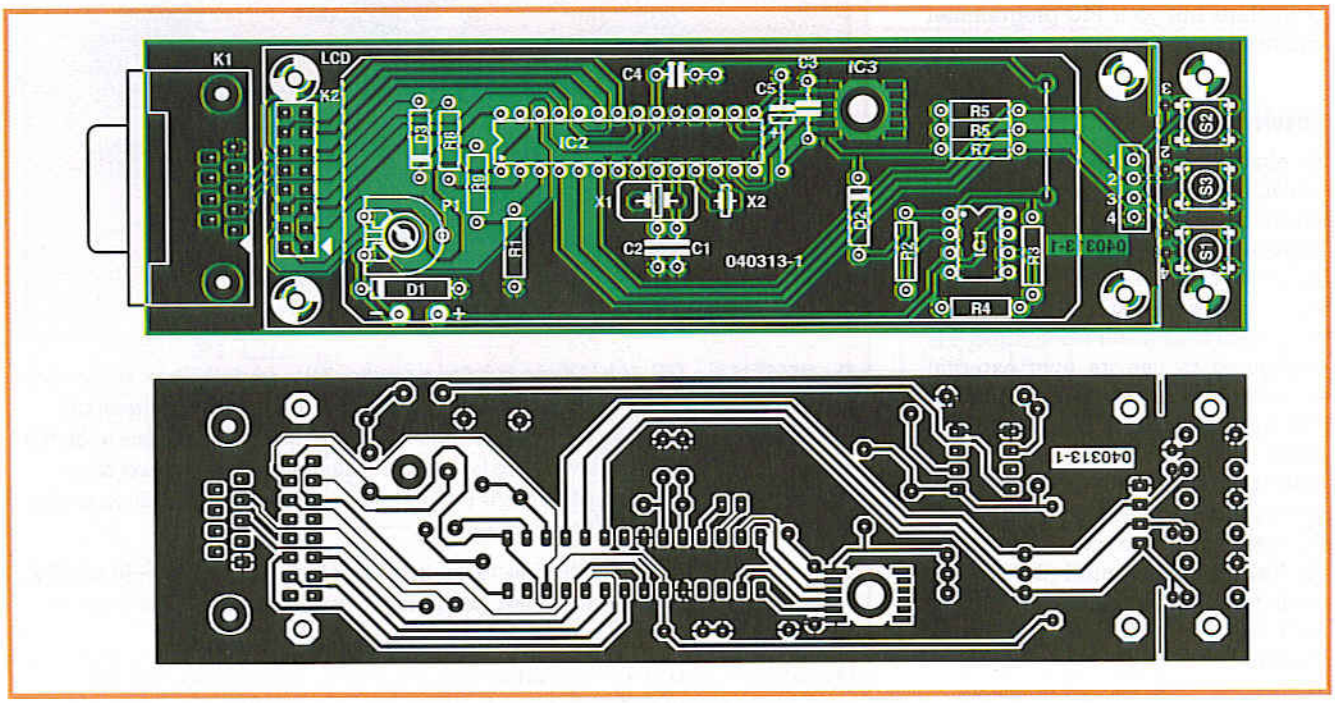


Figure 3. Copper track layout and component mounting plan of the PCB designed for the project.

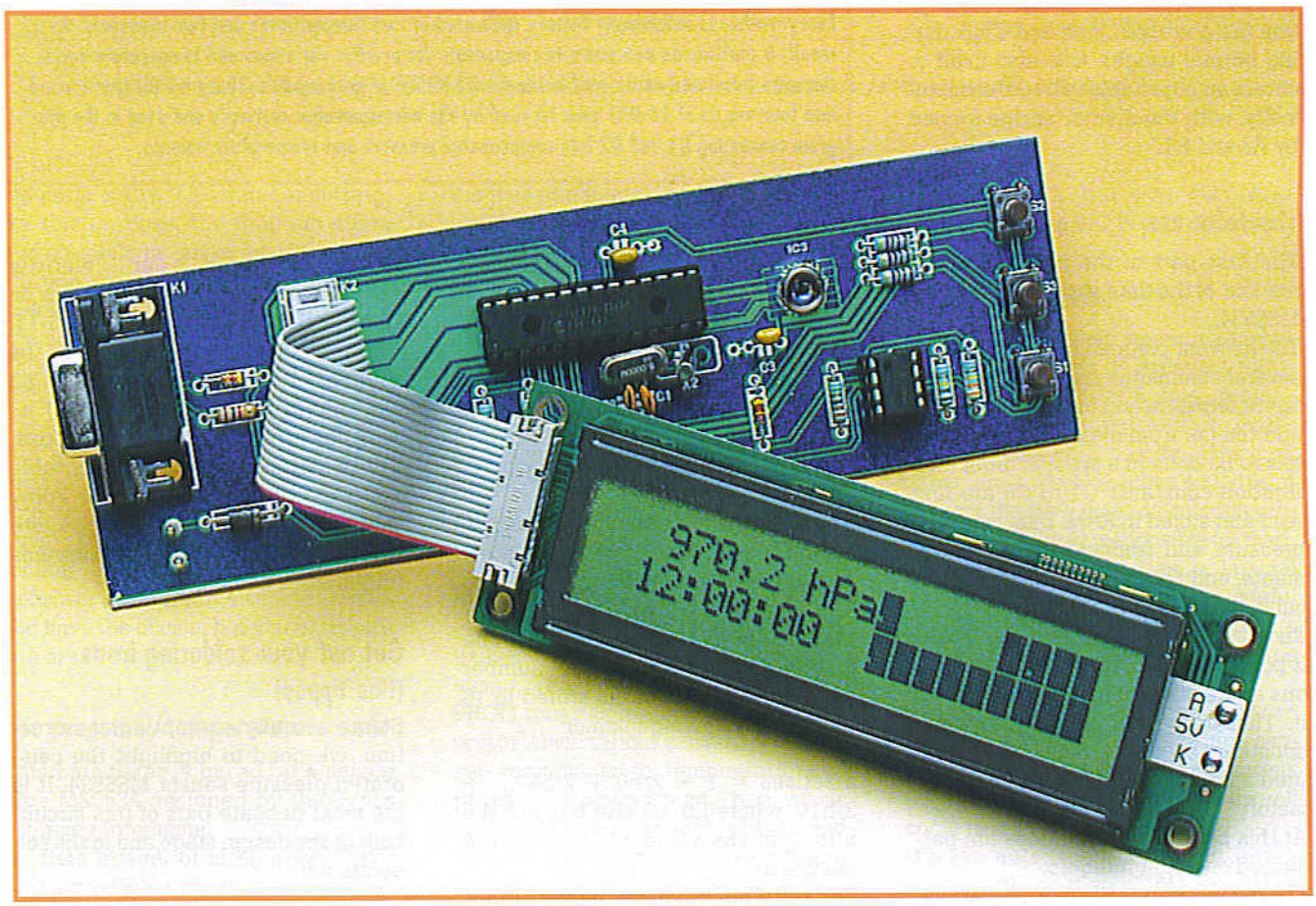


Figure 4. Finished prototype of the barometer/altimeter.

conditions, away from direct sunlight. The manufacturer recommends using a 2% silver soldering paste (Sn62Pb36Ag2), which will guarantee longevity and stability of the connections (this is confirmed by the author, and with his experience, we had better listen).

First you will need a very fine-tipped soldering iron which can heat up to about 225 °C. Begin by making an 8-mm diameter hole, through which the sensor body is slipped in from the PCB underside. Next, cover the corresponding 6 connections on the printed circuit with the silver soldering paste.

Insert the sensor in the prepared opening, being careful that it is perfectly flush with the PCB surface and that its legs are accurately positioned on the solder pads. Then solder as accurately and quickly as possible. Even if it all seems to go well, do not hesitate to verify each connection under a magnifying glass.

PCB and case construction

The printed circuit board (**Figure 3**) was designed single-sided and should not cause any special problems. The component layout is shown in the same illustration. It is possible to cut off the PCB section holding the pushbuttons to enable these to be mounted at the same level as the display. This may simplify 'boxing up' the project. The mini keyboard is then linked to the circuit by way of a special connector. Obviously you need to cut off the relevant board section before fitting the parts.

Socket K2 conveys data lines DB0 to DB3, RS and EN, to enable the PIC to drive the LCD display. The LCD is configured in 4 bit parallel mode to minimize the number of wires.
Mounting the components should not present problems once the sensor is installed. The integrated circuits may be mounted in (good quality) sockets. The only thing left is to make sure that the right polarity of the three diodes and integrated circuits is observed.

Once the circuit is finished and tested, apply a drop of adhesive on each of the four corners of the sensor to make sure the device remains securely in place. The assembled PCB is then placed in its box, in which a window is cut out so that the display is visible.

Instructions for use

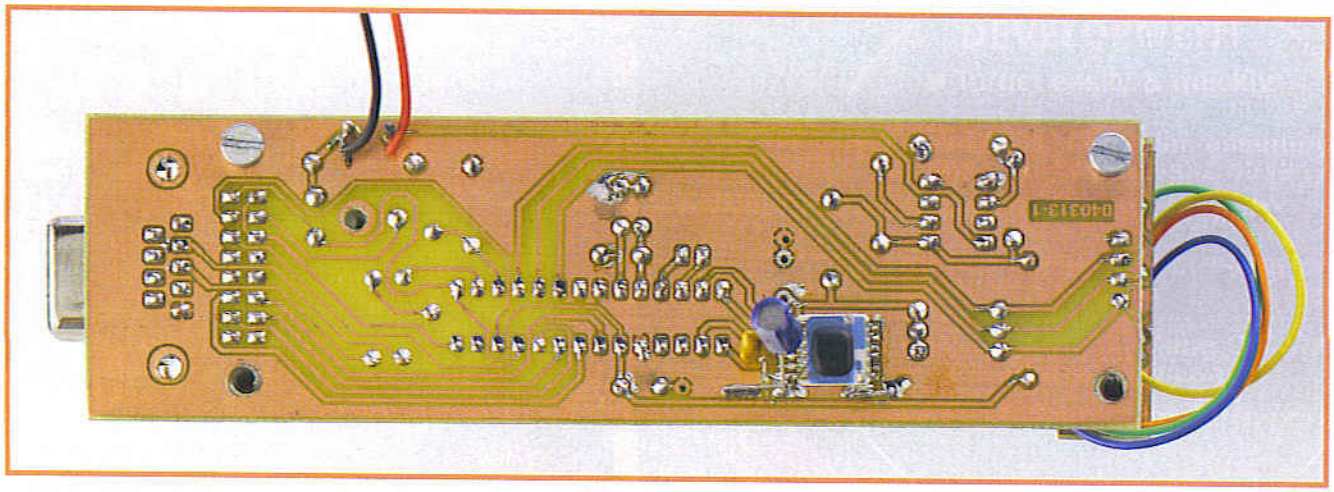
During normal use, the VALID button is used to switch from one mode to another:

Barometer
displays absolute pressure, time, and the trend in barograph form;

Altimeter
displays corrected altitude, time, and altitude variation;

Level meter
displays the difference in level in relation to zero level that was set, the time, and rise/fall variation.

In all cases, one of the barograph columns corresponds to one hour.



COMPONENTS LIST

Resistors:
R1 = 2kΩ2
R2 = 33 Ω
R3 = 330kΩ
R4 = 180kΩ
R5,R6,R7 = 4kΩ7
R8 = 1kΩ
R9 = 1kΩ5
P1 = 10kΩ

Capacitors:
C1, C2 = 22pF
C3,C4 = 100nF

Semiconductors:
D1 = 1N4001
D2,D3 = 1N4148
IC1 = ICL7663
IC2 = PIC16F876, programmed, order code 0**40313-41**)
IC3 = MS5534 (Intersema)

Miscellaneous:
K1 = 9-way sub-D socket (female), PCB mount, angled pins
K2 = HE-10 connector, 2 rows of 8 contacts
S1,S2,S3 = pushbutton DTS63N
X1 = 8MHz quartz crystal, miniature case
X2 = 32.768kHz quartz crystal
LCD, 2x206 characters, e.g., Vikay 2220
28-way IC socket
PCB, ref, **040313-1** from The PCBShop
Disk, project software, order code **040313-11** or free download

About the author

After receiving his BTS degree in Electronics and a few years of various professional experience, the author, G. Samblancat, returned to Computer Science studies at night. He currently divides his time between his physics lab, and the study of microcontrollers and DSP-based applications. He has had several circuits published in electronic journals, including Elektor Electronics (see a certain anemometer) and informed us that he is tempted to devote himself completely to electronics design activities.

The adjustments for:

– time in barometer mode,
– reference altitude (either the official pressure at 0 m, or true altitude) in altimeter mode or
– zero in level differential mode

are accessible by pressing VALID and SELECT for 1 second.

The SELECT button is used to modify the selection (Yes/No), or to increment the value during adjustment.
The VALID button is used to record the value. Attention: cancelling is not possible.

The ON/OFF button switches the PIC to standby and turns off the display, whereupon power consumption drops from 4 mA to 50 nA or so.

It is also possible to send pressure or altitude readings to a PC by using the Com port set to 9,600 baud. In this case, use the following syntax:
$ P press , where press is the *10 pressure in binary on 2 bytes (16 bits)
$ A altit, where altit is the altitude in meters and in binary on 2 bytes (16 bits)
$ D deniv, where deniv is the level differential in metres and in binary on 2 bytes (16 bits).

The author also proposes a small utility called **altibar.exe**, allowing you to display, as if by magic, temperature and atmospheric pressure data on the screen of your PC (refer to **Figure 5**).

Possible improvements

It can be argued that a graphical display should have been used from the start, but the tested model proved to be difficult to fine-tune and the display zone was really small. Too bad, otherwise we would have had room to draw little clouds or a big sun on the display. Over to the electronics specialists out there... the author is listening.

(040313-1)

Interesting links

Technical documents on the PIC:
www.microchip.com
Datasheet for the PIC16F876:
http://ww1.microchip.com/downloads/en/DeviceDoc/39582b.pdf
Pressure sensor manufacturer:
www.intersema.ch
Datasheet for the ICL7663 (copier quality!): http://pdfserv.maxim-ic.com/en/ds/ICL7663.pdf
Everything you ever wanted to know on the millibar:
www.convert-me.com/en/convert/units/pressure/pressure.millibar.en.html

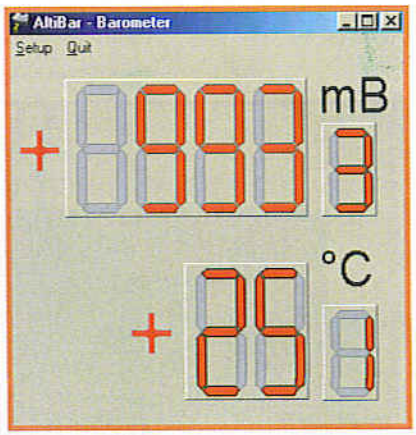
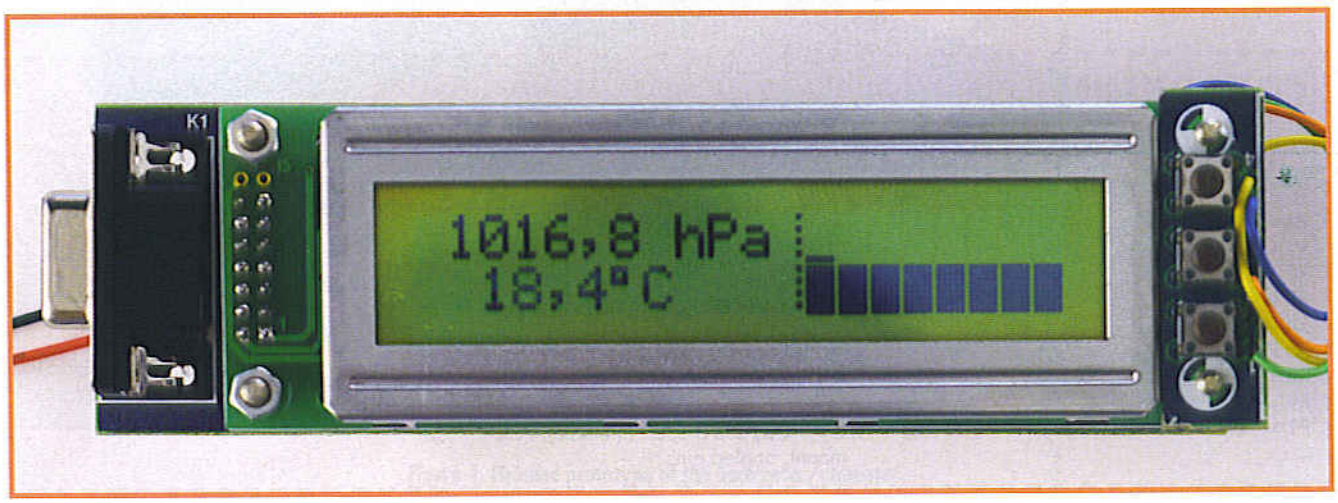


Figure 5. Screenshot showing the optional 'altibar' utility in action.



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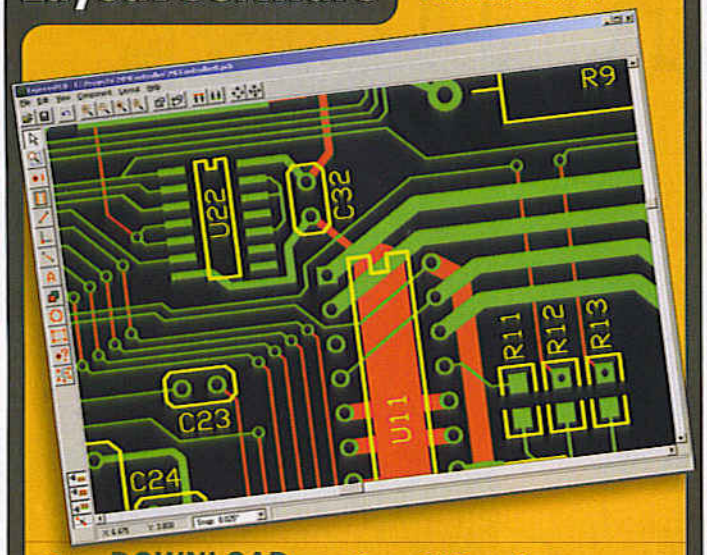

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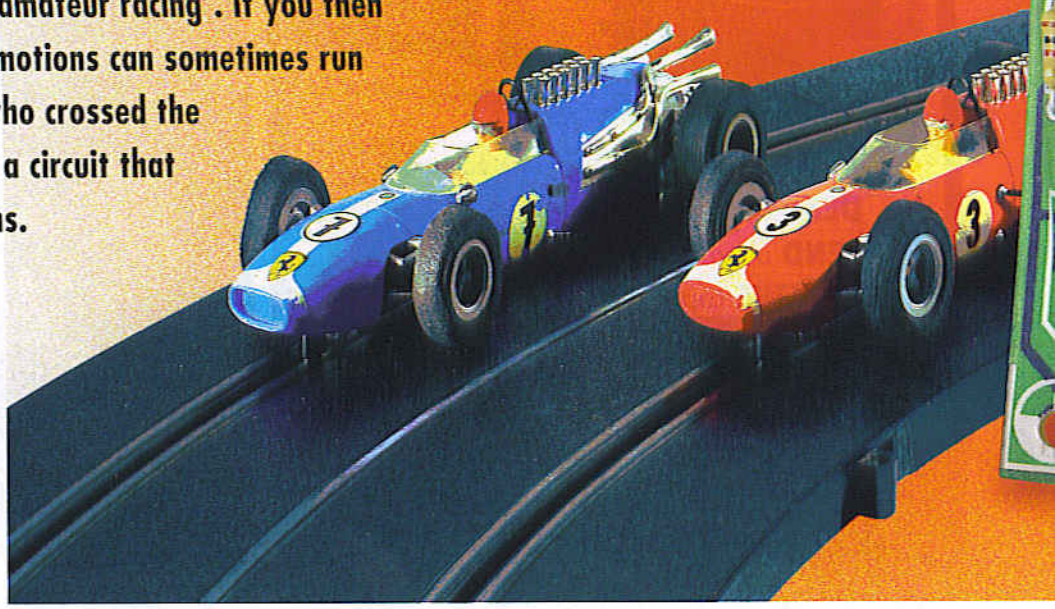
RACETRACK TIMER

Nico van Rooijen

A model racetrack is a nice toy for boys. Even the 'big' boys like to race a little every once in a while. Of course, it is no longer considered 'playing', but 'amateur racing'. If you then invite a friend for a match, the emotions can sometimes run high when it comes to deciding who crossed the finish line first. Here we present a circuit that can help you out in such situations.



fastest? It is often the case that the difference is easy to spot, but every now and then the front-runners are neck to neck and the winning margin is so small that it is a 'photo finish'. Installing a complete system of photo finish equipment on your model racetrack is a possibility, of course, but that is possibly going just a little too far. A little less involved, but just as accurate, is the following design.

The circuit is, because of the use of a microcontroller, of quite a simple design. The microcontroller makes is possible to measure time very accurately and make the timing independent from (a program running on) a PC. Because of the independence from a PC it is relatively easy to obtain an accuracy of 1/1000th of a second. In a PC there are a number of timers all running at the same time (such as system timer, USB timer, interrupts, etc.) which means that the accuracy can vary significantly. However, this does not matter to us now.

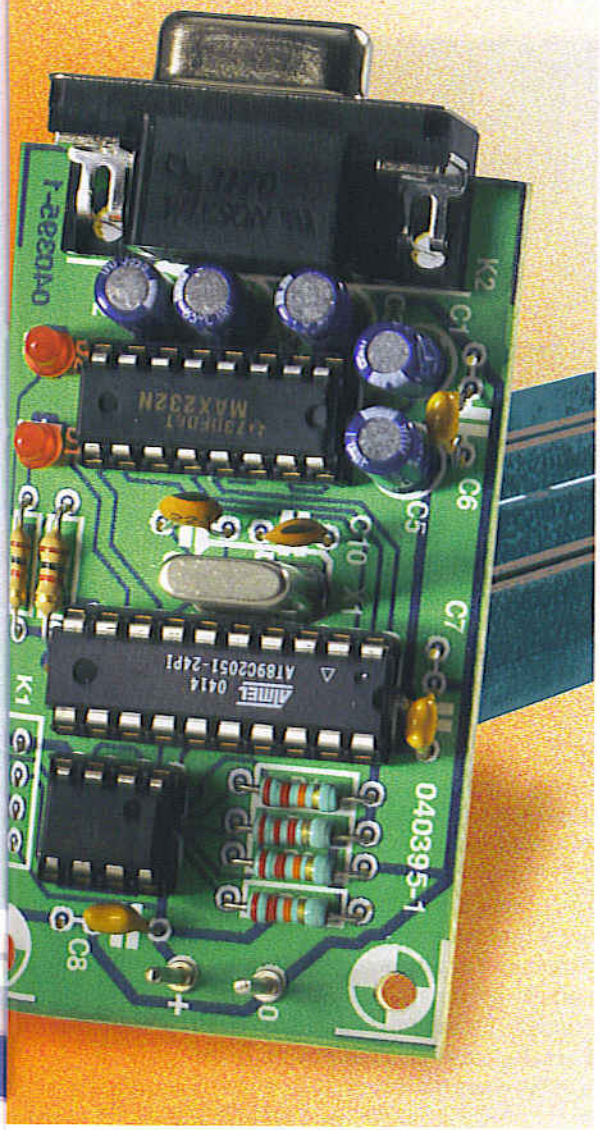
Hardware

Figure 1 shows the schematic of the hardware. D3 and D4 are infrared LEDs. These need to be mounted above the racetrack. Photo diodes D5 and D6 need to be mounted in the racetrack exactly opposite the LEDs so that they are in the best position to 'see' the light from the LEDs (also refer to Figure 5). When a car passes by, the photo diode is (briefly) shielded from the light emitted by the LED. This causes a change in current through the diode and the passing of the car is then detected by IC3. This dual opamp is configured as a comparator to compare the voltage across the photo diodes with a previously set voltage (R3/R6).
The microcontroller is a type 89C2051 and is clocked with X1 at 12 MHz. This is a high enough speed to accurately measure lap times down to 1/1000th of a second. The program running in the microcontroller sends the lap times in ASCII to the PC. To connect the microcontroller to the PC we use a well-known chip from Maxim, the MAX232. Diodes D1 and D2 give a visual indication when a passing car has been detected.

Practical realisation

Figure 2 shows the PCB layout for the circuit. The construction will take very little effort and there is also very little to go wrong. Make sure you do not forget the wire link under IC1. It is best to fit the (programmed) microcontroller in a socket. The female sub-D connecter is soldered directly on the PCB.
The positioning of the LEDs and photo diodes on the track has already been discussed. Note that resistor R7 is not on the PCB, but is soldered in series with the LEDs.

for the fast boys



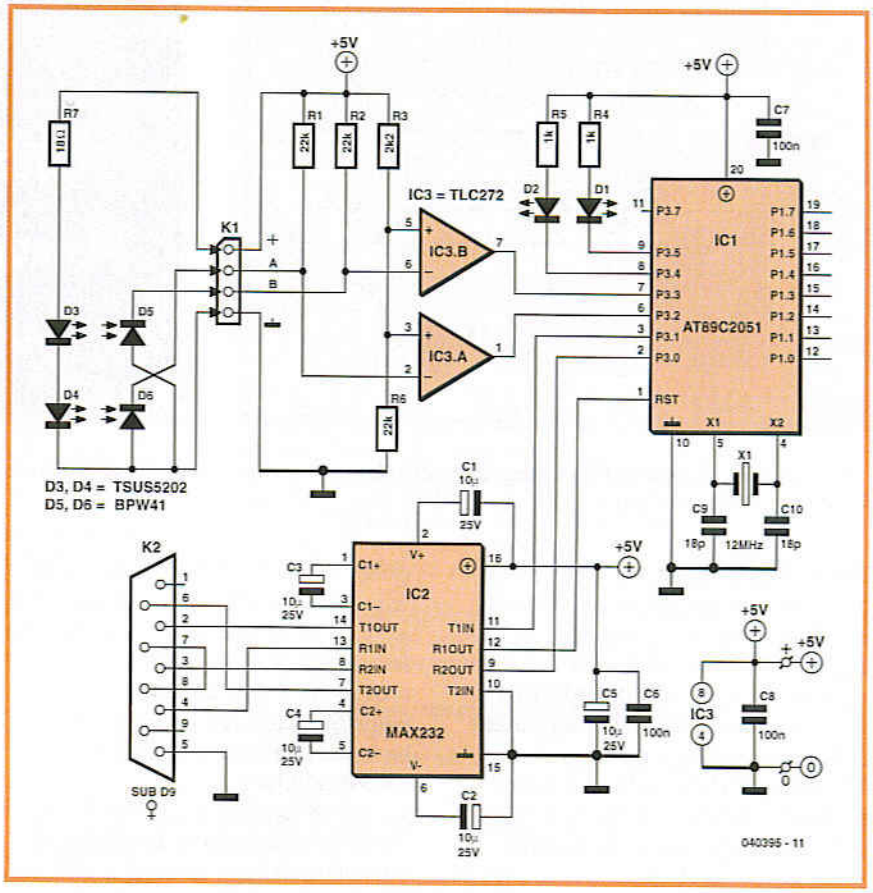


Figure 1. The circuit diagram of the racetrack timer.

COMPONENTS LIST

Resistors:
R1,R2,R6 = 22kΩ
R3 = 2kΩ2
R4,R5 = 1kΩ
R7 = 18Ω

Capacitors:
C1-C5 = 10µF 25V radial
C6,C7,C8,C11 = 100nF
C9,C10 = 22pF

Semiconductors:
D1,D2 = LED, low current, 3mm
D3,D4 = IR LED, e.g., TSUS5202
D5,D6 = IR PIN photodiode, e.g., BPW41
IC1 = AT89C2051-24PI, programmed, Publishers order code **040395-41**
IC2 = MAX232
IC3 = TLC272

Miscellaneous:
K1 = 4-way SIL connector
K2 = 9-way angled sub-D socket, (female), PCB mount
X1 = 12MHz quartz crystal
PCB, ref. 040395-1 from The PCBShop (see www.elektor-electronics.co.uk)
CD-ROM, project software, Publishers order code **040395-81** or free Download.

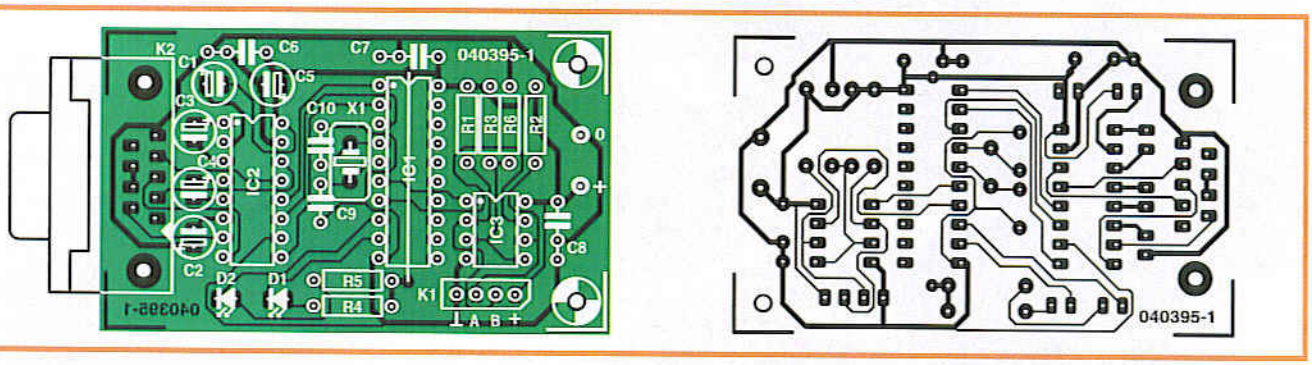


Figure 2. The PCB layout for the circuit. The RS232 connector is mounted directly on the PCB. Remember the wire link under IC1 when building!

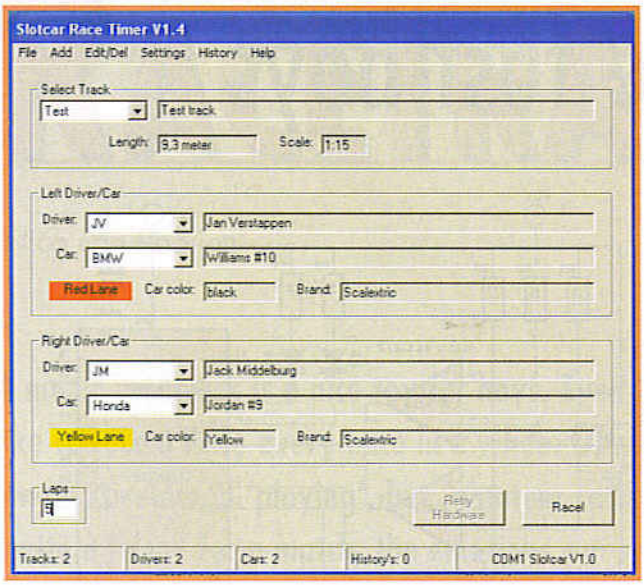


Figure 3. Overview of the settings in the PC software.

Figure 4. The program for the lap time and lap count in operation.

For the power supply a simple regulated adapter that delivers 5 V will suffice. The current consumption of the ICs is quite small, about 20 mA. The current through the infrared LEDs is the lion's share of the required current (>100 mA).

The connection with the PC is via a standard, straight through, 1:1 RS232 cable; i.e., **not** a null-modem cable.

Software

There are two separate pieces of software for this project: the software in the microcontroller and the software on the PC. The microcontroller that is available from us is already programmed, but for those among you who would like to program your own or would like to know more about it can download the source code free of charge from the *Elektor Electronics* website. The software for the PC can be found there too, look for file number **040395-11.zip**.

All the software is also available on a CD-ROM with order code **040395-81**.

The PC software is well organised (refer **Figure 3**). Besides selecting the track, it is also possible to select the drivers. You can also indicate the cars that are being raced and which colours they have. In order to be able to choose between different tracks, drivers and cars there first have to be different tracks, drivers and cars. These you can create yourself via the menu 'Edit/Add'. At bottom left you need to indicate how many laps you will race. The 'Race!' button leads to a screen-size overview, which displays the most important information (refer **Figure 4**). At the end of the race this nicely displays all the details and announces the winner. This information can be saved to make other calculations or, or be used to tease your opponent.

Finally: we wish you a lot of fun building the circuit. And then much fun racing, of course, because that's what started it all!

(040395-1)

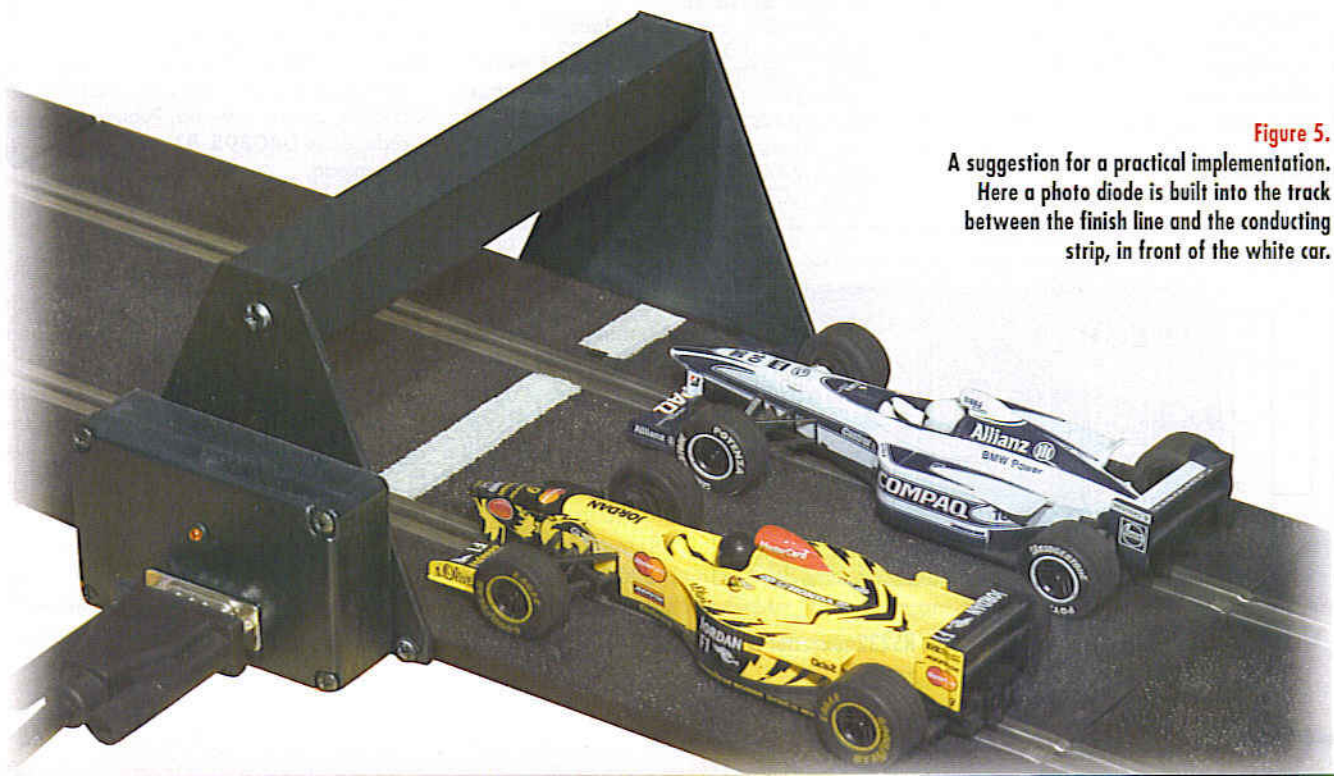


Figure 5.
A suggestion for a practical implementation. Here a photo diode is built into the track between the finish line and the conducting strip, in front of the white car.

In all mains-operated equipment certain important safety requirements must be met. The relevant standard for most sound equipment is Safety of Information Technology Equipment, including Electrical Business Equipment (European Harmonized British Standard BS EN 60950:1992). Electrical safety under this standard relates to protection from

- a hazardous voltage, that is, a voltage greater than 42.4 V peak or 60 V d.c.;
- a hazardous energy level, which is defined as a stored energy level of 20 Joules or more or an available continuous power level of 240 VA or more at a potential of 2 V or more;
- a single insulation fault which would cause a conductive part to become hazardous;
- the source of a hazardous voltage or energy level from primary power;
- secondary power (derived from internal circuitry which is supplied and isolated from any power source, including d.c.)

Protection against electric shock is achieved by two classes of equipment.

Class I equipment uses basic insulation ; its conductive parts, which may become hazardous if this insulation fails, must be connected to the supply protective earth.

Class II equipment uses double or reinforced insulation for use where there is no provision for supply protective earth (rare in electronics – mainly applicable to power tools).

The use of a a Class II insulated transformer is preferred, but note that when this is fitted in a Class I equipment, this does not, by itself, confer Class II status on the equipment.

Electrically conductive enclosures that are used to isolate and protect a hazardous supply voltage or energy level from user access must be protectively earthed regardless of whether the mains transformer is Class I or Class II.

Always keep the distance between mains-carrying parts and other parts as large as possible, but never less than required.

If at all possible, use an approved mains entry with integrated fuse holder and on/off switch. If this is not available, use a strain relief (Figure, note 2) on the mains cable at the point of entry. In this case, the mains fuse should be placed after the double-pole on/off switch unless it is a Touchproof® type or similar. Close to each and every fuse must be affixed a label stating the fuse rating and type.

The separate on/off switch (Figure, note 4), which is really a 'disconnect device', should be an approved double-pole type (to switch the phase and neutral conductors of a single-phase mains supply). In case of a three-phase supply, all phases and neutral (where used) must be switched simultaneously. A pluggable mains cable may be considered as a disconnect device. In an approved switch, the contact gap in the off position is not smaller than 3 mm.

The on/off switch must be fitted by as short a cable as possible to the mains entry point. All components in the primary transformer circuit, including a separate mains fuse and separate mains filtering components, must be placed in the switched section of the primary circuit. Placing them before the on/off switch will leave them at a hazardous voltage level when the equipment is switched off.

If the equipment uses an open-construction power supply which is not separately protected by an earthed metal screen or insulated enclosure or otherwise guarded, all the conductive parts of the enclosure must be protectively earthed using green/yellow wire (green with a narrow yellow stripe – do not use yellow wire with a green stripe). The earth wire must not be daisy-chained from one part of the enclosure to another. Each conductive part must be protectively earthed by direct and separate wiring to the primary earth point which should be as close as possible to the mains connector or mains cable entry. This ensures that removal of the protective earth from a conductive part does not also remove the protective earth from other conductive parts.

Pay particular attention to the metal spindles of switches and potentiometers: if touchable, these must be protectively earthed. Note, however, that such components fitted with metal spindles and/or levers constructed to the relevant British Standard fully meet all insulation requirements.

The temperature of touchable parts must not be so high as to cause injury or to create a fire risk.

Most risks can be eliminated by the use of correct fuses, a sufficiently firm construction, correct choice and use of insulating materials and adequate cooling through heat sinks and by extractor fans.

The equipment must be sturdy: repeatedly dropping it on to a hard surface from a height of 50 mm must not cause damage. Greater impacts must not loosen the mains transformer, electrolytic capacitors and other important components.

Do not use dubious or flammable materials that emit poisonous gases.

Shorten screws that come too close to other components.

Keep mains-carrying parts and wires well away from ventilation holes, so that an intruding screwdriver or inward falling metal object cannot touch such parts.

As soon as you open an equipment, there are many potential dangers. Most of these can be eliminated by disconnecting the equipment from the mains before the unit is opened. But, since testing requires that it is plugged in again, it is good practice (and safe) to fit a residual current device (RCD)*, rated at not more than 30 mA to the mains system (sometimes it is possible to fit this inside the mains outlet box or multiple socket).

* Sometimes called residual current breaker – RCB – or residual circuit current breaker –RCCB.

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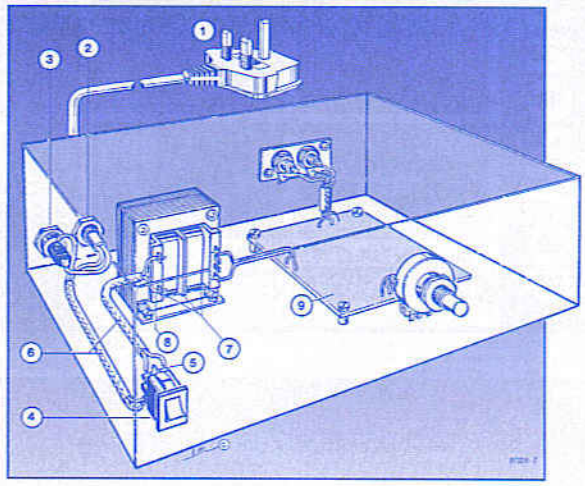

1. *Use a mains cable with moulded-on plug.*
2. *Use a strain relief on the mains cable.*
3. *Affix a label at the outside of the enclosure near the mains entry stating the equipment type, the mains voltage or voltage range, the frequency or frequency range, and the current drain or curent drain range.*
4. *Use an approved double-pole on/off switch, which is effectively the 'disconnect device'.*
5. *Push wires through eyelets before soldering them in place.*
6. *Use insulating sleeves for extra protection.*
7. *The distance between transformer terminals and core and other parts must be ≥ 6 mm.*
8. *Use the correct type, size and current-carrying capacity of cables and wires – see shaded table below.*
9. *A printed-circuit board like all other parts should be well secured. All joints and connections should be well made and soldered neatly so that they are mechanically and electrically sound. Never solder mains-carrying wires directly to the board: use solder tags. The use of crimp-on tags is also good practice.*
10. *Even when a Class II transformer is used, it remains the on/off switch whose function it is to isolate a hazardous voltage (i.e., mains input) from the primary circuit in the equipment. The primary-to-secondary isolation of the transformer does not and can not perform this function.*

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overall cable dia.	**5.6 mm**	**6.9 mm**	**7.5 mm**

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PVC sheath thickness	**0.3 mm**	**0.3 mm**	**0.45 mm**
conductor size	**7/0.2 mm**	**16/0.2 mm**	**24/0.2 mm**
Nom cond area	**0.22 mm²**	**0.5 mm²**	**0.95 mm²**
overall wire dia	**1.2 mm**	**1.6 mm**	**2.05 mm**

3-flat-pin mains plug to BS 1363A

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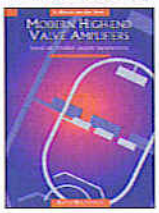

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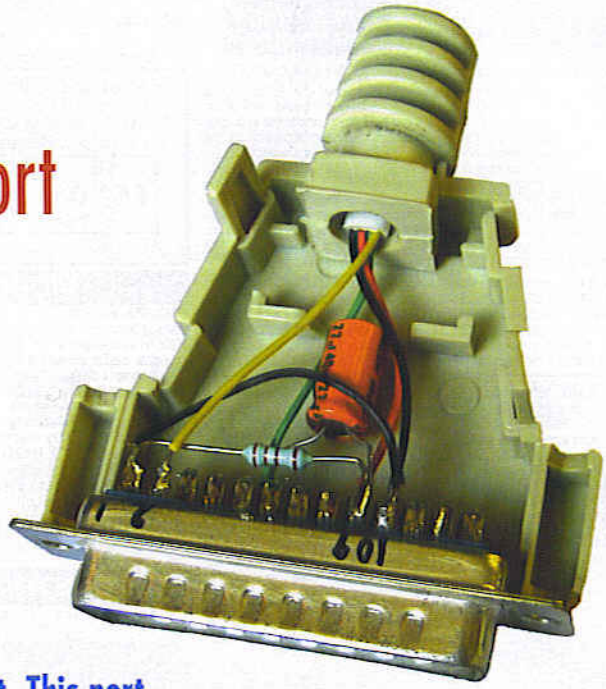
DELPHI FOR ELECTRONIC ENGINEERS

Part 7: I²C via the parallel port

Detlef Overbeek, Anton Vogelaar
and Siegfried Zuhr



In this part we will create an I²C communications channel via the parallel port. This port has been 'misused' for many years in all kinds of applications, but ever since the arrival of the recent versions of Windows it has become more difficult to gain access to the outside world via this route.

In the past it was fairly easy to directly access PC ports, but nowadays this happens via another software layer: a kernel driver in the form of a DLL. There are many of these available, from those that cover only the basics to those that are complete communications DLLs. The disadvantage of these is that the routines in such a DLL are often geared towards a particular task and are only suitable for use with certain circuits. It is also very difficult to gain an insight into the inner workings because the source code is usually not available. That makes it much more difficult when things don't work properly and you have to debug the code.
For these reasons we decided to use an as simple as possible DLL in this article to implement an I²C communications channel via the parallel port. The rest is done in Delphi, keeping everything accessible.
We start with the most important part:

Communications between an I²C chip and the program

The routines are combined in a separate, easily reusable unit, *UI2C.pas*.

Everything is included in this unit for communicating with a DS1621 temperature sensor. The interface has been reduced to only two instructions: the procedure *DS1621_init* to initialise the chip and the function *DS1621_RD* to request a measurement from the chip. The following routines have been implemented in Delphi for the communications:

`I2C_Start`	Procedure to put a start condition onto the bus.
`I2C_Stop`	Procedure to put a stop condition onto the bus.
`I2C_WrAck`	Procedure for the master to put an acknowledge condition onto the bus.
`I2C_WaitAck`	Procedure that reads the acknowledge condition from a slave.
`I2C_WrData`	Procedure that sends 8 data bits via the bus.
`I2C_RdData`	Procedure that reads 8 data bits from the bus.

With the help of these modules and two passive components in a DB25 plug (see **Figure 1**) it becomes possi-

ble to drive an I²C chip, in this case a DS1621 temperature sensor.
First we need to collect some information regarding this I²C IC. This is available from the manufacturer, Maxim. In this instance we need to find out how the chip is addressed on the bus. The I²C protocol works using a 7 bits addressing mode (partially with the new 10 bit addressing mode), where some of the address bits can be configured using a few IC pins. For this IC these are address lines A0, A1, and A2, meaning that a maximum of 8 of these chips can be connected to the same bus.

The datasheet also states the fixed part of the address (1001 binary for the most significant bits), which results in an address of 90_{hex} for writing and 91_{hex} for reading (address lines A0, A1, A2 are zero in this case). Bit 0 of the address is used to select either a write or read operation (for more details refer to the various I²C articles in Elektor Electronics and the datasheet for this IC).

We can use this information to write a routine to initialise the chip: *DS1621_Init*. The following instructions can be found inside this routine (also refer to the timing diagram in the datasheet):

- Initialise the communications using the start condition.
- Call the chip via a write action to its address.
- Wait for a reply. The chip should answer with an ACK if everything worked properly.
- You then tell the chip that you want to access its configuration register.
- This should again be answered with an ACK.
- You then write the information destined for the CNF register.
- When that has been received and processed successfully you should again get an ACK.
- Issue a stop condition to end the communication.

We are now ready to start the measurements:

- Initialise the communications using the start condition.
- Call the chip via a write action to its address.
- Wait for a reply. The chip should answer with an ACK if everything worked properly.
- Write the value EE_{hex} to the chip to instruct it to start the temperature measurements.
- When that has been received and processed successfully you should again get an ACK.
- Issue a stop condition to end the communication.

This completes the initialisation.

We now have to write a routine to read the resulting measurements: *DS1621_RD*.

The following instructions can be found inside this routine (also refer to the timing diagram in the datasheet):

- Initialise the communications using the start condition.
- Call the chip via a write action to its address.
- Wait for a reply. The chip should answer with an ACK if everything worked properly.
- Write the value AA_{hex} to the chip to instruct it to return the last temperature measurement.
- A new start condition should be issued, a repeated start, as shown in the timing diagram.
- This is followed by the address for the chip, modified to indicate that a read action is required. The address therefore becomes 91_{hex}.

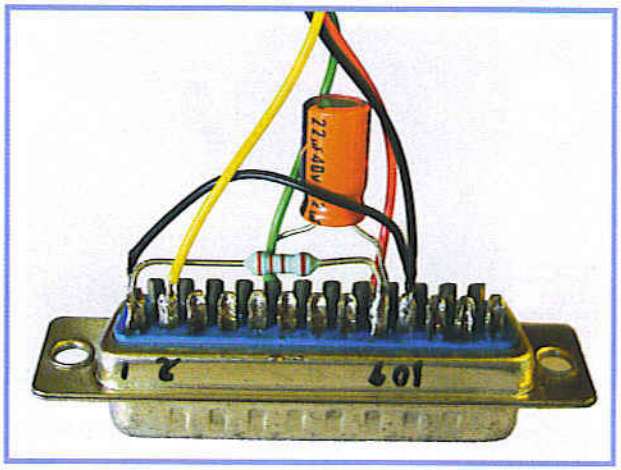


Figure 1. A resistor and electrolytic capacitor are all that's needed to connect the temperature sensor to the Centronics port.

- When this has been successfully received it is answered with an ACK.
- We use *I2C_RdData* to receive a data byte. This is the MSB as stated in the datasheet. This is stored in the variable *Dta* after the received byte has been shifted up by 8 bits, using the instruction Shl 8. This positions the data in the correct place in the variable.
- When this byte has been successfully received and processed we send an ACK using the routine *I2C_ACK (false)*.
- We now use *I2C_RdData* again to receive the second byte, which is the LSB. This is added to the variable *Dta* to give the result.
- When this byte has been successfully received and processed we send a NACK using the routine *I2C_ACK (true)*, followed by an *I2C_Stop* to end the communications.

The instruction *Result := SmallInt(Dta) Div 128* is used to convert the received data into a 16-bit signed integer, where $0000 equals zero degrees and every increment/decrement corresponds to a change of 0.5 degrees.

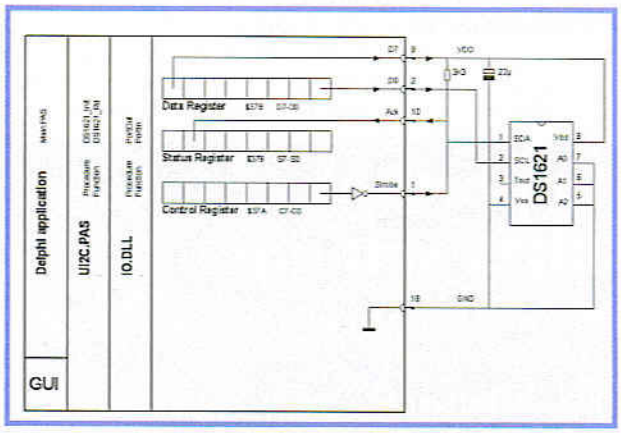


Figure 2. Schematic representation of the sensor and the three port registers.

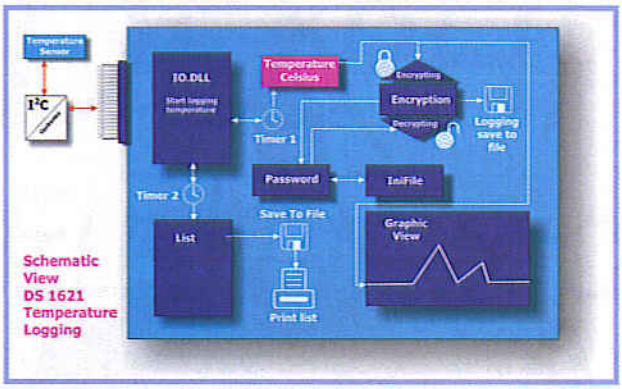


Figure 3. Overview of the operation of the complete program.

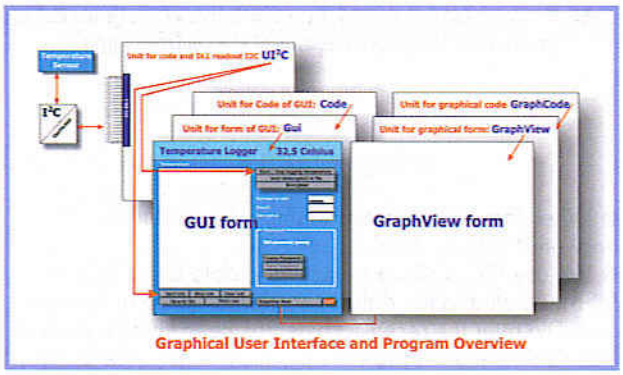


Figure 4. Overview of the units used in this program.

When the Result value needs to be displayed it is first divided by two, so that the 0.5-degree value is shown correctly.
Figure 2 shows how the sensor 'connects' to the registers and the associated modules.

The internal code - in Delphi

We'll now take a closer look at the actual Delphi code used to access the bus.
For writing to the parallel port we use a universal DLL (IO.DLL), which can be found on the Internet (www.geekhideout.com/iodll.shtml). This adds the facility to directly access the individual pins on ports under Windows 2000 and XP, using the routines *PortOut* and *PortIn*.

Important BIOS settings

Before you run the program you first have to check that several BIOS settings are correct:

The parallel port has to be configured to use port address 378_{hex} and use the Standard/Normal mode. If you don't do this then it may be possible that you can't read the sensor properly.

If you look at the procedure *I2C_Start* you'll see how the start condition is composed and output via the port. The start condition is a falling edge on the SDA line while the signal on the SCL line is high. For this we use the PortOut routine to make the SCL line high. A value of 81_{hex} is written to port $378. This value sets bits D0 and D7 of the data register on the Centronics port high. D7 is used to power the circuit and D0 is the SCL line.
We then use PortOut to write the value 00_{hex} to address $37A of the Centronics port, which makes pin 1 (strobe), and hence the SDA line, high. The strobe output has an open collector output and therefore needs an external pull-up resistor to +5 V.

But we also have to take the timings into account: it takes 2.5 µs to put the signal onto the port (depending on the motherboard used). The I²C bus can run at a maximum rate of 100 kHz, which corresponds to a half-period of 5 µs. There is therefore a difference that needs to be catered for by inserting a pause between the signals. This is implemented in the routine Dly5.

We read the de performance counter using the command *QueryPerformanceCounter*. Then we use *QueryPerformanceFrequency* to read the frequency at which the operating system (MS Windows) increments the performance counter. Using these details you can calculate the end value that you have to wait for, for an additional 2.5 µs to elapse. This happens in a loop where the actual value is repeatedly read until it equals the end value.
The start condition is then implemented as follows: we use PortOut to write a value of 01_{hex} to port $37A, making pin 1 (strobe), and hence the SDA line, low while SCL stays high. After a delay we write a value of 80_{hex} to port $378 to make clock line D0 (SCL) low. D7 stays high because it is used for the supply voltage. We finish the routine with a delay, after which the start condition is complete.

The stop condition is created in a similar way, with one difference: this time we need a rising edge on the SDA line while the SCL line stays high.
During communications both the master as well as the slave can transmit an ACK after receipt of a data block. The transmitting device waits for the receiving device to make the SDA line low, while the SCL line is high. This can be seen in the procedures *I2C_WaitACK* and *I2CWrACK*. The latter has been modified slightly so that it can send either an ACK or NACK. This has already been used for the reception of data. For a NACK the SDA line is high during a pulse on the SCL line.

For the sending of data the routine *I2CWr_Data* is used. This takes the parameter X, which contains the data to be sent. This procedure contains a loop that goes through all 8 bits. Before the transmission the byte is compared with a mask to determine whether a '1' or '0' has to be sent. We start with the highest bit, which means we have a value of 80_{hex} for the mask. After sending the first bit, the '1' in the mask is moved one bit to the right before going round the loop again. In this way all bits are checked and transmitted. According to the I²C protocol the data has to be put onto the SDA line, after which the SCL line is take high and then low again. This process can be seen in the code.

The reception of data happens in a similar way. All bits are processed again in a loop. When the SCL line becomes high the SDA line read using *PortIn*. If the

received bit was not a '0' then X is increased by '1' using *Inc(X)*. Before each received bit is processed the value in X is shifted one bit to the left using *Shl 1*, making bit 0 equal to '0' and gradually moving the bits towards their correct position. When all bits have been received the value in X is returned as the result.
All elements are now in place for the writing of the example program that reads and displays the measured values.

Operational overview

To help clarify how the program works, we've included two diagrams. The first diagram (**Figure 3**) gives an overview of the operation of the complete program.
The second diagram (**Figure 4**) shows how all the units fit together, starting with the unit that provides a bidirectional link to the temperature sensor via the Centronics port and the I²Cline. This uses *IO.DLL* to read from and write to the pins of the Centronics port and hence make it possible to obtain the temperature measurements.

Timers and the INI file

In order to include as many examples as possible in the program we have made use of two timers that can be configured independently. You can of course adjust the measurement interval to your own liking.
The first timer takes care of several things at the same time: the temperature display, the provision of a basic signal for use with the encryption and a signal for the graphical display.
The second timer is used to fill a list that can later be printed. There is also a password facility that can be configured independently and which uses an INI file for storage. This INI file is saved externally and is automatically read in when the program is started again.

Temperature logging

The temperature logger window (**Figure 5**) gives you a good idea how the program fits together and what it is capable of. We'll now cover the functionality of the program we're about to create. The program is called 'Temperature Logger' and it does exactly what it says on the tin. The measured values are stored and displayed in various ways. This can be via a list, a graphical representation or a stored log-file. The information can also be printed. All these procedures are standard issues in Delphi.

We create a new application using a GUI *(Graphical User Interface)* form. This is the main form which will hold all of the functionality; all other forms serve this Graphical User Interface. We recommend that you download the complete program (either from www.learningdelphi.info or www.elektor-electronics.co.uk) and examine the code in advance. You should then write the complete program from scratch, as you will learn the most that way.
We have made a special version of the code available for those of you who use Lazarus (a freeware alternative to Delphi), which can obviously be downloaded as well.

Program structure

It is a good idea to look back at Figure 4 again, which gives an overview of all the forms and units used, including their functionality.

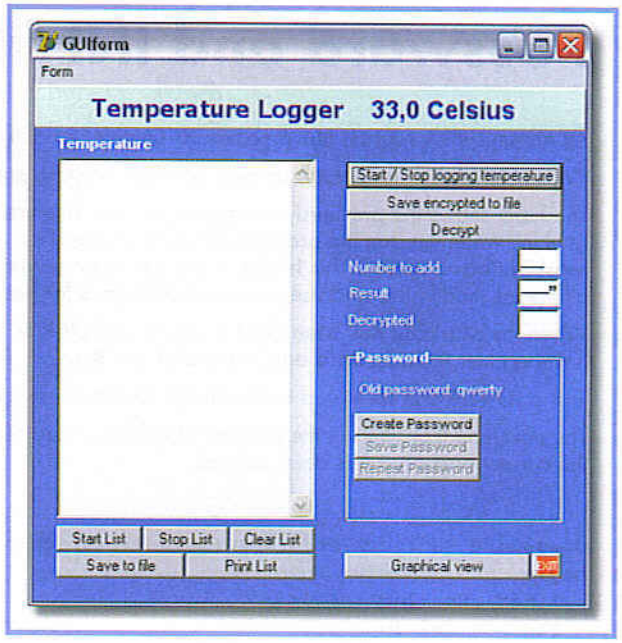


Figure 5. The main window of the temperature logger.

The temperature sensor is connected external to the computer. When you have finished the wiring (as shown in Figure 2), it is advisable not to connect the sensor to the PC straight away. This could cause interference and it is better to wait until the program is finished before connecting the sensor.

The unit *UI2C.pas* is a unit without a form, since it only contains code that interacts with *IO.DLL*. This arrangement makes it easier to see what everything does. It is easy to reuse parts of the general-purpose code in your own programs, so you don't re-invent the wheel every time. We have done this several times ourselves in this application.

The unit *Code.pas* contains the standard code for the GUI form. This consists of the form that becomes visible: the graphical interface *GUIform* and the code-unit *Gui.pas*, which is used by various other objects.
On the right in Figure 4 are three more blocks: again there is a *GraphViewForm* form for the creation of a graphical display during runtime, a unit called *GraphView.pas* that contains only code used by the other objects on the form, and another code-unit *GraphCode.pas*. A unit that has a display output is given the extension *.pas*, the form itself has the extension *.dfm*. This contains a description of all the objects placed on the form (it can be very useful to examine this file; with the right-hand mouse button it can be viewed as a text file). Another file extension is *.dcu* (Delphi Compiled Unit).

The following are put onto the form:

From the System tab:
- 2 Timers

From the Standard tab:
- 3 Buttons of type BitBtn
- 1 Panel
- 7 Labels

Password and INI file

As a bonus this program has a password section that makes use of an INI file.

Place a Groupbox onto the form and add three buttons and a label to it.

The label shows the previously entered password. This has been added to make the functionality clearer, and is obviously blank when you run the program for the first time. First, you need to click on the 'Create password' button, when a MaskEdit box appears. This is where you can enter a name. Digits are not accepted and it should consist of 6 letters. By all means modify this and use your own conditions for passwords.

When the MaskEdit has been filled in you should click on the button 'Save Password'. As is usual in these cases, you have to enter the password again and click on 'Repeat'. This is then confirmed with a click on the 'Confirm' button.

This password can be stored in an INI file, as previously mentioned.

The next time that you run the program it will be aware of the password and it won't perform some of the functions until the correct password has been entered.

```
procedure TGUIform.FormClose(Sender: TObject; var Action: TCloseAction);
begin
  Timer1.Enabled :=False;
  PasswordIni :=
    TIniFile.Create(extractfilepath(application.exename) +'Password.ini');
  // the third item is the variable that holds the actual password
    // end writes it to the ini file
  PasswordIni.WriteString('PASSWORD', 'Password', MyPassWord );
  StringList.free // The stringlist is created by ourselves
  // and is no visible object, so we are responsable for removing it from memory
end;
```

It is of course possible to encrypt this password. An example of how this works is shown in the unit code.pas.

```
Procedure EncryptIncommingSignal;
Begin
```

- 5 Buttons of type Button
- 1 Groupbox
- 1 MainMenu

From the Dialogs tab:

- 1 PrintDialog
- 1 SaveDialog

We place a panel at the top with two labels, one with the name of the program and the other for displaying the temperature. Next to this is timer 1 and on the left is a MainMenu where we can choose for the program to always be on top or displayed normally.
On the top-right are three buttons:

- Start/Stop logging temperature: this starts reading the measurements from the sensor. Pressing it again stops the readings from the chip. The readings are taken via timer 1. It is important to realise that this button has to be operated before the other functions on the form can be used.

- Save encrypted to file: this creates a file that contains the measurements captured over a certain period. You can choose the duration and interval yourself, for example by adjusting the timer interval.

- Decrypt is used to read back the temperature measurements. You can add a number to this yourself. Make sure that you first stop the reading of measurements, otherwise an error message will appear. After inputting the number you can start the measurements again. Next click on 'Decrypt' and you will see the original value. You could try to create your own version of this!
Below the buttons you should place the labels as shown in the example, with a maskedit field and two normal edit fields next to them.

The code

The code for the various sections should be taken from the example project. This contains extensive documentation on the way the program works. On the left side you place a Memo field with a Savedialog. This has a dual purpose. You can use it to store data (in a file) obtained from the sensor (Start/Stop Logging). It is also used to store the Memo in a file, once it contains data. At the bottom are a second timer and a Printdialog. The second timer is used to add the date and time to the temperature and place those details onto the Memo. A printed copy can be made via the PrintDialog. This dialog calls a printer driver that links into Windows. A simple subroutine is used to copy the contents of the memo to a printer canvas, where a hard copy can be created on paper.

At the bottom-right are buttons for Graphical View and Exit. Graphical View calls up another form where the temperature is displayed in a graphical format

```
    // Read out the position of the number:

  X1    := Getal div 100;      // determine hundred
  // The value of x div y is the value of x/y rounded in the direction of zero to the nearest integer
  Remainder  := Getal mod 100; // determine remainder
  // The mod operator returns the remainder obtained by dividing its operands
     // In other words, x mod y = x - (x div y) * y
  X2    := Remainder  div 10; // determine ten
  X3    := Getal mod 10;       // determine remainder

     // turn numbers into ASCII code
  s     := IntToStr(x1);       // Make string
  P     := Pchar(s);           // change string in PChar
  a     := P^;                 // Read PChar = Char
  x1    := Ord(a);             // Obtain ASCII number
    // Returns the ordinal value of an ordinal-type expression
    // X1 is a Delphi ordinal-type expression
    // The result is the ordinal position of X1
    // its type is the smallest standard integer type
    // that can hold all values of X1's type. Ord cannot operate on Int64 values
  s     := IntToStr(x2);       // Make string
  P     := Pchar(s);           // change string in PChar
  b     := P^;                 // Read PChar = Char
  x2    := Ord(b);             // Obtain ASCII number

  s     := IntToStr(x3);       // Make string
  P     := Pchar(s);           // change string in PChar
  c     := P^;                 // Read PChar = Char
  x3    := Ord(c);             // Obtain ASCII number

  S     := Chr(x1+100);
  S     := s + Chr(x2+100);
  S     := s + Chr(x3+100);
End;
```

(**Figure 6**). When you press on the Clear button on this window the display is wiped and the readings continue. Incidentally, the display has been created in almost the same way as for the oscilloscope in the previous article.

And finally, the Exit button stops the program. To prevent the readings from continuing when you stop the program there is an onClose event on the form, which contains a procedure that turns off the timer.

(040240-7)

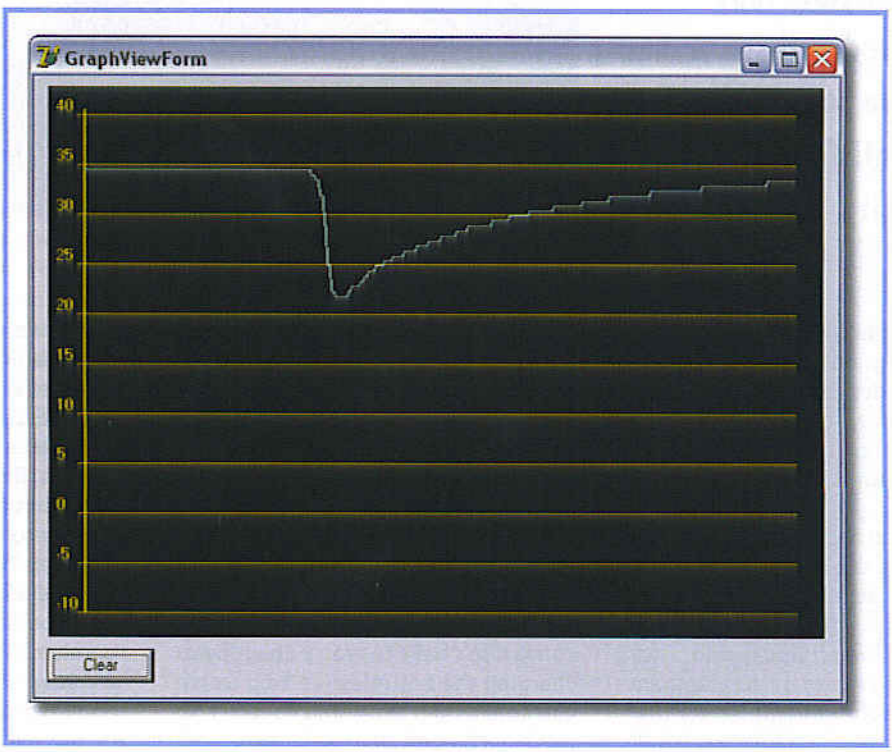


Figure 6. A graphical representation of the measured temperature.

Solar Lamp

Garden lighting without cables

Karel Walraven

Solar powered lights are nowadays available at incredibly cheap prices, so we won't advise you to build these yourselves. But you may be just like us: you've bought one of these devices and wonder what's inside it and how they could be produced so cheaply. We have taken one apart to satisfy your (and our) curiosity.

We start straight away with a look at the circuit diagram, since the outside of a solar garden lamp doesn't have much of interest to offer. The only noticeable part on the top is the solar panel (see **Figure 1**).

At the left of the circuit diagram in **Figure 2** you'll see the solar panel, which consists of 8 small cells, giving an open circuit voltage of about $8 \times 0.45 = 3.6$ V when illuminated. This voltage should always be greater than the charging voltage required for the two NiCd cells (about 2.8 V plus 0.3 V for the Schottky diode). The somewhat higher solar cell voltage makes certain that the batteries are still charged when there is less sunlight, albeit at a lower current.

The charging section is therefore very simple and doesn't include regulation. This isn't required because the solar cells behave like a constant current source; in other words, the voltage across the solar cells adapts itself to that of the batteries. In full sunlight the solar panel can produce about 50 mA, so we don't have to worry about overcharging the batteries (as long as we use at least ten times the capacity, in this case greater than 500 mAh).

The rest of the circuit consists of two parts: T1 and LDR R2 make sure that the converter (T2/T3) is only turned on when it is dark. R4 introduces some hysteresis, so the lamp won't flash during twilight.

The converter works as follows: a base current flows into T2 via R3 and it starts conducting. This provides a base current to T3 via R5 and this will also conduct. The current through inductor L1 will now gradually increase. At some point this current becomes bigger than T3 can handle and this causes a voltage drop to develop across T3. In other words, the collector voltage of T3 increases. This positive change is fed to the base of T2 via C1. This then conducts less, reducing the base current to

T3, which starts to turn off. This produces an avalanche effect, causing T3 to switch off very fast (a similar effect occurs when it is turned on).
The inductor has a tendency to keep the current flowing. Since it can no longer flow via T3, it flows via D2 instead, which lights up. Just like the solar panel, the inductor adapts its voltage automatically to the required LED voltage. It doesn't matter if there is a red, green or yellow LED with an operating voltage of about 2 V, or a blue or white LED that requires 3.5 V!

With the components shown, the converter works at about 80 kHz. The inductor looks like a slightly large resistor. If you replace it with a lower value the current increases, a higher value causes a decrease in current.
Now for a few more observations.
The converter is built using a PNP and an NPN transistor. This makes the current consumption zero during the day when the converter is in the off state. This is because both transistors either conduct or are in the off state at the same time. It would also have been possible to construct the converter using two NPN or PNP transistors. In that case one of the two always conducts and it won't be possible to have zero current consumption. You can see that a lot of thought has gone into this design!

Schottky diode D1 is added to prevent the batteries from discharging via the solar cells when there is only a little sunlight. Schottky diodes have only half the voltage drop of 'ordinary' diodes. The discharge current through the solar panel is less than 1 mA when it is dark. You could argue that the Schottky diode is superfluous since the converter itself uses 22 mA when it is dark, and another mA doesn't make much difference. When the batteries are flat out (0.6 V) the leakage current through the panel is insignificant, and the diode isn't required then either.
The manufacturer has made the assumption that when the batteries have been sufficiently charged during the day they won't run out overnight (12 hours times 22 mA = 264 mAh). The two NiCd cells should preferably never be fully discharged. At around 0.6 V the converter turns off and the current consumption drops to nearly zero. This discharge voltage is too low really and is bad for the cells; usually a minimum of 1.0 V per cell is suggested!

(050127-1)

Figure 1. The solar panel on top consists of 2 x 4 cells.

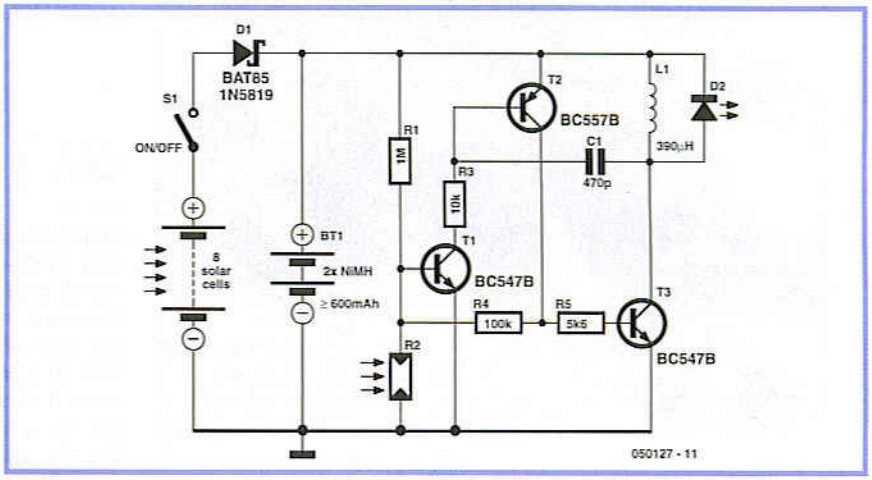


Figure 2. The circuit for the electronics in a solar lamp: a combination of a converter and a light detector.

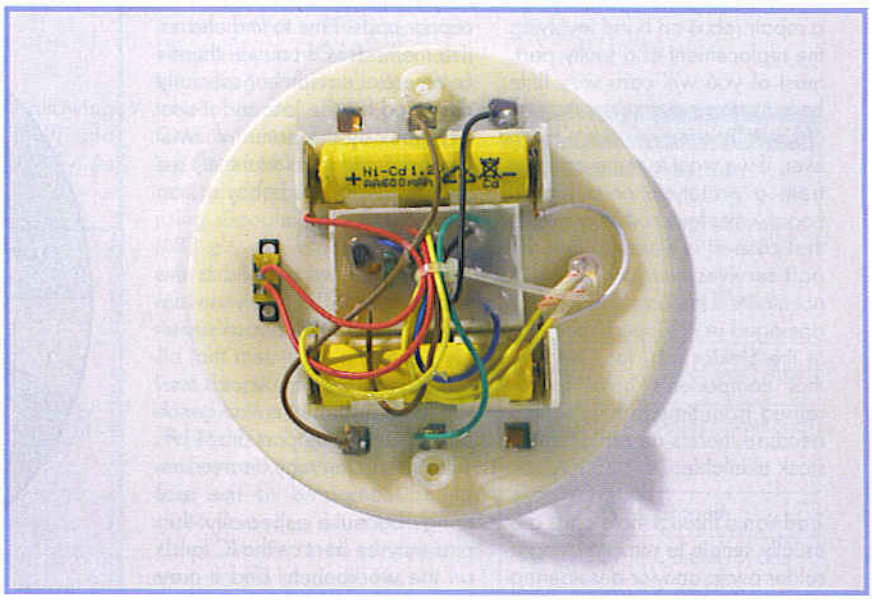
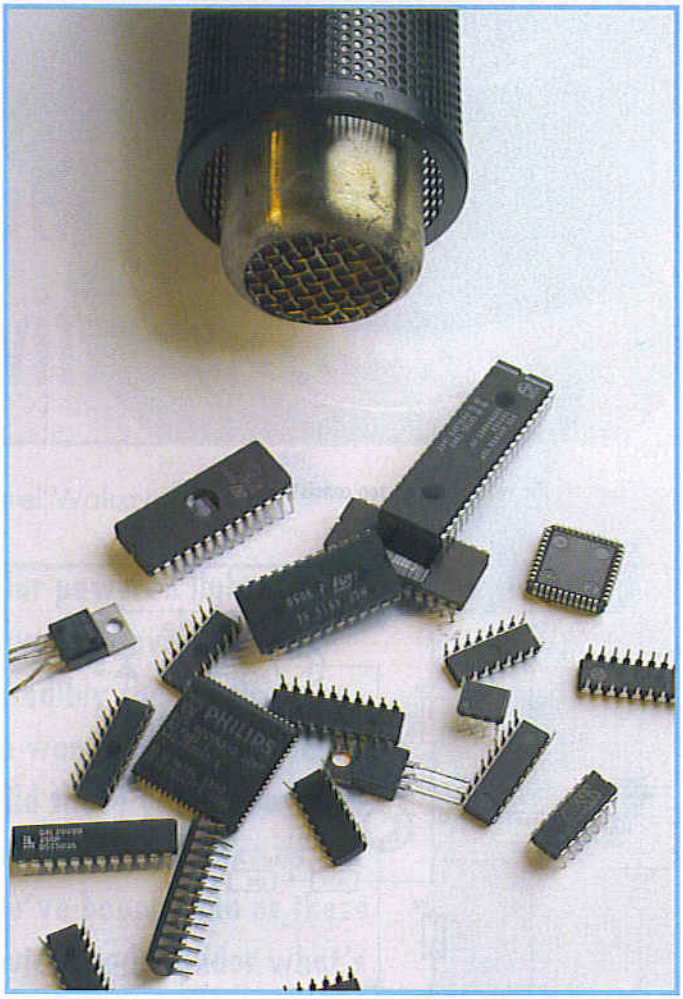


Figure 3. This is how the electronics fit inside the lamp.

Recycle those electronic parts!



Luc Lemmens
(Elektor Electronics labs)

Occasionally it seems there's no alternative to prying a component off a printed circuit board. When a repair job is on hand involving the replacement of a faulty part, most of you will care very little how it's done, as long as the precious PCB remains intact. However, if we want to remove a part from a prototype or a junked board, other laws suddenly rule: in that case, it is essential that the part survives intact while it will not matter if the board is severely damaged or scrapped later.
In the Elektor lab, too, we find that components have to be reused from time to time simply because there's no replacement stock available.

Traditional through-hole parts are usually simple to remove using a solder pump and/or desoldering braid. However, in the case of SMDs these tools are practically useless, particularly if we are to pry a multi-legged IC PLCC off a board, because in accordance with Murphy's laws, just enough solder will remain in place to keep the part firmly secured to the copper pads. Time to find alternative methods. Of course, there's commercial equipment specially designed for the job and it usually goes by the name of *SMD Rework Station*. Unfortunately the price tag is not one hobbyists can bear to look at.

The first 'crude' method is the paint stripper. The part you want to recoup from the board is simply heated to the extent that all solder joints become liquid; then rap the board on the workbench and hopefully the part drops off. This description may be oversimplified compared to the real thing, because especially thin pins may be bent as the IC lands on the workbench, and it may be surprisingly difficult to bend the lot such that the device can be neatly mounted again on the new board. Moreover, there is a real risk of the pins actually breaking. That is why we recommend carefully pulling the part off the board once the solder can be seen to flow.

The second method is a bit more subtle: detach pin by pin. For this trick we often use enamelled copper wire with a diameter of 0.2 mm (SWG36). The wire is slipped behind the IC pins and one end is firmly secured by soldering it in place. By heating the IC pins one by one and at the same time pulling at the free end of the wire, individual IC pins will be detached from the copper pads. The wire sort of pushes the solder tin from between the IC pins and the solder pads while also lifting the pins a little, allowing the component to come loose in the end. With this method, too, you have to be careful not too bend the pins too much — care and accuracy at this stage will save you a lot of messing about when re-mounting the part.

Sure, using off the shelf, brand new components is the preferred method in all cases, but it may not be feasible in all cases considering cost. And of course, it's a shame to throw away an entire board with expensive or rare parts still on it.

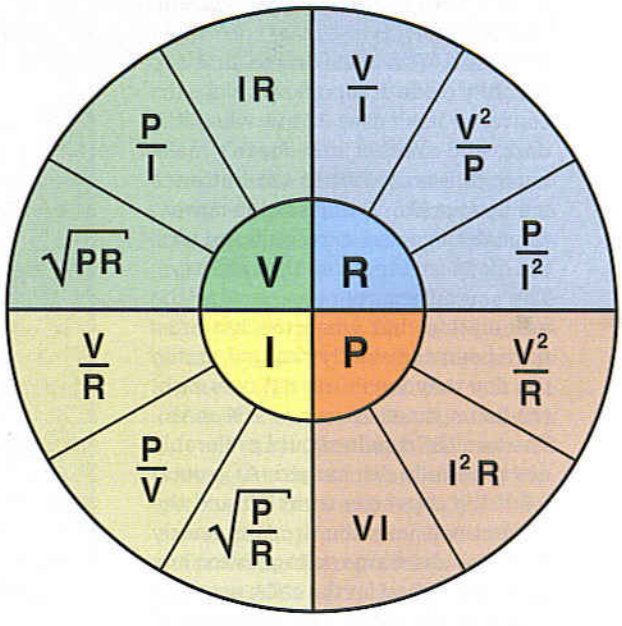
Many manufacturers indicate that their parts may be soldered three times without problems so there can be no objections or hesitations from that perspective.

(040470-1)

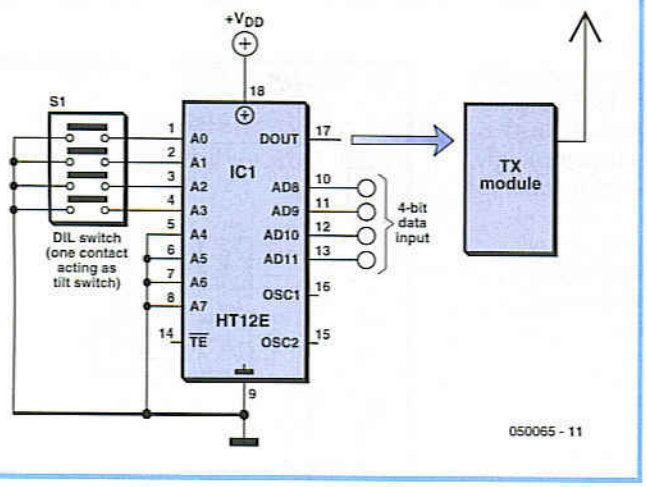
Ohm's Law wheel

Craig Kendrick Sellen
Has Ohm's Law got you going round in circles? Take a look at the wheel shown here and rotate no more. All derivations of Ohm's Law are arranged in one, simple to read chart. Simply select the desired unknown (*V*, *I*, *R* or *P*) from the inner circle of the wheel, then scan its quarter of the outer circle for one of the three equations that applies.
Of course, you can work in the other direction too if you have any two known values. For example, if the current *I* and resistance *R* are known, then the wheel indicates that the equation with which to find the power, *P*, is: I^2R. Similarly, if you want to find, say, *V*, it's *IR*.

(050078-1)



Data bit doubler for HT12E



Whether in a two-wire system or in combination with a transmitter, remote control IC type HT12E from Holtek is and remains a popular component. The component was first introduced in Europe by Maplin. It encodes four data bits (AD8-AD11) and eight address bits (A0-A7), the latter allowing up to 256 address codes to be set. The most recent appearances of the HT12E were in the July/August 2004 article 'Canon EOS Cameras go Wireless' and 'IR Transmitter with HT12E' in the December 2004 issue. Both articles can be downloaded from our website.

Those of you requiring more than four bits will appreciate this Design Tip, which enables the number of bits in control link (wireless or wired) to be doubled. One of the pins A0-A3 of the HT12E in a handheld (wireless) remote control is connected to a mercury tilt switch. Depending on how you hold the transmitter in your hand (with a light down or up tilt), the tilt switch will pull the relevant address line Low (i.e., to ground) or High. The eight data bits generated in this way may be processed at the receiver side by using two HT12D ICs. One of these is wired to the address that corresponds to the closed tilt switch (at the transmitter side), the other, to the address generated when the tilt switch is open.

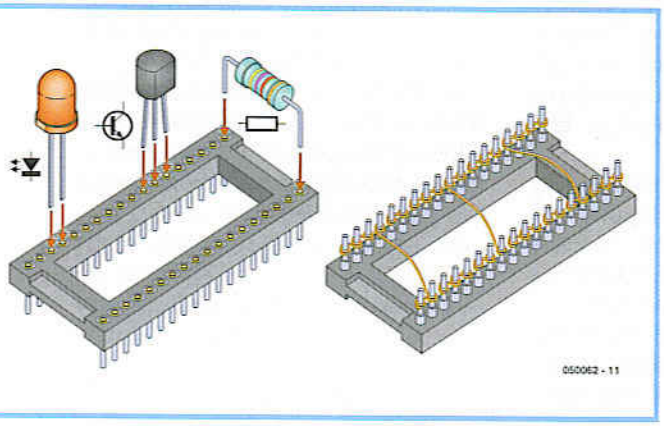
Have fun with the experiment!

(050065-1).

Low-cost plug-in board

Peter Lay

An IC socket with turned contacts can be used as a simple, low-cost experimenter's board allowing small circuits to be built and tested quickly and on the fly. As shown in the illustration, two, three or, if necessary, more pins are interconnected as required, while wires may be used to cross over to 'the other side'. The parts (resistors, capacitors, transistors, diodes, LEDs and so on) are simply inserted into the receptacles at the top side of the IC socket.



The circuit may be powered via a battery clip-on lead whose wires are either permanently soldered to the socket or plugged in like the components. As a matter of course, IC sockets with lots of pins are the most suitable.

(050062-1)

Low-cost LCD Modules

Luc Lemmens

LC-displays do not come particularly cheap in electronics retail. This is particularly true for graphic displays. If the size of the display is not important or if a small display is actually required, there is a cheaper alternative: an LCD module salvaged from a mobile phone!

With some luck these modules can be bought for a few pounds on eBay. They may, of course, also be salvaged from a discarded mobile phone. They generally have an I²S interface, so that driving them from a microcontroller is relatively simple. A brief search using Google (for do-it-yourself MP3 players, for example) may provide the necessary hardware and software information to use these displays yourself.

For example, on eBay we came across a display from a Nokia 3310 phone for just £ 3.00. This module contains the PCD8544 chip, an 84 × 48 pixel LCD matrix controller/driver from Philips, which can be controlled using the I²S interface. The datasheet for this IC contains all the necessary information to plumb the depths of the controller! The display conenctn data are shiown in the **table**. Also refer to these websites:

www.semiconductors.philips.com/acrobat/datasheets/pcd8544_1.pdf
http://home.mn.rr.com/sarmitage/avr.html
http://sandiding.tripod.com/lcd.html

(040174-1)

Display connection data

Pin	Signal	Function
1	VDD	Supply voltage (2.7V to 3.3V)
2	SCK	Serial Clock Input
3	SDIN	Serial Data Input
4	D/C	Data/Command
5	SCE	Chip Enable
6	GND	Ground
7	VOUT	Output voltage
8	RES	External Reset Input

QUIZZ'AWA

Martin Ohsmann is a Professor of Electrical Engineering and Information Technology at FH Aachen and a long-time contributor to Elektor Electronics. Through Quizz'away he aims at stimulating thought, speculation, construction and simulation as well as raise interesting questions.

This month we look at a very simple digital circuit (**Figure 1**). The gates used are TTL types from a 7400 or 74LS00 integrated circuit (worryingly, CMOS components are not suitable for the experiment).

Resistor R2 is adjusted until LED D1 just remains off when switch S is not actuated.

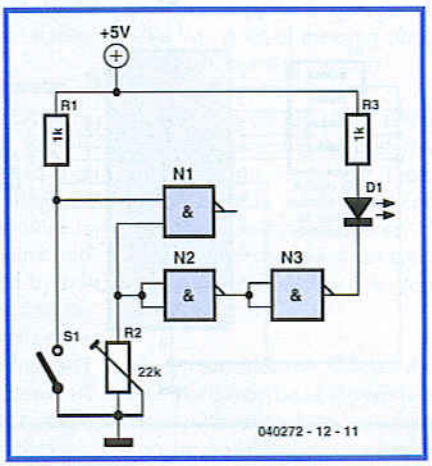


Figure 1. A simple 'digital' circuit.

Please send your answer to this month's Quizz'away problem, by email, fax or letter to:

Quizz'away, Elektor Electronics, PO Box 190, Tunbridge Wells TN5 7WY, England.
Fax (+44) (0)1580 200616.
Email: editor@elektor-electronics.co.uk, subject: 'quizzaway 9-05'.

The closing date is 30 September 2005

(solution published in the November 2005 issue). The outcome of the quiz is final. The quiz is not open to employees of Segment b.v., its business partners and/or associated publishing houses.

Solution to the June 2005 problem

(p. 78; 'Coils repelled or attracted?)

In any physics books covering electromagnetic induction you are sure to find Lenz's Law which states: the *induced potential difference due to electromagnetic induction is in such a direction as to oppose the change that produces it.* As we'll see below, this Law is not always that easy to apply in practice.

In the case of the test setup, it is the frequency of the current applied that determines whether the coils are attracted or repelled. Since both coils pass an alternating current, we really have to distinguish between the average and the instantaneous values of the force exerted. With sinusoidal currents, the average force is proportional to the cosine of the phase angle (cos φ). However, as we'll see, certain special circumstances enable both current to be inexactly in phase or anti-phase. **Figure 3** shows the results for two frequencies and the zero-current situation. How can the behaviour be explained?

First we need to examine the equivalent circuit of the setup, see **Figure 4**. The secondary circuit contains capacitor C and a current I_1 is injected into the primary-side branch (terminals a and b). There are reactive components only (capacitors and inductors), which are assumed to be ideal, i.e., loss free.

All voltages and currents are sinusoidal of a frequency *f*. As customary in alternating current theory, $\omega = 2\pi f$ is the angular frequency and *X* refers to the (frequency dependent) reactive resistances. The series connection of reactive resistances of the capacitor $X_C = -1/\omega C$ and the stray inductance $X_S = \omega L_s$ results in a reactance

$$X_2 = X_S + X_C = \omega L - 1/\omega C$$

at the secondary side.

Depending on the frequency *f*, different things happen. The simplest case arises when X_2 equals zero. This happens when the frequency equals the resonance frequency of the series circuit formed by L_s and *C*, because then the series network forms a perfect 'shunt' to the main inductance L_m of the transformer. The current I_1 therefore flows entirely in the secondary circuit, and the equation $I_1 = I_2$ applies. This condition is called *Case 1*.

The simplest way to make sense of the relative phases of I_1 and I_2 is to have a look at the 'junction' inside the transformer, and apply the 'current distribution rule' to it. We have

$$I_2 = \frac{X_m}{X_m + X_2} I_1$$

where $X_m = \omega L_m$.

As of the September 2004 issue Quizz'away is a regular feature in Elektor Electronics. The problems to solve are supplied by Professor Martin Ohsmann of Aachen Technical University.

This month's question is:

What happens when switch S is pressed — and why?

Hint:
The interesting thing about this circuit is that the switch is capable of controlling the LED although the output of NAND gate N1 is not connected! To solve the problem, it is useful to study the internal circuitry of a TTL NAND gate. Texas Instruments (www.ti.com) have available a datasheet showing the internal structure of several TTL family devices (7400, 74LS00, 74S00).

In order to carry out the experiment, the circuit is easily built on a piece of stripboard (**Figure 2**). Depending on the TTL family and the IC manufacturer, resistor R2 may take slightly different values.

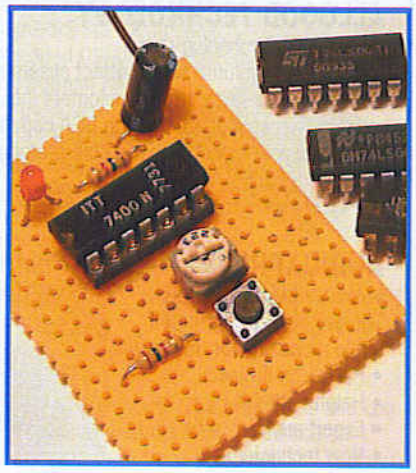


Figure 2. Veroboard construction of the circuit.

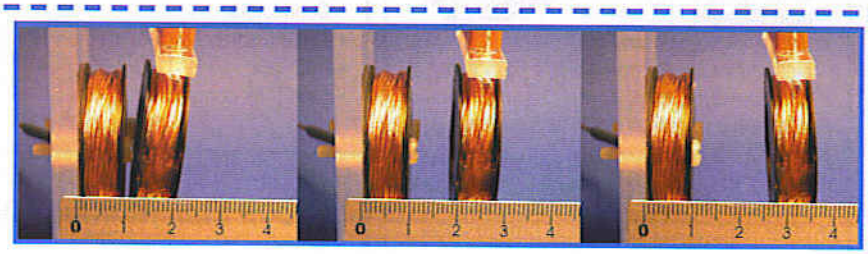


Figure 3. Left: 36 kHz = coil attracted; Centre: no current; Right: 48 kHz = coil repelled.

The decisive element is the denominator of the division. With $X_2 = 0$ we get Case 1, as before. However, when $X_2 = X_m = 0$, the denominator equals 0 and the equation may be accomplished with $I_1 = 0$. This is *Case 2;* no current flows; the circuit represents an infinitely high reactive resistance. This is exactly the point at which the sign of I_2 reverses in relation to I_1. Here, the series network L_m+L_s is in quasi parallel resonance with capacitor C. In other words, depending on the frequency being below or above this critical frequency, the coils will mutually attract or repel.

From a more practical point of view, it may be interesting to see how 'a lot of current' may be generated in the primary or secondary circuits. With Case 1, it is already great that the secondary circuit exhibits the reactive component $X_2 = 0$. Now, we use a second capacitor to 'compensate' the reactive component of the transformer's primary as well. Still Case 1, this causes series resonance in the primary circuit. The current I_2 is then only limited by losses. In this situation, it is possible to 'pump' a lot of current in the primary and secondary using relatively small voltages.

Examining the denominator of the current distribution rule in greater detail, you'll see the possibility of the quotient assuming the value –1 in the special case of $X_2 = -2X_m$, which results in $I_2 = -I_1$ i.e., the two currents being in anti-phase. Let's call this *Case 3*. An even deeper examination of Case 3 reveals that the input impedance of the complete network approaches zero, causing (in theory) immense currents.

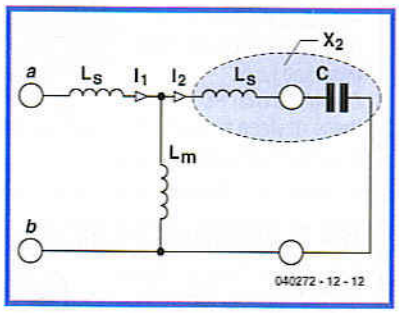


Figure 4. Two inductors as a transformer with capacitor C at the secondary side.

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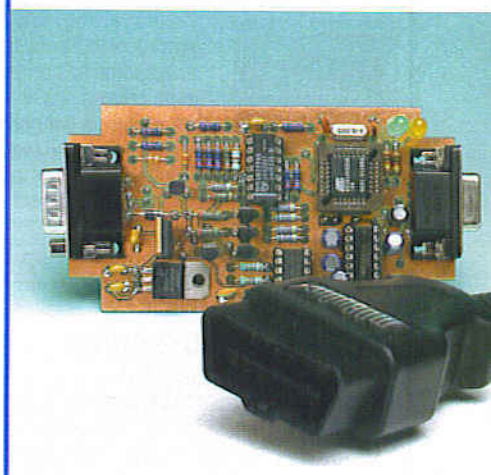

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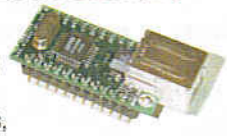

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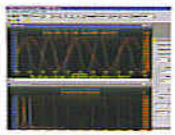

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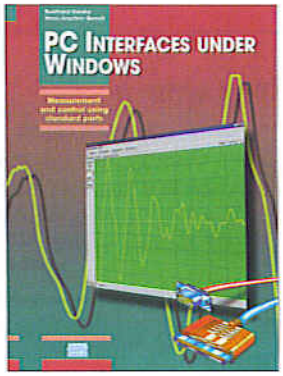

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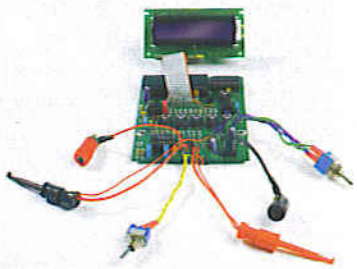

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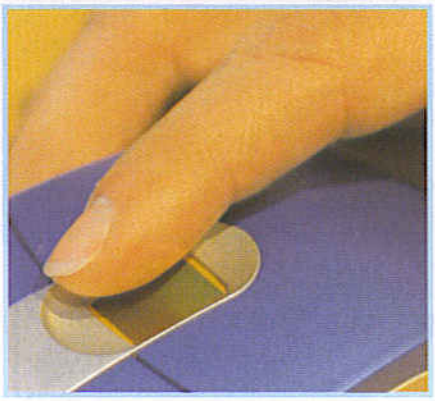

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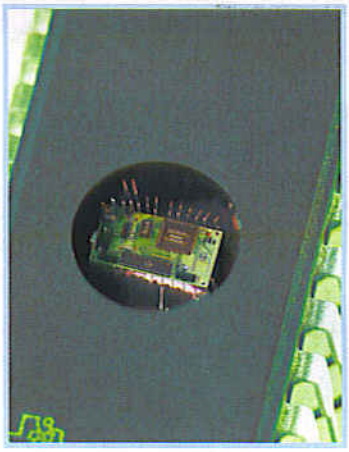

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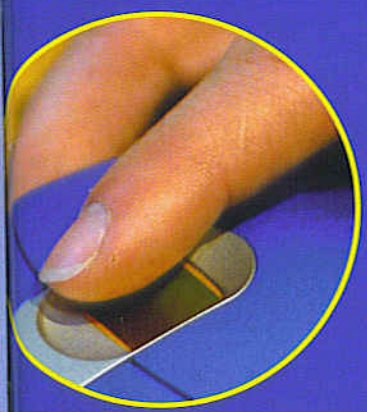

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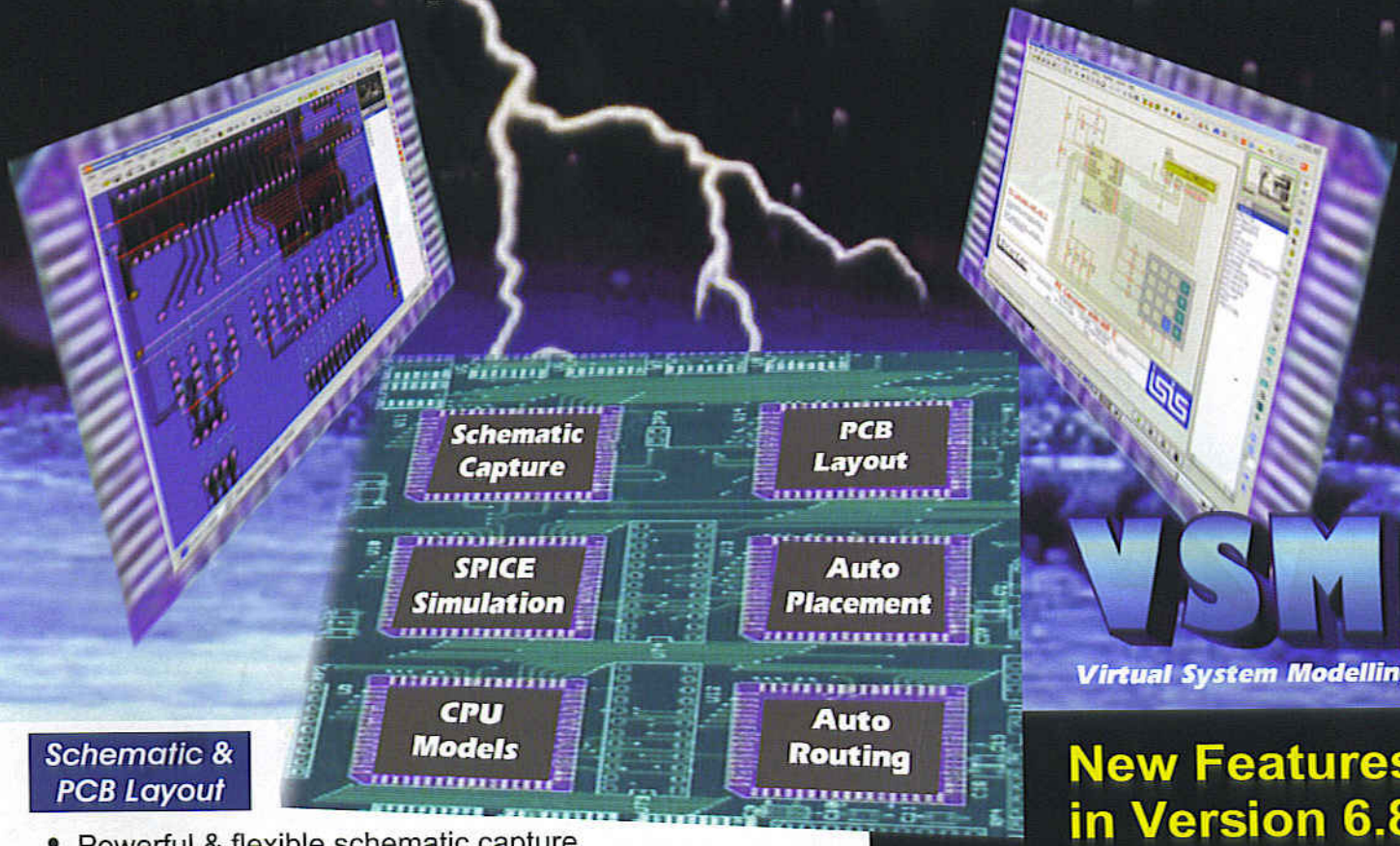

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